
User Manual

PhotoModeler 6

Eos Systems Inc.

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Eos Systems Inc.

+1-604-732-6658

support@photomodeler.com

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Welcome to PhotoModeler

This document describes the *PhotoModeler* and *PhotoModeler Scanner* products and their add-on modules. PhotoModeler® is a Windows program that helps you extract measurements and 3D models from photographs. By using a camera as an input device, PhotoModeler lets you capture accurate detail in a short time.

PhotoModeler Scanner has all the capabilities of PhotoModeler plus the ability to scan surfaces to extract dense point clouds. See *Dense Surface Modeling / PhotoModeler Scanner* for information on this product.

"PhotoModeler" will be used in this document interchangeably to refer to both the PhotoModeler and PhotoModeler Scanner products.

To use PhotoModeler, one or more photographs of a scene or an object are taken. The photographs are displayed on screen and the operator marks each photograph with the mouse, tracing and tagging features of interest. PhotoModeler then combines the data and locates the marked features in three dimensions. The marks become accurately measured points, lines, curves, cylinders or surfaces in a single, unified 3D space. The result is a 3D model that can be transferred to any graphics or CAD program.

For an overview of the PhotoModeler process, refer to the section *Overview of Producing a 3D Model*.

The Tutorial Movies are the best way to learn PhotoModeler. There are a few concepts in PhotoModeler that are unique and it is best to read the Quick Start Guide and watch the tutorials before embarking on your first project.

New for PhotoModeler 6

This section provides a quick overview of the major new features in PhotoModeler 6 since the Pro 5.2.3 release. See the file "changes.txt" in the install directory for a detailed list of all changes to PhotoModeler.

Existing PhotoModeler users will want to watch for "PhotoModeler 5 User Note:" for information on areas that have changed significantly or that may require some re-familiarization.

Major New Features

The major new features in PhotoModeler 6 are Shapes (geometric solids), Imports (import data from other 3D packages into PhotoModeler), a revamped User Interface (with paned interface), automatic processing, camera library with automatic camera-photo matching, printing, new exports (including Google Earth), new quality feedback and the Idealize Module. Each of these is described in more detail below.

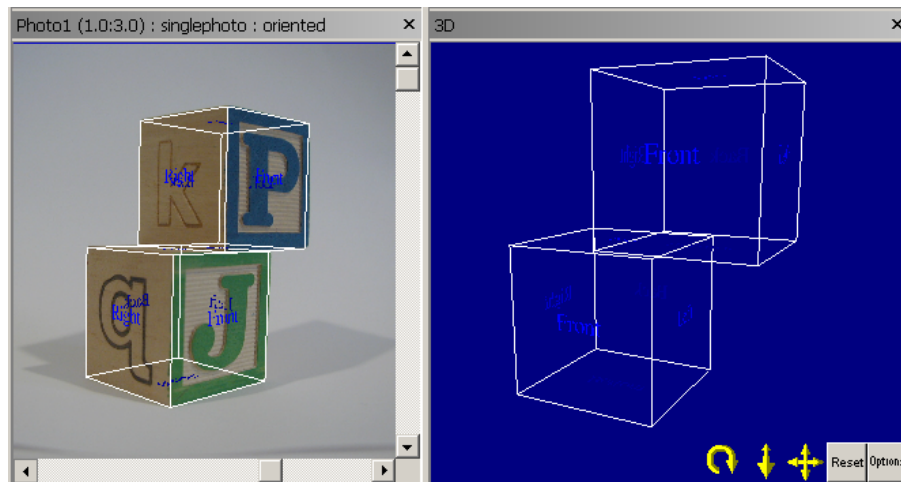
Shapes

Shapes are 3D geometric solid entities such as cubes, pyramids, and wedges that are easily added to photographs by marking their edges, using the Add Shapes toolbar:



PhotoModeler 5 User Note: Shapes provide another way of modeling geometric objects, as well as a way to solve camera position and/or inverse camera. PhotoModeler 6 has the concept of Points-based and Shapes-based projects - all projects created with PhotoModeler 5 and earlier versions are Points-based projects.

Shapes are a fast way to construct non-organic models using a solid geometry approach. These Shapes contain all 3D faces in the model, e.g. when you mark 7 edges of a box, the fully solved box has all six faces solved (even those you cannot see!). Shapes are 'CAD-like' - that is they have perfectly flat faces, perfectly perpendicular edges, etc.).



These Shapes can be solved on one photo or as many photos as needed. The Shapes are configurable. The ones that come with the installation are: rectangular box, pyramid, roof, truncated pyramid, truncated wedge and flat rectangle.

You can get CAD-like results over multiple shapes (e.g. having two shapes line up perfectly with each other) by using Shape Relations. The relations are: shape faces on same plane, shape sits on ground, faces are concentric, faces are aligned, faces are same size, shapes have same size, shapes are aligned and a shape parameter is equal to a constant or another shape parameter.

Like other Surfaces in PhotoModeler, Shapes can be textured and Surface Drawn. You can also attach other types of Surfaces (Path, Loft, etc.) to Shape Edges.

Under certain conditions a Shape will solve with no marking if it is sufficiently constrained by Shape Relations. Example, a wedge on a roof top has three size parameters, three translation parameters and three rotation parameters - if it has a same-size-shape relation the three size parameters will be defined, if it has a coplanar with roof top and two collinear edge relations the translation and rotation will be defined and the wedge does not need to be marked on any photo - it will be placed automatically in 3D.

Other standard PhotoModeler items such as points, lines and curves can be added to Shapes projects too. And visa versa, Shapes can be added to Points-based projects by using vertex pinning.

Shapes can be used for architectural models, cityscapes, industrial parts, or anything that is described well by boxes, wedges, pyramids, etc.

See *Shapes Modeling*.

Imports

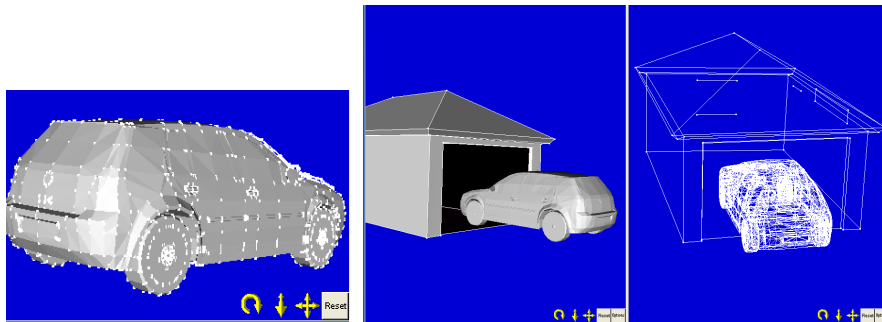
PhotoModeler now supports the importing of external models in DXF, OBJ, 3DS formats (along with the PhotoModeler text format). These models can be created using an external package or from an export of an existing PhotoModeler project.

PhotoModeler 5 User Note: Control Points are now a part of the Imports feature.

Points, lines and surfaces (triangles and meshes) can be imported as one of three types:

- **Control:** Used to orient and scale a project (the same as version 5's control points)
- **Pinned:** The imported model is scaled, translated and rotated to match existing points in a project.
- **Static:** The imported model is left in the external file's coordinate system and displayed along side the current PhotoModeler project.

Example of a model imported from a DXF file shown on the left. Key points of this model are then pinned to existing 3D points in a PhotoModeler project as shown on the right:



See *Working with Imports and Constraints*.

New Printing and Output

Any photo, 3D view or table can now be sent to the printer, a file or the clipboard.

The photos are output as image files including the currently visible marks and/or projections and may be output at the full resolution of the original image file or at the resolution of the current window.

3D Views can be output at any resolution specified or the resolution of the current window.

Tables can be exported as text files, to the clipboard as text or as comma separated (for import into Excel) or sent to the printer with headers and columns drawn in the same way as they are in the window.

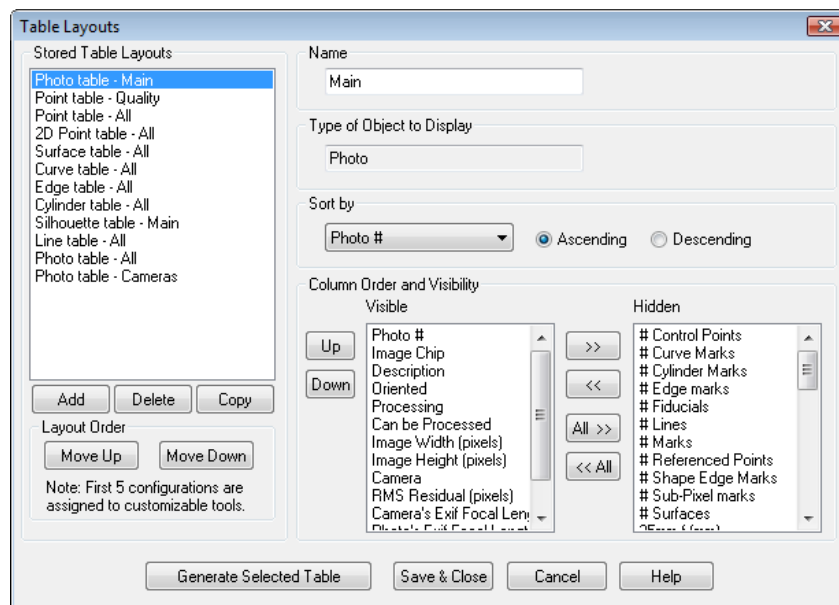
PhotoModeler 5 User Note: Tables are now exported (printer, file or clipboard) using the common File output menu (no longer from the table top toolbar).

See *Print and Output Options Dialog*.

Tables Revamp

Tables have been replaced to improve handling and performance. In addition there are two new table types and some useful features:

- Tables build and sort more quickly
- Line and 2D point mark tables have been added
- Tables can now be generated on demand, based on table type and various properties, but user defined table layouts (formerly called configurations) can still be created and stored, using the *Table Layouts Dialog*:



- Tables now support Grouping, which allows you to group rows of data based on one of the object properties. Provides an alternate method of sorting data (very useful for 2D Point Mark table grouped by Object Point for example).
- Column visibility can be set using a right click menu.
- Table Layouts can be saved via right click menu
- Columns can be frozen in place while scrolling

See *Tables*.

New Exports

- Maya export has been enhanced to include curves, lines and the camera positions (focal length and rotation) - useful for Maya users doing *Perspective Matching*. Goes well with new Idealize Module.

- PhotoModeler 6 has an exciting new capability to export data (wireframe, surfaces, and photo-textures) to Google Earth. Google Earth is the planet-wide ortho-photo browser supplied by Google. Here's an example of a simple model exported to and displayed in Google Earth:

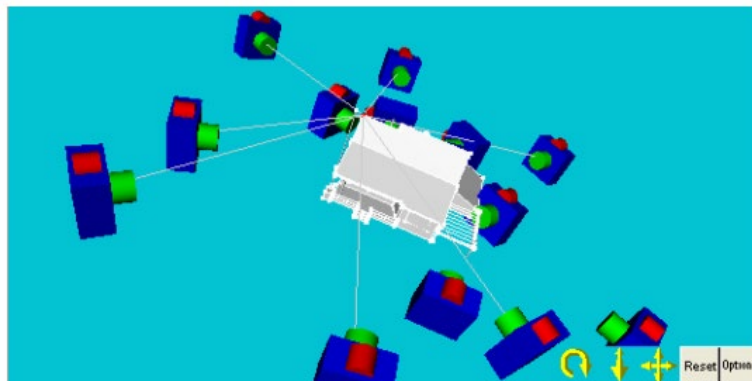


See *3D Model Export*.

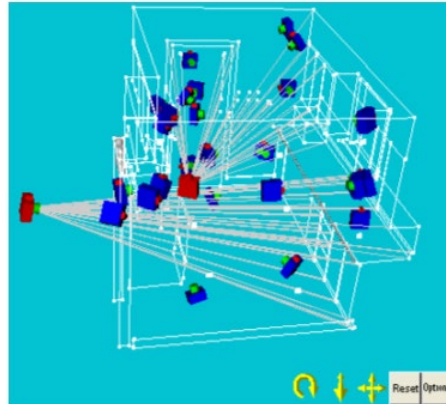
Quality Feedback in 3D Viewer

Some tools for evaluating model quality and analyzing data have been added to the 3D viewer.

- 'Rays' to indicate the light rays used to calculate a point. This helps identify poor angles, low number of references, helps determine what additional references would help strengthen the point. When 'Rays' are enabled, selected points will show rays from the point to each camera that represents the photo on which the point has been marked. This shows rays from a point to each of its photo's camera:



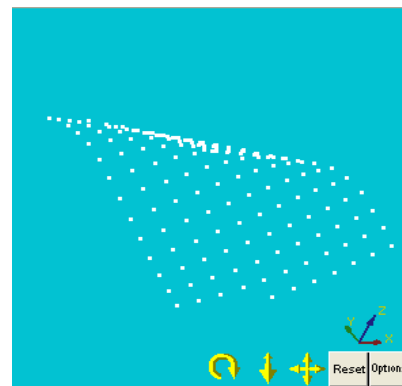
- Rays from a camera position identify which points were used to solve the position. When rays are enabled, camera stations show rays to each point imaged on the camera's photo.



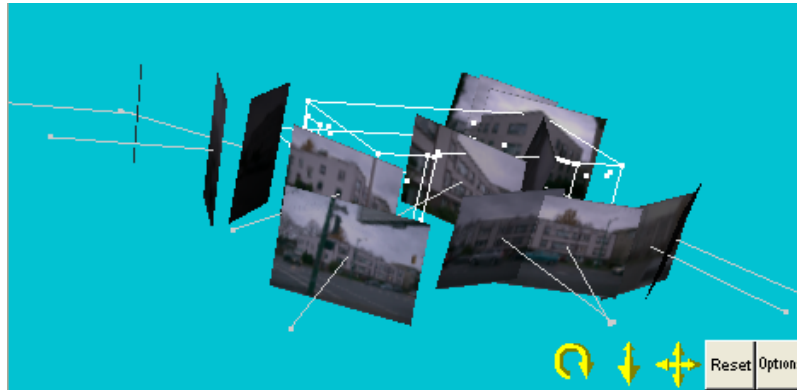
- Point Confidence Regions (see *Confidence Region*) display a visual representation of a point's strength.



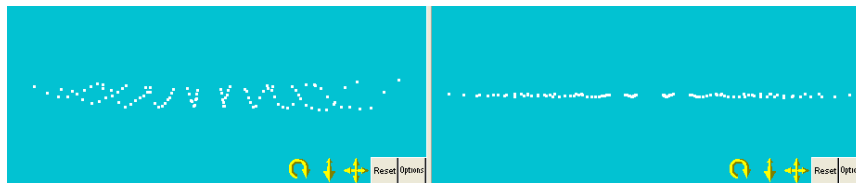
- A ground plane and/or offset axes help establish a visual orientation.



- The photographic data can be used in place of the camera station symbol to help identify the particular photo and to give a visual representation of how the 3D data is solved. When 'rays' are visible (see explanation above), rays intersect the image plane at the point's mark location.



- Exaggeration values help visualize small fluctuations in one axis.



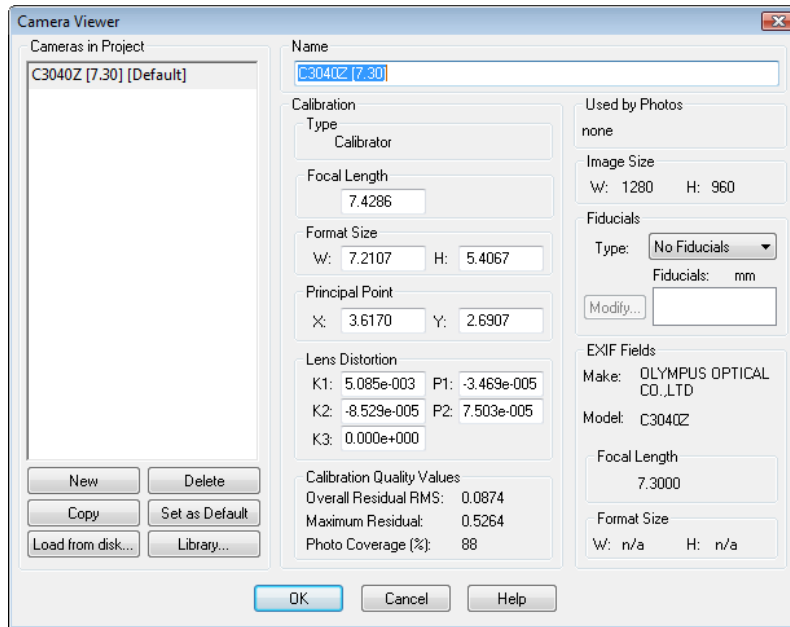
See *3D Viewer* and *3D Viewer Options Dialog*.

Camera Library and automatic camera matching

A new central database of calibrated cameras has been added - called the Camera Library. You can add and remove cameras from this database making it easier to keep track of your cameras (no more hunting for them on your disk!). In addition, when using images from digital cameras that store EXIF data (as most recent digital cameras do) the project startup Wizard automatically searches the library for matching cameras. This makes project startup much faster and easier. See *Application Data and File Locations* for information on where camera files (.cam) are stored on disk.

When a camera is calibrated using photos with EXIF information (full calibration or field calibration), you have the option of adding the camera to the library. Once cameras are added, the library is searched when photos (with EXIF) are added to the project. If a match is found the camera from the library is added to the project and automatically assigned to the photo.

The Cameras dialog has been revamped to include EXIF information



Other camera improvements are the storage of calibration quality metrics (as seen in dialog above) and storage of the calibrated point coverage. Point Coverage display (a red rectangle showing the extent of point coverage during calibration) is helpful to visually check whether points are marked within the part of the lens that was calibrated. This is controlled using the Coverage setting, on the *Visibility on Photos* pane.

See *Camera Viewer Dialog*.

Automatic processing (optional)

Projects will process automatically when a change is made that could affect the project's state (e.g. referencing a new point, dragging mark, etc.). When starting a project, as soon as the minimum requirements are met, photos will orient automatically. As a project grows and processing starts to take more time you will be asked if you would like to turn off automatic processing (then you manually process the project as you would in previous versions).

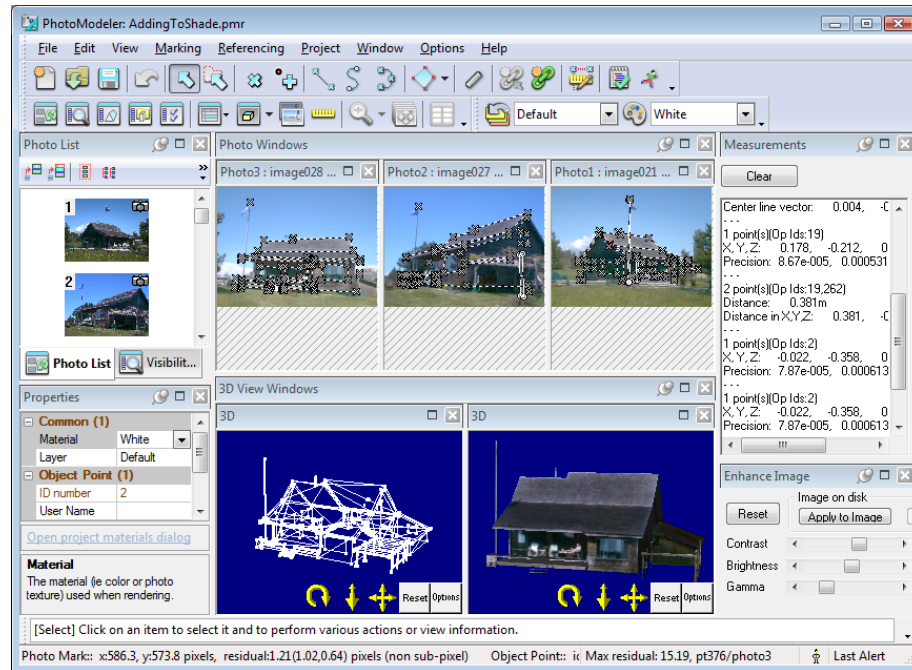
PhotoModeler 5 User Note: No longer do you need to pick the Process tool to process a project once you think you have met the minimum requirements (e.g. for number of marks and references), this is now done automatically.

Automatic processing can be turned on or off by clicking the *Status Bars* processing icon or on the *Project Information Dialog* box.

User Interface Revamp

The user interface has had a major overhaul to bring it to modern standards while at the same time improving ease-of-use and work flow.

The paned window interface allows full customization to match your preferred workflow and screen layout. The layout is saved when PhotoModeler is closed, as well user defined layouts can be save and restored at any time.



Other new interface features include:

New real-time-edit properties, with help feedback and hyper-text controls.

PhotoModeler 5 User Note: To view properties of a selected item, you no longer need to open a properties dialog from a right click menu (if the properties pane is visible), although you still have the option to do so.

Context sensitive cursors inform you of what mode you are in and what object type will be selected when you click.

New toolbars and menus group items in commonly used sets. A setting for a simplified toolset eases use for new users.

A new *Getting Started Panel* makes it faster to start up new or existing projects or perform other common tasks.

A number of dialogs now use Trees for easier navigation and ease of understanding (e.g. Preferences, 3D Viewer options)

'*Add/Remove Photographs Dialog*' dialog uses a new directory, file and thumbnail viewer mimicking the Windows explorer interface.

Hypertext controls are used in a number of places (one being the *Getting Started Panel* as shown above)

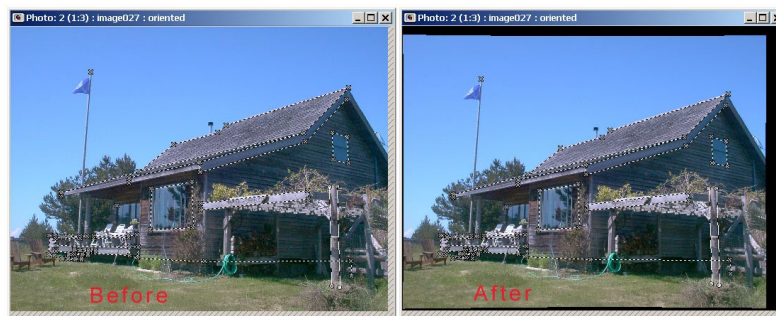
PhotoModeler has been given a facelift with new toolbar and menu icons. There are also new Preference settings for toolbar and menu icon sizes and overall 'themes'. Tooltips are also improved.

See *Working with Windows and Panes*.

Idealize Module

The Idealize Module is a new add-on module available for PhotoModeler 6 (in addition to the existing add-on modules of Coded Targets, and PhotoModeler Video).

The Idealize module will take an existing project and use the calibrated camera parameters to produce an idealized camera and images. That is it will re-map (pixel by pixel) any specified images removing any lens distortion, non-centered principal point and any non-square pixels. It will then adjust the existing marks to match the undistorted image and then assign an idealized camera to the project. The resulting images and camera positions should then be suitable for use in rendering packages which do not handle 'real world' cameras. An example of before and after Idealize:



See *Idealize Project*.

Other Interesting Changes and Features

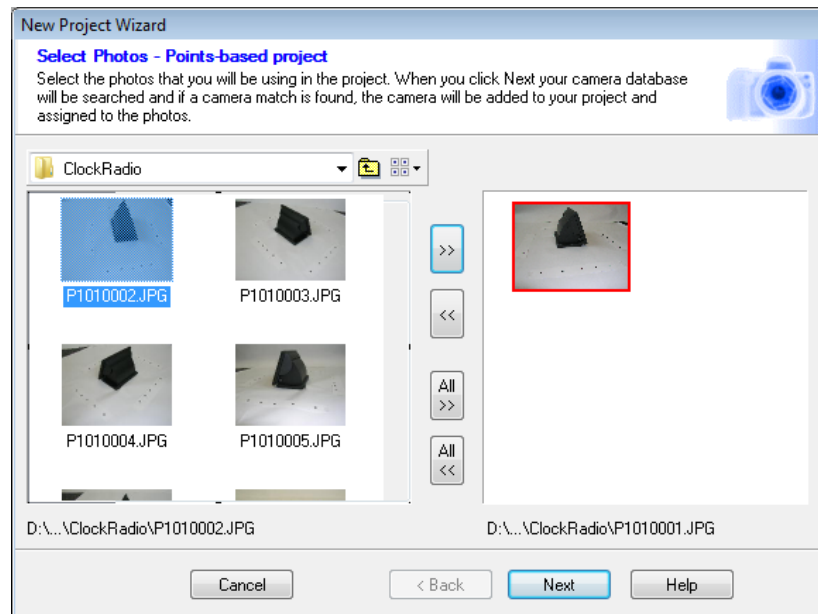
Streamlined project startup wizard (fewer panes)

The New Project wizard has been simplified and includes fewer steps to start a new project, based on the type of project selected on the *Getting Started Panel*.

A regular project can be created by simply selecting your photos, and if the associated camera(s) are stored in the database, your photos will be matched and the project is created (see explanation of the new camera matching feature above). Even without the camera matching, new project set up has been streamlined with far fewer panes required.

PhotoModeler 5 User Note: The number of startup Wizard steps has been drastically reduced and the order of steps has changed. Now, from the *Getting Started Panel* you select the type of project, then in the wizard you first select the photos for your project, then choose your camera (if a camera hasn't automatically been matched).

A brief explanation is shown at the top of each wizard pane, showing the project type and useful tips:



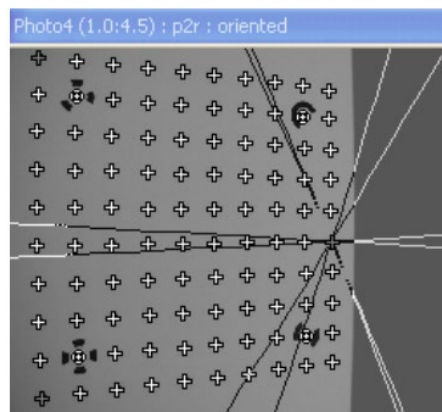
See *Creating a New Project*.

Revamped and Improved Point Referencing

Referencing is now more flexible and the choice of a destination and source photo is not as rigid. Selecting items on a photo (or now table or 3D view) cause it to become the source photo, you can then reference any selected items across any other photos (or now tables and 3D views). Clearing selection will enable you to select any new source photo.

PhotoModeler 5 User Note: No longer is there a strict 'source' and 'destination' photo. Referencing is more flexible but also easy to use.

In addition to auto-driving to the projected location, an epipolar line will be drawn for each oriented photo the source point is referenced on.



See *Referencing*.

Direct printing of coded targets

Coded targets can be created as either a PostScript file or sent directly to the printer.

PhotoModeler 5 User Note: You no longer need to first generate then print a .ps file when creating coded targets.

See *Create Coded Targets Dialog*.

Manual CT marking

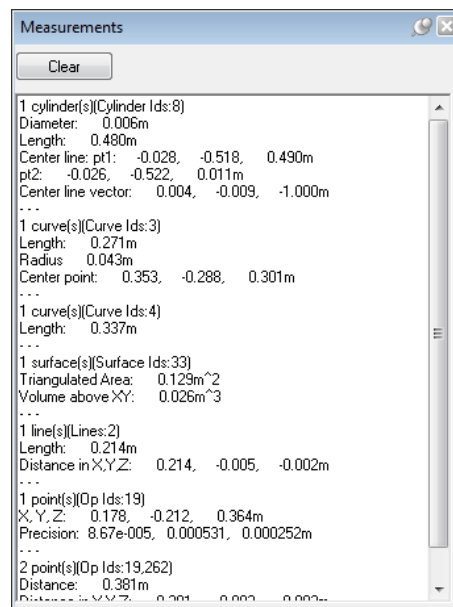
Coded Targets can now be manually identified (by drawing a box around them). The center target is sub-pixel marked and the code is automatically read from the image. Useful when automatic marking has missed a few targets due to its current settings.

PhotoModeler 5 User Note: Auto-marking no longer is the only way to mark coded targets.

See *Sub-pixel Target Marking*.

New Measurements Pane

The new measurement capability is a non-modal pane with a 'ticker tape' style display showing all measurements in a session (with current one color coded). The data is also user selectable for copying to clipboard.

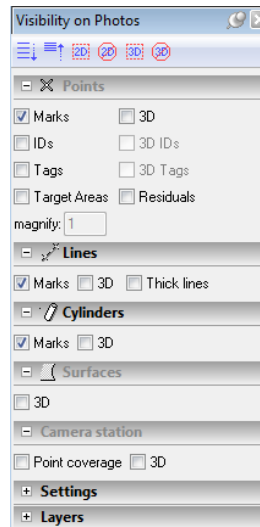


PhotoModeler 5 User Note: No longer do you have to enter Measure Mode. As long as you have the Measurements pane open and visible, measurements are shown based on what is selected in a photo, table or 3D Viewer.

See *Measuring Features*.

New streamlined Photo Visibility dialog

Projections and marks are now combined on one visibility dialog. To organize the larger number of controls on one pane, each object type now has its own collapsible task pane. To reduce clutter, these task panes appear only when a project has that particular type of object.



PhotoModeler 5 User Note: “3D” items correspond to what was formerly known as “Projections”.

See *Visibility Settings* and *Paned Interface*.

New Installable User Interfaces

You have the option of showing one of several toolbar layouts based on the type of project you will most often build (e.g. Full, Point, Shape, Road Scene etc). The toolbars show most commonly used tools for these types of projects and simplify the user interface.

PhotoModeler 5 User Note: Toolbars are still fully customizable, but these project type specific toolbars can be used as starting points for your own customized toolbar and menu setup.

See *Menu/Tool Reference*, *Installable User Interfaces* and *Preferences*.

Improved Orientation features

Improved orientation (especially on low angle projects) with new features that check camera angle and photo coverage so that photos are more solidly oriented in early project stages. During the first orientation stage, potential orientation photo pairs are checked for their angle and share-point coverage. If not meeting minimum criteria, weak pairs are thrown out leaving more stable pairs as the basis for orientation.

See *Adjustment and Processing* and *Orientation Problems Dialog*.

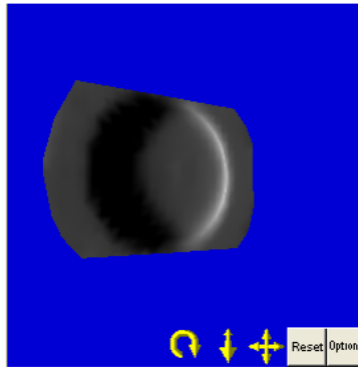
Masking out areas used for texturing

An optional mask file can be assigned to each photo to indicate areas not to include for texturing.

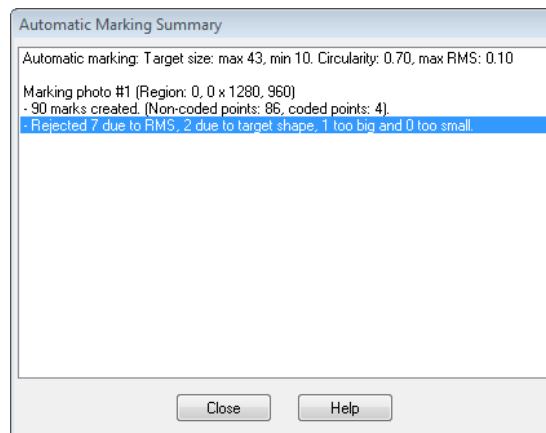
See *Photo Properties* and *Mask image file name*.

Smaller Changes and other UI Improvements

- Materials: The RGB value of a material can now be applied only when textures are off or blended with the texture to highlight objects.
- New side-light in 3D Viewer with improved settings for headlight/side light:



- Region select a temporary mode
- A new method of output triangular surfaces and meshes to formats that only support NURBS allows each triangle to be output as a separate surface.
- Automarking summary dialog:



- Projects are now 'Unitless' until scaled: Having units on an unscaled project is deceptive as the model will be correct relative to itself but without any real-world measurement to compare to the values have no relation to actual real-world distance. To reduce this confusion, by default, projects start in a unitless state and only have their units displayed once a scale has been added.

PhotoModeler 5 User Note: Project units are set on the Scale/Rotate dialog or when adding a distance constraints, or when importing points.

- Surface draw no longer re-associates with a new surface as you draw it. It is now possible to extend surface draw from one surface over top of another surface without the surface draw points become associated with the new surface they are on top of. Once you start a new set of surface draw the surface selected will always be the one used regardless of where the new points are placed.
- Property/Add/Remove dialogs: Cameras, Table Layouts, Constraints, Layers, Materials etc. have been revamped so that adding/removing/editing various properties is more standardized.
- Scale/Rotate clear – the scale rotate information can now be totally cleared instead of just disabled.
- *Alert popups* (small temporary information boxes that appear at bottom right of the application window at certain times) appear to provide more feedback and replace some dialog warnings to reduce the number of disruptions requiring an OK click.
- More information on the *Status Bars*, such as processing type, position of cursor in image, project status. The Status Bar is also interactive enabling you to toggle automatic processing on/off (by clicking the processing icon), and to display the point with the highest point mark residual (by clicking the project status point data section).

Technical Support

“We will make sure you succeed”

It is very important to us that all PhotoModeler customers are satisfied. We want to ensure that every customer can complete their projects with the desired level of quality and accuracy.

Eos Systems and our resellers/distributors are committed to helping you get started with PhotoModeler and making the most of the program. Please do not hesitate to contact Eos or your reseller for support and to have your questions answered. We are very responsive and we will make sure you succeed.

May we suggest some things to do before contacting support:

1. If you are new to PhotoModeler or haven't used a particular function before, please view the corresponding tutorial video and/or find the description in the help file.
2. Review the troubleshooting section of the Quick Start Guide and help the file and look in the index and glossary for relevant information.
3. Visit the support FAQ on the PhotoModeler web site to see if there are any suggestions there.
4. If you think you have found a bug or problem in the product, first try to repeat the problem and narrow down the circumstances under which it occurs.
5. If you cannot resolve your problem please do not hesitate to contact us. Visit our support web site to view our support policies.

When you call, e-mail or fax Technical Support, make sure you have the following ready:

1. A description of the problem,
2. A description of the hardware in the PC that PhotoModeler is running on,
3. Your PhotoModeler serial number (from the Help menu /About Dialog box or CD label - the serial number is the first 9 digits of your activation code), and
4. For phone calls, have PhotoModeler running and use a telephone beside your PC.

Contact

Technical Support is available from your full service dealer or if you purchased directly from Eos System, from Eos Systems also.

Eos Systems technical support policies are listed on the PhotoModeler website at www.photomodeler.com/support.htm. Your dealer's policies may be different.

Support Contacts:

Internet E-Mail: support@photomodeler.com

Web: www.photomodeler.com/support.htm

Modules and Licenses

Modules are add-on extra cost components for PhotoModeler. Three add-on modules are available: *PMV PhotoModeler Video*, *Coded Targets*, and *Idealize Project*. See also *PhotoModeler Activation* and *License Management Dialog*.

PhotoModeler Activation

Activation is a set of simple and quick steps taken after program installation in order to begin using PhotoModeler. If you've used Microsoft Windows XP, Microsoft Office or many of the Adobe products you have already used a similar activation system.

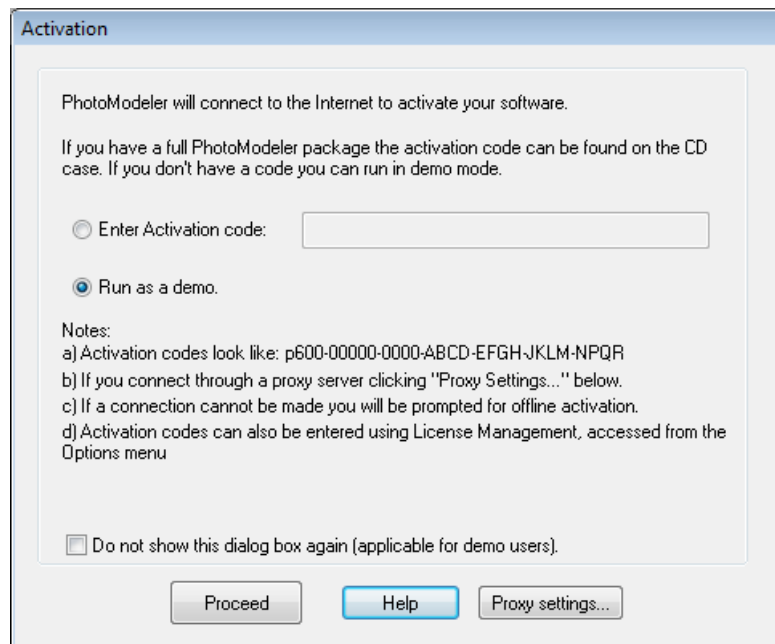
When PhotoModeler is first run it contacts a central server across the internet to 'activate' your software and tie it to the provided activation code (which is printed on the box and CD case labels, or provided by Eos or your dealer by email).

Our system does tie your license permanently to your computer hardware but it has built-in tolerance for changes to your machine, and you should have no problem re-activating your software after reformatting your hard drive, after upgrading hardware components in your computer, or when you move your software to a new computer.

Activation, re-activation or deactivation normally requires an Internet connection. This Internet connection can be on a different computer from where PhotoModeler is installed.

When you first launch PhotoModeler the *Activate PhotoModeler Dialog* will appear. You can also carry out various Licensing tasks (eg activation, module installation, license transfer and license deactivation) at any time using the *License Management Dialog*, accessible from the Options menu. This is also where you access the manual activation tools (see *Manual Activation*) if you need to do an offline activation (without connecting to the internet).

Activate PhotoModeler Dialog



When you click Enter Activation Code option, the edit box is enabled and you can enter the code supplied by Eos. Your activation code will be on the PhotoModeler box top flap, and/or on the CD sleeve. Keep this code in a safe place in case you need to reinstall and/or re-activate at some point.

Enter the code carefully making sure to enter the correct characters and include the dashes when typing it. If the code was supplied by email, simplest is to copy and paste the code (highlight, Ctrl-C to copy, then Ctrl-V to paste).

Note: If you do not enter an activation code, you can run PhotoModeler in demo mode which allows you to use PhotoModeler, but only with the supplied tutorial imagery. Check the "Do not show this dialog box again" checkbox if you intend to use this as a Demo and do not want to be prompted for your code. If you want to enter your code at a later date, you can use the *License Management Dialog*, accessed from the Options menu.

After you enter the supplied code click Proceed. A confirmation message will appear if activation succeeds.

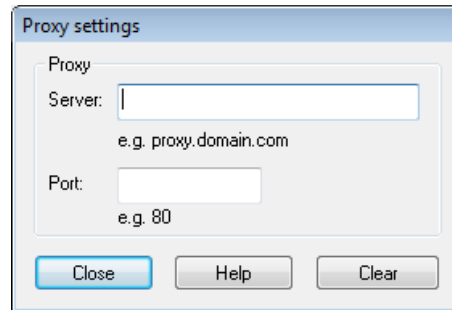
Note: No personal information or information about your computer configuration is sent online during Activation. There is a one-way formula of an internal machine configuration data which is encrypted and then passed to the server with your activation code. The server then locates your license and returns an encrypted registration key which automatically gets installed and authorizes the license on your machine.

PhotoModeler can be activated using the initial *Activate PhotoModeler Dialog*, the *Online Activation and Add Module Dialog*, and *Manual Activation*. You can also move an activated license using the online deactivation, or the *Offline License Move Dialog* (see

Move License to Another Computer). The licensing features can be accessed from the *License Management Dialog*.

If you are having any trouble with activation, see the *Activation Troubleshooting* section.

Proxy Settings



The proxy settings dialog is for users that have an internet connection through a proxy server.

If the Eos online activation server is not accessible via your connection settings (e.g. your firewall prevents access to certain internet sites), and if your network has a proxy setup, you can grant PhotoModeler online access for activation via your proxy.

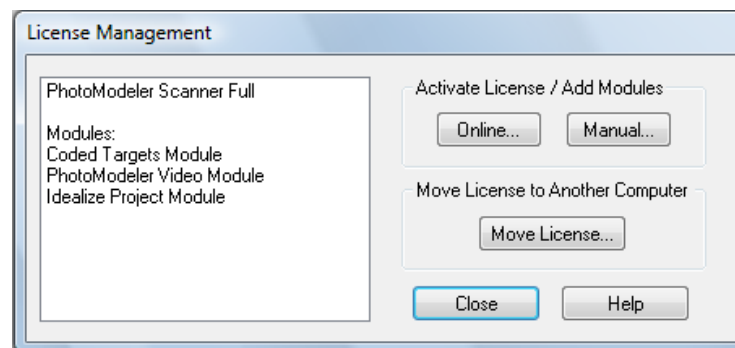
You enter the IP or domain in the 'Server' text box, and the port number in the 'Port' text box.

These Proxy settings are valid for the duration of the PhotoModeler session. Once PhotoModeler is closed, the proxy settings are cleared.

You can also clear the Proxy settings by pressing the Clear button.

Note: Generally PhotoModeler will use the connection settings as set in Internet Explorer and setting up your proxy settings here will typically not be required. However, in rare cases you may need to specify the proxy settings independently of Internet Explorer. You may need your network administrator's help with this if you have a complex network setup.

License Management Dialog



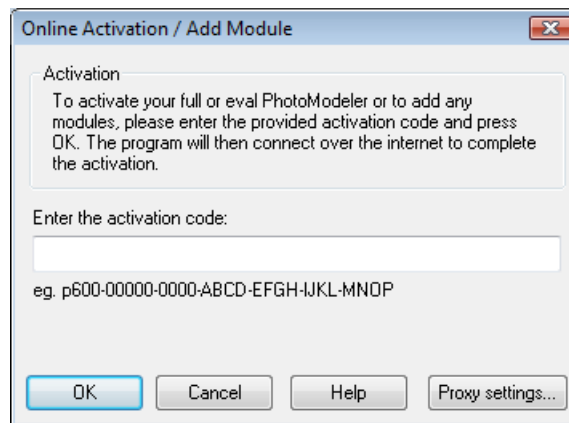
The License Management dialog shows the status of your current license(s), and allows you to perform various licensing tasks.

The area on the left shows:

- whether you are running the demo, trial or full version (PhotoModeler or PhotoModeler Scanner),
- the modules that are installed
- the status of the network license (ie the number of licenses in use on the network)
- the status of any trials and their expiries.

The buttons on the right allow you to activate (the full version or a module) using the online (*Online Activation and Add Module Dialog*) or offline (*Manual Activation*) method. You can also move an activated license using the online deactivation, or *Offline License Move* (see *Move License to Another Computer*).

Online Activation and Add Module Dialog



This dialog can be accessed via the *License Management Dialog*. Use this dialog to activate PhotoModeler or to activate an add-on module. Enter the key as supplied by Eos in the space provided and click OK. PhotoModeler will access the Eos license server over the internet and automatically activate your software.

If you need to access the internet via a proxy, you can enter the settings by clicking “Proxy settings...”. See *Proxy Settings* for more information.

If you do not want to or cannot access the internet from the computer on which PhotoModeler is installed, you can use *Manual Activation* to activate offline/manually.

Manual Activation

The image shows a 'Manual Activation' dialog box with three steps. Step 1 is 'Enter your Activation Code.' with a text field for the 'Activation code:' and notes: 'a) Activation codes look like: p600-00000-ABCD-EFGH-IJKL-MNOP' and 'b) If you have a full PhotoModeler package the activation code can be found on the CD case.' Step 2 is 'Machine ID:' with a text field containing '320573731-39126215' and instructions to contact Eos Systems Customer Support. Step 3 is 'Enter the Registration Key you received (by phone/email or from the Eos web site):' with a text field for the 'Registration Key:'. At the bottom are 'Activate', 'Cancel', and 'Help' buttons.

The Manual Activation dialog provides a way to activate PhotoModeler without necessarily accessing the internet from the computer running PhotoModeler. No information is sent over the internet from this dialog.

The manual activation process involves providing Eos your Activation Code (which is shown on the PhotoModeler box and CD sleeve) and Machine ID (as shown in the Machine ID field). Please be sure to correctly quote your Activation code and dash separated numeric Machine ID in one of four ways:

- the PhotoModeler website (if you have internet access from a different computer) at <http://www.photomodeler.com/order/getlic.php>. This is an automated system and can be accessed 24hours/day
- by email, send an email to support@photomodeler.com
- by telephone
- by fax

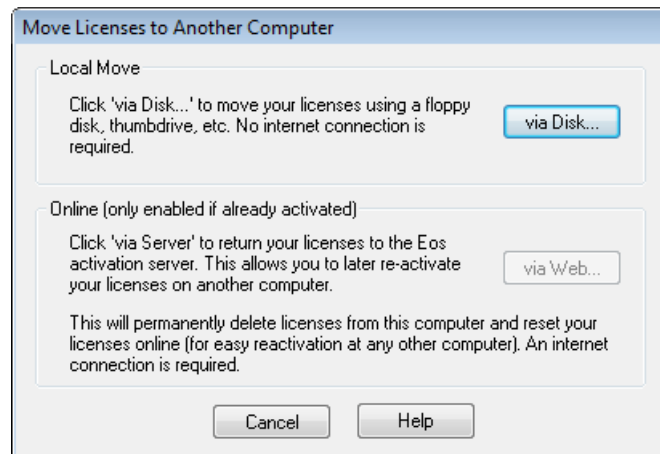
Once your machine ID and activation code are received, Eos will process the information then generate and return to you a numeric key that you enter in the box labeled Registration key. The Registration key will be a dash separated numeric key and will look like similar to this:

79822631-1239874563

We will do our best to process requests as quickly as possible, but note that if you send your information by email, telephone or fax, we can only process it during regular working hours (Monday-Friday, 9am to 5pm PST). The webpage is available 24 hours/day.

Note: If you provide the wrong Machine ID, the generated Registration Key will cause your activation to fail, and you will need to contact Eos to renew your license. If you are using the web page or sending your Machine ID by email, it is safest to use copy and paste (highlight the code and press Ctrl-C, and then Ctrl-V to paste) to avoid typos.

Move License to Another Computer

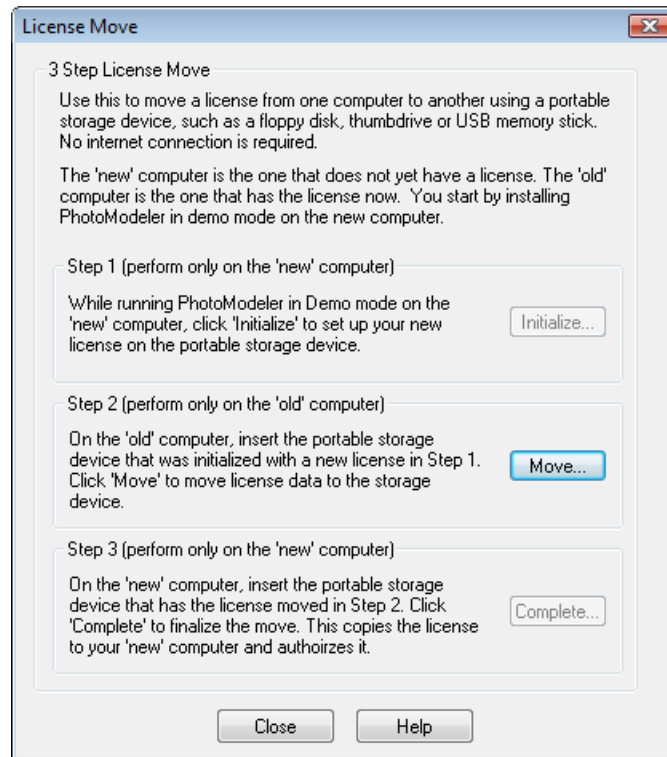


Once PhotoModeler has been activated you can move the activated license to another computer in two ways, via a floppy disk/portable storage, or via the Eos web server. This dialog provides you with the two options:

- Moving via portable disk: Click “via Disk...” to use a floppy disk, thumbdrive or other portable disk to do an *Offline License Move*.
- Deactivation: Click “via Web...” to permanently deactivate the current license. This method resets your license on the Eos license server and frees it so that you can activate on a new computer. An internet connection is required for this option.

If you are running on a network floating license, there are not transfer methods available. See *Network Floating Licensing* for more information.

Offline License Move



The License Move dialog implements the license move process using a floppy disk, thumbdrive or memory stick etc. The process will move a license from the currently licensed computer (ie the 'old' computer) to the unlicensed (ie 'new' computer). The process has 3 steps:

- Step 1: Install PhotoModeler on the 'new' machine. When prompted for activation, select "Run as Demo" to run PhotoModeler in Demo mode. Then open this dialog via the License Management Dialog. Insert the portable disk and click 'Initialize...'. You will be prompted to select a folder on the portable disk in which a temporary license will be written.
- Step 2: On the currently licensed 'old' computer, insert the portable disk containing the initialized license from Step 1. Click 'Move...' and then select the folder containing the temporary license file and the current license information will be copied to the temporary license file initialized in Step 1.
- Step 3: On the 'new' computer, while running in Demo mode, insert the portable disk with the temporary license file and click 'Complete...'. You will be prompted to browse to the folder containing the temporary license file and the license will then be copied to the 'new' computer.

No information is sent over the internet using this method.

Network Floating Licensing

During installation of PhotoModeler with a network floating license, you would have selected a folder on your network as the 'network share' folder. Then when prompted to enter your activation code for the first installation, your license will be set up in that network share folder. Subsequent installations on the network do not need to be activated as they will use the network share folder's license (provided the network share folder has been set up properly during each installation).

Users on the network will be able to run PhotoModeler concurrently up to the number of 'seats' purchased. Your network floating license agreement will determine the number of concurrent PhotoModeler 'seats' that can be running at any given time. After the number of active seats on the network reaches the limit, PhotoModeler will display a warning at start up and will close.

A 'seat' is freed once someone running PhotoModeler shuts it down.

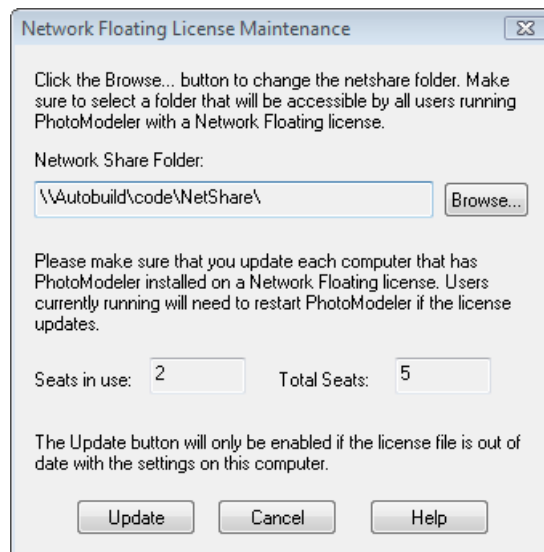
You can view the current status of the network license to check the number of 'seats' in use on the *License Management Dialog*.

If you need to change the location of the Network Floating license due to changes to the network structure etc, use the *Network Floating License Maintenance Dialog*.

If the network connection is lost, you will be prompted at various times while PhotoModeler is running to renew the connection and restore the license. If you cannot renew the license (ie. reconnect to the network share folder), PhotoModeler cannot run and will shut down. If you do restore the connection, you will be able to continue working.

All users on the network need an uninterrupted connection to the network share folder while running PhotoModeler with a network floating license.

Network Floating License Maintenance Dialog



The Network Floating License Maintenance dialog provides a way to move a license if there are changes to the network share location.

The “Update” button will remain disabled until there is a change to the network share folder. Click “Browse...” to select a new folder that will contain the network floating license.

Note that if you change the Network Share folder, each computer running on the Network Floating license must be updated. If other users are running PhotoModeler while these changes are underway, they will lose their license and need to restart PhotoModeler. Each user will need to use this dialog to point to the new network share folder.

For your information, the number of seats in use, and the total number of seats allowed is shown, but of course this cannot be changed. If you need to increase the total number of seats, contact Eos Systems for licensing changes.

Activation Troubleshooting

We trust that this system will be virtually transparent for the majority of customers. However there is always a possibility of something going wrong during the process. This section addresses possible problems:

Firewall

If your firewall is blocking requests, use the following to set up your firewall:

- Main server IP address: photomodeler-act.com
- Port: 80 (Standard HTTP)

Moving PhotoModeler to another machine

Moving PhotoModeler to another computer is a matter of selecting the offline or online method (see *Move License to Another Computer*). The offline method uses a portable disk, while the online method returns license to the server. Both methods allow you to re-activate on a new computer.

No internet connection

An offline activation method is available if you do not have Internet access on the computer where PhotoModeler is installed. If no Internet connection is found during activation, or the activation server is not reachable, a warning message will appear. You may need to set your Proxy settings, or you can choose to manually activate (see *Manual Activation*). This can be via email, phone or using an Internet browser (on a machine that does have Internet access) to visit a special page to generate a registration code.

Code entered but error reported

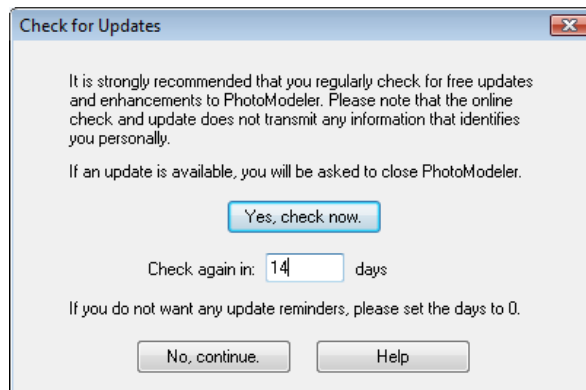
If you are sure that you have entered the code correctly and you still see an error message, the problem may be that PhotoModeler cannot reach the activation server. You may be using a proxy server or have a firewall (Windows XP/Vista firewall, ZoneAlarm, BitDefender, etc.). Make sure you have given permission for PhotoModeler to access the Internet in your firewall or if you are using a proxy server ensure that the proxy server settings are correct in the activation dialog (see *Proxy Settings*).

Error Message shown

When there is a problem at any stage of activation, an error message will be displayed, in most cases specifying the type of problem encountered with an error code. If you cannot resolve the problem, please contact Technical Support quoting your activation code and the exact text of any displayed error codes.

Update Check Reminder

It is important to keep your PhotoModeler up to date. Eos Systems releases free upgrades to improve the program, improve robustness, and add small features. To assist with this update task is the automated update check.



The Update Check Reminder Dialog will appear at regular intervals to ask if you want to check for a more recent version of PhotoModeler. This check uses the Internet to query our server for a more recent version. At any time you can also check for an update without being reminded by clicking 'Options', 'Check For Updates...' on the PhotoModeler menu or by clicking 'PhotoModeler Online Update' on the Start menu. See also the *PhotoModeler Online Update* section.

The first time you run PhotoModeler after installation, the Update Check Reminder dialog will appear asking you to confirm a check for available updates. After that, the dialog will only appear when you start PhotoModeler if you have not checked for an update during the interval period (initially set to 14 days). You can set the interval period on this dialog when it appears, or on the 'General' page of *Preferences - Application Settings*. If you set the interval to 0, the Update Check Reminder dialog will never appear.

To go ahead with the update check, click 'Yes, check now.' PhotoModeler will then find your internet connection, visit the PhotoModeler website and compare versions - this all done in the background. If an update is available, you will be prompted to close PhotoModeler and proceed with the download and installation. If no update is available, you will be notified that you are running the most current version. In either case, the date of the check will be stored and you will be reminded to check again for an update in the number of days shown.

If you do not want to check for an update, click 'No, continue.' The current date will be stored and you will be reminded to check again for an update in the number of days shown.

Privacy and Personal Information

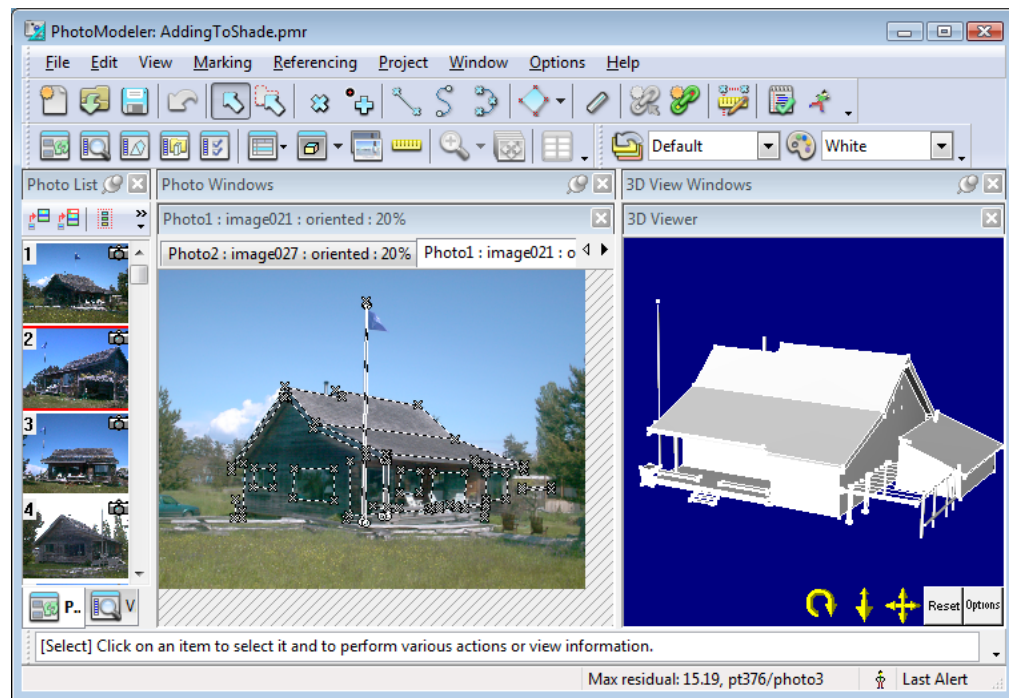
Please note that no personal information is transmitted during the update check procedure. The activation code may be sent to check for license compatibility.

User Interface

PhotoModeler is a program that runs under Microsoft Windows (2000, XP, and Vista). It may also run with most Windows NT, 98 and Me systems also but it is not supported on those platforms. PhotoModeler follows the user interface conventions established by the Windows operating environment.

Elements of the PhotoModeler Screen

PhotoModeler's screen contains: a caption, a main menu, toolbars, a work space, and a *Status Bars*. Optionally there can be other panes visible, such as the *Photo List Pane* as shown below:



Caption Area

The caption area at the top of the application window contains four buttons and a program title. The title contains the program name "PhotoModeler" and the name of the active project.

The caption area can be used to move the entire application around the screen. This is done by pressing the mouse button down on the caption area and holding it down while moving the PhotoModeler window to its new location.

The button (the PhotoModeler icon) on the extreme left of the caption area is the System Box. Double clicking on this button closes the application. Clicking once on this button exposes a menu with standard Windows System Menu choices. These choices allow the user to size, move and close PhotoModeler.

The left-most button in the right group of the caption area is the minimize button. Clicking on it turns PhotoModeler into a minimized bar on the desktop toolbar.

The next button is the maximize/restore button. It can be used to make PhotoModeler as large as possible, or to restore PhotoModeler to its last un-maximized size.

The last button is the "X" close button. It will close/exit PhotoModeler when pressed.

Main Menu

The main menu bar appears immediately underneath the caption area. The entries, on this menu bar, each access a popup menu containing specific PhotoModeler tasks. Selecting a menu choice with the mouse or keyboard causes that task to be started. Not all tasks are always available on the menu. For instance, if you do not have anything selected, the "Delete Selected Items" menu item will be disabled. Menu selections which are not appropriate at a particular time cannot be selected. These inappropriate menu choices are shown dimmed. When these menu items become appropriate PhotoModeler enables them and allows you to select them.

You can also dock and undock the main menu bar. If you move your mouse over the left edge (the gripper) of the main menu bar, the cursor will change into a four arrow cursor indicating that you can move the menu bar. If you click and hold the mouse down while your mouse cursor shows the four arrows, you can drag the main menu bar anywhere on your screen. The main menu bar can be docked at the edges of the screen or 'floating' and undocked. As you move towards the top, bottom, left, or right edges, of the PhotoModeler window, the menu bar will become 'docked' and snap into position. You can also have the main menu bar 'float' anywhere on your screen. You can move or customize the main menu bar at anytime.

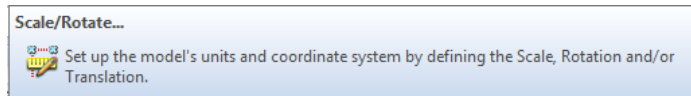
Note that the main menu bar cannot be hidden like the toolbars. However, if you want to add or remove tools from the main menu bar, you can do so using *Toolbar Customization*. See also *Menu/Tool Reference*.

Tools

A tool is used to accomplish a task or set a mode. Tools are represented by graphical buttons on toolbars or menu items under the menus. A tool on a toolbar or menu is used by clicking the left mouse button.

The type of tools available (displayed or enabled) at any one time depends on the project being worked on and the type of window that is active, and in some cases what is selected.

When the cursor is moved over the tool a "tool tip" text message appears to help you remember what each tool does. If you dislike this or the tip causes problems with your system you can turn them off in the *Toolbar Customization* dialog. You can also control whether the short cut key for each tool appears in the "tool tip" using the same customization dialog. Tool tips look like this :



See also *Menu/Tool Reference* for more detail on the types of tools available and what each tool does.

Note: You can also get information about what a tool does by reading the *Status Bars* contents at the bottom of the main PhotoModeler window. As you move your mouse over a tool (either a tool on any of the toolbars or under any of the menus), a brief explanation of the purpose of the tool and its shortcut key (if it has one) is shown on the status bar.

Toolbars

Under the main menu bar are toolbars containing a series of tools. These graphical buttons initiate commonly used PhotoModeler tasks. The *Menu/Tool Reference* lists and describes tools used available in PhotoModeler. This section provides a brief overview of toolbars and the more commonly used tools.

If you click the right mouse button down while over any part of the toolbar or main menu bar, a list of available toolbars is shown. By selecting any of the toolbars in this list, you can toggle the toolbar's visibility on or off. You can also set any toolbar's visibility using *Toolbar Customization*.

There are also options to set up your toolbars based on the type of projects that you commonly do, i.e. *Installable User Interfaces*. See Toolbars and Menus section of *Preferences - User Interface*.

Like the main menu bar, you can dock and undock toolbars. If you move your mouse over the left edge of a toolbar (the gripper) the cursor will change into a four arrow cursor indicating that you can move the toolbar. If you click and hold the mouse down while your mouse cursor shows the four arrows, you can drag the toolbar anywhere on your screen. Toolbars can be docked at the edges of the screen or 'floating' and undocked. As you move towards the top, bottom, left, or right edges, of the PhotoModeler window, the toolbar will become 'docked' and snap into position. You can 'float' your toolbar anywhere on your screen.

When the toolbar is floating, you can hide it by clicking the close button on the top right of the toolbar. To make it visible again, right click anywhere in the menu or toolbar area and select a toolbar to toggle its visibility.

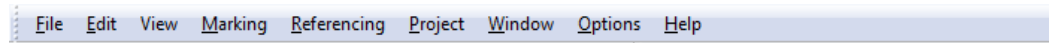
When you first install PhotoModeler, the Standard Toolbar and Modes Toolbar will be visible. Other toolbars will be hidden (hidden toolbars can be made visible by right clicking anywhere in the menu or toolbar area and select a toolbar to toggle its visibility, or using the *Toolbar Customization*).

The toolbars show most commonly used tools for these types of projects and simplify the user interface (all tools shown on toolbars are also available as items on the Main menu; the toolbars provide quick access to the most often used tools).

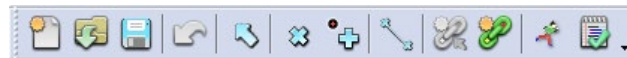
The following shows one of the typical toolbar setups in PhotoModeler:



The top row is the main menu:



Under the menu are the main toolbars:



Under the main menu is the Standard toolbar which contains the following tools (from left to right):

- Getting Started – starts a new project (see *Getting Started Panel*)
- Open Project – open an existing project from disk
- Save Project – save the current project to disk
- Undo the previous action
- Select Items mode – enter the mode where you can select items in photos, tables, 3D viewers
- Mark Points mode – mark points on features in a photo
- Sub-pixel Target mode – mark targets by dragging a region around a target
- Mark Lines mode – draw lines between points
- Quick Reference – reference two or more selected items across photos, tables, 3D viewers
- Referencing mode – reference selected items across photos, tables or 3D viewers
- Process – process the project
- Project Status Report – display project data to gauge quality



To the right of the Standard toolbar is the Layers and Materials toolbar which contains the following tools (from left to right):

- Layers – add, remove, rename layers in the project
- Current Layer – a dropdown box used to assign or set a layer to selected items
- Materials – add, remove, edit materials in the project
- Current Material – a dropdown box used to assign a material



Under the Standard toolbar is Open Views toolbar which contains the following tools (from left to right):

- Photo List – shows the *Photo List Pane* from which you can open photos
- *Visibility on Photos* - shows visibility pane on which you can set what items appear on photos

- Shapes Explorer – shows the *Shapes Explorer* pane from which you can add or edit shapes in a project
- *Imports Explorer* – shows the Imports Explorer pane from which you can add or edit imported items in your project
- Properties – toggles the visibility of the *Properties Pane* which displays various properties of selected items
- Tables – shows a dropdown list of table related tools to generate or open various tables (see *Tables*)
- Open a 3D View – opens a new *3D Viewer* in the 3D Viewers pane
- Enhance Image – toggles the visibility of *Enhance Image Pane* which allows you to modify the display of photos
- Measurements – shows the Measurements Pane which displays measurement information about selected items (see *Measuring Features*)
- Photo Zoom tools – a dropdown list of various zoom and pan actions to be used on photos
- Zoom to Fit All – used to adjust the zoom of all open photos so that they fit and are fully visible in their photo windows
- Tile Active Pane – tiles all windows in the active pane

See *Menu/Tool Reference* and *Preferences* for more information on tool functions and how to set up a new user interface.

Note: Toolbars are fully customizable. See *Toolbar Customization*.

Also Note: You can remind yourself about the function of tools by placing the mouse cursor over a tool and reading the 'tooltip'.

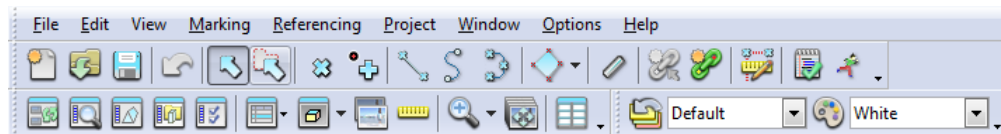
Installable User Interfaces

To improve work flow specific to certain project types, PhotoModeler has a set of Installable User Interfaces. These are toolbar layouts that group project type specific tools while (by default) hiding others that are not typically used. Menus also optionally hide less common tools.

You set the User Interface type (and menu item hide delay) on the Toolbars and Menu page of *Preferences - User Interface*. The options are *Type 1: Full*, *Type 2: Points Projects*, *Type 3: Shapes Projects*, *Type 4: Road Scene Projects*, *Type 5: Other Projects*.

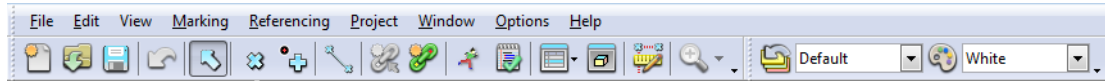
Type 1: Full

The 'Full' type shows a full set of tools on the toolbars and menus always display as expanded to show all menu items:



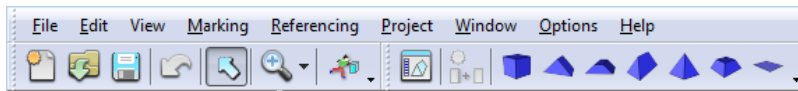
Type 2: Points Projects

The 'Points' type shows the set of tools most commonly used for points projects and menus always display as expanded to show all menu items:



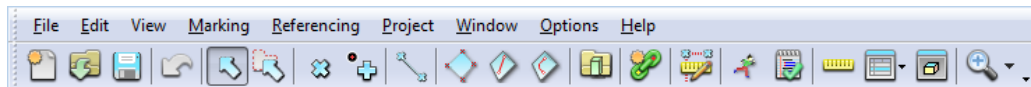
Type 3: Shapes Projects

The 'Shapes' type shows the set of tools most commonly used for shapes projects and menus by default initially display with hidden items:



Type 4: Road Scene Projects

The 'Road Scene' type shows the set of tools commonly used for road scene projects. Menus always display as expanded to show all menu items. This type displays the simplest tool set and also allows for maximizing your application screen space for photo, table or 3D View pane display:

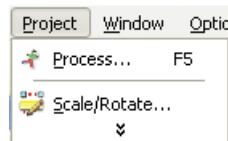


Type 5: Other Projects

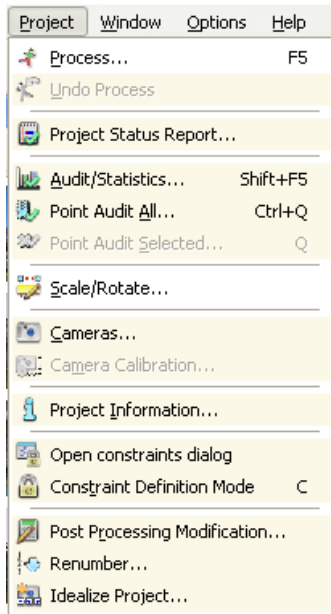
This type is the same as *Type 1: Full*. It is included in case you want an addition user interface type for special customizations.

Hidden Menu Items with User Interfaces

This also provides a way to simplify the tool set which helps you quickly find the tools you need. For example, the Road Scene Project and Points Project type hide some less common menu items. For example, the project menu below shows items hidden:



but if you hold the mouse over the menu for a few moments, or if you click the expand button (down arrow) the menu expands to show all items (those previously hidden are shaded in yellow):



Note: You can optionally choose to always show expanded menus in these user interface types on the 'Other' tab of the *Toolbar Customization* dialog.

Customizing Installable User Interfaces

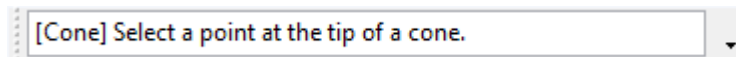
Toolbars, menus, keyboard shortcuts can be customized, regardless of the user interface type currently loaded, using *Toolbar Customization*.

Toolbar customizations are stored when PhotoModeler exits. See *Application Data and File Locations* for information on the location of stored layout files.

Note: Customizations are stored per installed user interface. For example, if you load the Shapes Projects User Interface type and make changes to the toolbar layout or keyboard shortcuts etc, these customizations are stored with the Shapes Projects User Interface type. The customizations will not apply to other types. This allows you to have several customized layouts based on your project work preferences.

Instruction Bar

The Instruction Bar is a toolbar that provides instructions to the user based on the current mode and state the program is in.



The tool is a long text box on its own toolbar. It can be made visible or hidden by right clicking on the toolbar area and checking the check box next to "Instruction Bar". This toolbar (like all toolbars) can be docked along the top, sides or bottom of the main window or it can be 'floating' within the main window by clicking and dragging its handle at the left

edge of the toolbar. When docked on the side the text will not show so it is not useful in that configuration.

The bar's width can be set by changing the ini setting called InstructionBarTextBoxWidth in the [General] section of the program's initialization file (see [Application Data and File Locations](#) for information on where the ini file is stored on disk). When set to -1 the bar will be full application width.

The instructions will change as you enter different modes. Within a mode that requires multiple steps (such as creating a Loft Surface), the instructions will change to help with the next step.

If instructions are not available for a particular mode, the Instruction Bar will be blank.

Other Toolbars

Other toolbars are available but are hidden from view by default:



The Surfaces toolbar includes all tools found under the Surfaces submenu. This toolbar provides quick access to the many surfacing tools available in PhotoModeler.



The Photo Zoom/Pan Tools toolbar includes tools to perform common actions on photos, such as zooming in or out, resetting zoom, panning etc.



The AutoTools toolbar includes tools commonly used for PhotoModeler's automated features: AutoMarking, AutoReferencing, Weld and Automark.



Pane Tools toolbar includes tools commonly used to interact with windows in a pane, such as tiling, maximizing, splitting vertically/horizontally.



Add Shape Tools includes the tools used to add shapes to a project and add shape relations.

Note: Any toolbar can be set to hidden or visible. You can also add or remove tools from toolbar, using Toolbar Customization.

Also note: There are options to set up your toolbars based on the type of models you do, using [Installable User Interfaces](#). See also [Preferences - User Interface](#)

Toolbar Customization

Any of PhotoModeler's toolbars or its menu bar can be customized. This means you can add/remove buttons to/from any toolbar or the main menu bar. You can also create your own toolbars on which you can place tools you most often use.

There are two ways to open the Toolbar Customization dialog. You can click the "Customize Toolbar..." button under the Options menu on the main menu bar. You can also right click anywhere on a toolbar or menu bar and select the "Customize..." option.

Note that while in Customization mode, no tools will function in PhotoModeler. Also note that when you exit PhotoModeler, your toolbar and menu positions and customized settings will be saved so that when you next open PhotoModeler, your customized user interface will be restored. These settings are stored in XML files on disk (see *Application Data and File Locations*). A separate set of customizations is stored for each toolbar type, corresponding to the active project type toolbar when customized (see *Installable User Interfaces* and *Preferences - User Interface*).

The toolbar customization dialog has four tabs: Toolbars, Commands, Keyboard, and Options, as described in the following sections.

Toolbars

This tab shows a list of available toolbars. The column of checkboxes to the left of the toolbar names indicates the current visibility. You can toggle the visibility of any toolbar (except the Menu Bar) by checking or unchecking the box next to the toolbar. To create a new toolbar click the "New..." button and give the new toolbar a name. To delete a toolbar, select the toolbar to delete and click "Delete" (note, this will delete your toolbar from the configuration permanently). To rename a toolbar, click the "Rename..." button and rename the toolbar.

Commands

This tab shows all of the customizable tools in PhotoModeler. The categories refer to the main menu bar menu items, such as File Edit, Marking. The Commands window at right shows the tools in each of the categories. Not all tools are shown here, since certain tools only appear in certain conditions (e.g. PMV tools only show when a PMV project is open). Therefore only tools that apply to all project types can be customized.

To place a tool onto a toolbar, click and drag a tool from the Commands window into position on a toolbar in the PhotoModeler window.

To remove a tool from a toolbar, click and drag a tool from the menu or toolbar and move it off the toolbar. Once a small "X" appears on your mouse cursor, release the mouse button. The tool will no longer be visible on your toolbar but it will remain in the list of available tools in the Command window should you wish to restore it.

To move a tool from toolbar to toolbar or to/from the main menu bar, simply click and drag the tool into its new position while you have the Customize Dialog open.

Keyboard

Keyboard shortcuts are one, two or three key combinations that duplicate an operation that can also be initiated by a menu selection or a toolbar choice. Some frequently used operations in PhotoModeler can be accessed more easily by using keyboard shortcuts.

For instance, if you wish to undo your last action you can hold down the control key while pressing the letter "z".

Shortcut keys are specified for some of the more common menu choices. These shortcuts are displayed next to the menu selection that they access.

The shortcut keys can be customized as you see fit, and this is where it is done.

This tab shows all of the customizable tools in PhotoModeler, categorized as in the Commands section. It allows you to assign keyboard shortcut to any of the customizable tools. The complete list of default (before customization) shortcut keys is given in the section *Keyboard Shortcut Reference*.

PhotoModeler is installed with a default set of keyboard shortcuts but you may wish to change those shortcuts to match your particular need or to match another similar piece of software. Most m

To set a shortcut, select the command at left, click the Press new shortcut key edit box to activate it, then press the desired key or combination of keys on your keyboard, then click Assign. The shortcut will appear in the Key assignments list. A warning message appears if the shortcut is used already, giving you the option of overriding it or canceling the assignment. To remove a key assignment, select the shortcut in the Key assignments list and click the Remove button. To restore shortcuts to factory defaults, click Reset All.

Options

This tab allows you to set various personal options for the look of your toolbars. You can set the whether icons are large (i.e. double the normal size), whether to show "tool tips" (called ScreenTips) on toolbars (i.e. a text message with an icon appearing at your mouse cursor when your mouse is over a tool briefly describing the purpose of the tool), whether the ScreenTip shows the tool short cut key, and the style of menu animations (i.e. the style of graphical animation that the menus use when activated). If your toolbars hide tools that are not used often, you can also reset usage data to show all tools without delay. You can also select the type of menu animation on this dialog.

Workspace


The workspace is the area used to open photographs, 3D Views and Tables. It is empty when PhotoModeler is started. The workspace can contain many tiled or overlapping windows or panes or icons. See also *Paned Interface*.

Status Bars

The status bar is the space at the bottom of the PhotoModeler screen reserved for messages. It displays information about the currently selected items (in this example a point was selected on a photo, and the mouse cursor is over a photo and automatic processing is off):

Photo Mark: x:561.4, y:673.4 pixels, residual:0.20(0.05,-0.19) pixels (non sub-pixel) Max residual: 24.03, pt73/photo8 1172, 864

Or, when the mouse is over a tool on the toolbar, it shows a brief description of the tool (in this example, the mouse cursor is over the Mark Points tool, processing is underway, and the Last Alert is available so that when clicked the most recent Alert Popup will display, see *Alert Popups*):

Mark points on targets or features in a photo. Note that points must be referenced to get a 3D position.  Last Alert 

When hovering the mouse cursor over various sections of the toolbar, tooltips are shown to briefly describe the information shown. Note that when selected item data is shown on the status bar, hovering the mouse over that part of the status bar will show the text also in the tooltip window. This is so that even if screen resolution or application window size is too narrow, you can still display the information without any text hidden or cut-off from view.



Also, some parts of the status bar are clickable (see below).

There are also sections on the status bar reserved for Project status showing data for the point with the highest residual, the state of automatic processing (a running icon when automatic processing is on, a standing icon when off, also the icon displays action symbol during project processing), and the 2D position of the mouse cursor when over a photo.

When the project status section of the Status Bar is clicked, a tool menu appears which when clicked shows the photo and selects the point mark with the highest residual (and the photo is brought to the front). This feature is only enabled while in select mode.

You can toggle *Automatic Processing* by clicking the Automatic Processing icon.

When a single item is selected in the model, the status bar will show information about that one item. These single-item status bars are described below. When more than one item is selected the status bar simply shows the count of each item type. For example this status bar shows that 3 marked points, 1 curve and 1 line are selected, that the maximum residual is 0.53 for point 95 on photo 4, that automatic processing is on (running processing man) and the mouse cursor is over a photo at a position of (584,588):

Selected - marked points:3, curves:1, lines:1 Max residual: 0.53, pt95/photo4  584, 588 

Marked Point Status Bar

Photo Mark: x:<x>, y:<y> pixels, residual:(<vector> <x-resid>,<y-resid>) pixels (<sub-pixel type>)

- <x>,<y> is the position of the selected point on the photograph image in pixels. (0,0) is upper left corner.
- <vector> is the residual error of the project 3D object point as a vector (the smaller the better).
- <x-resid>,<y-resid> is the *residual* error of the projected 3D object point in pixels (the smaller the better).
- <sub-pixel type> indicates whether the point has been marked with one of the sub-pixel marking tools, and if so, which one.
- At the end of the mark status bar is the 3D Object Point status bar (see below) for the Object Point associated with the selected Marked Point

3D Object Point Status Bar

Object Point: ID :<ID>, tightness:<tightness>%, on photos used <photos>, unused <unused photos>.

- <ID> is the *Point ID* of the point
- <tightness> is the % projection error for this point (smaller is better)
- <on photos used> is the list of photos that this point is marked on
- <unused photos> is the list of photos that this point is marked on that are not used in processing

Control Mark Status Bar

Control Point Mark: name:<name> x:<x>, y:<y> pixels, residual:(<x-resid>,<y-resid>) pixels

- <name> is the name of the underlying Control Point as seen in the *Imports Explorer*
- <x>,<y> is the position of the selected point on the photograph image in pixels. (0,0) is upper left corner.
- <x-resid>,<y-resid> is the *residual* error of the projected 3D object point in pixels (the smaller the better).
- At the end of the mark status bar is the 3D Object Point status bar (see above) for the Object Point associated with the selected Control Mark

Fiducial Status Bar

Fiducial Mark: name:<name> x:<x>, y:<y> pixels

- <name> is the name of the Fiducial given by the user
- <x>,<y> is the position of the selected point on the photograph image in pixels. (0,0) is upper left corner.

Surface Status Bar

Surface: ID:<ID>, <3D>, material:<mat-name>, layer:<layer-name>, num triangles: <nt>, type: <type>

- <ID> is the identification number of this surface (a unique number among all surfaces)
- <3D> flags whether the surface has 3D position (i.e. can appear in the 3D Viewer and projections). Says 'not 3D' if the selected surface cannot be computed with 3D position and shape.
- <mat-name> is the name of the material assigned to this surface
- <layer-name> is the name of the layer this surface is assigned to
- <num triangles> is the number of triangles in the Surface. For a three point surface this will equal 1, for a four point surface it will equal 2, and for other surfaces 0 (Surface shape cannot be computed) or N (where N is the number of triangles used to compose the overall surface)
- <type> is the type of the selected Surface (such as "Defined by a path", or "Loft", etc.

Surface Draw Point Status Bar

Surface Draw Point: x:<x>, y:<y> pixels Object Point: ID:<id1> Surface ID: <id2>

- <x>,<y> is the position of the selected point on the photograph image in pixels. (0,0) is upper left corner.
- <id1> is the ID number of the underlying Object Point
- <id2> is the ID number of the associated Surface

Note: If a surface draw point is selected in the 3D Viewer, no XY location is shown.

Line Status Bar

Line: point ID's:(<id1>,<id2>), material:<mat-name>, layer:<layer-name>

- <id1>,<id2> are the ID's of the points that make up the line
- <mat-name> is the name of the material assigned to this surface
- <layer-name> is the name of the layer this surface is assigned to

Cylinder Mark or Cylinder Object Status Bar

Cylinder: ID:<ID>, dia:<diameter>, len:<length>, cl:(<x>,<y>,<z>), angle:<angle>, error:<err>%, material:<mat-name>, layer:<layer-name>, on photos used: < on photos used> unused <unused>.

- <ID> is the ID number of the Cylinder object
- <diameter> is the diameter of the computed cylinder object
- <length> is the length of the computed cylinder object
- <x>,<y>,<z> is the vector of the center line of the computed cylinder
- <angle> is the worst angle between photographs that image this cylinder (larger is better)
- <err> is the percentage error of the cylinder calculation (smaller is better)
- <mat-name> is the name of the material assigned to this cylinder
- <layer-name> is the name of the layer this cylinder is assigned to
- <on photos used> is the list of photographs the Cylinder's mark appears on.
- <unused> is the list of unused photographs the Cylinder's mark appears on.

Curve - open Status Bar

Curve: ID:<ID>, <3D>, <is planar> on photos used <p1> unused <p2>.

- <ID> is the ID number of the Curve object
- <3D> indicates if the curve has a valid computed 3D position and shape.
- <is planar> appears if the curve is set to "planar" (which means the curve is projected onto the best fit plane so as to make it perfectly flat). A curve can be set to planar by checking the "planar" checkbox in the curve's properties. <is planar> will not appear in the status bar if the curve has not been set to "planar".
- <p1> is the list of photographs the Curve's mark appears on.
- <p2> is the list of unused photographs the Curve's mark appears on.

Curve - closed Status Bar

Closed Curve: ID:<ID>, <3D>, <is planar/circle> on photos used <p1> unused <p2>.

- <ID> is the ID number of the Curve object
- <3D> indicates if the curve has a valid computed 3D position and shape.
- <is a circle> appears if the closed curve is set to "circle" (which means the closed curve is projected onto the best fit plane and then fit to a circle). A closed curve can be set to a circle by checking the "circle" checkbox in the curve's properties. A circle is planar by

definition so the status bar will not indicate that the closed curve is also planar. "is a circle" will not appear in the status bar if the closed curve has not been set to "circle". If the curve is planar but not a circle then this says "is planar".

- <p1> is the list of photographs the Curve's mark appears on.
- <p2> is the list of unused photographs the Curve's mark appears on.

Edge Status Bar

Edge: ID:<ID>, <3D>, angle: <angle> on photos <p1> unused <p2>.

- <ID> is the ID number of the Edge object
- <3D> is the string "3D" (which means the Edge has a correct 3D position) or "not 3D" (which means the Edge cannot be computed in 3D - either not on enough oriented photos or the angle is too low).
- <angle> the maximum angle between the Edge Mark projection planes that define the Edge. The closer to 90 degrees, the better. When angle is too small the Edge cannot be computed or if it is computed it will be inaccurate.
- <p1> is the list of photographs the Edge's mark appears on.
- <p2> is the list of unused photographs the Edge's mark appears on.

Camera Station in 3D Viewer and Projections Status Bar

Camera Station: ID:<ID>, user name:<name>

- <ID> is the ID number of the camera station
- <name> is the name of the station's photograph given by the user

Imported Control Point in 3D Viewer or Projections Status Bar

Input Control Point:: name:<ID> x:<x> y:<y> z:<z> <units>

- <ID> is the name of the imported control point
- <x>,<y>,<z> is the real world 3D position that was imported
- <units> is the units of the x,y,z position.

Imported Control Line in 3D Viewer or Projections Status Bar

Input Control Line:: pt1:<id1> to pt2:<id2>

- <id1> and <id2> are the names of the imported control points this control line connects.

Alert Popups

Alert Popups are small warning or alert messages that appear at certain times in the bottom right corner of the PhotoModeler application window. These messages replace some warning dialogs (which means less disruption as they can be ignored), but also display useful feedback such as:

- the result of *Automatic Processing* or when it has been enabled or disabled
- when units have changed
- when a point mark residual is high
- when inverse camera settings have changed

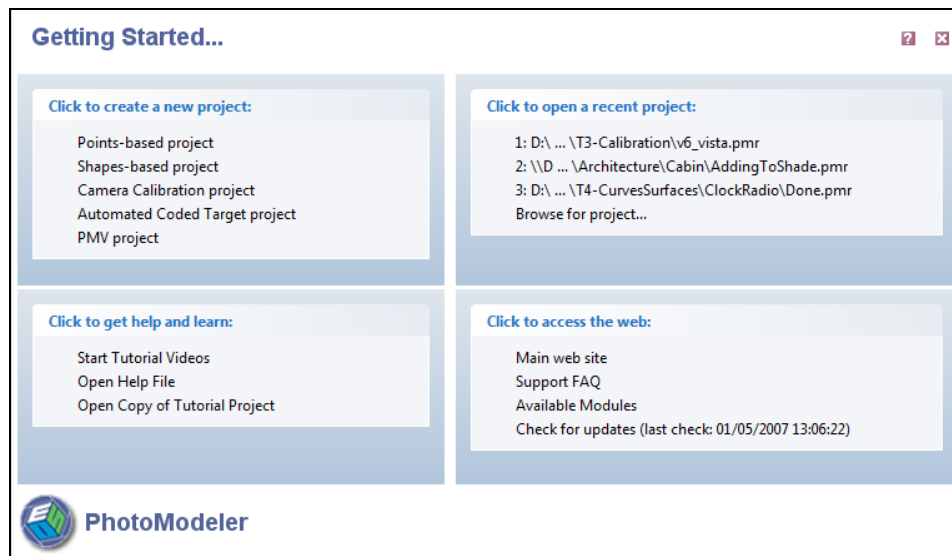
- when there have been certain processing problems
- when a point is marked outside of the camera's point coverage boundary

The alert popup will show for a few moments and then automatically scroll out of view. The popup will remain up while the mouse cursor is placed over it. You can also redisplay the most recently shown popup by clicking the "Last Popup" section of the *Status Bars*.

Some alert popup preference settings can be found in *Preferences - Processing and Cameras* on the Process page.

Getting Started Panel

The Getting Started Panel appears when the program is started or when the Getting Started tool is chosen. The Getting Started Panel is the main interface in PhotoModeler for loading projects and starting new projects but also provides convenient access to the tutorials and help resources, recent projects, and the PhotoModeler web site.



There are 4 sections to the dialog: 1) Create a new project, 2) Open a recent project, 3) Get help and learn and 4) Access the web

Create a new project

The first step in creating a new project is to decide what type of project you will be creating. Options include: Points-based, Shapes-based, Camera Calibration, Automated Coded Targets (if Coded Target add-on module is installed) and a PMV project (if the PhotoModeler Video add-on module is installed). See *Creating a New Project* for information on the steps to create projects of these types.

Open a Recent Project

This section provides quick links to reopen recently saved projects, as well as a tool to browse for projects on disk. Note that no project paths will appear in this section until at least one project has been saved.

Get Help and Learn

There are some great resources available to assist you in learning PhotoModeler:

- **Start Tutorial Videos:** Installed tutorials cover many basic and advanced PhotoModeler techniques. Watching tutorial videos is a great way to familiarize oneself with the user interface and many of the tools and features of PhotoModeler.
- **Open the Help file** – the Help file contains instructions on the PhotoModeler tools and features, as well as definitions and background information on photogrammetry in general.
- **Open Copy of Tutorial Project** – probably the best way to learn PhotoModeler is by working on real projects. The quickest way to interact with an example project is to open one of the installed tutorial projects and see how it was constructed. This option creates a copy of the tutorial project and allows you to edit and experiment with it without the worry of overwriting the original project.

Access the Web

The PhotoModeler web site has useful information on program updates and announcements as well as various pages on modeling tips and project examples. This section provides quick links to the PhotoModeler web site, a list of frequently asked questions, and information on add-on modules. This section also provides a quick way to check if you are running the latest version (see also the *PhotoModeler Online Update* section).

User Interaction

The user interacts with PhotoModeler by using a mouse to point at things and the keyboard to enter information. "Selection" is a key concept in PhotoModeler and is described below.

The Mouse

The mouse position is represented by a cursor which tracks its movement on the computer screen. PhotoModeler changes the shape of this cursor to represent the currently selected tool. Most operations require a single click of the left mouse button but occasionally the right button is used. In this document reference to a mouse button click will always mean the left mouse button unless indicated otherwise.

Some operations may require that the left mouse button be pressed and held down while the mouse is moved. This is called a "drag" operation.

The left mouse button is also used to select menu choices and to depress toolbar buttons. The right mouse button is used to bring up menus and if the user so desires to cancel

continuous operations such as line draw, edge draw, curve draw or referencing point advance.

See also *Mouse Button Reference*.

Selecting Items in a Window

Many operations in PhotoModeler work on "selected" items. You select these items and then perform the operation on the selection set. Move, delete, scale, rotate and measure are some of the operations that work with selected items.

Selection is usually done with a mouse but some operations for selection can be processed through menus and the keyboard.

See the section, *Selection and Visibility*, for more detail.

Undoing Changes

Sometimes when editing a project you inadvertently make a change which is different from what you had intended. If you make this type of change, the "Undo" facility will restore your project to the state it was in before you made the change.

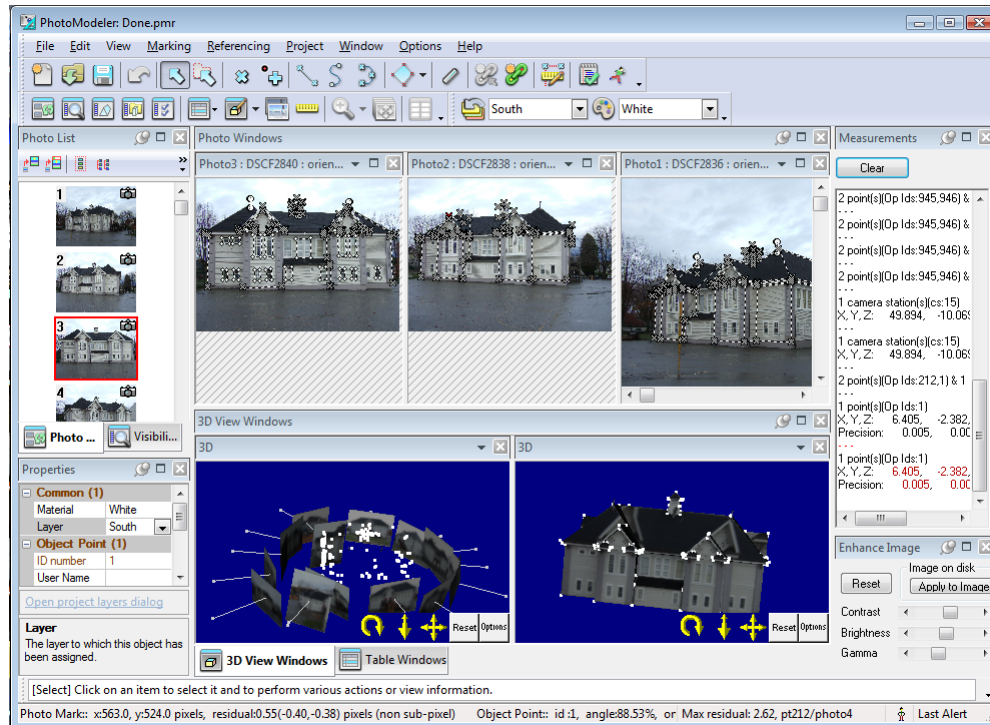
To undo a change, select "Undo" from the Edit menu. PhotoModeler will undo the effects of your last change and update the computer's display. The "Undo" tool icon changes to a "Redo" icon and when clicked will redo the change that was just undone.

Not all changes can be undone. If a change can be undone, the Undo menu item is selectable, otherwise it will be dim.

Working with Windows and Panes

Paned Interface

Several "Panels" are used in PhotoModeler to help organize your workspace by grouping windows of the same type: Photographs, 3D Viewers, Tables and various other information and action panes. Much of the interaction between the user and PhotoModeler will take place through these panes.



The example above shows the PhotoModeler application with several panes showing, including the Photo List (tabbed with Visibility on Photos), Photo Windows (containing three photos), Measurements pane, Properties pane, 3D View Windows (containing two separate 3D Views), and Enhance Image. Each of these panes is described below. This screen shows just one example of how panes can be laid out in PhotoModeler. There are many layout possibilities.

The layout of panes is very interactive as you can position all of your panes into many different configurations, which can be adjusted to best suit your workflow. See [Pane Interaction](#).

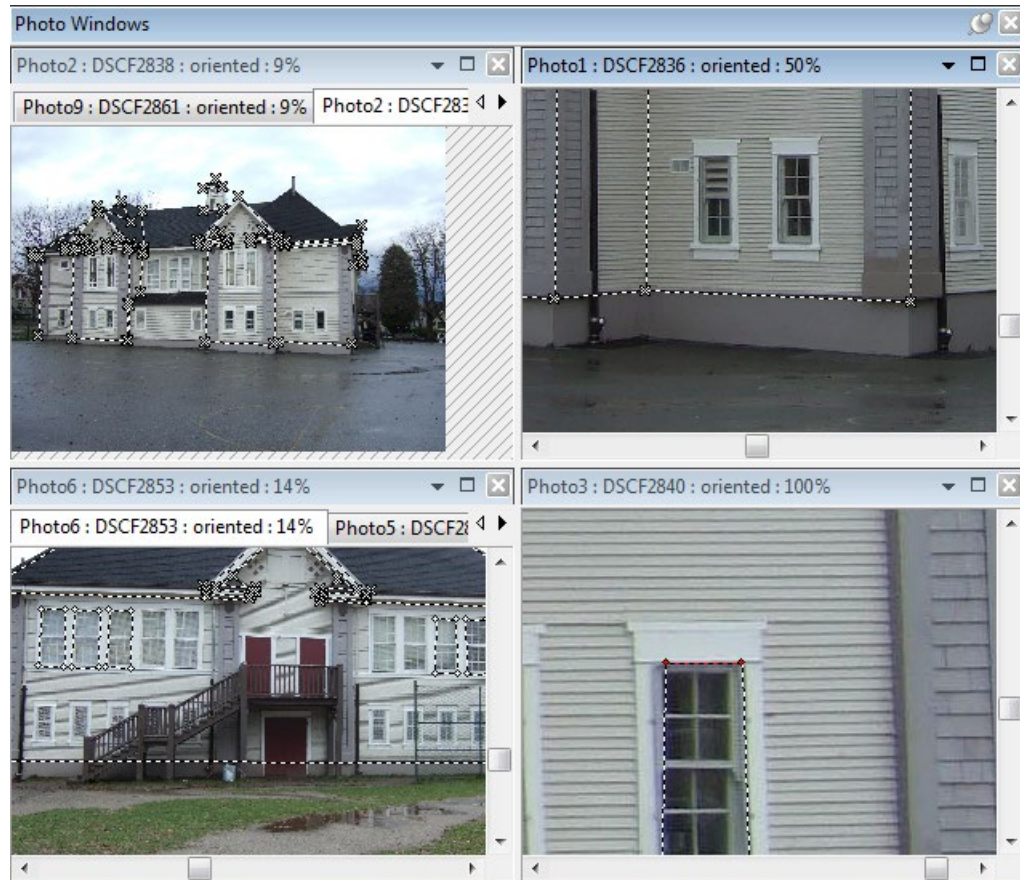
The main pane types are Photo Windows, 3D View Windows, Table Windows, and Other Action and Information Panes. See [Description of Panes](#).

Description of Panes

Below is a brief description of each of the pane types. In each section, examples of various ways to display sub-panes within main panes are shown.

Photo Windows

Open photographs will always be contained in the Photo Windows main pane. The main Photo Windows pane can be docked, pinned, moved etc. anywhere on your screen, as described in the [Pane Interaction](#) section. Photo Windows contain the collection of open photograph windows. A Photograph Window displays one photograph. It is used to mark the features of the 3D model.



The example above shows 6 photos open in the Photo Windows pane. Notice how you can tab photos on top of each other (two sets of tabbed photos at left) while other photos stand alone. See [Pane Interaction](#) for information on how to adjust your pane layouts.

Photograph windows within this pane can be repositioned by dragging their title bar, but must remain within the Photo Windows main pane.

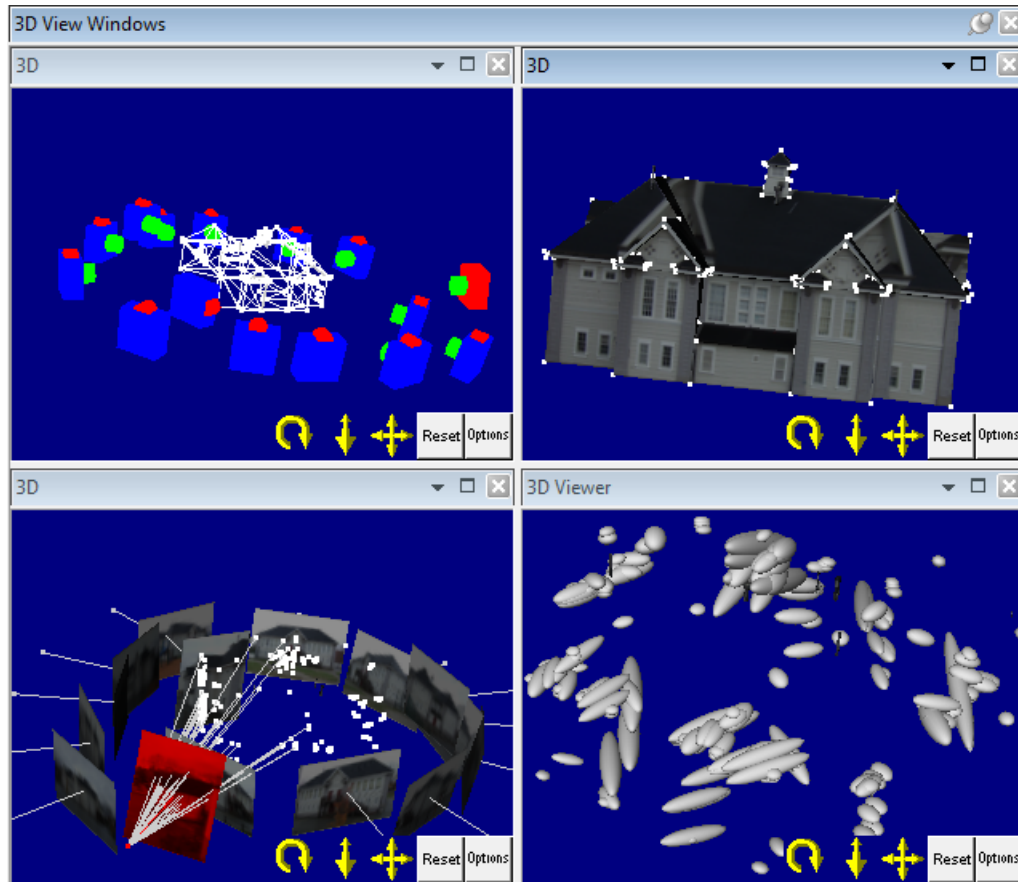
Clicking the small down arrow at right on the photo pane title bar will reveal a menu containing common pane interaction tools such as Maximize/Tab, Tile etc. These and the tools on the main Window menu (e.g. Tile, Maximize etc), as well as the tools on the Photo Windows submenu of the Window menu apply to these photo window subpanes.

Use the Alt-F6 shortcut to switch between photo windows, if multiple photos are opened.

3D View Windows

The 3D View Windows main pane can be docked, pinned, moved etc. anywhere on your screen, as described in the [Pane Interaction](#) section. 3D View Windows contain the collection of open 3D Viewer windows. A 3D Viewer is used to display the processed 3D

data in graphical form. Open 3D Viewers are always contained in the 3D View Windows pane.



In the example above, the 3D Views pane contains four separate 3D Views, each displaying the model with different options (see [3D Viewer Options Dialog](#)).

3D Viewer windows within this pane can be repositioned by dragging their title bar, but must remain within the main 3D View Windows pane. 3D Views can be positioned next to each other (as in the example) but can also be tabbed as shown in the Photo Windows pane example. See [Pane Interaction](#) below for information on how to adjust your pane layouts.

Clicking the small down arrow at right on the 3D View pane title bar will reveal a menu containing common pane interaction tools such as Maximize/Tab, Tile etc. These and the tools on the main Window menu (e.g. Tile, Maximize etc), apply to these 3D View subpanes within their parent pane.

Use the Alt-F6 shortcut to switch between 3D View windows, if multiple 3D Views are opened.

Table Windows

The Table Windows main pane can be docked, pinned, moved etc. anywhere on your screen, as in the *Pane Interaction* section. Table Windows always contain the collection of open tables (e.g. Point, Photo, Curve, etc). *Tables* are used to display the processed 3D data in spread-sheet form.

Table Windows

Point table - Quality

Id	Name	RMS Residual (pixels)	Larg Resic (pi...	Photo Largest Residual	Photos	X Precisi...	Y Precisi...	Z Precisi...	Tightne (m)	Angle (deg.)	Use In Proces...	F
212		2.2914...	2.6235...	4	3,4,12	0.0062...	0.0060...	0.0036...	0.0198...	71.403...	yes	n
2		1.2766...	2.5996...	1	1,3,2,4...	0.0050...	0.0045...	0.0030...	0.0157...	81.447...	yes	n
218		1.9395...	2.5166...	2	1,3,2	0.0058...	0.0120...	0.0052...	0.0157...	60.840...	yes	n
172		1.7640...	2.5027...	3	3,4,8,13	0.0070...	0.0123...	0.0062...	0.0224...	69.794...	yes	n
239		1.8540...	2.4749...	15	14,11,15	0.0088...	0.0070...	0.0043...	0.0270...	81.572...	yes	n
124		1.8929...	2.4471...	13	8,7,13	0.0129...	0.0163...	0.0059...	0.0125...	36.029...	yes	n
8		1.3506...	2.3894...	14	1,3,2,4...	0.0049...	0.0044...	0.0031...	0.0179...	87.182...	yes	n

2D Point table - All

Objec Point ID	Photo #	X (pixels)	Y (pixels)	Residual X	Residual Y
17	10	131.50...	1441.5...	0.1266...	1.0334
17	14	1105.5...	1641.0...	-0.501...	-0.476
17	15	1888.0...	1048.0...	0.0821...	0.1395
Object Point ID: 18					
18	1	304.50...	1515.5...	1.3950...	0.5399
18	2	174.00...	1372.5...	-1.464...	0.0463

Photo table - Main

Photo #	Image Chip	Description	Oriented
1		DSCF2836	yes
2		DSCF2838	yes

3D View Windows **Table Windows**

Tables within this pane can be repositioned by dragging their title bar, but must remain within the Table Windows pane. In the example above, three tables are contained in the Table Windows pane. The Point Table at left is docked beside two tabbed tables (2D Point table and Line table). Also notice that the Table Windows pane is tabbed with the 3D Views pane which provides a quick way of switching between 3D View and Table display, without having to close/reopen. Provides an efficient usage of screen space.

Clicking the small down arrow at right on the table pane title bar will reveal a menu containing common pane interaction tools such as Maximize/Tab, Tile etc. These and the tools on the main Window menu (e.g. Tile, Maximize etc), apply to these Table subpanes within their parent pane.

Use the Alt-F6 shortcut to switch between table windows, if multiple tables are opened.

Other Action and Information Panes

Other panes are used to display the various information (e.g. *Measurements Pane*, *Properties*) and also provide the interface for various actions (e.g. *Photo List*, *Shapes Explorer*, *Imports Explorer*, *Enhance Image Pane* etc.). Many of these panes have their own toolbar to perform various actions. See the sections below for a description of these other panes.

Photo List

Please refer to the *Photo List Pane* section for details on this pane.

Visibility on Photos

The Visibility on Photos pane contains various tools used to control what and how items are displayed on photos. Tools are grouped and each panel in the pane can be hidden or expanded to reveal type specific controls.

The Visibility on Photos pane has its own toolbar to control which panels are shown, and also has tools to show/hide all or none of the 2D and or 3D items in photos.

See *Visibility and Selection Control* for details on this pane.

Properties Pane (overview)

The Properties pane shows type specific information about selected items. When an item (e.g. point line etc.) is selected in a photo table or 3D Viewer, the property sheet of the selected item is displayed, which shows data like Material, Layer, ID number etc. When multiple types of items are selected, the Properties pane will show common properties as well as the data specific to the items selected. When a cell is clicked, a description of that property is shown at the bottom of the pane.

See *The Objects That Make Up a Model* for details on the information displayed on this pane when certain items are selected.

Shapes Explorer Pane

The Shapes Explorer pane contains the controls used to add, delete, edit or view shapes in your project. The Shapes Explorer has its own toolbar allowing you to perform shape related tasks such as setting the shape marking mode, switch vertex, renaming shapes and navigating between shape components during shape marking.

The Shapes Explorer is made up of various windows used to display and interact with the shapes in your project. See *Shapes Modeling* for details on this pane.

Imports Explorer Pane

The Imports Explorer pane contains the controls used to add, delete, edit or view imports in your project. The Imports Explorer has its own toolbar allowing you to perform import related tasks such as adding an import from disk, deleting an import, and navigating between import components during import marking.

The Imports Explorer is made up of various windows used to display and interact with the imports in your project.

See *Working with Imports and Constraints* for details on this pane.

Enhance Image

The Enhance Image pane shows controls to vary the Contrast, Brightness and Gamma of the active photograph. The pane shows the enhanced settings for each photograph as they become active. The pane also has controls along the top to apply settings to image on disk, Restore original image, and Reset image enhance settings.

See *Enhance Image Pane* for details on this pane.

Measurements Pane (overview)

The Measurements pane shows measurement data based on what is currently selected in a photo, table or 3D Viewer. Data is displayed in a 'ticker tape' format showing measurement as items are selected, where possible. The pane also has a control to clear the display.

See *Measuring Features* for details on this pane.

Pane Interaction

Panes can be moved and sized in many ways (e.g. docked, tabbed, hidden, floated, resized, spread across one or more monitors etc). This helps to group window types and organize your workspace for ease of workflow and also helps maximize valuable screen space when many windows are open.

Some panes contain sub-panes which must remain within the parent pane (e.g. Photos within the Photo Windows pane, 3D Viewers within the 3D View Windows pane). Subpanes act just like regular panes and can be docked, tabbed etc. relative to each other but these 'sub-panes' must always remain within their parent pane.

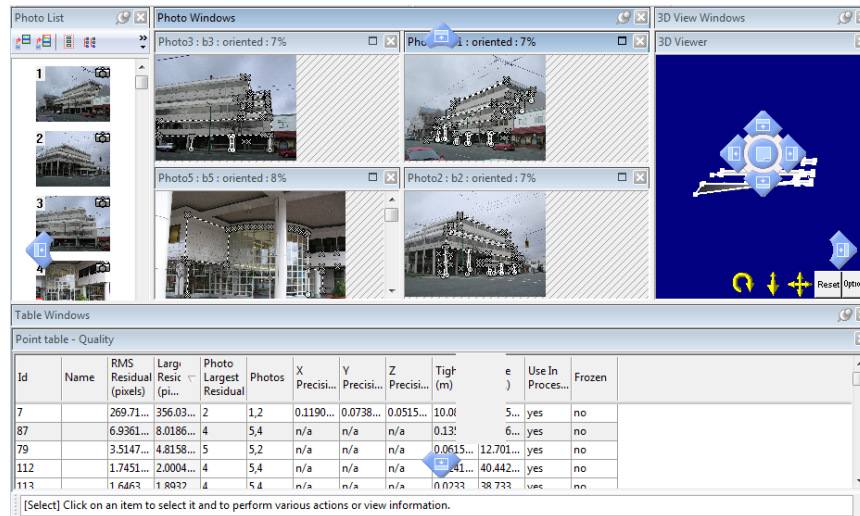
Pane Visibility

Panes can be made visible using the controls on the "View" menu and "Open View Tools" toolbar. Panes can be hidden using the close button ("X") in the top right of the pane.

Pane Positioning

Main panes (e.g. Photo Windows, 3D View Windows, and Tables) can be moved, docked, tabbed etc. relative to other main panes, and they can also be floated. Main panes allow you to group subpanes and help organize your application workspace.

To move a pane left click on a pane title bar and drag the pane into the desired location. While you drag, a 'ghosted' image of the pane will appear until you release the mouse in the desired location. While you drag the pane over other panes a series of graphical position placeholders called "*Docking Context Stickers*" appear that help you position your panes in desired locations, as shown here:

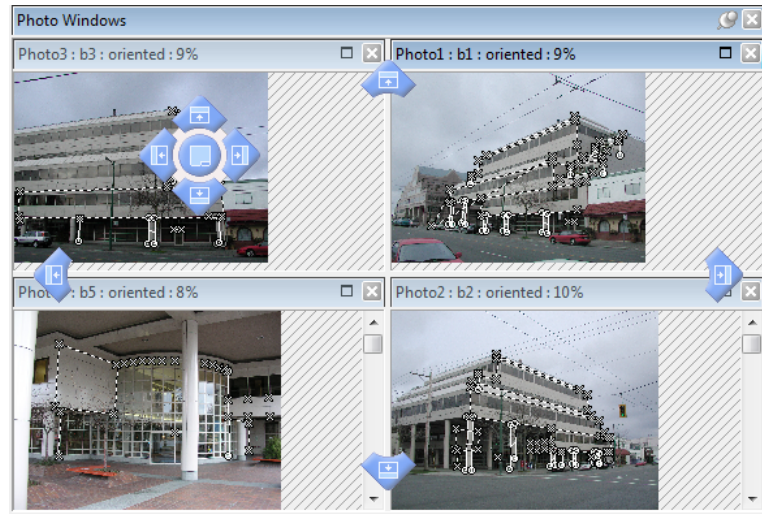


When placed or 'dropped' onto one of these stickers, the pane 'snaps' into position. For example, when dropped onto the arrow sticker at the edge of the application window, the pane is docked at that edge of the application window. When placed onto one of the centre arrow stickers, the pane is docked immediately adjacent to that pane, shifting other adjacent panes accordingly.

When placed onto the centre 'tab' sticker, the pane is tabbed with that pane (i.e. the panes are activated by clicking the pane tabs that appear at the bottom edge of the pane). To untab a pane, you drag the tab off the bottom tab row and move the ghosted pane over a new sticker.

When placed off of any sticker, the pane will move in a 'floating' position. When the pane is floating, you can still drag the title bar and dock but double clicking a main pane title bar toggles between your previous floated position and your previous docked position).

When dragging sub-panes, stickers appear only within the parent pane (where appropriate, such as the Photo Windows, 3D Views or Tables main panes), since you must contain your sub-panes within the parent pane, as shown here:



When panes are docked relative to each other, you can resize the pane by dragging the border between two panes. Placing the mouse cursor over the border will cause it to change to a 'resize' cursor, and while this cursor is shown, clicking and dragging the mouse cursor over the pane border will resize the pane. Resizing will affect adjacent panes.

Pane Pinning

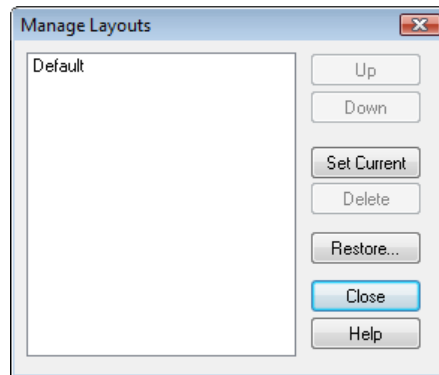
Panes that have a 'pin' button at the top right of the pane title bar can be unpinned and minimized to the edge of the application window. Clicking the pin icon minimizes the pane to the nearest side edge and places a tab on the margin. When the mouse cursor is over this tab the pane becomes visible and stays visible while the mouse is positioned within the pane. The pane rolls back into the margin after a few seconds after the mouse is moved off of the pane. Clicking the pin button again unpins your pane and returns it to its docked position. The pane can be repositioned or re-docked only when unpinned. The pin button has a tool-tip called "Auto-hide".

Pane Layout Storage/Retrieval

Changes to your pane layout are stored when you exit PhotoModeler but you can store your own customized layouts using the pane management tools.

On the Window menu, there are two submenus to manage pane layouts: Mange Main Pane Layouts shows tools for your main panes (e.g. Photo Windows, 3D Viewers, Imports Explorer, etc), and Manage Photo Pane Layouts - show tools for the photo windows. On these submenus you can open pane management dialogs (see *Manage Layouts Dialog*), save your current pane layout, or load a previously saved pane layout.

Manage Layouts Dialog



Depending on the menu option selected, this dialog will either show the layouts for your top level pane layout (i.e. the positioning/sizing etc of all main panes in the applications, such as Photo Windows, 3D View Windows, Table Windows) or your Photo Windows (i.e. the positioning/sizing etc of the panes just within the Photo Windows pane). See *Paned Interface* for more information.

Use the Up/Down buttons to change a stored layout's position in the list. The first layout in the list will be loaded when PhotoModeler is started and is also overwritten with the current layout on exit.

The Set Current button uses the selected layout and applies it to your current workspace, replacing the active layout. If the active layout has not been saved it will be lost.

The Delete button permanently removes a layout from the list of stored layouts. It will no longer be accessible.

The Restore... button sets the factory default layout as installed from CD.

The Close button closes the dialog and the Help button brings up this Help topic.

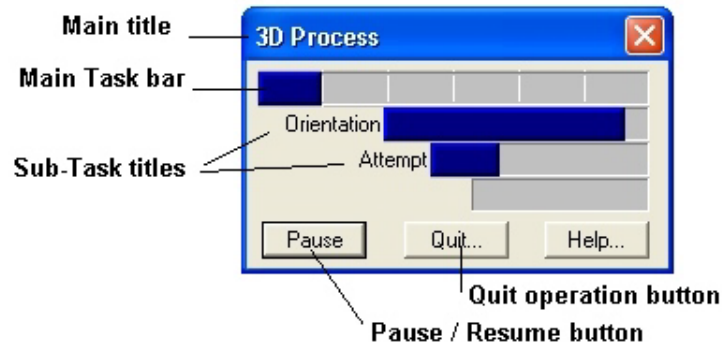
Progress Dialog

The Progress Dialog provides feedback on the progress of long operations. It appears for operations that take more than three seconds to complete. The Progress Dialog displays several bars that show what percentage of an operation is complete.

The most important bar is the top one, called the "Main Completion Bar". This bar shows the amount of time left for the overall operation to complete. The operation being carried out is named in the Main Title caption area.

Below the main bar are subordinate completion bars. These bars show the amount of progress for sub-tasks. The second bar from the top shows the remaining time for the current sub-task of the main task. The third bar shows the remaining time for the current sub-task of the current sub-task of the main task.

Progress Dialog Example



This example will clarify how the Progress dialog works. A Progress Dialog is shown in the figure above. The main task is called "3D Process". This particular form of the dialog appears when the user is processing to create the 3D data from the markings. This operation takes some time, so the Progress Dialog is shown.

The top bar shows eight segments (each vertical line in a bar separates segments). Eight segments mean that the "3D Process" task has eight sub-tasks. The current bar is filled to the third segment, indicating that the first three tasks of eight are complete.

Step four of "3D Process" can contain many steps. These steps are shown in the next bar down called "Attempt". When there are many steps, the vertical bars separating the segments are not drawn. The diagram shows that we are about 10% through the maximum number of iteration attempts in processing. Each Attempt is composed of nine sub-tasks and three have been completed in the diagram. The fourth sub-task is "Solve Equations" and we are about 75% finished that one.

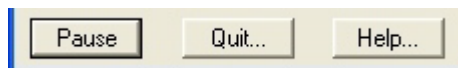
So to complete 3D Process from the state shown in the diagram above would require that the bottom sub-task, "Solve Equations" complete, then the remaining "Solution Steps", then the remaining "Attempts" and then the remaining steps in "3D Process" all complete. At any time, a glance at the Progress Dialog bars will let you know how much work remains to be done.

Progress Dialog's Basic Rule: A bar does not expand until the bar below it is completely filled in.

Sometimes there will be only one bar shown and sometimes all four bars will be used. When the top bar is full, the process is complete and the Progress Dialog will disappear from the screen.

For some complex operations all four bars will be in use and a small animated set of vertical bars will appear in the lower left to let you know the operation has not stopped.

Progress Dialog Buttons



There are three buttons at the bottom of the Progress Dialog. The first is the Pause/Resume button. Normally this button is labeled "Pause". It can be clicked at any time while a Progress Dialog is displayed. When it is clicked, the task that is currently executing is put on hold. The user can then perform any other windows operation without PhotoModeler consuming any CPU resources.

The "Pause" button changes its name to "Resume" when pressed. When the "Resume" text is displayed on this button, the current task in PhotoModeler is stopped. Clicking on this button will resume the operation and change the text back to "Pause".

Clicking on the "Quit.." button will bring up a query dialog asking if you wish to terminate the current operation. If you say no, the operation continues. If you say yes, the current operation terminates and puts the application program back into a reasonable and stable state. The "Quit.." button can be used whether the operation has been paused or not.

The "Help.." button brings up a help description on Progress Dialog and it also pauses the current operation. After you have finished reading help, you will need to click on the "Resume" button.

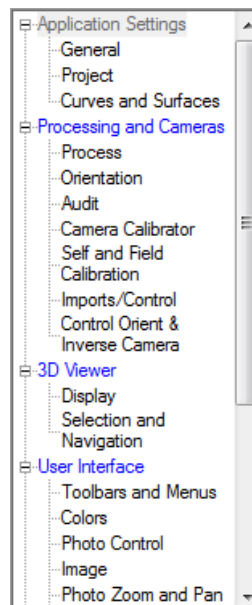
See *Processing Dialog* also.

Preferences


The Preferences Dialog is opened from the Options / Preferences... menu item.

The Preferences dialog provides the user a way to change program options that are saved from session to session. These settings are saved in the PhotoModeler ini file (see *Application Data and File Locations* for information on where the ini file is stored on disk).

The dialog has pages of controls in several categories. On the left of the dialog a tree control shows a list of main categories that can be expanded to show various sub-categories of settings. Clicking a sub-category of the tree will display that page of settings.



Each page on this dialog is described below.

A small caution sign like this one  means that the preference field controls an important aspect of PhotoModeler. These should only be changed if you understand completely what you are doing. For further information on these you may contact Eos Systems technical support.

Preference Dialog Controls



There are five buttons at the bottom of the Preferences dialog, accessible regardless of which page is currently displayed.

When the 'OK' button is pressed any changes you have made to settings on any or all pages will be written to the ini file. Some of these settings will take effect right away while others will not take effect until PhotoModeler is next started (a message box will tell you this). If no changes have been in any dialog control made then pressing OK will make no changes to the current saved settings.

When the 'Cancel' button is pressed, any changes that have been made on any page will be ignored.

The 'Help' button will open the PhotoModeler Help file pointing to the section describing the currently active page.

When the "Reset ALL fields to default values" button is pressed, all preferences settings on all pages will reset to the state when the program was first installed and what Eos Systems considers to be suitable defaults.

When the "Reset this page to default values" button is pressed, all the preferences settings shown on the active page will reset to the state when the program was first installed and what Eos Systems considers to be suitable defaults. The settings on other tabs will not be changed in any way.

Preferences - Application Settings

General:

Startup

- ☒ The application should restore it's last size and position upon starting
- ☒ Show Getting Started

Application Updates

Update check interval (days):

General Application Settings

- ☒ Acknowledge DDE commands
- ☒ Use check box for boolean property grid values


Decimal places on measure pane:

Pane Activation (Mouse-in)

- Mouse-in activates photo ☐
- Mouse-in activates 3D viewer ☐
- Mouse-in activates table ☐

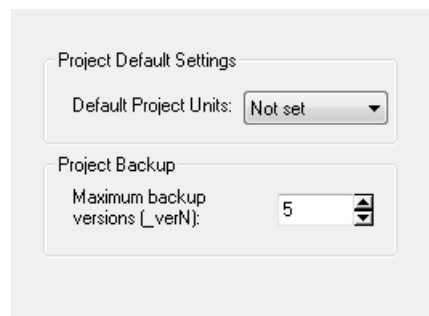
Optional warnings/dialogs (check to show)

- ☒ Images inconsistent with camera
- ☒ Add only a few new photos at a time
- ☒ Duplicate point names in merge
- ☒ Edit a 'varies' property field
- ☒ Surfaces display differently than in v4
- ☒ All photos matched with cameras
- ☒ Fast texture size greater than OpenGL
- ☒ Quality texture size greater than OpenGL
- ☒ Adding offset when no scale/rotate
- ☒ Adding offset when point not coded
- ☒ Adding RAD offset to even point id
- ☒ Rebuild textures after processing
- ☒ Table layouts from active table
- ☒ Adding non-EXIF camera to library
- ☒ Number of triangles from auto-surfacing
- ☒ Print full coded target range
- ☒ Modifying import data
- ☒ Affine invalid and offsets in project
- ☒ Adding rotate using offset point
- ☒ Allow PointMeshes in project merge

Field	Description
Startup	
The application should restore it's last size and position upon starting	If checked, PhotoModeler will reopen each time in the position and size when it was last closed.
Show Getting Started Panel	If checked, the <i>Getting Started Panel</i> appears when PhotoModeler is first launched providing quick access to recent projects, new project wizards, help documents and links to key websites.
Application Updates	
Update check interval	The number of days between checks made online for updated versions of the software. Setting this to zero (0) means no checking for updates will be done.
General Application Settings	
Acknowledge DDE commands	 If checked, commands sent to PhotoModeler via DDE will be acknowledged so the sending program knows they have been received.
Use check box for boolean property grid values	If checked, checkboxes appear on Property grids, otherwise text TRUE or FALSE appear.
Decimal places on <i>Measurements Pane</i>	The number of decimal places to show when measurement data displays on the Measurements pane.

Pane Activation (Mouse-in)	
Mouse-in activates photo	Check to enable activation of a photo pane when the mouse cursor enters the photo. Otherwise activation requires a mouse-down/click.
Mouse-in activates 3D Viewer	Check to enable activation of a 3D Viewer pane when the mouse cursor enters the 3D Viewer. Otherwise activation requires a mouse-down/click.
Mouse-in activates table	Check to enable activation of a table pane when the mouse cursor enters the table. Otherwise activation requires a mouse-down/click.
Optional Warnings	
Optional Warnings	From time to time warnings and yes/no dialogs appear to provide advisements about your project and interaction with PhotoModeler. This section provides a way to enable or disable the warnings that have a 'Do not show me again' checkbox. Check to enable the warning. Uncheck to disable the warning so that it does not appear.

Project:



Field	Description
Project Default Settings	
Default Project Units	The units that are set by default when a new project is started.
Project Backup	
Maximum backup versions (_verN)	Controls the number of backup version pmr files that are saved.

Curves and Surfaces:

Tessellations (3D Viewer and export)

3D Curves are tessellated to within this percentage of the project size (0.0001-5.0):

Objects are tessellated so that no triangle has an angle greater than this with neighbor triangles (degrees, 0.5 - 89):

Surfaces: Cylinders:


General Surface Settings

☐ Surfaces default to double sided

☒ Always use the starting surface for surface draw points

General Curve Settings



Curve algorithm tessellation tolerance (pixels):



Field	Description
Tessellations (3D Viewer and export)	
3D Curves are tessellated to within this percentage of the project size (0.0001-5.0)	Controls the tessellation tolerance for NURBS curves that are converted to line segments for the 3D Viewer AND for those 3D export formats that do not handle native NURBS.
Objects are tessellated so that no triangle has an angle greater than this with neighbor triangles (degrees)	Controls the tessellation tolerance for NURBS Surfaces and Cylinders that are converted to triangles for the 3D Viewer AND for those 3D export formats that do not handle native NURBS. A smaller value means more triangles and a finer tessellation. 25 degrees works well for cylinders but a smaller value (such as 10 degrees) works better for surfaces.
General Surface Settings	
Surfaces default to double sided	If checked, all new Surfaces have their "double sided" property turned on.
Always use the starting surface for surface draw points.	When checked the surface that is first clicked when starting a surface draw will define the plane of that entire surface draw line/curve, otherwise the surface draw will snap onto the nearest surface on each mouse click.
General Curve Settings	
Curve algorithm tessellation tolerance (pixels)	 Controls the tolerance (in pixels) that the NURBS curve algorithm uses. The larger the number, the faster curves compute (but also less accurately).

Preferences - Processing and Cameras

Process:

Optimization termination Maximum iterations: <input type="text" value="20"/> Solution tolerance: <input type="text" value="0.0005"/> Bundle Stability Measure: <input type="text" value="1e-005"/>		Default Point Standard Deviation Weights (pixels) <table border="1"> <tr> <td></td> <td>x</td> <td>y</td> </tr> <tr> <td>Marked points:</td> <td><input type="text" value="1"/></td> <td><input type="text" value="1"/></td> </tr> <tr> <td>Sub-pixel target points:</td> <td><input type="text" value="0.1"/></td> <td><input type="text" value="0.1"/></td> </tr> </table>			x	y	Marked points:	<input type="text" value="1"/>	<input type="text" value="1"/>	Sub-pixel target points:	<input type="text" value="0.1"/>	<input type="text" value="0.1"/>
	x	y										
Marked points:	<input type="text" value="1"/>	<input type="text" value="1"/>										
Sub-pixel target points:	<input type="text" value="0.1"/>	<input type="text" value="0.1"/>										
Project Status Report Only report parameter correlations over this %: <input type="text" value="95"/>		Background Processing and Alerts Prompt to turn off background processing if it takes longer than (sec): <input type="text" value="2"/> <input checked="" type="checkbox"/> Show the % of approximated points alert When more than this % of points are approximated: <input type="text" value="50"/> <input checked="" type="checkbox"/> Show could orient alert <input checked="" type="checkbox"/> Show outside of calibration area alert										
<input type="checkbox"/> Remove high residual points and photos during processing												

Field	Description
Optimization termination	
Maximum iterations	 Controls how many iterations global optimizer will run before giving up trying to find a solution.
Solution tolerance	 Controls how close the Total Error bar values have to be together before global optimizer decides a solution has been reached.
Bundle Stability Measure	Some projects do not have a strong mathematical solution. Processing has trouble deciding what is the correct solution. A weak mathematical project (that is otherwise correct with correct references, good calibration, etc.) is an indication that results cannot be always trusted. In this case processing fails. The Bundle Stability Measure value itself is a matrix stability measure. It can be lower to 1e-3 from the default 1e-5 for example to make some mathematically unstable projects solve (complete Processing). Long focal length calibrations are a project type that may benefit from this change.
Project Status Report	
Only report parameter correlations over this %	Controls which correlation values are shown in the <i>Project Status Report</i> .

Default Point Standard Deviation Weights (pixels)	
Marked points	 Controls the one-standard-deviation (68% probability level) that a Marked Point is within its true location. The size of the final Total Error (see <i>Final Total Error</i>) in a processing will be affected by this value. If this value is close to the true marking precision for all points (and other things like camera parameters are good) then the final Total Error (sigma0 value) will come out close to 1.0.
Sub-pixel target points	 Controls the one-standard-deviation (68% probability level) that a Sub-pixel Target Marked Point is within its true location. See the Marked points value above for the relationship to <i>Final Total Error</i> .
Background Processing and Alerts	
Prompt to turn off background processing if it takes longer than: (sec)	The maximum length of time to perform background processing before being prompted to switch to manual processing.
Show the % of approximated points alert	A popup alert (bottom right of screen) will appear if the check box is checked, and if there are more than the specified percentage of points calculated only by approximation.
Show could orient alert	If checked, a popup alert (bottom right of screen) will appear when enough points are referenced for possible orientation.
Show outside calibration alert	If checked, a popup alert (bottom right of screen) will appear if a point is marked outside of the calibration point coverage area (i.e. the area of the lens that was solved during calibration).
Other	
Remove high residual points and photos during processing	This setting enables the automatic search and unreferencing of points with high residuals during processing. In addition, photographs may be set to 'do not use in processing' if they no longer meet the minimums. By default the feature is on for Automatic Coded Target projects only. See also <i>Total Error Dialog</i> .

Orientation:

Orientation Point Counts

Number of points to include in relative orientation:

Number of points to include in orientation check:

Valid orientation checks

Roll angle check

If roll angle is greater than:

Use this weighting factor against the solution:

Distance check






If a projected point is closer to camera than:


Use this weighting factor against the solution:

Low Angle Marked Point Filter Check

Perform Angle Checks: ☒

Fit Error Threshold:

Field	Description
Orientation Point Counts	
Number of points to include in relative orientation	 Controls the number of points chosen from all photo points to be used during relative orientation stage. A low number speeds up orientation but there is a greater chance of failure or incorrect orientation.
Number of points to include in orientation check	 Controls the number of points studied to allow relative orientation pick from multiple conflicting solutions. See Valid orientation checks below.
Valid orientation checks	
If roll angle is greater than ___ use this weighting factor against the solution: ___	 These two values control how PhotoModeler picks from multiple conflicting solutions to orientation. This weights against cameras that are rolled upside down because this is uncommon.
If a projected point is closer to camera than ___ use this weighting factor against the solution: ___	 These two values control how PhotoModeler picks from multiple conflicting solutions to orientation. This weights against cameras that placed extremely close to the model data because this is uncommon.
Perform Angle Checks	 If checked, photo pair angles are checked before setting up orientation pairs so that pairs with low angles do not cause poor orientation results.

Fit Error Threshold	 The threshold used to determine whether photo pairs have low angles. Generally the higher the value, the closer the 'fit' and therefore the lower the angle difference. Increasing the threshold causes the check to be more strict. This setting is very project dependent and may require some trial and error to find the best setting.
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Camera Calibrator:

The Camera Calibrator page controls the *Camera Calibration* process.

Custom Calibration Control Positions

Control Point 1:	X:	<input type="text" value="0"/>	Y:	<input type="text" value="1"/>
Control Point 2:	X:	<input type="text" value="1"/>	Y:	<input type="text" value="1"/>
Control Point 3:	X:	<input type="text" value="0"/>	Y:	<input type="text" value="0"/>
Control Point 4:	X:	<input type="text" value="1"/>	Y:	<input type="text" value="0"/>

Auto-referencing

Required number of photos to be referenced for each point in stage one:

Targets and Sub-pixel Marking



Ratio of largest target in image to image size:






Ratio of smallest target in image to image size:

Target circularity shape threshold:

Targets are black on light background: ☒

Use LSM sub-pixel marking: ☒

Field	Description
Custom Calibration Control Positions	
Four Planar Control Point Positions	 The positions in 2D of the four control points that lie on a plane. Only relative size is important (that is these are not absolute values). Change this only if you are using a non-standard calibration sheet or slide.
Auto-referencing	
Required number of photos to be referenced for each point in stage one	 One of the stages of calibration is an automatic referencing of points. The first time this happens the camera parameters are known only very roughly so it can be difficult to do well. To make this more robust we force each point to be referenced on at least this many photographs before being accepted. You may need to lower this if the first stage auto-referencing is failing due to too few points found.

Targets and Sub-pixel Marking	
Ratio of largest target in image to image size	 The size of the targets as they appear in the calibration images. This is the largest target in all images (the target closest to the camera). Ratio of image size.
Ratio of smallest target in image to image size	 Like above but for the smallest target image or the size of the target farthest from the camera in all calibration photos.
Target circularity shape threshold	 How elliptical the targets can get before being rejected. 1.0 is close to a perfect circle (which would not allow for any perspective (as circles become ellipses)).
Targets are black on white background	 If checked the targets are black filled circles on a white background.
Use LSM sub-pixel marking	 If checked the auto-marker uses the accurate Least Squares Matcher in calibration.

Self and Field Calibration:

The Process page controls those options to do with Processing and in particular Self/Full Calibration.

Camera Calibration (self or field)

Calibrate when greater than these number of good points on all photos:
☒ Calibration in one camera projects is a full field calibration (otherwise self-calibration).
☒ Self-calibration uses Std. Dev. Weights

Solve during self-calibration (per photo) [Standard Deviations in boxes]

Focal length (mm): ☒ 0.1
Principal Point (* format size) X: ☐ 0.001 Y: ☐ 0.001

Format size (mm) Width: ☐ 0.5 Height: ☐ 0.5


Lens distortion K1: ☒ 0.001 K2: ☒ 0.0001 K3: ☐ 0.0001 P1: ☒ 0.001 P2: ☒ 0.001

Solve during full field calibration

Focal length: ☒ Pixel aspect ratio for fiducial cameras: ☒

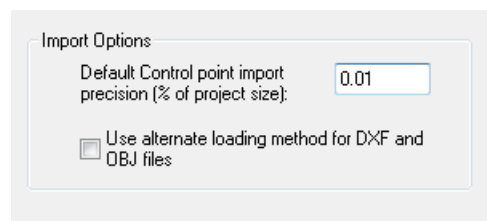
Format size Width: ☒ Height: ☐ Principal Point X: ☒ Y: ☒

Lens distortion K1: ☒ K2: ☒ K3: ☐ P1: ☒ P2: ☒

There are many settings here and their relationship to processing is complex so we give this whole section a caution sign . While many of these settings are complex they are important and for advanced projects you may find yourself adjusting some of them. If after reading the descriptions below you still require guidance please contact Eos Systems technical support.

Field	Description
Camera Calibration (self or field)	
Calibrate when greater than these number of good points on all photos	⚠ When there are more than this many 'good' points (see <i>Preferences - Processing and Cameras</i>) on every photo then self-calibration or full calibration can execute during global optimize.
Calibration in one camera projects is a full field calibration (otherwise self-calibration)	If checked, and there is only one Camera assigned to all photos in the project then a field camera calibration is done instead of a self-calibration. See <i>Field Calibration</i> .
Self-calibration uses Std. Dev. Weights	⚠ If checked then self-calibration uses the weighting factors found in the "Solve during self-calibration" section. If not checked self-calibration uses a free form un-weighted solution which may produce more consistent results but is far less stable (esp. if principal point is being solved for).
Solve during self-calibration (per photo) [Standard Deviations in boxes]	
Solve during self-calibration (per photo)	⚠ The check boxes in this section control whether a parameter will be solved for during self-calibration. Due to insufficient geometry or low point count perhaps fewer parameters will provide a better solution. The Post processing report described below can sometimes give you insight into this. The edit boxes control the weights (one standard deviation values) for the parameters.
Solve during full field calibration	
Solve during full field calibration	⚠ The check boxes in this section control whether a parameter will be solved for during field-calibration. Due to insufficient geometry or low point count perhaps fewer parameters will provide a better solution. The Post processing report described below can sometimes give you insight into this.

Imports/Control:



Field	Description
Default Control point import precision (% of project size)	Controls the default value used for Control Import precision.
Use alternate loading method for DXF and OBJ files	When checked, the import uses the 'FBX' loading system rather than PhotoModeler's native system.

Control Orient Inverse Camera:

Do exhaustive control orient search when fewer than these number of control points: 30

Inverse Camera Parameter Standard Deviation Weights

☒ Use Standard Deviation Weights during calibration of Inverse Camera parameters

Focal length (mm): 2 Principal Point (% of format) X: 0.005 Y: 0.005

Radial lens distortion K1: 0.001 K2: 0.001 Format size (mm) W: 1 H: 1




Decentering lens distortion P1: 0.001 P2: 0.001 Pixel aspect ratio for fiducial cameras: 0.001






Thresholds for minimum number of control points

Basic minimum: 4 For inverse focal length: 1

For inverse principal point: 1 For inverse format size: 1


Minimum % image coverage by control points: 10

Field	Description
Do exhaustive control orient search when fewer than these number of control points	 Controls how many control points are used when searching for the optimal set of three control to do the initial closed form resection. The larger the number the greater chance it finds the best set but also slower.
Inverse Camera Parameter Standard Deviation Weights	
Use Standard Deviation Weights during calibration of InverseCamera parameters	 Single photo resection with InverseCamera does a mini-global optimization. If checked this tells that optimizer to use the standard deviation weights found below.
Inverse Camera Parameter Standard Deviation Weights	 All the standard deviation values for all parameters used in Inverse Camera calibration.

Thresholds for minimum number of control points	
Basic minimum	 Controls how many marked control points any photo must have to be considered for control resection. This value cannot be less than three.
For inverse focal length	 Controls how many additional control points are required above the minimum to also solve for the camera's focal length.
For inverse principal point	 Controls how many additional control points are required above the minimum to also solve for the camera's principal point. Must be at least two.
For inverse format size	 Controls how many additional control points are required above the minimum to also solve for the camera's format size ratio.
Minimum % image coverage by control points	 Controls how big an area the marked control points must cover in any photo for it to be considered for control resection and InverseCamera.

Audit

The Audit page controls those options to do with how PhotoModeler determines project quality during Audit and Processing.

There are many settings here and their relationship to processing is complex so we give this whole section a caution sign .

These settings will not be described in detail in a table form but instead in terms of generalities.

Audit studies a number of factors to determine the quality of a project and to determine how best to perform the global optimize step so as to improve accuracy and maximize the chance of success.

The most important numbers for that control are under the 'Bad' and 'Weak' columns to the left of the dialog. If a particular value falls under the bad level then that entities is set so it will not be used in processing. For example, if a photo has fewer than 5 points or less than 3% image coverage by points, then it is labeled "bad" and it will not be processed. If a point is labeled bad (for example its angle maximum is below 15 degrees) then it is not processed either by the global optimizer.

If Photos or Points are labeled "weak" this means that they may not be used in the first stage of a two stage processing. This allows the "strong" data to start the solution off on the best footing and then the weaker data is added in the second stage.

The 'Marginal', 'Ok', 'Average Marginal' and 'Average Ok' settings are used mostly in the *Audit Dialog* details tabs to provide suitable feedback to quality. These thresholds are also used by the Audit Summary to provide suitable feedback and suggestions.

Angles and 3D Points

Two important values on this Preferences Audit Page are the Angle Maximum Bad and Weak values. These affect how 3D points are computed and handled in optimization and during normal intersection calculations.

A point that has a maximum angle (the largest angle between all light ray pairs) less than the Bad Angle setting will not be computed in the intersection calculation (for instance when referencing points on oriented photos) and will not be carried in the optimization. This point will not be 3D and will not appear in the 3D Viewer or 3D Export but can be seen in Point Table and its low angle maximum will be displayed.

Point's light ray pairs that have an angle less than the Bad Angle setting will not be used in the intersection calculation. That is they will not affect the calculation so light ray pairs with better angles will be used alone. If the Bad Angle setting is 0 degrees then all light ray pairs are used (unless in that very rare case where the light ray angle is exactly 0 degrees).

Point's light ray pairs that have an angle greater than the Bad Angle setting but less than the Weak Angle setting will be weighted against in the intersection calculation. The lower the angle the less that pair will be used in the 3D calculation. If the Bad Angle setting is equal to the Weak Angle setting then no variable weighting is done.

Preferences - 3D Viewer

Display :

The screenshot shows the 'Display' preferences window for the 3D Viewer. It is divided into several sections:

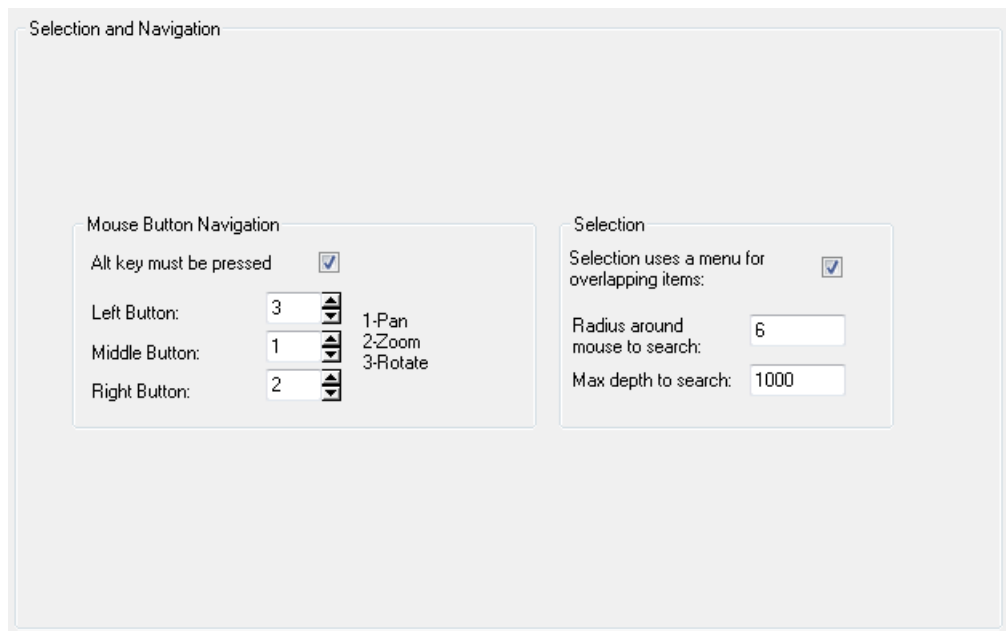
- Texture Settings:**
 - Texture quality (0.0 - 1.0): 1
 - Texture resampling quality (0: nearest neighbor, 1: bilinear, 2: bicubic): 0
 - Default and projection texture size (square - pixels): Fast: 512, Quality: 1024
 - Use ambient light alone when textures visible (ie no headlight): ☐
- 3D Viewer Colors:**

	Red	Green	Blue	
Ambient light:	50	50	50	Pick
Shaded Headlight:	175	175	175	Pick
Textured Headlight:	250	250	250	Pick
Side Light:	250	250	250	Pick
Background:	0	0	128	Pick
- Default Stereo View:**
 - 3D viewers use stereo view: ☐
 - Offset between stereo views: 0.1
- Axis:**
 - Overlay axis size: 25
 - Overlay axis position: 0
 - 0-bottom right, 1-bottom left, 2-top right, 3-top left

Field	Description
Texture Settings	
Texture quality	Controls the quality and rendering speed of the 3D Viewer when textures are displayed.
Texture resampling quality	Controls what form of resampling is used when texture maps are created by PhotoModeler from photos for the 3D Viewer. Bicubic resampling is the slowest but usually produces the best quality.
Default and projection texture size (square - pixels)	Controls how large the created texture map files are for the 3D Viewer and for projections. The maps will be square of this size (e.g. 512 by 512). A power of two value will make rendering faster (i.e. 256, 512, 1024). The larger the value the better the quality but the slower the navigation. This is only the default for the 3D Viewers as it can be controlled independently per 3D Viewer in the 3D Viewer options dialog.
Use ambient light alone when textures visible	If checked the headlight is turned off when the model is textured.
3D Viewer Colors	
Ambient light	The RGB setting for the ambient light in the 3D Viewer scene.
Shaded Headlight	The RGB setting for the light located at the view camera for the 3D Viewer scene for use when surfaces are displayed as shaded .
Textured Headlight	The RGB setting for the light located at the view camera for the 3D Viewer scene for use when surfaces are displayed as photo textured.
Side Light	The RGB setting for the side light for the 3D Viewer scene.
Background	The RGB setting of the window background.
Axis	
Overlay axis size	Size of the corner overlay axis when displayed.
Overlay axis position	The corner position of the overlay axis when displayed.
Default Stereo View	
3D Viewers use stereo view	When checked makes each 3D Viewer display a red/blue stereo anaglyph. With the appropriate colored glasses you can see the object in the 3D Viewer "pop" out of the screen. This is the default setting as each 3D Viewer can be controlled independently in the 3D Viewer Options dialog.

Offset between stereo views	The amount of horizontal offset between the two stereo channels. This is a trial and error value to be set to get a reasonable disparity offset (not too big and not too small). This is the default setting as each 3D Viewer can be controlled independently in the 3D Viewer Options dialog.
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Selection and Navigation :



Field	Description
Selection	
Selection uses a menu for overlapping items	When checked and a selection click is done in the 3D Viewer a menu will come up showing all overlapping items that are close to the click location. The menu allows you to pick which is the object you want selected. When unchecked, the selection is made on the “best” choice.
Radius around mouse to search	Number of pixels around clicked mouse position to search for objects to select (in the 3D Viewer and Control Point Dialog 3D View).

Max depth to search	Depth of model to search for selection. The longest side of the model is divided by this number and any objects with in that distance will be considered for selection.
Mouse Button Navigation	
Alt key must be pressed	When checked the "Alt" key on your keyboard must be pressed while navigating using the mouse button down and drag method. When unchecked navigation can be done by just mouse down dragging. Note that selection can still be done provided you do not drag the mouse while selecting.
Left Button	One of three actions to assign to each of the associated mouse buttons, 1 for Pan, 2 for Zoom, 3 for Rotate.
Middle Button (scroll wheel button)	
Right Button	

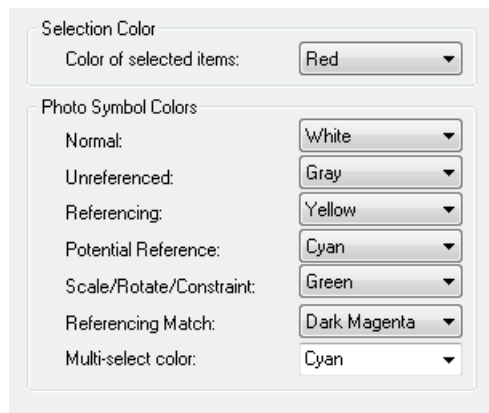
Preferences - User Interface

Toolbars and Menus:

Field	Description
User Interface	
Type	The setting to display the toolbar set associated with various types of modeling projects. See <i>Installable User Interfaces</i> .

Menu	
Show shortcut keys in menus	If checked, shortcut keys for the actions will appear in menus beside the action.
Number of recent projects to display	Controls how many recent projects are listed at the bottom of the File menu.
Display time to expand menus (secs) when menu items hidden	When menus only show commonly used tools, this setting controls the delay (in seconds) while mouse cursor is on menu before the full menu appears.
Icon Sizes	
Toolbars	The width and height (pixels) of the tool icons shown on the toolbars.
Menus/Popups	The width and height (pixels) of the icons shown on the main menu bar and on right click popup menus.
Large Size	The width and height (pixels) of the icons shown on the toolbar when 'large icons' are selected on the Toolbar Customization dialog.

Colors:



The screenshot shows a 'Color Settings' dialog box. Under 'Selection Color', 'Color of selected items' is set to 'Red'. Under 'Photo Symbol Colors', the following settings are visible: 'Normal' is 'White', 'Unreferenced' is 'Gray', 'Referencing' is 'Yellow', 'Potential Reference' is 'Cyan', 'Scale/Rotate/Constraint' is 'Green', 'Referencing Match' is 'Dark Magenta', and 'Multi-select color' is 'Cyan'. Each setting is represented by a dropdown menu.

Field	Description
Selection Color	
Color of selected items	The color of items when user-selected on photos or in the 3D Viewer.
Photo Symbol Colors	
Normal	The color of unselected marks on photos.
Unreferenced	The color of unreferenced marks on photos.
Referencing	The color used during referencing to denote items to be referenced.

Potential Reference	The color of the best referencing candidate during manual referencing.
Scale/Rotate/Constraint	The color used to denote the items active for the Scale/Rotate or Constraints when those dialogs appear.
Referencing Match	The color used to denote an item that appears to be a good candidate for a match during referencing.
Multi-select color	The color used to highlight items when multi-selecting in the 3D Viewer (i.e. when the mouse cursor moves over an item in the multi-select popup menu.

Photo Control:

The screenshot shows the 'Photo Control' settings dialog. It is divided into three main sections:

- Photo List:** Contains 'Image Chip Size (pixels):' with input fields for 80 and 60, and a checkbox 'Open Photo List when project opened:' which is checked.
- Memory Check when opening photos:** Contains 'Show memory warning:' (checked), 'Memory type to check (1-Physical 2-Page File 3-Virtual):' set to 1, and 'Memory used threshold (%):' set to 90.
- Various Photo Settings:** Contains two checked checkboxes: 'The "Open Photos showing selected items" tool tabs photo windows that do not show selected items so they are out of view' and 'Always zoom to fit image if there is extra window space'.

Field	Description
Photo Control	
Image Chip Size	Image Chips are the small images shown in the <i>Photo List Pane</i> , the <i>Add/Remove Photographs Dialog</i> , and the <i>Photo Table</i> . The size of these small images can be changed with these controls. This is useful for high resolution screens (to make the chips more visible).
Open Photo List when Project opened	If checked, the <i>Photo List Pane</i> opens automatically when a project is opened.

Various Photo Settings	
The "Open Photos showing selected items" tool tabs photo windows that do not show selected items so they are out of view	If checked, the "Open Photos showing selected items" tool will display only those photos showing the selected item and other windows will be tabbed. When not checked, all photos remain visible whether they show the selected items or not.
Always zoom to fit image if there is extra window space	If checked the photo window will automatically display the photo in as large a size as the containing window allows.
Memory Check when opening photos	
Show Memory Warning	Controls whether a memory check is performed when opening photos using the settings below.
Memory Type to Check	Controls what type of memory is checked. Select "1" for Physical memory (RAM), "2" for Page File, "3" for virtual memory.
Memory Used Threshold	The threshold at which a warning appears. When this percentage of memory is used up, the memory warning will appear (if enabled).

Image:

Marking Guides/Helpers
☒ Guarantee contrast of guide/ghost lines
 No Xor rubber band during creation of:
☐ Silhouettes ☐ Curves
 The thickness of the guide line displayed during surface creation (screen pixels, 0 - 10):
 Marking snap-to distance (pixels):

Photo display
 Width of lines when set to 'thick' (screen pixels, 1 - 7):
 Point ID's font size:
 Transparent point ID's: ☐
 Show User Names as well as point ID: ☒
 Rotate photos based on EXIF information when adding to a project: ☐

Resampling (photo images)
 Resampling Type (3D Off):
 Resampling Type (3D On):
 (1=Normal, 2=BiLinear, 3=BiCubic)

Image resolution check thresholds (%)
 For non-fiducial cameras:
 For fiducial cameras:

Field	Description
Marking Guides/Helpers	
Guarantee contrast of guide/ghost lines	If checked all ghost/guide lines (line, curve, edge draw etc.) are drawn to guarantee contrast regardless of the image contents, although the contrast may be lower in some cases.


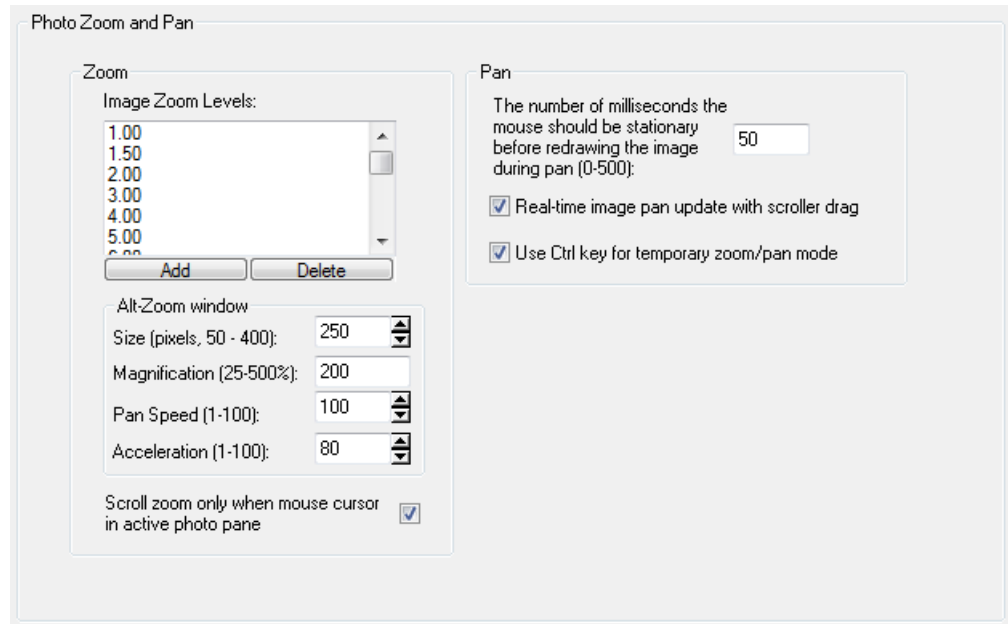
No Xor rubber band during creation of silhouette/curves	An xor (exclusive or) rubber band is the light gray line that follows the cursor during curve and silhouette marking. Some people may find the line distracting so here it can be turned off for both marking types.
The thickness of the guide line displayed during surface creation (screen pixels, 0 - 10)	Controls the width in pixels of the guide/ghost line used to outline the path in multi-point Surface create. Setting to zero (0) will turn surface path guidelines off.
Marking Snap To distance	If the Point Marking tool is clicked within this distance to an existing Marked Point symbol, the position "snaps" and a new point is not created.
Resampling	
Resampling Type 3D Off	Controls the type of resampling done during image display when no 3D items are shown. It can be set to Nearest Neighbor, BiLinear or BiCubic. The latter are slower but provide smoother display at high zooms.
Resampling Type 3D On	Controls the type of resampling done during image display when 3D items are visible. It can be set to Nearest Neighbor, BiLinear or BiCubic. The latter are slower but provide smoother display at high zooms.
Photo Display	
Width of lines when set to 'thick' (screen pixels, 1 - 7)	Controls the width of lines drawn on photos when the "thick" setting is checked in the <i>Visibility Settings</i> .
Width of lines when set to 'thin' (screen pixels, 1 - 7)	Controls the width of lines drawn on photos when the "thin" setting is checked in the <i>Visibility Settings</i> .
Point IDs font size	Controls the font size, in 'points', of the ID's that display on photos.
Transparent point ID's	Controls whether point ID's appear transparent.
Show User Names as well as point ID	When Point ID display is on (<i>Visibility Settings</i> or <i>3D Model Export Dialog</i>) and this item is checked then a point's user name will be shown also.
Image Resolution Check thresholds	
Image resolution check thresholds (%)	 Controls how much the size of an image can vary from the size stored with the Camera before a warning comes up saying the image size is too different.

Photo Zoom and Pan:



Field	Description
Zoom	
Image Zoom Levels	Controls the zoom levels used by zoom tools in photo display.
Alt-Zoom Window	
Size	Controls the size of the Zoom-Window brought up by the ALT key. e.g. 100 means the window will be 100x100 screen pixels.
Magnification	Controls the zoom factor of the Zoom-Window brought up by the ALT key. Note: 100% = 1:1.
Pan Speed	Controls how fast the Zoom-Window pans when you move the cursor out of the window. (1 is slowest and 100 is fastest). Very fast machines may need lower values than default.
Acceleration	Controls how much the Zoom-Window pan speed accelerates as the cursor is moved farther outside the window. (1 means you have to move very far to get the pan speed to increase and 100 means you hardly have to move the cursor a few pixels away from the window for the speed to increase).
Scroll zoom only when mouse cursor in active photo pane	This controls how a mouse scroll wheel change affects the zoom on the active photo. When checked, the mouse must be over the active image to zoom.

Pan	
The number of milliseconds the mouse should be stationary before redrawing the image during pan (0-500)	Controls the redraw speed of image panning (for pan mode and use of the scrollbars). Depending on the speed of your machine you may want to change this time delay setting. You can balance the speed of panning versus the quality of the pan. If you have a fast machine try lowering the setting (perhaps to zero) to get high quality, smear-less panning or if you have a slow machine, and panning is too slow or not interactive enough, try increasing this setting.
Real-time image pan update with scroller drag	Controls whether or not the image in a photograph window is panned in real-time when the vertical or horizontal scroll bar is dragged. If turned off the image will refresh only after scrolling is stopped and the mouse is released. Note: You may want to change the time delay before the image repaints during a pan. See the Preference setting "The number of milliseconds the mouse should be stationary before redrawing the image during pan above.
Use Ctrl key for temporary zoom/pan mode	If checked, the Ctrl key will bring up the Temporary Zoom Area/Pan mode cursor when the mouse is over a photo, otherwise the Ctrl key will act in a standard Windows fashion.

Themes and Layouts:

Themes

Overall 'look' / theme:

0

0 - NativeXP

1 - Style 1

2 - Style 2

☒ Use 'luna' colors
 ☐ Make each tab a unique color

Override themes

Top level panes:

1

Property grid:

-1

MDI panes:

-1

-1 = do not override

Layouts

☒ Save current window layout as default layout on exit

Field	Description
Overall 'look' / theme	Controls the color and graphical style for panes and user interface. Set various visual themes which are used to display panes
Use 'luna' colors	Controls whether a 'luna' blue color tints the user interface.
Make each tab a unique color	Controls whether tabs can each be a different color.
Override themes	
Override themes	Provides the option to display various panes at different levels in separate themes. -1 disables the override.
Layouts	
Save current window as default layout on exit	When checked, any changes made to pane layouts will be stored with the default layout, and restored when PhotoModeler is started next.

Photo Projections:

Performance

Use accurate (but slow) lens distortion correction for internal 3D projections: ☒

Projection accuracy vs speed (as value increases projections become faster but less accurate, 1-10):

Non-rendered Projections

Use non-rendered projections for:


☐ Points

☐ Lines

Projections Colors

	Red	Green	Blue	
Points:	<input type="text" value="0"/>	<input type="text" value="255"/>	<input type="text" value="0"/>	<input type="button" value="Pick"/>
Lines:	<input type="text" value="128"/>	<input type="text" value="255"/>	<input type="text" value="128"/>	<input type="button" value="Pick"/>
Surfaces:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="255"/>	<input type="button" value="Pick"/>
Curves:	<input type="text" value="100"/>	<input type="text" value="255"/>	<input type="text" value="255"/>	<input type="button" value="Pick"/>
Cylinders:	<input type="text" value="255"/>	<input type="text" value="255"/>	<input type="text" value="0"/>	<input type="button" value="Pick"/>
Edges:	<input type="text" value="255"/>	<input type="text" value="0"/>	<input type="text" value="255"/>	<input type="button" value="Pick"/>

☒ Projections use object's material (instead of these preferences)

Field	Description
Performance	
Use accurate (but slow) lens distortion correction for internal 3D projections	 Operations that have to reverse lens distortion can use a slow accurate method or a faster one. When this is checked most operations that involve a 3D point to 2D photo-point projection will use the slower but more accurate method. This affects things like the calculation of marking <i>residuals</i> , the accuracy of the curve algorithm, unreference point weld, automated referencing, etc. This should normally be on by default.
Projection accuracy vs. speed	Controls how accuracy projections are. The more accurate they are the slower they are. If the camera has quite a bit of lens distortion (such as very wide angle lens) then a low value may be required. Setting this to a larger value makes the program more responsive when projections are turned on.
Non-rendered projections for: Points, Line, Control Points, Control Lines	The default projection mechanism on images is to use a full rendering and then merge with the photographic data. This mechanism can be quite slow and if your requirement is to only project point data (and sometimes lines) this option will give a faster and more accurate projection. Not all the same projection options are available in both cases though.
Projection Colors	
Points/ Lines/ Surfaces / Curves / Cylinders/ Edges	The color of points, lines, surfaces, cylinders, edges and curves when projected onto photos if the above check box is not checked.
Projections use object's material (instead of these preferences)	If checked, the projection of the model onto photographs is done with the object's material (as in the 3D Viewer). Otherwise the colors in the following controls are used.

Preferences - Marking and Referencing

Referencing:

<input checked="" type="checkbox"/> Auto-focus window during referencing	Delay before auto driving: (milliseconds, 10 - 1500):	300
<input checked="" type="checkbox"/> Referencing Auto-Drive is on when the application starts	Weld search distance (pixels):	10
<input checked="" type="checkbox"/> Referencing Auto-Photo-Advance is on when application starts	Potential reference highlight threshold (pixels:)	4
<input type="checkbox"/> Include coded points when automatic referencing	Max number of Reference Helper Lines (-1 for all):	-1

Field	Description
Auto-focus window during referencing	If checked, the photo is automatically activated when the mouse moves over it while in referencing mode.
Referencing Auto-Drive is on when the application starts	If checked, the referencing auto-drive-to-point option is on for the first referencing.
Referencing Auto-Photo-Advance is on when application starts	If checked, the referencing auto-advance-to-next-photo option is on for the first referencing.
Include coded points when automatic referencing	If checked coded points will be included when autoreferencing sub-pixel non-coded target points.
Delay before auto driving (milliseconds, 10 - 1500)	Controls how long a delay there is before referencing auto-drive takes place.
Weld search distance (pixels)	Controls what distance is considered to be a valid matching point on a photo for weld.
Potential reference highlight threshold (pixels)	Controls the distance from the epipolar line that a candidate item for referencing will be highlighted during manual referencing.
Max number of Reference Helper Lines (-1 for all)	Controls the number of helper/epipolar lines that will appear while referencing. Select -1 (for all), 0 or 1.

Target Marking:

Automarking Automatic Segmentation Settings

Edge Filter Sigma (pixels):
2

Edge Strength High Threshold (0.01-1.0):
0.2

Allowable Edge Gap (pixels):

Edge Strength Low Threshold Ratio (0.01-1.0):
0.15

Use Fast Automatic Segmentation:
☐

Whole image automatic marking

Manual sub-pixel marking

Ignore a border around the image (% of smallest image dimension, 0 - 45%):
2





Ignore a border around the image during calibration (% of smallest image dimension, 0 - 45%):
0.5




Sub-pixel method threshold size (pixels):
150

Colors

Image channel/type (-1=Gray, 0=Red, 1=Green, 2=Blue):
1

Default target color (0=Black on White, 1=White on Black, 2=White OR Black):
2

Field	Description
Automarking Automatic Segmentation Settings	
Edge Filter Sigma	 The edge detector used in the automatic mode of the Auto-marker uses this Gaussian shaping factor to filter and detect. The larger the value the less noise prone the detector is but the less it is able to detect some of the sharp edges in coded targets (if they are used).
Allowable Edge Gap	 The amount of allowable gap between pixels in an edge when loops (for target regions) are being detected. The bigger this number the slower the detection and the more weird regions picked up but the more robust the detector generally.
Use Fast Automatic Segmentation	 This setting controls whether a faster segmentation method is used during automatic target marking. This can speed up the first stage of target automatic marking dramatically when targets are high contrast (such as with retro-reflective targets).
Edge Strength High Threshold	 The threshold used to determine what is a valid edge pixel (relative to the strongest edge in the image). The higher this value the less noise that is picked up but the less robust the detector becomes to variations of contrast across the image.

Edge Strength Low Threshold Ratio	 The threshold used to determine what is a valid edge pixel (relative to the high edge strength threshold above). This is the low threshold for a hysteresis decision function during edge following.
Whole image automatic marking	
Whole image automatic marking	 These two settings control what area of an image is used during automatic marking (see the <i>Automatic Target Marking Dialog</i> and <i>Camera Calibration</i>). For example a 1% border on a 3000x2000 image means that no targets will be marked within 20 pixels of all four edges of the image. There is greater chance that targets marked very close to the image edges will have lower accuracy and so these settings allow you to control how much is ignored.
Manual sub-pixel marking	
Sub-pixel method threshold size (pixels)	 Controls which sub-pixel target algorithm is used during manual sub-pixel point mode. If the width or height of the drawn rectangular region is greater than this value then the Centroid method (faster/less accurate) is used, otherwise the LSM method (more accurate) is used.
Colors	
Image channel/type	The image 'channel' to use when sub-pixel or automatic target marking. Marking in just one channel may improve marking precision because there will be less negative effects of chromatic aberration of the lens. Most digital cameras have more green sensors than red or blue and this is why the green channel is the default.
Default target color	When sub-pixel marking or automatic marking, PhotoModeler can detect whether targets are black on white or white on black. However, if you consistently use a certain type of target, you might want to switch to the applicable setting, which can improve marking speed.

Preferences - Exports and Output

Exports:

Exports

Format specific settings in Export

DXF Point ID text height: ☐ Wavefront: Use old map style.

☐ VRML1: All faces should be double sided.

Max

Point size: Name prefix:

☒ Image Planes Size: Opacity:

Maya

☒ Use point ID's for locator names

x: y: z:

Locator scale:

IGES

Non-NURBS triangulated surfaces: (1=Exported as NURBS triangles, 2=Exported as a single NURBS surface, 3=Ignored)

Shininess Conversion Factors

3DS: OBJ:

VRML 1: VRML 2:

General Texture Settings

Angle threshold that defines a flat section in map (degrees):

Put intermediate maps on disk at (MB):

Non-texture pixel color:

Background pixel color:

☒ Do automatic brightness balancing in quality textures

VRML 2

Smooth faces with angle less than:

☒ Use 'Examine' mode ☐ Include sky

Sky color 1:

Sky color 2:

Sky color 3:

Field	Description
Format Specific settings in Export	
DXF Point ID text height	Controls the size (in % of project size) of the TEXT entities exported in DXF when Point ID export is requested.
Wavefront: Use old map style.	If checked, the OBJ exporter uses the old style texture map statements instead of the mtl file.
VRML1: All faces should be double sided	If checked, all surfaces are set to be double sided in VRML 1 exports.
Maya	
Use point ID's for locator names	Instead of an incrementing number use the specific point numbers for the locator names.
Locator scale:	The magnification scale applied to all locators
IGES	
Non-NURBS triangulated surfaces	When exporting surfaces, non-NURBS surfaces will automatically be converted into NURBS triangles.
VRML 2	
Include sky	Include the sky environment, shows a background 'sky' in VRML viewers.
Use 'Examine' mode	Force the VRML view into examine mode (rather than Fly, Walk, etc.)

Smooth faces with angle less than	Any faces with an angle less than this value will be smoothed.
Sky Colors 1, 2, 3	The colors to fade between when displaying the sky environment.
General Texture Settings	
Angle Threshold that defines a flat section in map (degrees)	The quality texture map is split into areas of local flat sections of the 3D model. This angle threshold defines how flat those sections are. The higher the value the more a section of the model can be curved and still be tied together into one flat ortho-area in the output map.
Put intermediate maps on disk at (MB)	Intermediate texture map data is built for each photo before the final texture map is created. These intermediate maps are kept in memory for speed but in large projects (large number of photos and large texture map output) this can consume too much memory. When more RAM will be used by the intermediate maps than this setting, the maps are stored on disk instead of in memory. This allows very large projects to be textured with a small sacrifice in speed. The more physical RAM you have the higher this value can be.
Non-texture pixel color	The RGB color of the pixel in the output texture map within a flat ortho-area where there is no valid photographic data available .
Background pixel color	The RGB color of the pixel in the output texture map outside of the flat ortho-areas.
Do automatic brightness balancing in quality textures	If set, do some basic balancing of the brightness of a whole photograph to minimize changes in brightness across the texture output.
Shininess Conversion Factors	
Conversion Factors for various formats	These values control how the PhotoModeler Material Shininess value converts to each format's value for shininess, which is usually non-linearly defined.

Preferences - Coded Targets

Coded Targets:

Coded Targets

Default Target Set

Target Set: 3

0 = ringed coded targets
1 = ringed dots
2 = dots

3 = 8 bit set
4 = 10 bit set
5 = 12 bit set
6 = user set

User Set Parameters

Start of code band ratio: 2.25

End of code band: 3.5

Number of code bits: 8

Print settings

Font scale: 2.5

Default paper size: 8.5 x 11 inches

Color of lines dividing targets: Red 100 Green 100 Blue 100 Pick

Field	Description
Default Target Set	
Target Set	Determines the default set of targets used when setting up a project. 0 - <i>RAD Targets</i> , 1 – Ringed dots, 2 – plain dots, 3 – 8bit, 4 – 10bit, 5 – 12bit, 6 – user set.
User Set Parameters	
Start of code band ratio	If set #6 is chosen as the target set, the user can enter in the code ring start band ratio.
End of code band ratio	If set #6 is chosen as the target set, the user can enter in the code ring end band ratio.
Number of code bits	If set #6 is chosen as the target set, the user can enter in the number of bits in the code.
Print Settings	
Font scale	Controls the size of the ID next to the targets when printing coded targets. See <i>Create Coded Targets Dialog</i> .
Default Paper Size	Controls the default paper when printing sheets of targets. See <i>Create Coded Targets Dialog</i> .
Color of lines dividing targets	Controls the color of dividing lines between targets when printing targets.

Automatic Project:

Point Removal
 Remove non-CT points within a disk around CT points: ☐ Disk height (project units): Radius (project units):

Point Weld
 Do point weld on coded points: ☐
 if they project on all images to within: pixels.

Show/Hide panes
☒ Show Settings file pane
☒ Show Coded Target Settings Pane

☒ Renumber points

Field	Description
Point Removal	
Remove non-CT points within a disk around CT points	Non-coded points are deleted when they lie within a 3D 'disk' around a coded target point (see disk parameters below).
Disk Height	The height of the disk around a coded target point that will be searched for non-coded points (if the disk check is enabled). Value is in project units.
Disk Radius	The radius of the disk around a coded target point that will be searched for non-coded points (if the disk check is enabled). Value is in project units.
Point Weld	
Do point weld on coded points	Coded target points can sometimes be mismarked due to code bit occlusion or distortion. Enabling this option allows the program to weld mismatched coded target points if their projection lies within the specified search distance (see search distance below).
If they project on all images to within	The distance in pixels of a projected coded target on a photo in which a mismatched coded target will be welded to another.
Show/Hide Panes	
Show Settings file pane	When checked the pane asking for a settings file will be shown during the wizard, otherwise the pane will be skipped.
Show Coded Target Settings Pane	When checked the pane asking for default coded target settings will be shown during the wizard, otherwise the pane will be skipped and project Default Target Set (set above) will be used.

Other	
Renumber Points	When checked and if there are a mix of coded and non-coded target points, coded target points will use their codes starting at 1, while non-coded targets will be renumbered sequentially starting at 1000.

RAD project:

RAD project

Stage 1

Target type: 0

Max target size: 200

Min target size: 4

Fit error: 0.2

Stage 2

☐ Run stage 2 auto-marking

Target type: 1

Max target size: 200

Min target size: 4

Fit error: 0.2

☐ Auto-reference ☐ Process

☐ Field calibration

☐ Un-referenced marks rejected

☐ Show photos while marking

Automatic referencing

Number of Photos: 3

Search distance: 0

Offset point range

Start: 0 End: 0

Target color: 0 0=Black, 1=White, 2=Both

Translate, Scale, Rotate

Units: meters

Translate: Point ID: 0 x: 0 y: 0 z: 0

Scale: Point ID1: 0 Point ID2: 0 Scale distance: 1

Rotate: Left: 0 Front: 0 Bottom: 0

Right: 0 Back: 0 Top: 0

Field	Description
Stage 1	
Target type	Corresponds to the type of targets used during the autoproject. Use 0 for RAD targets, 1 for ringed dots, 2 for dot targets, 3 for 8-bit set, 4 for 10-bit set, 5 for 12-bit set, 6 for User-set. Typically for a RAD project, you'll leave this at the default of 0.
Max target size	The maximum size of inner dot within the RAD target (in pixels).
Min target size	The minimum size of inner dot within the RAD target (in pixels).

Fit Error	When targets are occluded or somehow distorted, PhotoModeler can still find sufficient target area to mark, though the more distorted the target is, the higher the 'Fit Error'. There may be times when the mark is not as reliable due to the occlusion or distortion. If you lower the Fit Error threshold, more target marks will be 'rejected' and will not be marked. Increasing the threshold will allow more marks to be 'accepted' and marked. The default value of 0.2 works well for most projects.
Stage 2	
Run stage 2 auto-marking	Controls whether stage 2 automarking happens, where ringed dot or non-ringed dot targets are auto-marked, auto-referenced, and/or processed. Stage 1 typically processes coded targets, while stage 2 processes the non-coded targets.
Target type	Corresponds to the type of targets used during the autoproject 2 nd stage. Use 1 for ringed dots or 2 for dot targets.
Max target size	The maximum size of the dot target (inner dot on a ringed dot target), in pixels.
Min target size	The minimum size of the dot target (inner dot on a ringed dot target), in pixels.
Fit Error	When targets are occluded or somehow distorted, PhotoModeler can still find sufficient target area to mark, though the more distorted the target is, the higher the 'Fit Error'. There may be times when the mark is not as reliable due to the occlusion or distortion. If you lower the Fit Error threshold, more target marks will be 'rejected' and will not be marked. Increasing the threshold will allow more marks to be 'accepted' and marked. The default value of 0.2 works well for most projects.
Auto-reference	Whether autoreferencing is done after stage 2 auto-marking.
Process	Whether the project is processed after stage 2 auto-marking.
Field calibration	Whether the project is field calibrated during processing after stage 2 auto-marking.
Other	
Un-referenced marks rejected	Controls whether points that have been marked but not automatically referenced get removed at the end of an autoproject.
Show photos while marking	Controls whether the photo is displayed after it has been automarked.

Automatic Referencing	
Number of photos	The minimum number of photos that a point needs to be marked on before it will be referenced during <i>Automatic Referencing</i> .
Search Distance	The distance that is scanned by the program from a potential referencing match during <i>Automatic Referencing</i> . When this setting is 0, the search distance used will be the maximum <i>tightness</i> of coded target points (in absolute units not percentage) after the first coded target marking and processing.
Offset Point Range	
Start and End	The range of id's to which offsets will be applied. See <i>RAD and Coded Target Offsets</i> .
Target Color	The color of targets, i.e. black (on white), white (on black), or a mix.
Translate, Scale, Rotate	
Units	The units used for applying translate and scale settings.
Translate Point ID and x,y,z	The translate Point ID and the known x,y,z coordinates
Scale	The scale distance using two points (Point ID 1 and Point ID 2) and a known distance (Scale distance) between them.
Rotate	The point ID's corresponding to the axes used to set up the rotation, where the Left/Right axis corresponds to the X axis, the Front/Back axis corresponds to the Y axis and the Bottom/Top axis corresponds to the Z axis. Note you only need to assign point id's to two of the three axes if you are defining the Rotation. See <i>Adding Scale and Rotation</i> for more information

Preferences - PMV

This page has the preference for the PMV PhotoModeler Video Module. See the *PMV PhotoModeler Video* section for more details on PMV projects.

Decimal places used for export

2D Position:

2D Residual:

3D Position:

3D Tightness:

Memory Cache

The number of epochs that should be loaded in memory at one time:

The number of epochs should keep their images in memory at one time (must be less than the number of epochs in memory):

The number of epochs that should be 'read ahead' into the cache at a time:

Tracker's Matching Criteria Between Epochs

Acceptable target contrast change (1.0=no change) min: max:

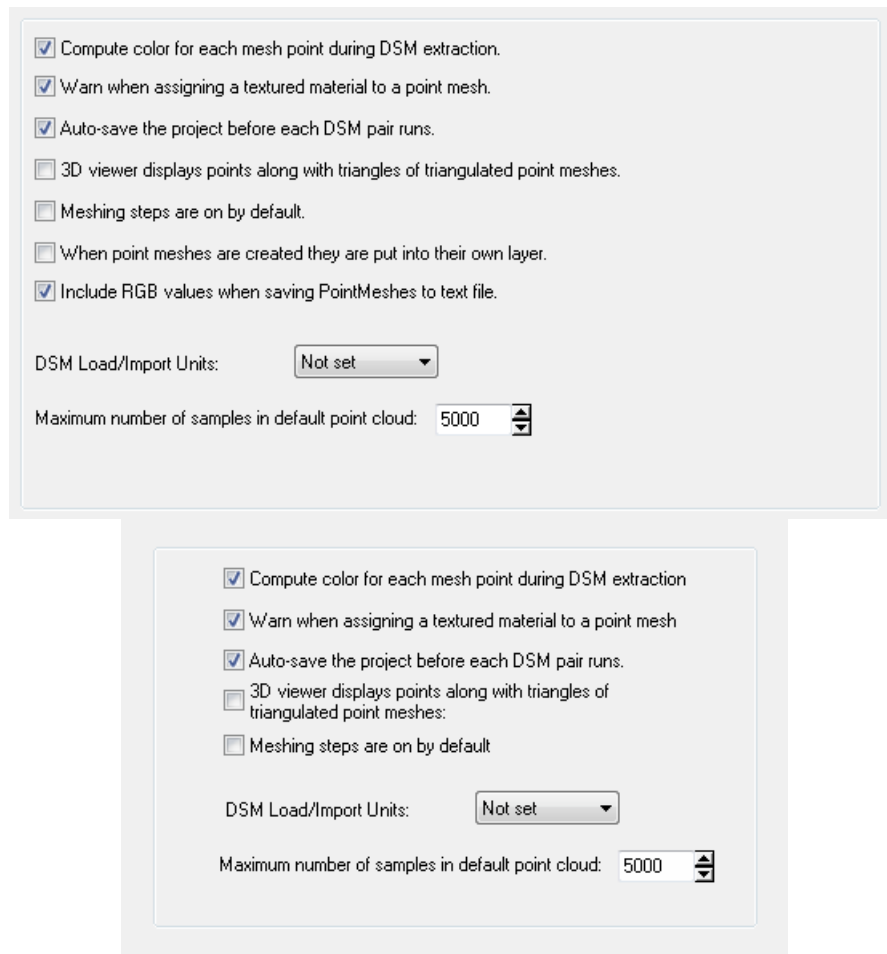
Acceptable target radius size change (1.0=no change) min: max:

Minimum Edge Slope/Contrast Ratio:

Field	Description
Decimal places used for export	Number of decimal places to put after numbers exported in the Epoch Report.
Memory Cache	Settings that control how the cache handles images and project data. If you have a lot of RAM in your computer and are dealing with PMV projects with many epochs upping these values might help performance.
Tracker's Matching Criteria Between Epochs	
Acceptable target contrast change	When matching a target in the current epoch to a target in the previous epoch, the two targets must have similar contrast defined by this range. For example setting these numbers to 0.5 and 2.0 would mean that the new target matches if its contrast is between half and twice that of the previous epoch target.
Acceptable target radius size change	Similar matching constraint as above but for the radius of the target.
Minimum Edge Slope/Contrast Ratio	A threshold for whether to accept a target as valid during tracking. It is a measure of the ratio between the edge slope and contrast (this is a measure of target edge sharpness).

Preferences - Dense Surface

This page has the preference for the Dense Surface settings. See the *Dense Surface Modeling / PhotoModeler Scanner* section for more details on these types of projects.



Field	Description
Compute color for each mesh point during DSM extraction	Allows you to view your Dense Surface as point cloud simulating a photo texture, as color data from the photo is mapped to points in the point cloud.
Warn when assigning a textured material to a point mesh	A warning will display when assigning a textured material to a point mesh, as point meshes obtain their texture from the 'texture photo' property, not from the material.
Auto-save the project before each DSM pair runs.	Save the project as [Project Name]_AutoSave.pmr before DSM is run on each pair of photos.
3D Viewer displays points along with triangles of triangulated point meshes	Points and triangles are shown when displaying triangulated point meshes.

Meshing steps are on by default	Controls if the meshing steps are on or off by default when creating a new DSM.
When point meshes are created they are put in their own layer	When a point mesh is created, a layer is created and assigned to the new point mesh.
Include RGB values when saving PointMeshes to text file	When checked the RGB values will be included in the .txt file when in addition to the XYZ values. When unchecked the RGB values will not be exported. See <i>Load / Save PointMesh</i> .
DSM Load/Import Units	The units to apply when loading or importing a dense surface file.
Maximum number of samples in default point cloud	This setting is used to compute the default sampling rate in the <i>DSM Options Dialog</i> . The sampling rate's default value is computed for new projects until manually overwritten or when the 'Recompute default sampling rate' verb is clicked. This preference value defines the maximum number of samples that could be generated for a pair of photos but the actual number of samples will usually be smaller than this (due to non-rectangular extents, missing matches, etc.). The sampling rate is computed such that the maximum number of samples will be this value.

Help

Help information is always available from the PhotoModeler menu under the heading Help. In addition, most dialog boxes have a help button. Clicking on the Help button of a dialog will bring up help information for that dialog. The Help document can also be accessed from the *Getting Started Panel*.



On the left of the Help File Viewer are three tabs: Contents, Index, and Search.

- Contents: shows a tree view of chapters in the document
- Index: shows a list of indexed terms in the document
- Search: provides a way to search the document using keywords

A good way to use the Help is to use the Search feature. Enter a term for which you want information and click List Topics. A ranked list of relevant sections appears. Double clicking on a topic will take you to the section in the document. You can then switch back to Contents view which will indicate your current location in the document. This will usually lead you to your topic of interest, and should also provide background or related information.

You can also navigate through the document using the “Previous”, “Next” and “Back” buttons on the toolbar. Pressing “Next”/“Previous” will take you to the next/previous page in the document, which allows you to read the document sequentially. When skipping through various sections in the document, pressing “Previous” will return you to the previous page.

If you have an internet connection you can also visit the FAQ (Frequently Asked Questions) web page on the PhotoModeler web site easily by using the “PhotoModeler on the Web” menu item under Help.

Training

In addition to help there are extensive video tutorials. You can access these tutorials from the Help menu or *Getting Started Panel*. A separate help file starts that provides access to the videos. Along with the videos there are images and sample projects so you can follow along with the tutorial videos. This is the best way to learn PhotoModeler.

PhotoModeler Online Update

Eos Systems is constantly working to improve PhotoModeler by adding new features and improving existing features. Eos Systems regularly posts updates or 'patches' on its website for users to download.

To make the update process as effortless as possible, PhotoModeler has tools that enable you to quickly check whether you are running the most up-to-date version. There are three ways to do this:

1. Under the Options Menu there is an item called "Check for Updates...". When this item is chosen, your computer will connect to the internet and check the PhotoModeler web site to see if the version of PhotoModeler that you are running is up-to-date. If you are not running the most current version, you will be prompted to save your project and close PhotoModeler and proceed with the installation. If you proceed, the updater will download the required setup files and will then prompt you to begin installation.
2. You can also check for updates from the Windows Start menu (Start/Program Files/PhotoModeler /PhotoModeler Update). The update process is the same as from the Options Menu except you do not need to be running PhotoModeler to check for updates as the Start menu is accessible at all times.
3. Allow the automated check to remind you. See the *Update Check Reminder* dialog.

Note: if you are running the most current PhotoModeler version available, a message will appear informing you of this. You will not be prompted to download and install any files unless an update is available. Also, if an update is available and you do not want to install it, you can cancel the installation.

Privacy and Personal Information

Please note that no personal information is transmitted during the update check procedure. The current license maybe verified during this process.

Application Data and File Locations

PhotoModeler writes per-user data on disk for storage/retrieval of various information: Pane Layouts, Shape Library, Camera Library, Table Layouts, Target Templates, Toolbar Layouts, the ini file (a file storing user preferences), and licensing information.

These files are copied to a directory on your disk that is intended for 'writable' application data:

- Windows XP and 2000: "Documents and Settings\<user>\Local Settings\Application Data\PhotoModeler"
- Windows Vista: "Users\<user>\AppData\Local\PhotoModeler"

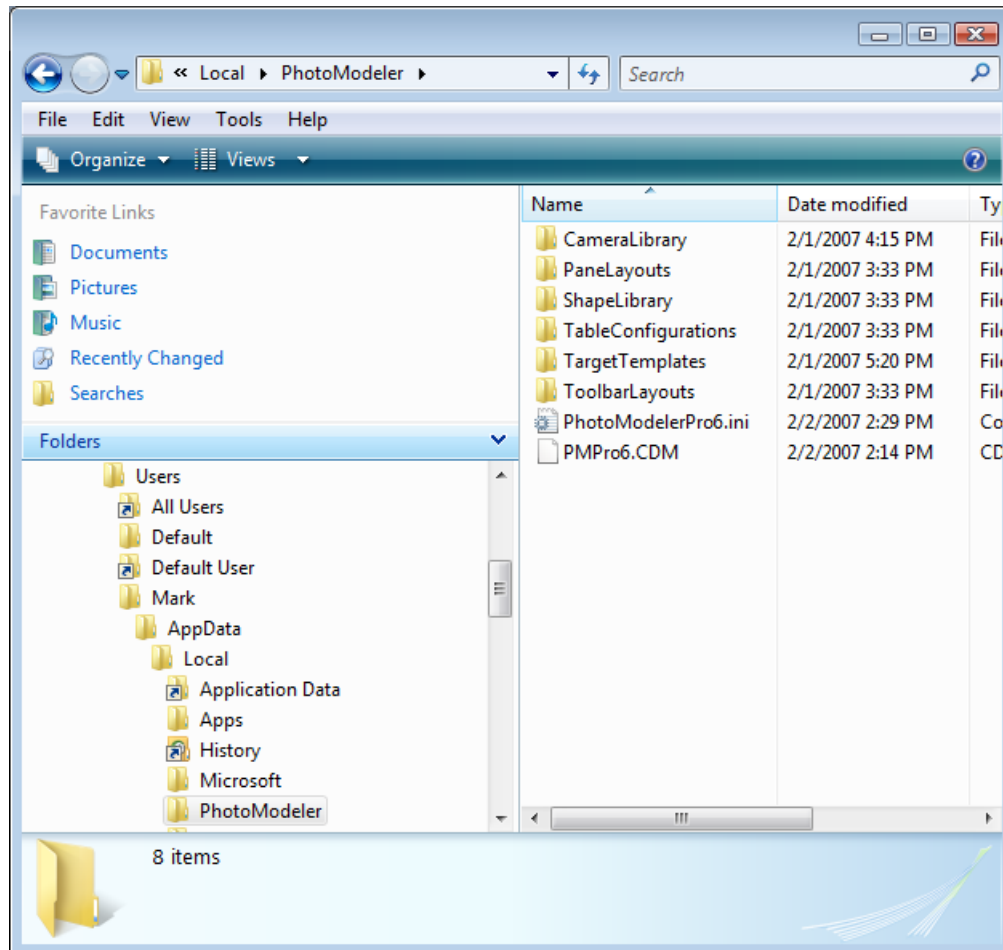
These files are maintained by PhotoModeler (e.g. toolbar layouts) or modified by a user from within PhotoModeler (e.g. camera library).

These locations are in a subdirectory based on your Windows account user name (e.g. substitute your account name for <user> in the directory paths shown above). This allows users that share a computer running PhotoModeler to maintain their own settings and application data.

When you first launch PhotoModeler, a shortcut to the application data folder is written to your My Documents folder:

- Windows XP and 2000: "My Documents\PhotoModeler" folder called "PhotoModeler Program Data"
- Windows Vista: "Windows Account Name\Documents\PhotoModeler"

The following screen capture shows the directory structure for the PhotoModeler application data:



"CameraLibrary" Folder

When adding a camera to the camera library (e.g. after a *Camera Calibration* or *Field Calibration* or from the *Camera Library Dialog*) the associated .cam files get stored in this directory. Cameras in this directory are scanned during *Camera Matching*.

“PaneLayouts” Folder

The layout of your panes gets stored in the “default layout” file when exiting PhotoModeler. You can also create custom layouts using the *Manage Layouts Dialog*. This folder stores all pane layout files.

“ShapeLibrary” Folder

This folder contains the installed configuration and toolbar bitmap image files for Shapes (see *Shapes Modeling*). A shape needs to be defined by a set of parameters, which are stored in associated configuration (.ini) files in this directory. The toolbar bitmap images are also stored here.

“TableConfigurations” Folder

This folder contains table layout files which are used when loading tables to restore column visibility, sort order, column order etc. A set of layouts are installed by default, but you can also create your own in the *Table Layouts Dialog*.

“TargetTemplates” Folder

This folder contains target templates which are used when marking non-circular template targets. A set of templates are installed into this directory, from which you can select for use in your project. See *Defining Target Templates* dialog for more information.

“ToolbarLayouts” Folder

This folder contains the files that are used to store toolbar layouts. A toolbar layout stores customizations, toolbar locations, keyboard shortcuts and more. Also note that you can load a toolbar layout that suits the type of project you are working on (see *Preferences - User Interface* for information on User Interface Type and see *Toolbar Customization* for more information on ways to customize your layouts.

Other files in the PhotoModeler folder

The root folder contains 3 other files:

- PhotoModelerPro6.ini – this file stores various user preferences. Most of these settings can be changed on the *Preferences* dialog box. In rare instances, you may need to edit this file manually (e.g. when requesting specialized technical support).
- Pmpro6.cdm – a file used internally by PhotoModeler during installation. This file should not be moved, edited or deleted.

Overview of Producing a 3D Model

A 3D model is a set of connected 3D points, edges, curves and cylinders or shapes which represent an object. Three dimensional points have coordinate values for each of the Cartesian axes (X,Y, and Z).

The points and edges in the 3D model can be connected by lines and/or by patches, called Surfaces. These connections help the user to visualize the three dimensions when the model is projected onto a flat surface such as a computer monitor or a printed page.

This section provides an overview of the process of creating a 3D model with PhotoModeler, from start to finish.

There are eight steps to producing a model with PhotoModeler:

1. Create a calibrated or approximate camera description,
2. Plan the Measurement Project,
3. Take photographs of the object or scene,
4. Import the photographs into PhotoModeler,
5. Mark features (e.g. points, shapes etc.) on the photographs,
6. Identify which points are the same,
7. Process the data, and
8. Export the resulting 3D data to a CAD or graphics program.

The following sections describe each of the eight steps in greater detail. Also note that steps 1, 2 and 3 are treated differently if you are handed unknown photos and are using InverseCamera.

Create a calibrated or approximate camera

PhotoModeler requires a description of the camera used to take the photographs. This description needs to be created only once and is used for every subsequent project done with this camera.

Each different camera or each lens/camera combination needs its own description. This description includes data on the focal length, imaging scale, image center and lens distortion. PhotoModeler uses this information to build a proper geometrical relationship between points on the photograph and points in 3D space. The camera description file describes the camera, the lens and the scanner as a set. If any of these change, a new calibration is required.

The camera descriptions can be approximate or fully calibrated. Creating an *Approximate Camera* requires entering in information about the camera and creating a camera file.

Creating a calibrated camera involves taking photos of a calibration pattern (supplied with the package) and running the *Camera Calibration*.

When you want to start quickly with a new camera the best way is to create an *Approximate Camera* first, use it in PhotoModeler and then at a later date when higher accuracy is required, create a calibrated version of the camera description. See the section *Working with Cameras* for additional background.

Plan the Measurement Project

In multiple photo projects each point (and curve, edge, cylinder) that is to be modeled should appear on two or more photos and these photos must meet certain geometrical constraints. For this reason, the positions of the photographs need to be thought out. Refer to the section of the Quick Start Guide called Guide For Taking Photos for some guidelines. When you become more familiar with the technique you will be able to plan the camera positions on the spot.

The camera settings when taking project photos should match the settings of the camera during calibration. Features such as image stabilization, auto-rotation, sharpening etc should be disabled when taking project or calibration photos.

When planning the photographs, you should also take care to ensure that all the desired points and detail will be captured in the photograph. For example, if you require the overall shape and dimensions of the facade of a building but also require some fine detail on some ornamentation, then you should take some close-up photographs as well. The close-up photographs capture the detail and the overall long distance photographs capture the whole facade.

Take Photographs of the Object or Scene

Once you have decided how many photographs you will take and where you will take them from, you can go to your object or your site and take the photographs. Special care should be taken to ensure good exposure and good focus.

Note: The photography requirements for a PhotoModeler Scanner project are different than those for a regular PhotoModeler project. See *DSM Photo Requirements* for more information on photography for PhotoModeler Scanner projects.

It is a good idea to take more photographs than you strictly need for the Measurement Project. Some of the photographs may have bad exposure or bad focus, or perhaps at a later date you may wish to measure more points than originally planned. Refer to the section of the Quick Start Guide called Guide For Taking Photos for other details.

Note: When taking photographs, you should also measure the distance between at least two points on the object. This distance will be used to add scale to your end product, the 3D model. Additional measured distances can be used to check the accuracy of the result.

This section deals mostly with multiple-photograph projects. The requirements for single photograph control-based projects are not as strict and are described at the end of this section.

For best results some guidelines should be followed when positioning the camera during photography. The following is a summary of some guidelines for how photographs should be taken. These guidelines are each discussed in detail in this chapter.

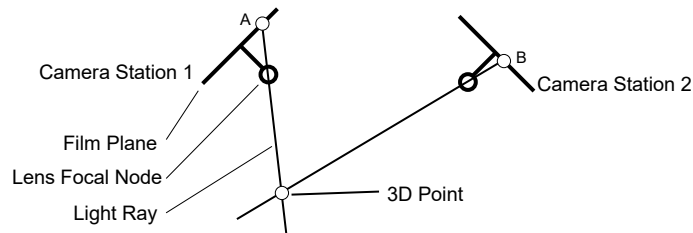
Photography guidelines:

- try to get the angles between the shots as close to right angles (90 degrees) as possible,
- take at least three photographs but it is a good idea taking more than you think you'll need to avoid having to return to the site to take more,
- try to get all important points on at least three photographs,
- try to get as much overlap between adjacent photographs as possible,
- try to get photographs from both above and below the object, if possible,
- take many photographs of the object but use at most four at the start until you determine you need others, and accurately measure the distance between two clearly visible points in the scene for later use as scale in your project.

While these guidelines refer mostly to multiple photo point-based projects they apply to shape-based projects too. They do not apply that much to single photo projects but there is a sub-section below addressing that topic.

Background

PhotoModeler generates the 3D positions of points by projecting straight lines from the camera position, through the point on the film or CCD and out into space. When two such rays are used, the intersection of the rays gives the point position. The following figure depicts this method:



Locating a Point in Space from Two Rays

Representations of two Camera Stations are shown in this figure. Each of these shows the position of the film or the imaging chip and the focal node of the lens at the moment the picture was taken. These representations are simple two dimensional drawings but are sufficient to describe the method.

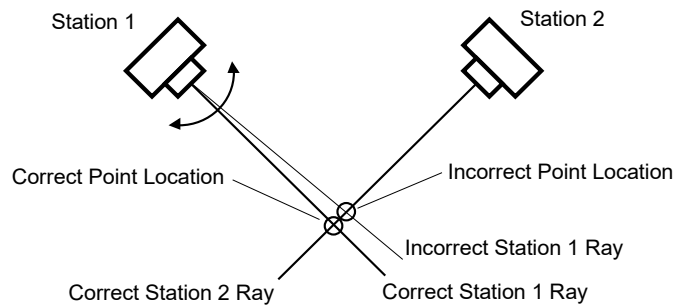
Assume the user has identified the Marked Point A on photograph 1 and the Marked Point B on photograph 2 as being the images of the same point. PhotoModeler knows where the camera was at the time of the two exposures and it uses this along with A and B's 2D location in the film plane to calculate the 3D Point location by intersecting the two straight lines.

Guidelines

The following sections describe photography guidelines for a PhotoModeler project. See *DSM Photo Requirements* for more information on photography for PhotoModeler Scanner projects.

Guideline 1: Get Good Camera Angles

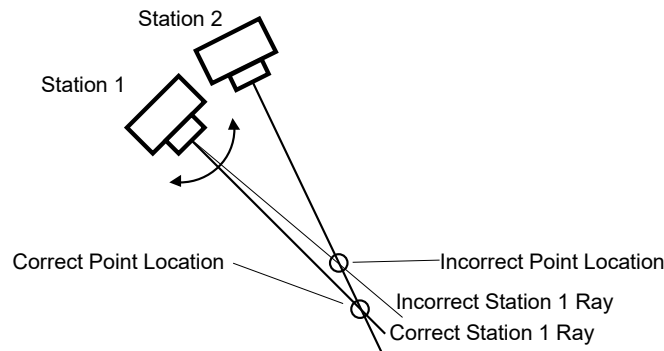
The process of measurement is never perfect. Measurement is instead the process of reducing and minimizing errors so as to maximize accuracy. If PhotoModeler has incorrect camera positions or orientations, it will generate an incorrect position for the 3D point. The figure below shows such a case. It depicts two cameras in which the orientation of Station 1 has been calculated incorrectly by a few degrees. PhotoModeler then incorrectly calculates the position of the 3D point because of the shifted light ray.



Point Location Error with Good Camera Positions

In the figure above and the figure below, Station 1 has the same position and the same angle error. On the other hand, in the figure below, Station 2 is close in angle to Station 1. The small error gets multiplied and the resulting position of the 3D point is much farther off the mark.

The closer the angle between the light rays is to a right angle (90 degrees) the smaller any possible error will be. It is for this reason that the angle between the Camera Stations should be as close to a right angle as possible.



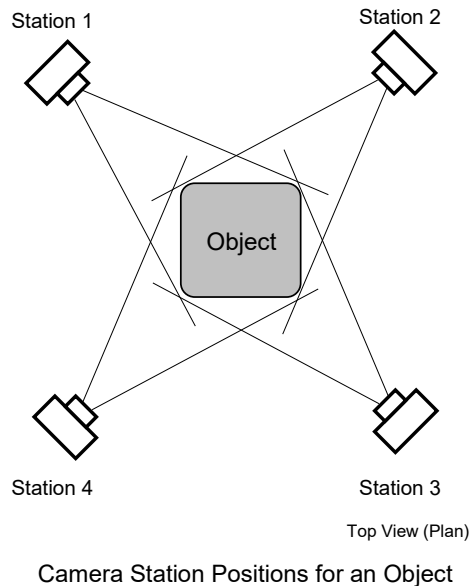
Point Location Error with Bad Camera Positions

Guideline 1: Take photographs with good angular separation (close to 90°). Do **not** take all your photographs with similar points of view.

A few examples might make it easier to understand how to apply Guideline 1. The following sections show some of these examples.

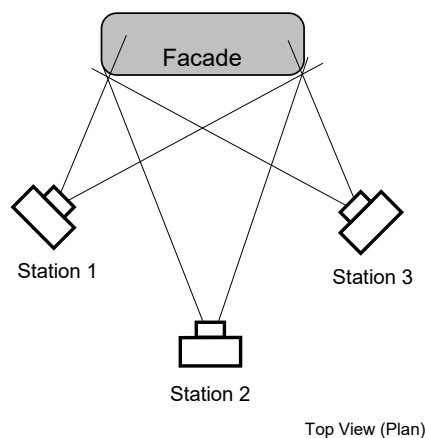
Photographing a Box Shaped Object

If you are measuring a box shaped object and you are using four photographs, take the photographs off the four corners of the object. All the photographs can be taken at the same level but one or two sides of the box will not be photographed. Often missing a side is not important. The figure below shows the top or plan view of such a camera layout:



Photographing One Face of an Object

If you are measuring just one face of an object then three Camera Stations would normally suffice. The figure below depicts such a camera layout:



Camera Station Positions for a Facade

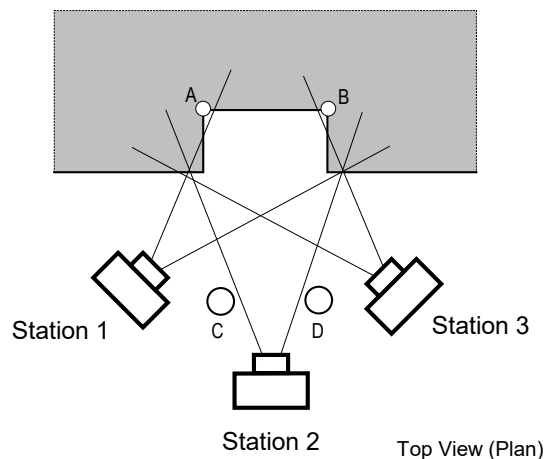
All of the points on the face of the object show up in three photographs. The Camera Stations are not all at right angles (station 1 and 3 are close to this ideal) but they are in good positions none the less.

Guideline 2: Take at Least Three Photographs

Another form of error is introduced during measurement by marking imprecision. Nobody can mark a point perfectly, and occasionally the point you wish to identify is fuzzy or hard to position exactly in the photograph. If PhotoModeler has good Camera Station positions, but imprecise point locations in the photographs, the projected 3D point will be inaccurate. To reduce this problem, we would mark the desired point in three or more photographs. That way, if the point was positioned incorrectly on one of the photographs, the other two photographs could compensate for it. If it is marked on only two photographs, marking errors cannot be found and will cause an inaccurate 3D point to be created.

Guideline 2: Take at least three photographs of the object or scene. Try to get all important points to show on at least three photographs. For highest accuracy, try to image all points on four or more photographs. It is usually a good idea taking more photos than you think you might need so that when it comes to starting your project you have a collection to choose the best ones from. You may realize that not all detail was captured in some photos, so having a stock of photos to choose from can save you a trip back to the scene. Also try to be aware of objects in your scene that are obstructing key features, and try to take photos of these features so they are clearly visible, which in some cases may require taking multiple photos of a specific feature within the scene.

The figure below shows an interesting case of trying to get each point imaged on three photographs. In this example we are measuring a hole, a dent in some object or an inset doorway/alcove in a building. When the hole has straight edges, it is difficult to get points A and B imaged on three photographs if only three stations are used. To get around this problem we would take two more photographs at positions C and D. Some of the outside points would be imaged on five photographs and points A and B would be imaged on three photographs.

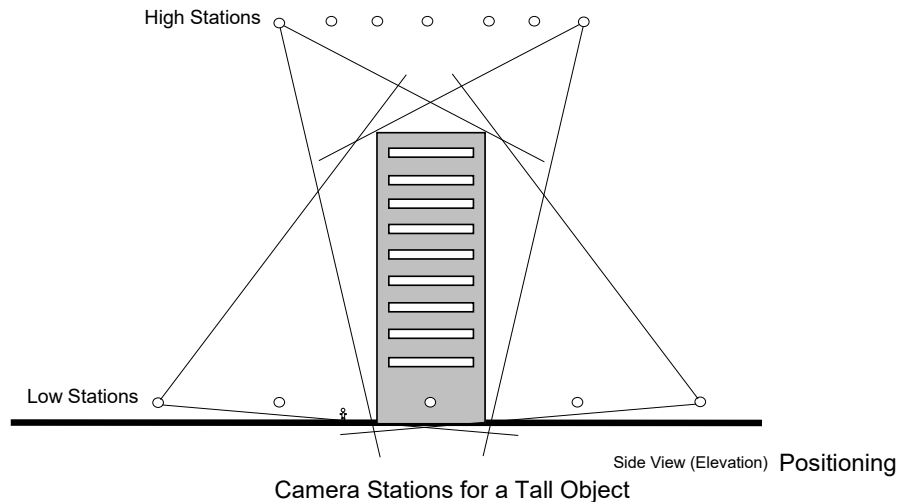


Camera Station Positions for an Alcove

Guideline 3: Get Good Horizontal and Vertical Separation

Another way of satisfying Guideline 1 (keeping the angles between the photographs close to right angles) is to separate the Camera Stations not only horizontally, as shown in the previous figures in this chapter, but to separate them vertically also. Two cameras can have right angles between their views in any three dimensional orientation. The Camera Stations do not need to be all at one level.

The figure below is a somewhat extreme example of this. In this figure a tall building is being measured. All the photographs could be taken from the ground, but the points along the roof line would be very far away from the ground level photographs, and hence would be harder to mark (because they would be smaller in the photographs than points along the ground). This would make the roof top points less accurate than the ground level points. The ideal solution would be to take some photographs from above the building. This could be done if there were adjacent buildings that were taller, or if an airplane or helicopter was used. In this case the Camera Stations above the building, and at ground level on one side of the building, are close to being 90° apart.



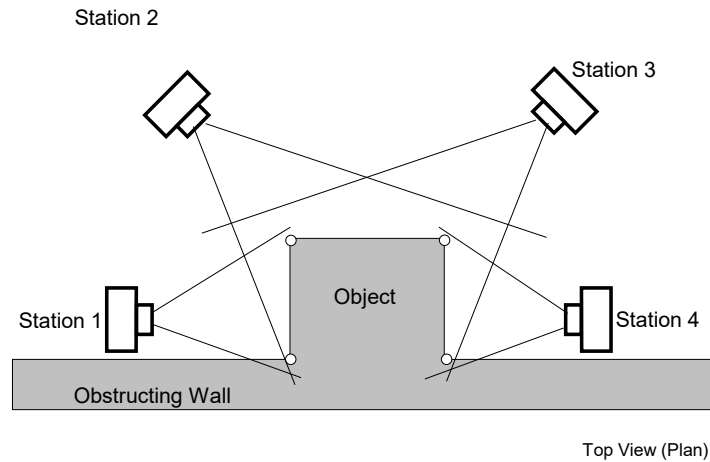
Guideline 3: Try to take photographs with good vertical and horizontal separation. Try to surround the object of interest and try to get above and below it.

Guideline 4: Get Good Photograph Overlap

PhotoModeler needs points marked in two or more photographs. Photographs taken side by side should contain many of the same object features and points.

PhotoModeler wants as many points referenced across photographs as possible, but the user wishes to minimize the marking task since it takes time. To balance these two, it is best if the photographs overlap as much as possible. The figures in this chapter all show the overlap between adjacent photographs.

The figure below shows a case in which two photographs have no overlap because of an obstruction. A box shaped object is being measured, but on one side of it there is a wall stopping the photographer from capturing the fourth side. For this reason, the photographs at Station 1 and 4 do not overlap. In other words, they share no common points on the object. This measurement can be done, but some of the points marked will appear on two photographs only. These points near the wall will probably have lower accuracy than the rest of the measurement because of a lack of redundancy and poor strength in the geometry of the network of points and cameras.



Problem with Photographs with No Overlap

One way to get around the problem presented in this figure is to add a fifth Camera Station located between Stations 1 and 4 but above the wall, looking down. This fifth Camera Station will have overlap with Stations 1 and 4 thereby increasing the accuracy of the top points near the wall. It might also share some points with Stations 2 and 3 increasing the redundancy and network strength even more.

Guideline 4: Try to get good overlap of the photographs. In other words, try to make sure a high percent of the points in any one photograph show up in the adjacent photographs.

Guideline 5: Take Many Pictures, Use Only Those Needed

In many measurement situations, having to repeat the picture taking is expensive. Sometimes the object or scene you photographed no longer exists or has changed. Sometimes the site where pictures were taken is hard to reach and going back to redo the photography would be expensive. The photographs themselves are inexpensive and this is especially true of digital cameras.

For these reasons, it is a good idea to take many photographs of the object you are measuring. This way, if some of the photographs do not turn out, or if you wish to add some detail to the 3D model that was originally unplanned, you can use your existing photographs instead of going back to retake pictures.

Guideline 5: Take as many pictures of the object or site as you can, or as your budget will allow. As you start a project use perhaps three to six photographs. Add photographs later if you determine that some part of the scene or object is too difficult to measure with the current set of photographs.

Once the basic photographs have been taken, as outlined in Guidelines 1 through 4, extra photographs can be taken:

- closer up to get more detail,
- farther away to encompass more of the object or of its surrounds,
- in-between the planned Camera Stations,
- higher and lower than the planned Stations,
- with rolled (portrait vs landscape) positions if field calibration is a possibility, and
- with different exposure and aperture settings (if allowed by your camera).

Guideline 6: Measure the Distance Between Two Points

When you are taking the photographs you should measure the distance between two points that you are photographing. You will use this distance to add scale to your 3D model. Sometimes, if you are modeling an object to produce a rendering, you may not need an accurate scale for your model in which case you need not measure a scale distance.

To get a scale, choose two points that are close to the largest dimension of the object you are measuring. In addition choose points that will appear on many photographs. Measure, or estimate by some means as accurately as possible, the distance between them. Make sure that you will be able to identify and clearly mark these points on your photographs. If you are measuring a facade, the width of the facade at its base is often a good scale choice. Record this distance for use as your scale later. The points you pick for scale should also be easily marked. That is, they should not be rounded corners nor be fuzzy features. The absolute accuracy of the dimensioned drawings depends to a large extent on how well you measure and mark the scale.

The absolute accuracy of the final 3D model will depend on the accuracy and precision of the scale. Make sure that the two points being used to measure scale are:

- easily identifiable in many photographs,
- a large distance apart,
- sharply defined by high contrast straight edges or corners (or ideally on circular targeted points).

By taking the above precautions, your scale will be easy to measure and the scale points will be easy to mark with high precision. The result will be a model with accurate scale.

See *Adding Scale and Rotation* in the Help file.

Guideline Summary

To summarize, the guidelines to follow when taking photographs for measurement are:

- try to get the angles between the shots as close to right angles (90 degrees) as possible,
- take at least three photographs,
- try to get all important points on at least three photographs,
- try to get as much overlap between adjacent photographs as possible,

- try to get photographs from both above and below the object, if possible,
- take many photographs of the object but use only four at the start until you determine you need some others, and
- measure the distance between two visible and clearly delineated points.

You do not need to follow these guidelines strictly, but you should be aware of them. The closer you come to meeting these guidelines, the easier the measurement process will be and the more accurate the measurements.

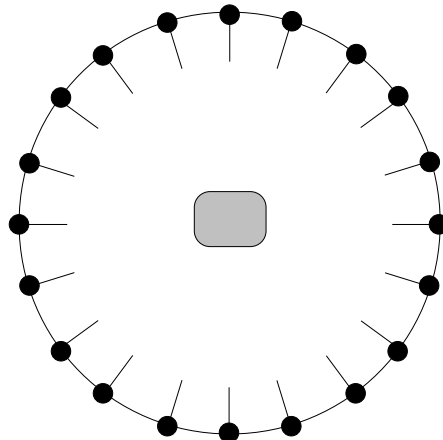
See *DSM Photo Requirements* for more information on photography for PhotoModeler Scanner projects.

The Ring Method

A good method for taking photographs in many situations that covers many of the guidelines is the concept of "rings". Remembering this concept of 'photograph rings' is a good way to cover most of the photography guidelines without having to remember them all.

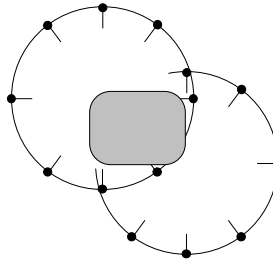
Photographing an object using "rings" is quite easy:

Set up the first ring: Stand such that all of the object(s) being measured can be seen in the viewfinder of your Camera and it fills most of the viewfinder. Take a picture. Step around the object as if a string ties the Camera to the center of the object and the string always stays tight. Take many photos as you step around:

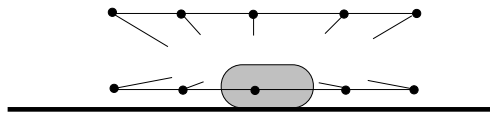


Top View of Camera Positions in a Ring around Object

Set up other rings: Stand closer to the object now so a bit less of the object shows up. You might then want to center around an important part of the object. Take the photos.



Set up height rings: Raise the camera so it points down at the object more and repeat the previous set of rings. Also lower the camera so it points up and repeat the rings. Take the photos.



Side View of Camera Positions in a two Rings at different heights

Set up an overall view ring: Stand even farther away from the object to cover the object under consideration and some of the surrounding area. Step around this larger ring taking photographs.

This ring method looks like it uses many photographs. You do not have to take all the photographs shown here but instead use it as a guide. Also taking more photographs than you plan to use in your PhotoModeler project is good because photographs tend to be inexpensive and going back to the object or the site tends to be expensive or impossible. You never know when you might need something in one of those other photographs!

If possible take one or more photos covering the whole object or scene or as much of it as possible (ie from above). This can help 'tie' together the sides of the object or scene as a few key points from all sides can be marked and referenced in these overview photos.

Not all scenes or objects lend themselves to a pure "ring" method. Try modifying it to meet your needs, remembering to vary the angles, vary the distance and vary the height.

Single Photograph Projects

PhotoModeler is capable of carrying out many different types of projects with only a single photograph.

The key to single photograph projects is that you provide some additional information in terms of assumptions or knowns to help PhotoModeler solve the 3D problem.

This additional information comes in the form of Shapes, Control Points or Constraints.

The requirements for photographs used in single photograph projects are not as strict as with multiple-photograph projects as described above. The main requirements are:

- the photographs be clear and in focus,
- the known objects (shapes, control points, constrained edges & lines) be clearly visible and spread out over the photograph, and
- if trying to recover all the camera parameters in an Inverse Camera procedure, the photograph should be in three point

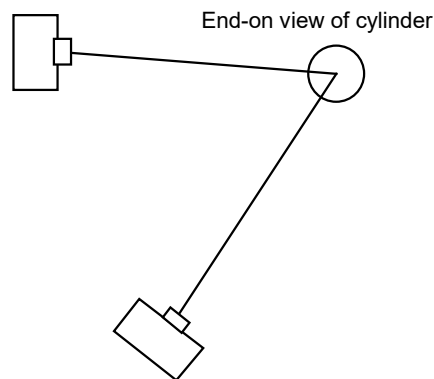
perspective (i.e. have three vanishing points). Think of taking a picture of a building from its corner instead of face-on.

Photography for Curves, Edges, and Cylinders

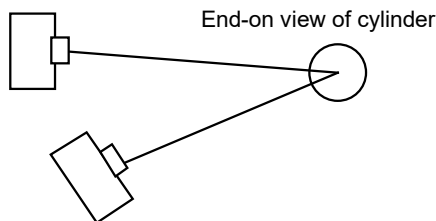
There are some additional requirements when taking photographs when you know you will be modeling with curves, edges and/or cylinders. See section below for more detail on curves.

PhotoModeler's edge, curve and cylinder algorithms depend on a good angular separation between the photos as rotated about the object centerline. The angle ideally should be 90 degrees but you will get good results down to as low as 15 degrees. Where we refer to "cylinder" below you can replace "edge" or "curve section" and the meaning is the same.

The following diagram shows the end-on view of a cylinder and the two camera positions for two photos being use to reference it. This example would give a good cylinder result.



This next example would give a worse result because the possibility for error in the cylinder or edge algorithm is greater.



Another way of thinking of the requirement is this:

- if you have vertical edges or cylinders then you need photographs that move along the horizontal direction
- if you have horizontal edges or cylinders then you need photographs that move along in the vertical (height) direction.

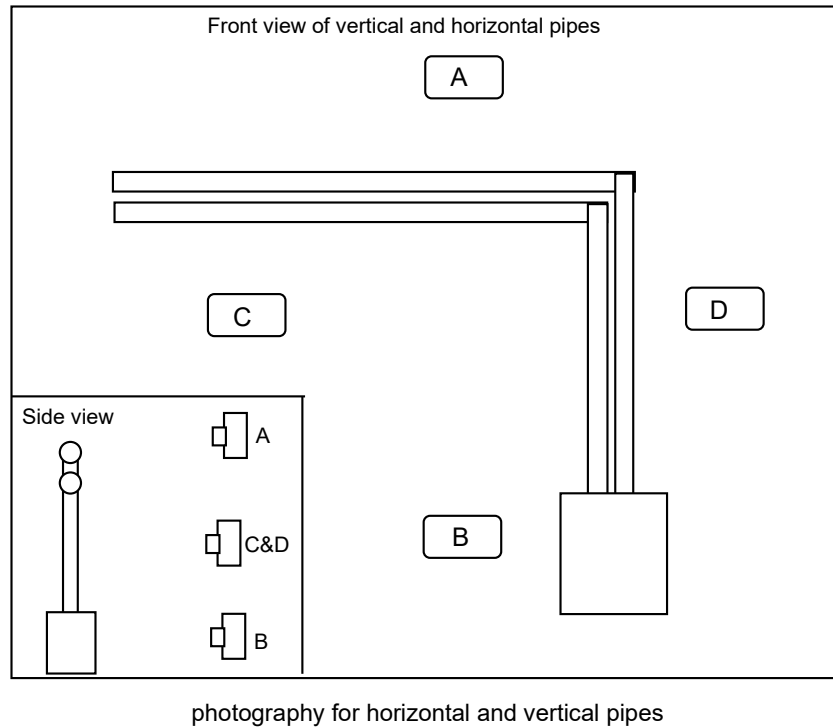
Using cylinders as an example again we show an example in the figure below. If you were to use just photographs A and B you would get good results for the horizontal pipes because of the good angle separation about the horizontal pipe centerline. On the other

hand A and B would be bad photographs for the vertical pipes because there is very little angle about the vertical pipe center line.

Photographs C and D are good photographs for marking the vertical pipes but are poor for the horizontal pipes.

This means that to model both sets of pipes you would either need all four photographs in the project or you could use a two photo combination like A and D but that would not be ideal.

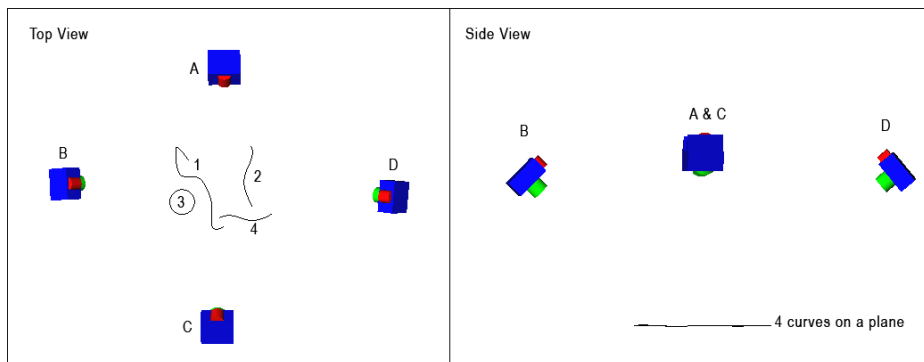
You can think of Edges and thin pipes/cylinders and small segments of curves as thin short sections of pipe/cylinder. In this way this example encompasses all object types.



Photography for Curves

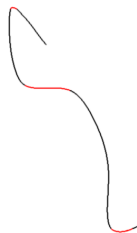
The requirements for taking photos in a project with curves is similar to the edge and cylinder description above but because a curve is not a straight segment, it can be both horizontal and vertical. This can make the photography more challenging.

You need both vertically separated photos and horizontally separated ones and the curve has to be marked and referenced on all of these photos. It is similar to the vertical and horizontal pipes example above. Imagine we had a circle curve, two 'straight-ish' curves and a complex curve on a plane. What photos would give good angles for all parts of all curves?



Curves 2 and 4 are close to being straight and require only two photos to model them well. Curve 2 is captured well by photos B and D and curve 4 is captured well by photos A and C.

Curves 1 and 3 have sections that point in all compass directions. For the circle 3, you might be able to mark and reference on just two photos but there will be areas that are not solved and only the circle fitting will overcome the deficiencies. Curve 1 is not fitted and if you were to use just photos B and D the parts shown below in red would not solve (and this may mean the end of the curve is missing or most is missing depending on which end the curves 'starts' at (where the shared referenced point is).



If all four photos are marked with curve 1 then it should solve completely.

Import the Photographs into PhotoModeler

Once all the photographs are taken, they can be imported into PhotoModeler. See the section called *Importing and Using Photographs* for details.

Mark Features on the Photographs

The individual photographs are shown on the screen in PhotoModeler. You mark points, curves, edges, cylinders, or shapes on the photographs to denote the features that are important to you. Higher level features such as lines and surfaces are then built on these marked features.

The *Building a 3D model* section describes the marking steps and other steps that are needed.

Identify which Points are the Same

PhotoModeler uses the marks in multiple photographs to determine where a point is in three dimensions. When you mark a point or a line in a photograph, you need to mark the same point or line in all photographs in which it appears. PhotoModeler needs to know that these are the same points; it cannot infer that information from the photographs.

For example, if you were measuring an automobile and had taken four photographs of it, then the headlights would show up in two of the photographs. You would mark the outline of the headlights in both photographs and then tell PhotoModeler, using a process called "referencing", to associate the points on one photograph of the headlight to the points on the other photograph of the same headlight.

The section on *Referencing* describes these steps. Single photograph projects based on control points do not require this step.

Note that in a single photo project a different method of calculating 3D is used and this referencing step is not required but the addition of Constraints is.

Process the Data

Once the initial marking and referencing is complete, you will tell PhotoModeler to process the data using the Process tool on the toolbar or Project menu. See *Processing Dialog* for more information on processing options.

If you have *Automatic Processing* turned on, PhotoModeler will automatically process your data once you have provided enough information for PhotoModeler to use.

If you have been reasonably careful in your work, PhotoModeler will work on the data for a few moments (the amount of processing time depends on the number of photographs and the number of Marked Points) to produce a three dimensional model.

See the section on *Processing Points-Based* for further details.


Automatic Processing


Projects can optionally be set to process automatically when a change is made that could affect the projects state. When starting a project as soon as the minimum requirements

(see *Minimums*) are met, photos will orient automatically. The processing status icon on the status bar (see *Status Bars*) will briefly change to show that processing is taking place, and once done, the icon will revert to the 'running' icon.

As a project grows and processing starts to take more time a message will appear asking if you would like to switch off automatic processing. Once turned off, you must manually process the project by using the Process tool.

Automatic processing can be turned on or off by clicking the status bar processing icon or on the *Project Information dialog* box.

When Automatic Processing is enabled the icon looks like this: 

When disabled the status bar icon looks like this: 

Export the Resulting 3D Data to a CAD or Graphics Program

Once the three dimensional model has been created by PhotoModeler you can save your results and export the model to another program (you can also output a view to printer, file, or clipboard, see *Output to Printer, Clipboard or File*). The 3D model can be read by any program that can read DXF, 3DS, OBJ, VRML, IGES, 3DM, STL or RAW files. The section called *Using Your 3D Model with Another Program* describes this further.

If you want simple measurements, such as lengths or areas, you can get these directly from PhotoModeler, and for this purpose you do not need to export it to a CAD program. The section *Measuring Features* describes doing measurements within PhotoModeler.

Once the initial measurements and modeling are complete you can continue to work on the model in PhotoModeler by adding more points and lines and by re-executing the 3D processing step. Basically you can repeat steps 5 through 8 (as shown at the start of this chapter) as often as you would like. You can even repeat steps 1 through 4 if you wish to add additional photographs to the project.

In PhotoModeler you can also define a scale by indicating the known length of a marked line in a photograph. A rotation and coordinate system can also be defined for the object if that is important during your CAD modeling. The *Improving your 3D model* section goes into more detail on this subject.

Working with Measurement Projects

PhotoModeler treats each set of photographs and the information needed to produce a 3D model as a *Measurement Project* or simply "project". PhotoModeler saves the state of your work in a project file and allows you to resume working with saved project files.

PhotoModeler does not save each photograph image in the project file, instead the project file refers to your photographs which are stored separately on the hard disk. When your 3D model is complete, PhotoModeler can export many different file formats from your project.

A project can be returned to at any time to refine your measurements or to add detail to your 3D model.

Creating a New Project

Project Types

To create a new project click on the Getting Started Tool on the toolbar, or select "Getting Started..." from the File menu.

PhotoModeler will open the *Getting Started Panel* where some initial selections can be made. The Getting Started Panel provides up to 5 different project type options, Points-based, Shapes-based, Camera Calibration, Automated Coded Target Project (with the Coded Targets Module), and PMV project (with the PhotoModeler video module).

Note: You can also drag and drop images from Windows Explorer directly onto the PhotoModeler window to start a quick project without going through the wizard. See *Drag and Drop*.

Points-based project

Choose "Points-based project" when you are carrying out most PhotoModeler projects including single and multiple photo projects. See *New Project Wizard* for information on the steps to create this type of project.

The sequence of steps when creating a Points-based is:

- select your project photos (see *Project Wizard: Select Photos*),
- provide the source of the camera information (see *Project Wizard: Camera Source*). Note that if your photos have sufficient EXIF information, and if you have the camera(s) that took the photos stored in your Camera Library, PhotoModeler will automatically match and assign the appropriate camera to your photos (see *Camera Matching* and *Camera Library*).

Shapes-based project

Select this option when you intend to use shapes. See the *Shapes Modeling* section for more detail. See *New Project Wizard* for information on the steps to create this type of project.

The sequence of steps when creating a Shapes-based project is:

- select your project photos (see *Project Wizard: Select Photos*),
- provide the source of the camera information (see *Project Wizard: Camera Source*). Do note that if your photos have sufficient EXIF information, and if you have the camera(s) that took the photos stored in your Camera Library, PhotoModeler will automatically match and assign the appropriate camera to your photos (see *Camera Matching* and *Camera Library*).

Camera Calibration project

Select this option when you are calibrating a camera. See the *Camera Calibration* section for more detail. See *New Project Wizard* for information on the steps to create this type of project.

When creating a Camera Calibration project, you simply select your calibration images (see *Project Wizard: Select Photos*). When you press the Next button after adding your images a new project will be created and a dialog will appear. You then execute the process from the *Camera Calibration Dialog*.

Automated Coded Target project

Choose “An Automated Coded Target project” when you have a set of photos taken using coded targets and you wish to fully automate the project. This option allows for automatic marking, referencing and processing of all photographs, as well as adding scale/rotate and/or constraints.

For more information on the settings file see *Project Wizard: Automated Coded Targets Project*. This project type is available only if the Coded Target Module is installed.

PMV project

Choose “A PhotoModeler Video Project” when you are doing video projects with targets. See the *PMV PhotoModeler Video* section for more information on this type of project. This project type available only if the PMV Module is installed.

New Project Wizard

The wizard leads you through a series of panes gathering photos and information about your camera and project. If you do not wish to create a new project you may press Cancel at any time to abort the wizard. To advance to the next pane press the Next> button and to return to the previous pane press the <Back button. This section describes the functions of each pane in the wizard. The top portion of the wizard panes briefly outlines the purpose of each pane.

Note: Coded Target and PMV project type paths aren't available in the wizard unless the add-on modules are installed. See *Modules and Licenses* for more information on available add-ons.

The first step for most projects is to select your photos, but photos can always be added or removed later using the *Add/Remove Photographs Dialog*. See *Project Wizard: Select Photos* for more information.

The next steps typically involve choosing the 'camera' that took the photos in your project. See *Working With Cameras* for more detailed information about camera types etc. The wizard shows several camera options so PhotoModeler can set up the camera for optimal use and accuracy. See *Project Wizard: Camera Source* for more information.

The following is a description of the Project Wizard panes.

Project Wizard: Select Photos

This pane allows you to add photos to your project. The pane has three components: toolbar, image file on disk viewer, and project image viewer. The small toolbar contains controls for navigating and viewing images on disk and in your project. The file viewer on the left side of the pane lists images in the directory currently selected; the file viewer on the right shows images that have been added to the project. When starting a new project, the right side will be empty, and the left side will show images in the current directory, which by default will be the directory of the most recently saved PhotoModeler project.

Select the directory to browse using the Directory Selector drop down control on the toolbar. Note that when the mouse cursor is positioned over the selector, the full path of the directory is shown in the tooltip. Once a directory containing images is selected, the left side of the dialog will show images in that directory. Only image types supported by PhotoModeler will display in this area (see also *Add/Remove Photographs Dialog*).

Navigate up to the current directory's parent directory by clicking the 'Move up' button on the toolbar. You can also type the path of the directory in this control.

Display images (on disk and in project) either as thumbnails or in a list showing file details, by selecting either 'Details' or 'Thumbnails' in the View Style drop down tool on the toolbar. The icon shown on the View Style tool shows the current view style. Showing 'Details' allows you to view image information (i.e. name, size, type, date modified); showing 'Thumbnails' allows you to view a small 'thumbnail' version of the images.

Note: the size of the thumbnails can be set on the Photo Control page of the Preferences dialog. See *Preferences - User Interface*.

Once your images are shown in the left pane, you select the images that you want to add to the project and then click ">>" button to move them into the project. You can also double click these image files to move them into your project. To add all images in the directory to the project, click the "All>>" button. Once an image is added to the project, it will not be shown in the left pane. You can add images from one or more separate directories. Images can be removed from the project by clicking "<<" (for selected project images) and "All<<" to remove all images from the project.

The ">>" button enables when an image file is selected on the left, while the "<<" button enables when a project image is selected. When images are selected, the path of selected image is shown below their respective frames

Once you have selected all the images you wish to add to your project press the Next> button to advance to the next wizard screen. Remember that you can add or remove photos at any time using the *Add/Remove Photographs Dialog*, but the "Next >" button will not enable until you add at least one image to the project.

Next you input camera information, see *Project Wizard: Camera Source*.

Note: If your photos have sufficient EXIF information, and if you have the camera(s) that took the photos stored in your Camera Library, PhotoModeler will automatically match and assign the appropriate camera to your photos (see *Camera Matching* and *Camera Library*), so the wizard will complete when clicking "Next>". A Camera Matching notification will appear noting the camera that was matched with the photos. If you have a mix of photos with varying focal lengths and not all photos were matched with a camera in the library, a dialog will appear giving you the option to a) manually assign cameras to each photo (i.e. click Yes to bring up the *Project Wizard: Camera Matching* pane), b) select a single source (i.e. click No to bring up the *Project Wizard: Camera Source* pane, or c) to reselect a consistent set of photos (i.e. click Cancel to bring up the *Project Wizard: Select Photos* again).

Project Wizard: Camera Matching

If you have a mix of photos from different sources (e.g. with varying focal lengths) and not all photos were matched with a camera in the library, a grid is shown showing photo information. The cells in the Camera column each have a drop down control allowing you to select the source of the Camera. This drop down becomes visible when you click on the Camera cell in the grid. Within this drop down control, you have the option of 1) Browsing for a camera on disk to assign to the selected photo, 2) assigning a Default generic camera to the selected photo, or 3) selecting from a camera on in your camera library.

Do note that once your project has been set up, it is possible to import or create new cameras that you can assign to your photos. See *Photo Properties* for more information on camera assignment.

Project Wizard: Camera Source

This and subsequent panes guide you through setting up a camera for use with PhotoModeler.

The term "camera" is used to refer to all the equipment used to turn a real-world view into a digital image. In the case of a digital camera that will be the only device used, in the case of a film camera setup this also includes adjustments for the scanner. If any changes are made to the equipment a new camera must be setup to reflect these changes (e.g. If you change a camera's lens, or zoom or crop your images differently when you scan prints).

Do note that if your photos have sufficient EXIF information, and if you have the camera(s) that took the photos stored in your Camera Library, PhotoModeler will automatically match and assign the appropriate camera to your photos (see *Camera Matching* and *Camera Library*), so this pane will not appear.

If the camera you are creating has already been used in a PhotoModeler project (and you have a copy of the project containing the camera, or a stored .cam file) you should select the "A calibrated camera (from library or from disk) or a camera previously used in PhotoModeler" radio button. This enables the controls which allow you to select a specific camera, from:

- the *Camera Library*, a central repository on disk where calibrated cameras are stored (see also *Application Data and File Locations* for information on location of this and other files used by PhotoModeler), or

- the project in which the camera was used. Click Browse... to find the appropriate project. If the selected project contains more than one camera, a dialog box shows the list of cameras in the project allowing you to select the one you want loaded.

If the camera that took the photos is from an unknown source, that is, a camera that has not been calibrated and/or used in a PhotoModeler project before (e.g. in forensics, accident reconstruction, or historical architecture), select the "An unknown camera, whose parameters will be solved by:" radio button, which enables 4 other options when selected:

- Control Points/Imports [need 5 or more control points] – Select this option when you intend to use control points or imports to solve the camera and for orientation. See *Imports* for more information on this type of project. This option is only available if the 'Points-based' project was selected on the *Getting Started Panel*.
- Shapes [predefined shapes such as boxes, wedges, pyramids, etc] – Select this option when you intend to use *Shapes* in your project. This option is only available if the 'Shapes-based' project was selected on the *Getting Started Panel*.
- Constraints [need 3 or more parallel and perpendicular lines in perspective] – Select this option if your photo(s) have strong perspective and show features that define 'axes' constraints. See *Working With Constraints* for more information. This option is only available if the 'Points-based' project was selected on the *Getting Started Panel*.
- Approximation [camera will not be solved – suitable for photo review only] – Select this option if it is a film camera or if you know nothing about the camera, have no information about the scene in the form of control points or imports, or your photos aren't suitable for shape or constraint use. This option also can be used to set up an 'EXIF' camera which uses the photo's EXIF information (if present) to create an approximate camera. The next pane, *Project Wizard: Camera Type*, will ask for more information about the camera

Once you have selected the camera source requested by this pane press the Next> button to advance to the next wizard screen. The Next> button will enable once you have made a valid selection.

Project Wizard: Camera Type

When you are using an approximate camera for the first time with PhotoModeler you have three options:

1. Film Camera: If you are using a film camera and you know the camera's parameters such as Focal Length, Principal Point and Distortion parameters, you can enter these manually. The wizard will ask you a series of questions about the camera and the photographs that you took.
2. Approximate Digital Settings: Choose this option if you want to review photographs and you do not want to properly set up the camera in PhotoModeler. Your project may not process if the settings do not match well enough to your actual camera, especially since your camera will have very basic and generic digital camera parameter values. You can set up a proper camera at a later date and assign it to your photographs. If this option is selected, you have provided enough information to start your project work. Clicking "Next>" will end the wizard.
3. EXIF Setup: Choose this option if you want to set up an approximate camera in PhotoModeler based on the images' *EXIF* information. This option is enabled only if your project images have enough data to form an approximate camera setup. Your project may not process if the settings do not match well enough to your actual camera. You can set up a proper camera at a later date and assign it to your photographs. If this

option is selected, you have provided enough information to start your project work. Clicking "Next>" will end the wizard.

Project Wizard: Film Camera Setup

When you are using a film camera, PhotoModeler needs information on the Film Format and Film Alignment Method:

- **Film Format:** By default the format size is 36mm (typical of a 35mm camera) and the focal length is 45mm. If the camera is a medium format or large format film camera (i.e. not a 35mm camera) then you will be able to choose the format here and if the actual format size is known, select the "Other format size, enter width:" radio button and enter the format width. The format height will be automatically calculated based on the aspect ratio of the photos already added to the project.
- Enter your camera's focal length in the edit box provided. The focal length of your camera can normally be read off the camera's lens or can be found in a manual or specification sheet. If you are using a digital camera refer to the actual (physical) focal length NOT the 35mm equivalent. If you cannot find your camera's focal length use the default estimate provided by the wizard.
- If the actual Focal Length is known, enter it in the space provided. However, the focal length will be approximated based on the format size.
- The information in this pane is used to set the Camera's format size (fw, fh). If no fiducials are being used at all then the exact format size is critical to getting good measurements.
- **Film Alignment:** If you are using a film camera, you may have fiducials or a reseau grid. A fiducial is a reference point that appears in each photograph. The fiducials can be used to recover the position of the film in the camera at the time of exposure.
- **Fiducials come in different forms:** The two point insert and the full frame 9 point insert (available from Eos), the corners of the focal plane opening (if seen in the images) can be used as four fiducials, and metric cameras (designed specifically for photogrammetric measurement) have built-in fiducials or a reseau. A reseau is a grid of crosses on a glass plate in front of the film in the camera.
- If the prints or negatives have been consistently scanned and there are no fiducials, select this non-fiducial default setting.
- If your film camera has fiducials, a reseau or the images can be used with frame fiducials (the four corners of the imaged black rectangle around the print) then enter the appropriate type using the 'Fiducials' controls to set up the type of fiducials used in your camera. When selecting the "Eos 2" or "Eos 9" fiducial insert, a diagram will appear demonstrating the fiducial offset measurement. Unless you select Other Fiducials, this is the last pane and the Finished button will be enabled. When selecting the "Other Fiducials" you will be prompted in the next wizard pane to set them up (see *Project Wizard: Fiducials Setup*).

Project Wizard: Fiducials Setup

You have specified that this film camera has fiducials and they are frame or other custom fiducials:

- **Full frame fiducials:** PhotoModeler may already know the rough size of the format but fiducials must be very accurately defined. For this reason, it is recommended that you open the camera back and measure the exact height and width of the format (as shown in the diagram on this pane). For example, a nominal format size for a 35mm camera is

36mm wide by 24mm high but if you measure your camera you might find it is 36.2 by 23.8 mm. You would enter these measured numbers here.

- If you have film loaded in the camera and cannot do this measurement now, enter the nominal format size (i.e. 6 x 6 cm, 5" x 4", 36 x 24 mm) and then correct the fiducial later in the *Camera Viewer Dialog*.
- Custom Fiducials: If you are using a film camera with non-standard fiducials, you can define the fiducials here.
- Press the Add button to add new fiducials. After hitting Add, you can edit the name and X,Y position. Note the X,Y position of the fiducial is in mm and it relative to a 0,0 point at the upper left of the image. Normally you will have one fiducial (the most upper left one on the image) at 0,0mm. Remember to choose a name for the fiducial that will be obvious when you are marking the fiducials on the photos.

This is the last pane in the Film Camera set up process. When finished setting up the film camera, the Finished button will appear and when clicked will end the project wizard.

Project Wizard: Choose PMV Project Type

This wizard screen prompts for which type of PhotoModeler video project you would like to create. A type 1 project requires static cameras and can be used to track objects where all points are moving. A type 2 project requires some static points in the project but the camera positions can change between frames. See the introduction in the *PMV PhotoModeler Video* section for more information.

Project Wizard: Welcome (Type 1 PMV Project)

The Project Wizard welcome screen lists the steps required to complete a standard PhotoModeler Video project (type 1). The wizard will guide you through steps 1, 2 and 3. If you do not wish to create a new project you may press Cancel at any time to abort the wizard. To advance to the next pane press the Next> button.

See *The PMV Procedure - Type 1* section for more information on how to setup a PMV project.

Project Wizard: Load Cameras (PMV)

This wizard screen prompts for the cameras used to shoot the PMV sequence. Press the "Load Camera" button to add a camera. This will bring up a file section box where you can choose a .PMR, .PMV or .CAM file to load cameras from. The list box in the middle of this wizard screen will show all the cameras loaded so far. You should load a camera definition for each camera used when shooting the sequence.

Project Wizard: Load Images (PMV)

This wizard screen prompts for the images to be used in the project. Pressing the "Select Image Sequence" button will bring up a file section dialog. Since PMV is a video project, there will be one image frame per epoch per camera. The image frames can be either in separate files (one image file (e.g. TIFF or JPEG file) per epoch per camera), or combined in one AVI file (one AVI file per camera). See *The PMV Images* section for more information.

When the file dialog appears, choose one image from the sequence or an AVI file. If a single image file is selected the wizard will then search the current directory for the other

images in the sequence. If a valid sequence or AVI file can be found you will be prompted to select which camera was used to take the sequence. The camera, sequence name and number of images will then be displayed in the wizard pane. Add all the image sequences you require for the project.

Project Wizard: Starting Epoch (PMV)

This wizard screen prompts for starting epoch number. If you would like to track your sequence backwards select the last epoch, if you would like to track forwards select the first epoch.

Project Wizard: Finished (Type 1 PMV Project)

You have reached the end of the PMV project setup wizard for a type 1 project. When you press the Finished button a new project will be created based on your answers to the wizard's questions. If you wish to change any of your settings you may use the back button.

Once your new project is created you will need to mark, track, reference and process your project. See the *PMV PhotoModeler Video* section for more details on PMV projects.

Project Wizard: Welcome (Type 2 PMV Project)

This Project Wizard welcome screen lists the steps required to complete a type 2 PhotoModeler Video project. The wizard will guide you through steps 1, 2 and 3. If you do not wish to create a new project you may press Cancel at any time to abort the wizard. To advance to the next pane press the Next> button.

See *The PMV Procedure - Type 2* section for more information on how to setup a PMV project.

Project Wizard: Type 2 Image Format

This Project Wizard screen lets you select how the images for each epoch in a type 2 project are to be identified. The options are: a) each epoch's images are in a sub-folder, in this case each epoch has a separate folder that contains the images used for it; b) the images use the same naming scheme as type 1 projects do: "AAAATTTT.jpg" where AAAA is an identifier that is unique within the epoch TTTT is the epoch number and jpg is the image format extension.

Once the image type is selected use the browse button to select the root directory where the images or sub-folders are located.

Project Wizard: Type 2 Directory Order

This Project Wizard screen is displayed if you are creating a PMV type 2 project where each epoch's images are in sub-folders. All the sub-folders in the selected parent directory are displayed as well as the number of image files within each. You can select a folder from the list and use the buttons on the side to change the order of the epochs and/or remove directories you do not want included in the project.

Project Wizard: Finished (Type 2 PMV Project)

You have reached the end of the PMV type 2 project setup wizard. When you press the Finished button a new project will be created based on your answers to the wizard's questions. If you wish to change any of your settings you may use the back button.

Once your new project is created you will need to mark, track, reference and process your project. See the *PMV PhotoModeler Video* section for more details on PMV projects.

Project Wizard: Automated Coded Targets Project

This pane allows you to select the type of automated project.

A 'RAD project' is almost fully automated, and works with the PhotoModeler RAD targets (see *Coded Targets*). Various parameters for this type of project can be set on *Preferences - Coded Targets*.

An 'Automatic project with additional parameters' allows you to adjust various parameters during the wizard. You can also use a 'settings file' for this type of project. A 'settings file' is a file stored on disk that contains the settings used in a previous project setup. The settings file is useful and can save you time when your project work is repetitive and consistently uses the same project settings. If you have gone through the wizard and you have stored a "settings file". You can enter the name of the file (or Browse... for it) here.

An Automated Coded Targets Project typically relies on the use of Coded Targets. See *Automated Coded Targets Project* for information on how to set up this type of project.

Project Wizard: Automated Project Stages (Automated Coded Targets Project)

This wizard screen is displayed when you are setting up an automated coded target project. See also *Automated Coded Targets Project*.

On this screen you choose which stages you want to execute during the automation. There are two automatic marking stages, two processing stages, an automated non-coded target referencing stage and two coordinate system scale/rotate stages.

Depending on which options you choose, other valid options will become available. Also depending on which options you choose, other wizard screens will appear when you press 'Next', asking for the appropriate parameters for the requested stages.

The stages are described here:

"Automatic Marking Stage 1" performs coded and non-coded target marking. It is typically used to mark (and reference) some coded targets. The "Targets that are Coded in Stage 1" radio buttons control what type of target marking is done in this stage. If the 'None' button is selected, no coded target searching will be done (and hence no further automated processing can be done because there will be no referenced points). If the 'Some' button is selected, both coded and non-coded targets will be marked using the same settings. If the 'All' button is selected; only coded targets will be marked in this stage. The corresponding settings pane is: *Project Wizard: Marking Stage 1 Settings (Automated Coded Targets Project)*.

"Processing Stage 1" performs a Processing (Orientation and Global Optimization) on the coded targets that have been marked and referenced in the first stage. This computes the 3D locations of the points. This option is available only if "Automatic Marking Stage 1" is chosen and one of the "Some" or "All" options is chosen.

“Automatic Marking Stage 2 (Non-coded Targets only)” performs non-coded target marking and is used only when you want to mark your coded targets and non-coded targets with different settings. This option is available only if “Automatic Marking Stage 1” and “All” options are chosen. Stage 1 Marking is used to mark the coded targets and Stage 2 Marking is used to mark the non-coded targets. The corresponding settings pane is: *Project Wizard: Marking Stage 2 Settings (Automated Coded Targets Project)*.

“Automatic Referencing” performs automated referencing on non-coded points. Available if the “Automatic Marking Stage 2” option is chosen or the “Automatic Marking Stage 1” - ‘Some’ targets option is chosen. The corresponding settings pane is: *Project Wizard: AutoReferencing Settings (Automated Coded Targets Project)*.

“Processing Stage 2” performs a Processing (Orientation and Global Optimization) on all the points (coded and non-coded) referenced so far. Available only if the “Automatic Referencing” option is chosen.

“Setting Translate / Scale / Rotate” sets up the affine transformation of the coordinate system for the project based on coded targets. The corresponding settings pane is: *Project Wizard: Scale/Rotation (Automated Coded Targets Project)*.

“Setting Distance Constraints” sets up one or more distance constraints used when one wants to achieve the highest scale accuracy. The corresponding settings pane is: *Project Wizard: Distance Constraints (Automated Coded Targets Project)*.

One typical scenario would be a project that has just coded targets. In this case you would pick these options: “Automatic Marking Stage 1”, “Targets that are Coded in Stage 1 = All”, “Processing Stage 1”, and “Setting Translate/Scale/Rotate”.

Another project type might have a mixture of coded and non-coded targets, where the coded and non-coded targets were the same size, where there were sufficient coded targets to orient every photo, and where sufficient photos and points exist to ensure successful automatic referencing of non-coded targets. In this case you would pick these options: “Automatic Marking Stage 1”, “Targets that are Coded in Stage 1 = Some”, “Processing Stage 1”, “Automatic Referencing”, “Processing Stage 2”, and “Setting Translate/Scale/Rotate”.

Two additional controls allow you weld targets that are coded but mis-marked (e.g. due to code occlusion), and delete non-coded point marks that lie in a 3D “disk” volume around a coded target. The settings that control these are on the Coded Targets panel of the Preferences dialog - see the Coded Targets section in *Preferences - Marking and Referencing*.

In addition there are some hidden options to further control the processing of Coded Target Auto projects. These options can be set in an ini file (either in a Settings file or the regular PhotoModeler ini file, see below). You can control whether to delete Marked Points that appear on only one photo, add a 2nd stage of auto-referencing, add a 3rd stage of processing and add Fit NURBS Surface to points named during auto-referencing. These various options are intended to improve robustness of fully automated projects. If you are unsure when to use these to best advantage, please contact technical support.

The following are ini file strings that can be added to enable the various options. For example, the first setting could be manually added to a coded target settings ini file like this (see *Application Data and File Locations* for information on where the ini file is stored on disk):

```
[TargetStages]
RejectUnusedMark=TRUE
```


Marker Reject

When set to TRUE, all marked points that are not referenced (e.g., they remain on only one photo) after all auto-processing is complete, are deleted. This is a way to clean up an auto-project and leave only referenced and 3D points. You would not use this option if you intend to do any manual work (such as referencing) after the automation completes.

```
Coded Target Project Settings file setting: "RejectUnusedMark"  
Default: FALSE  
Settings file section: "TargetStages"
```

2nd Stage AutoReferencing

Adding the 2nd Stage Auto-Referencing and the 3rd Stage Processing stages can, in some automated projects, result in a more robust model, with a higher number of solved 3D points.

```
PhotoModeler ini file setting: "Do2ndStageAutoRef"  
Default: FALSE  
PhotoModeler ini file section: "AutoProject"  
(Note you can also set the minimum number of photos used during 2nd  
stage Auto-referencing with "2ndStageAutoRefMinPhotos" setting  
[default = 3] in the same section)
```

3rd Stage Processing

Adding the 2nd Stage Auto-Referencing and the 3rd Stage Processing stages can, in some automated projects, result in a more robust model, with a higher number of solved 3D points.

```
PhotoModeler ini file setting: "Stage3Processing"  
Default: FALSE  
PhotoModeler ini file section: "AutoProject"
```

Automatic Point Cloud (Fit NURBS Surface)

When this is set to TRUE, after all the processing is complete, all points that have been named during automatic referencing (auto-reference has a point naming option), will be collected together and a Point Cloud NURBS Surface will be created from them. (Note: this 'point cloud' is not a DSM point cloud, it is a surface as defined by the 'Fit NURBS Surface to selected points' tool)

```
Coded Target Project Settings file setting: "DoAutoPointCloud"  
Default: FALSE  
Settings file section: "TargetStages"
```

Project Wizard: Marking Stage 1 Settings (Automated Coded Targets Project)

This wizard screen is displayed when setting up an automated coded target project. The top line shows which coded target set will be marked (if coded targets are being marked, the set to be searched for was defined in an earlier wizard pane). The properties set here will be used by the automatic target marker when the wizard finishes. See ***Automatic Target Marking*** for details on these parameters. Note that if you are marking just coded targets, you can often err on the large size for the “Maximum center target size”. If the “Show images as they are marked” box is checked then each photograph’s image will be displayed in the user interface before the automatic marking starts on it so you can watch the progress.

Project Wizard: Marking Stage 2 Settings (Automated Coded Targets Project)

This wizard screen is displayed when setting up an automated coded target project and a second marking stage was requested in the stages pane. The properties set here will be used by the automatic target marker when the wizard finishes marking just non-coded targets. See ***Automatic Target Marking*** for details on these parameters.

Project Wizard: AutoReferencing Settings (Automated Coded Targets Project)

This wizard screen is displayed when setting up an automated coded target project and the non-coded target automatic referencing stage was requested in the stages pane. The properties set here will be used by the automatic referencer when the wizard finishes. See ***Automatic Referencing*** for details on these parameters. Note that the Search distance when left at the default of 0.0 will use the maximum ***tightness*** of coded target points (in absolute units not percentage) after the first coded target marking and processing.

Project Wizard: Scale/Rotation (Automated Coded Targets Project)

This wizard screen is displayed when setting up an automated coded target project and the Translate / Scale / Rotate stage was requested in the stages pane. This type of coordinate system transformation is defined based on coded targets. For example, you might have a scale bar with two known coded targets at either end. By entering those codes here and the know distance, scale can be automatically set up when the other processing stages have completed.

If you know the translation for a coded target you can check the ‘translate’ check box, enter the target code ID and X,Y,Z position. If the target is successfully identified during automatic marking, the project will be translated to match. (e.g. To shift the project into a specific coordinate system you could assign a target as 0,0,0).

If you know the distance between two coded targets you can use this to scale your project. Check the ‘scale’ check box, enter the target code IDs of the two targets and the distance between them. If both targets are successfully identified during the automatic marking, the project will be scaled to match the distance entered.

If you know which coded targets define the axis for your coordinate system you can check the 'rotation' check box and fill in the required rotation information on the following pane:
Project Wizard: Rotate (Automated Coded Targets Project).

Note: the target code IDs mentioned above are the numbers you find printed on the targets by the *Create Coded Targets Dialog*.

Project Wizard: Rotate (Automated Coded Targets Project)

This wizard screen allows you to set up a coordinate system rotation for an automatic coded target project based on the coded target identifiers. This pane will only be displayed if you check the activate check box on the previous pane (*Project Wizard: Scale/Rotation (Automated Coded Targets Project)*).

Activate two of the axes and enter the coded target IDs of the points that define them. This is similar to the scale/rotate option in the *Setting Rotation* dialog. The Next button will enable only when 2 axes are defined (you cannot define all 3).

Note that the numbers entered here are the code numbers for the coded targets and not the Point IDs seen on same targets after a project is done. Code numbers are printed on the coded target paper in a small font. For example, a target that might have code number 5 ("5" is shown on the printed coded target sheet), when the project is complete the point might have the ID 1005 or 2005. Coded points and non-coded points are kept distinct by placing them into their own thousands series. "5" is the number that would be entered in this dialog if that was the target of interest.

Project Wizard: Distance Constraints (Automated Coded Targets Project)

This wizard screen allows you to set up one or more distance constraints for an automatic coded target project based on the coded target identifiers. Two or more distance constraints can provide more accurate scale than the single scale distance found in the *Project Wizard: Scale/Rotation (Automated Coded Targets Project)* pane.

Review the "*Working with Constraints*" and "*2 points to be a given distance apart*" user manual sections to learn more about distance constraints and how constraints are processed.

When the pane first opens there is one distance constraint called "Unnamed" defined. Select the name field and give it a new name. Then in the Pt1 ID and Pt2 ID boxes enter the coded target IDs for the targets at either end of the known distance (this is often a scale bar). In the Distance box enter the known distance between these two targets. If you will allow the distance to vary because you know the scale's precision you can uncheck "Fixed" and enter in a known precision value.

To add a second distance constraint, press the Add button, and repeat the steps above. When the known distances have been added, press the Next> button to continue.

Note that the numbers entered here are the code numbers for the coded targets and not the Point IDs seen on same targets after a project is done. Code numbers are printed on the coded target paper in a small font. For example, a target that might have code number 5 ("5" is shown on the printed coded target sheet), when the project is complete the point might have the ID 1005 or 2005. Coded points and non-coded points are kept distinct by placing them into their own thousands series. "5" is the number that would be entered in this dialog if that was the target of interest.

Project Wizard: Offsets (Automated Coded Targets Project)

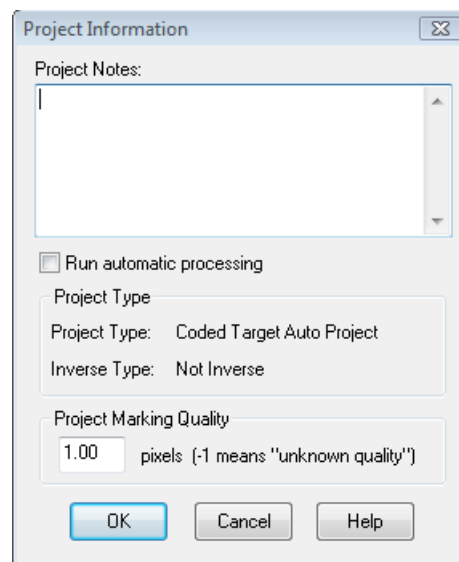
This pane allows you to set up offset points (see *RAD and Coded Target Offsets*) in a project, based on the ID's of the coded target points. Enter the range of points for which you have set up offset points.

Project Wizard: Finished (Automated Coded Targets Project)

You have reached the end of the automatic coded target project setup wizard. When you press the Finished button a new project will be created based on your answers to the wizard's questions. The stages selected will now run (usually beginning with auto-marking). If you wish to change any of your settings before the run, you may use the Back button.

If you are planning on reusing the settings just entered in the wizard you can enter the name of a settings file where all the options and values (other than the photo file names) will be saved. This settings file can be loaded at the start of the project wizard next time you create a new automated coded targets project. The file is saved if there is a valid 'Settings file' name when the Finished button is pressed. See also *Automated Coded Targets Project*.

Project Information Dialog



The Project Information Dialog is accessed by the Project Information menu item from the Project menu. It contains information specific to the whole project.

- **Project Notes:** This is a text block of any length that can be left blank or be used for any text the user desires to describe a particular project.
- **Run Automatic processing:** This check box enables *Automatic Processing*. Note that automatic processing can also be toggled on/off by clicking the processing icon on the status bar (see *Status Bars* for more information on its interactive controls).

- **Project Type:** This shows the type of project you created when using the wizard. The type of project cannot be edited and is used when setting up the User Interface when the project is opened.
- **Inverse Project Type:** This shows the type of Inverse camera that was setup using the project wizard. If the project uses a known or calibrated camera (i.e. the camera will not be solved during processing) this will show "Not Inverse". If this is a Shapes, Control Point/Import, or Constraints project, and if the camera was set up as unknown, the type of inverse camera will be shown here. The Inverse Project Type cannot be edited and is used when setting up the User Interface when the project is opened.
- **Project Marking Quality.** This value allows the user to specify the expected quality of point marking in the project. For example, a project with all sub-pixel targets might have a quality of 0.5 pixels whereas a project that was all manually marked and with a number of guessed points might have a quality of 10 pixels. This value is used by the automatic Reference Checker. A value of -1 means that the Reference Checker is turned off during processing. Older projects will be set to -1 by default but can be changed if you wish reference checking to be done. See the *Reference Checker* section for more information.

Opening an Existing Project

To return to a project you have saved with PhotoModeler, choose "Open Project..." from the File menu or click on the Open Project tool on the toolbar. A File Selection dialog will appear listing all the projects which have been saved in the current disk directory. You may select a project from this directory or change directories and disk drives to open any existing PhotoModeler project. Each selected project will display its description string at the bottom of the File Selection dialog.

You can also drag a project file (.pmr) from Windows explorer onto the PhotoModeler window to open it (see *Drag and Drop*).

PhotoModeler keeps track of the recently used projects. You can open one of these projects quickly by using the Open Recent Project menu item under the File menu. The number of projects listed is controlled by a setting on the General page of *Preferences - Application Settings*.

See also *File Description Dialog*, *Creating a New Project*, *Drag and Drop* and *Saving a Project*. If an older version PhotoModeler file is being opened please see *New for PhotoModeler 6* for further information. In some cases you may see the *Image Check Dialog*.

Merging Projects

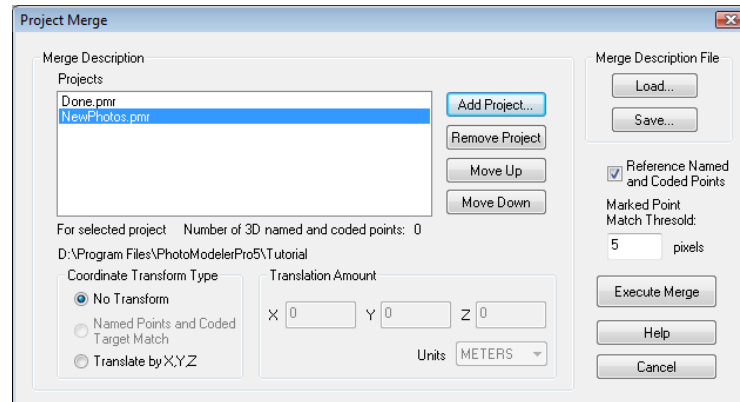
There are some circumstances where a larger project will be broken down into smaller projects. When the smaller projects are complete you may want to combine the projects together to complete the model, view the completed model, reprocess etc.

Project Merge is useful for:

- A very large project with large number of photographs that are more easily handled as smaller projects.
- Working with projects across multiple staff, different sites or different offices.

Project Merge is the facility that allows you to combine PhotoModeler projects together. The merging of projects is controlled by the Project Merge Dialog.

Project Merge Dialog



The Project Merge Dialog is opened from the File Menu, "Open Merged Project..." item.

This dialog contains a number of different sections that control how projects are merged and then opened. See the following sections for details.

Project List

The first step in merging projects is to inform PhotoModeler which Project files to process. This is done by adding Projects to the Project List using the "Add Project" button. When this button is pressed a file dialog appears so you can pick a .pmr Project file. When the file dialog is closed, the Project is fully loaded into memory.

Projects can be removed from the list by first selecting them with the mouse and then pressing the "Remove Project" button.

The order of the project merging is important (as described in the *Merge Processing* section) so the Move Up and Move Down buttons allow you to reorder the Projects. The Project at the top of the list is the "base" Project and each Project in the list is merged in turn into in as you step down the list.

Below the Project List, is some information about the currently selected project. There is the full path name of the Project and a count of the number of user-named points in that Project.

Transform Type

One of the key elements to merging projects is to ensure they share the same coordinate system and scale. Project Merge will apply a coordinate transformation to all the imported 3D objects in a Project as it is merged into the current "base" project.

There are three methods of coordinate transformation:

- No transform: PhotoModeler performs no coordinate transformation when a sub-project has this Transform Type. This method is appropriate if the sub-project (and usually base project also) was done with control points or had a three point Scale/Rotate applied. In

this way it is up to the user to ensure the coordinate systems are consistent across the sub projects.

- Translation: PhotoModeler performs no rotation but does translate all the 3D data by the X,Y, Z values specified on the dialog in the Translation Amount area. This method is appropriate if the sub-projects are scaled and rotated using any form of Scale/Rotate (or by Axes Constraints), and they just need to be offset from each other by a known distance.
- Named-Point Match: PhotoModeler performs a match between like-named points, computes the best least-squares coordinate system fit (involving translation, scale and rotation), and applies this transform to the project being merged in. This method is appropriate when there is some overlap between the sub-projects and the sub-projects are not done with control points. Before the projects are loaded they must have at least four 3D Object Points with user applied names (see *Object Point Properties*).

Note: Any project being merged (base project or other), will have any active Scale/Rotate permanently applied to its coordinates before the merge takes place. This ensures the scale and any desired rotation is consistent before applying other coordinate transforms.

Examples of each of the three transform types in use are:

- No transform: modeling of a factory or process plant where a control point network has been set down by a survey crew and the sub projects are all built around these control points.
- Translation: measuring a long accident scene that has been done in sections to capture different parts of the scene. The sub-projects are all scaled and rotated and the distance along the road between each project was measured at the scene.
- Named-Point Match: a large archaeological dig is being processed by a number of staff. The photographs of each sub-project overlap and there are shared points between sub-projects. These points are named the same in each sub-project. The merge ensures the sub-project fit together optimally at these points.

Merge Description File

The list of Projects and their coordinate transform types can be saved in a special file called the "Merge Description File" with file extension .pmm. This file is an ASCII file that you can view in a text editor if you wish.

You save your current merge list by pressing the "Save..." button in the Merge Description File area. A file dialog will appear allowing you to name the file.

You can then load that description at a later time.

A common approach to handling a large project would be to work on the sub-projects and then execute the merge only to see or export the file result. You may then be executing the merge quite often as you go back to change items in the sub projects. The Merge Description File makes this easier.

Merge Processing

When the "Execute" button is pressed the merge process occurs and the resulting merged project (if the merge was successful) is loaded into PhotoModeler. The resulting merged project is indistinguishable from a standard PhotoModeler project. This project can be saved, have photos, tables and 3D viewers opened, be ortho-photoed, be textured, and be processed.

These are the steps taken during merge:

1. The base project is loaded and has its Scale/Rotate (if any) applied to all its 3D data.
2. The next project in the list is loaded and has its Scale/Rotate (if any) applied to all its 3D data.
3. If this project requires a named-point match transform, all Object Points that are 3D in the base project and this project are searched for and if they have exactly the same user name (case sensitive), they are matched. If there are sufficient matches (3 or more points) a coordinate transformation is computed for this project.
4. The 3D data in the project is transformed as requested (either none, translated, or the results of 3. applied).
5. All types of data in the project (points, lines, edges, cylinders, curves, materials, layers, photographs, stations, etc.) are merged into the base project.
6. If the check box, "Reference Named and Coded Points", is checked then any user-named/coded target object points with the same name/id respectively are referenced together (note this is independent of the named-point match coordinate transform). For the coded target points (see *Coded Targets*) to be merged properly all projects being merged must share the same code set (8 bit, 10 bit, 12 bit, etc.). If this option is not selected and the code already exists in the destination project the point being merged will become uncoded. As with name matching, coded targets can also be used to establish the coordinate transform.
7. If the current project has a photograph with a file path name that is identical to a photograph in the base project, all the marking on that photograph (points, edges, cylinders, curves, etc.) are copied and merged into the matching photograph of the base project. All Marked Points are searched to see if they are within the distance in pixels specified in "Mark Point Match Threshold" box of another Marked Points. If so they are welded.
8. If there are any projects left in the merge list, it goes back to step 2.

Once the processing is complete the final project is loaded into PhotoModeler like any other normal project.

Saving a Project

If you save your project, you will be able to work with it again the next time you use PhotoModeler. A saved project is a permanent record of the photographs, marked features and the 3D model you have created with PhotoModeler. You should save your work often.

To save a project choose "Save Project" or "Save Project As ..." from the File menu, or click on the Save Project tool on the toolbar.

If your project has been saved at least once, PhotoModeler will save it with the same name when you select "Save Project" or the Save Project tool. If you select "Save Project As ..." PhotoModeler will always ask you to name your project.

PhotoModeler assigns the file extension "PMR" to all saved projects.

If you have previously saved your project, PhotoModeler will create a version copy of the previously saved file. PhotoModeler stores multiple versions of a file this way. Each time the project is saved a new version is created with a file name consisting of the loaded project with _verX appended where X is a number starting at 1. When you look in your

directory you might see a number of these. The file without a _verX is the latest file. The file with _verX where X is the biggest number of the set is the next most recent version.

If you make a mistake or your system crashes for some reason and you wish to return to your previously saved project, just load one of the _verX.pmr files.

For example if PhotoModeler was set to save 5 versions you might see this in your directory:

crttut.pmr - file you would work with as it is most recent

crttut_ver7.pmr - the next most recent version

crttut_ver6.pmr

crttut_ver5.pmr

crttut_ver4.pmr

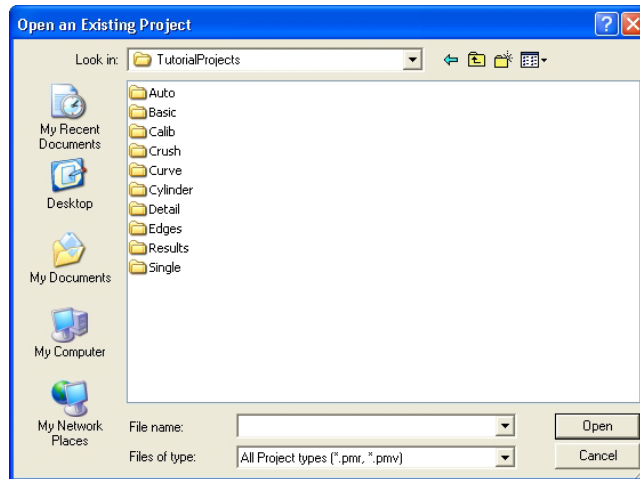
crttut_ver3.pmr - the oldest version

If you would like PhotoModeler to save more or fewer versions you can change the value "MaximumVersions" found on the Project page of *Preferences - Application Settings*.

See also *Creating a New Project* and *Opening an Existing Project*.

File Description Dialog

There are a number places in PhotoModeler where file names are required. These are: opening projects, opening cameras and opening control files. Each of these file requests uses a standard Windows file dialog:



See your Windows documentation for more detail on all the facilities of this dialog. Note that this dialog box may appear differently based on your installed operating system.

Check and Repair

The Check and Repair facility runs in the background to check for any errors in the Project / PMR file. The Project is automatically checked for errors after it has been loaded from disk, before it is saved to disk and before Processing and Audit.

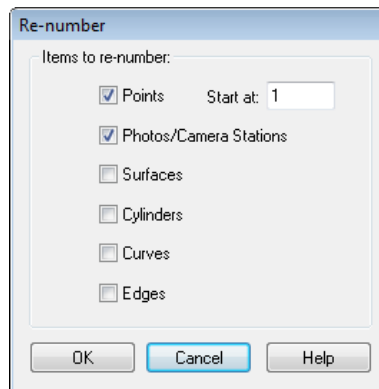
During normal operation of the program the user will not even be aware of the functioning of Check and Repair. Check and Repair only becomes visible when an error has been detected in the project. A Check and Repair report dialog will first appear stating how many errors it has found and asking if it should proceed with the repair or not. If you say "yes" to the repair it then reports again whether the repair was completely successful. The checklog.txt file, stored in the PhotoModeler install directory, contains all the details of the errors detected and the repairs made.

If you are having a lot of Check and Repair messages in a particular project, the Project might be very badly corrupted. Send the PMR file and the checklog.txt file to Technical Support for help.

If a Check and Repair reports a number of errors when you are saving a Project to disk, it might be a good idea to first not do the repairs but continue with the save, then save the Project again to another file name and this time ask for the repairs to be done. This way you have two project files to work with in case there are problems with the repairs.

Projects that are badly corrupted may not repair successfully as too much information might be missing. In this case try loading previous versions of the file to see if they are corrupted.

Renumber Dialog



PhotoModeler uses a sequential numbering ID system for many objects (points, surfaces, photos/camera stations, etc.). These numbers will often form gaps due to items being deleted, referenced or unreferenced etc. If you would like your object identifiers to be renumbered so that they are in sequence you can use this renumbering tool.

Note: You do not need to redefine constraints, photo sets, scale/rotation/translation etc. after you renumber; adjustments will be made automatically.

You can renumber Points, Photos/Camera Stations, Surfaces, Cylinders, Curves or Edges by selecting the checkbox next to the items to be renumbered and then pressing the OK

button. Renumbering cannot be undone so you may wish to save your project before hand. For points, you can set the number from which to start the sequence by entering the start number in the “Start at” box.

If you have coded targets in your project that have IDs in the 1000's, they will be renumbered to start at 1 (regular non-coded points get bumped up to start at 1000). ,

Drag and Drop

PhotoModeler supports the dragging and dropping of files onto the PhotoModeler window. You can drag and drop .pmr files, .cam files and image files onto PhotoModeler.

As with standard Drag and Drop operations in Windows, you select one or more files in Windows Explorer, click and hold the left mouse button, and drag the cursor on top of the PhotoModeler window. PhotoModeler will indicate it can accept the files. You then release the left mouse button to “drop” file files into PhotoModeler. The files are handled in this way:

- dropping a .pmr file will open it (closing any currently open projects),
- dropping a .cam file will add the camera to the currently open project or if no project is open, a 'quick setup' project will be created and the camera assigned as the default,
- dropping an image file will add the image to the open project or if no project is open a 'quick setup' project will be created and the image added to it. The image is assigned to the default camera.

When dropping multiple files at one time .pmr files are ignored. If you drop a combination of images and .cam files when no project is open the first .cam file will be set as the default camera and the images will be assigned to it. This is a short-cut for starting projects with a known camera.

Drag and Drop provides a quick and convenient way to start projects and add images/cameras to a project.

Working with Cameras

Deciding on a Camera and Scanner

Deciding on the camera and optionally the scanner to use with PhotoModeler will probably be the most important and one of the more difficult decisions to make. Often our decisions are made for us because of a lack of resources or what we have on hand. Sometimes we have free reign to pick the perfect camera for the job. Whichever is your situation, you will need to consider the ramifications of the camera/scanner choice.

The camera/scanner combination you use will affect the results you get with PhotoModeler. Generally, the higher the image quality of the camera, lens and scanner and the higher the image resolution, the more accurate your 3D results will be.

We separate cameras into three categories: film, video and digital.

Digital Images from Photographs

To get photographs into digital form requires some form of scanner or digitizer. If you are using a film camera you will need a film scanner and if you use video you will need a digitizer board. Digital cameras have their own digitizers built-in and then they hook up to you computer through a cable or via a small memory card.

Camera Ease-of-Use

In terms of ease-of-use with PhotoModeler, we would rank digital cameras as the easiest, video in the middle and film as the most difficult.

Camera Accuracy

In terms of high accuracy results with PhotoModeler, we would rank high-end digital cameras as the best, then film, then consumer cameras digital cameras in the middle and video as the worst.

Your Camera Requirements

In this section we describe possible requirements and then suggest the best choice of camera/scanner for those requirements.

- I want to create models quickly and I want them to look good but accuracy is not my prime concern.

Use a low-end or consumer-grade digital camera. You could also use a video camera with a digitizer board, but you will need to spend more time calibrating at the start.

- I want the best accuracy PhotoModeler can give me and I am not too worried about cost.

Use a very high-end digital camera. Calibrate the camera using the **Camera Calibration** and verify with field use and calibrations. Use high contrast circular targets and the sub-pixel target marker.

- I have a video camera and I would like to get started as soon as possible with PhotoModeler.

Buy a digitizing board that produces a nice stable image and captures at 640x480. You will probably need to calibrate the camera and digitizer using **Camera Calibration**. You can also perform a quick video format size calculation as described later and forego the full calibration.

- I have a bunch of existing photographs. I have the negatives and I have access to the cameras that took them.

Since these photos have no **fiducial** or **Film Plane Insert** you will need a full frame film scanner. For best results you will need to calibrate the camera using the **Camera Calibration**. Another option is to have the negative scanned at a local lithography house (check printers, desktop publishing and lithographers in the **Yellow Pages**). They can do full frame scans to high accuracy but are generally very expensive.

- I have a bunch of photographic prints and an office flatbed scanner.

This is a common case and you can still get good results with PhotoModeler. It will not be as accurate as using a good digital camera or film with fiducials but for many people it is the most practical approach.

You can get very good accuracy if you have full frame prints. Full frame prints show the 36x24mm rectangle imaged on the print. In other words the print is made right up to the sprocket holes. If you have full frame prints you can then use the "frame fiducial" type camera in PhotoModeler and get good results.

Prints made normally (i.e. you average "one-hour photo" prints) will not be made full frame and the cropping will be inconsistent from photo to photo. These prints can be handled by PhotoModeler by using one of the print size camera types.

You can also use the **Inverse Camera** feature if you know nothing about the camera that took the photographs.

Special Considerations with Film Cameras

Digital cameras are the easiest to use and high quality digital cameras can produce excellent results. Film cameras are not used as often today in measurement but there are cases where they are still important.

If you are using your own film camera you will want to read the sections on fiducials and fiducial setups.

If you are using prints or negatives supplied by someone else (for example in a forensic or accident reconstruction case) then read the sections on using no fiducials and on the **Inverse Camera** section.

Using a Film Camera with Fiducials or Réseau

When dealing with film pictures and film scanners it is important to preserve a frame of reference so that PhotoModeler knows where the picture was relative to the camera at the time of exposure. When negatives are printed or scanned they may be cropped and the cropping position is often random. Unstable cropping may cause trouble for PhotoModeler. This can be corrected by using one of two frames of reference: one is the image of the film plane mask (see the figure in the **Approximate Camera** section); the other is the image of

the Film Plane Insert. The Insert is a piece of plastic supplied with PhotoModeler that you glue into the back of your 35mm camera (see the section below called *Modifying a 35mm Camera for use with non-full-frame scanners* for more details).

Deciding to use the Film Plane Insert or the film plane mask depends on a number of factors:

	Film Plane Insert	Film plane mask corners
Scanner	Can use most film scanners	Requires a full-frame scanner
Camera	Needs to be modified	No modification required
Ease-of-Use	Easy to mark and see	Can be more difficult to mark

Some scanners can be used with good results with no Film Plane Insert nor any type of fiducial. The Kodak PhotoCD Auto-gate is one such scanner. Experiment with your camera and scanner to see if you get satisfactory results without fiducials. You can start to use fiducials at a later date if you find you want higher accuracy.

If you are in the forensic field or often deal with historical photographs you may not have fiducials or a full-frame to work with. In this case you will use the *Inverse Camera* feature of PhotoModeler to reconstruct the frame of reference.

Using Non-full frame Scanners, PhotoCD and Film Cameras

PhotoModeler supports the use of film cameras through scanning. A film negative or positive can be converted into a digital image by scanning it. One of the most convenient and least expensive ways of scanning film is via Kodak's PhotoCD.

Once the pictures have been shot on film, the film is developed and sent to an authorized Kodak PhotoCD developer. The film is scanned on a high resolution, high speed scanner and stored on a CD-ROM in PhotoCD format. PhotoModeler can work with images directly off the CD-ROM in PhotoCD format, or the PCD files can be loaded onto hard-disk for improved performance.

While PhotoCD is convenient, inexpensive and high resolution it does have one drawback. Kodak never designed PhotoCD to be used for measurement so they did not design their scanner to have high inter-frame position accuracy. The positional accuracy is low enough that PhotoModeler may have trouble using PhotoCD images scanned with Kodak's normal procedure. If you are using PhotoCD with no fiducials make sure your negatives are scanned all in one film strip with the PhotoCD AutoGate scanner. This will give the most consistent results.

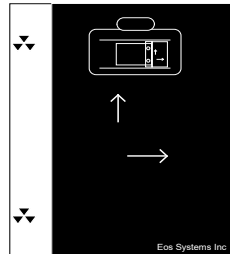
Using a scanner (such as PhotoCD) is best done with a fiducial insert. If the scanner is very consistent (the PhotoCD auto-gate scanner is sometimes this way) you can forego fiducials and use the PhotoCD with no fiducial camera type.

To get the best accuracy with PhotoCD or any other non-full-frame scanner requires a reference for position, scale and rotation of the film relative to the lens and camera body. This is accomplished by modifying a 35mm camera with the Eos Film Plane Insert. One way to think about this scanner problem is to imagine that the CCD imaging chip in your home video camera was not firmly affixed to the camera. Imagine that the chip moved up and down, rotated and changed shape as you filmed. The resulting video would be jumpy and jerky and would be hard to watch. This is similar to the problem PhotoModeler has with any non-full-frame scanner (such as PhotoCD).

The PhotoModeler package comes with a small piece of plastic film that you glue into your 35mm camera. This insert provides the frame of reference needed to make PhotoCD and other non-full frame scanners more accurate. The next section describes how this can be done.

Modifying a 35mm Camera for use with non-full-frame scanners

The Eos Film Plane Insert is a small piece of plastic film that looks like this:

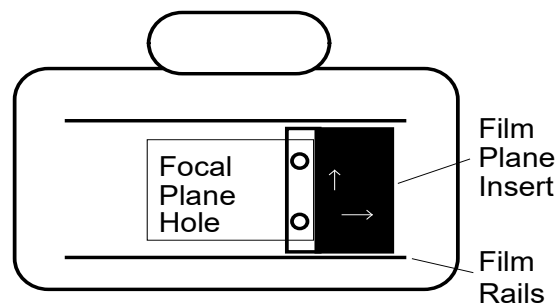


This item may be purchased as an option – contact your dealer or the Eos Systems sales department. To use this insert glue it into the camera between the film rails projecting out into the imaging area.

Warning: If you are the least bit worried about damaging your camera or its shutter with glue or solvent, we suggest that you buy and modify an inexpensive used camera body compatible with your current lenses. This procedure may damage the insides of a 35mm camera. Eos Systems cannot be held responsible for any damage related to the attachment of the Eos Film Plane Insert.

To modify the camera, follow these steps:

1. Find the Eos Film Plane insert and make sure it is clean.
2. Open the back of your 35mm camera.
3. On the right side of the camera beside the focal plane hole and between the film rails locate a flat spot large enough to accommodate the Film Plane Insert.



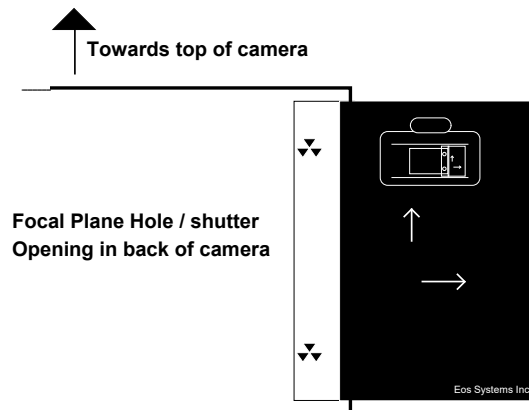
4. Position the Film Plane Insert so that the clear section with the two back symbols projects over the focal plane hole. Make sure none of the black background area covers the hole.
5. Glue the Film Plane Insert in this position.

We have found that the solid glue stick (such as the UHU Stic™ made by FaberCastell) works well. Place only a small amount of glue on the back of the large black part of the Film Plane Insert and make sure no glue gets on or close to the clear section of the Insert.

6. Let the glue dry, load some film and try taking some photographs.

On this first test roll you might consider taking the eight calibration pictures. See [Camera Calibration](#).

After the insert is attached it should look like this when you open the back of your camera:



Note that the fiducials are upside-down and on the right but when you look at an image created with the camera the fiducials will be right-side-up and on the left. This is because a camera flips the image coming in through the lens.

Calibrating a Camera with Eos Insert Fiducials

Once the Film Plane Insert has been installed, the camera and a lens need to be calibrated before PhotoModeler can use the resulting photographs. Refer to the section on [Camera Calibration](#) for more information on performing calibration.

Calibrating a camera with the Film Plane Insert is not much different from calibrating a digital camera. The only extra step is that the [Fiducial Marks](#) need to be marked by the user on each image before processing.

Using Film Negatives without the Film Plane Insert

You may have a number of photographs of an object taken before you obtained PhotoModeler, before you inserted the Film Plane Insert in your camera or you may not wish to use the insert. Can you use these with PhotoModeler? The answer is "yes", but a few conditions must first be met if you want high accuracy:

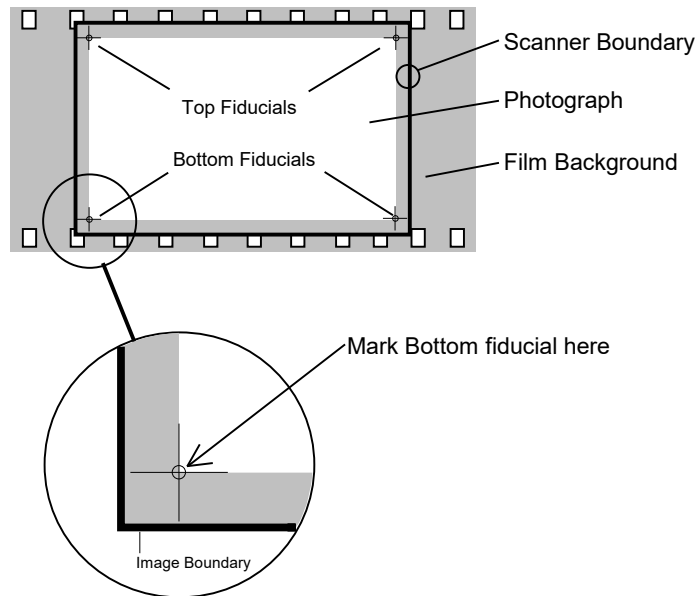
1. You must have the camera and the lens that took the photographs or one completely identical to it.

2. You cannot use PhotoCD to scan the negatives. (note PhotoCD is OK in this situation for low to medium accuracy projects)
3. You must have access to a scanner that will scan the whole negative including the imaged frame border. A scanner that scans more than 36mm by 24mm on a 35mm negative will do.
4. The photographs must not be taken at night or in dark conditions such that the frame edges are not imaged on film.

If these conditions are met then you can scan your negatives with the frame border and mark two to four frame corners as the fiducial marks.

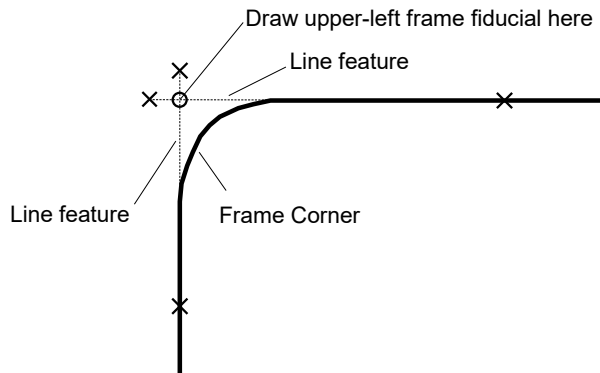
If these conditions are not met you can still get reasonable results by using the appropriate non-fiducial camera type or by using the *Inverse Camera* procedure.

The figure below shows where you would place the fiducial marks on the images instead of on the Film Plane Insert triangular fiducial marks:



Using a full frame scanner is not that different from doing projects with PhotoCD but we do suggest that you try to mark all four corner fiducial points. The minimum number of fiducials is three for a photograph to be used with a frame camera. You will get the highest accuracy if all four corners are used.

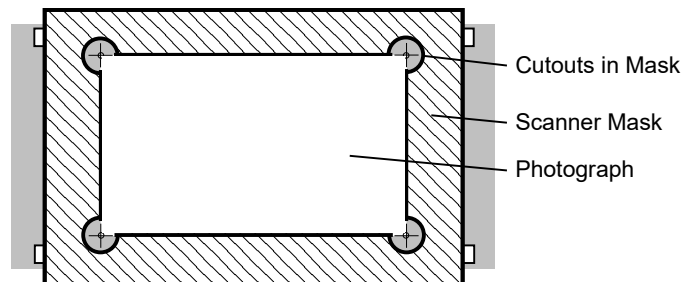
A good way to mark the frame corners in PhotoModeler (especially when they are rounded) is to use some dummy line features as construction lines. Line them up along the frame edge and then use the line intersections to mark the fiducial.



Modifying the Scanner Mask

Some 35mm negative/slide scanners have a large enough scan area to scan the frame edges of 35mm film. Most of these scanners also come with a holder or mask that crops the photo to less than 36x24mm. If you want to use the film holder/mask and still use the corners of the frame as fiducials, the holder will need to be modified. If the holder is plastic an Xacto knife can be used. A small file or sandpaper can also be used depending on how much material has to be removed.

The following figure shows how the four corners of the holder/mask have been filed out so the scanner can "see" the corners of the frame. Make sure when you do this that enough of the frame is visible in each corner so you can get an accurate estimate of the frame corner position.



One should also be aware when using scanned photos done by an outside contractor that they may not understand this issue of frame edges and return scans to you that may look to be full frame but are not (instead of seeing the frame edge in your photographs you might be seeing the edge of the plastic mask). Do not mark the four corners of the mask as the fiducials. You will get bad results since the mask has no relationship to the camera

Advanced Fiducial Setups

Above we have discussed the Eos Film Plane Insert with its two fiducial points and we have discussed using the corners of the film frame as four fiducial points. There are times when you will want to use more than four fiducials:

- PhotoModeler has a minimum of three fiducials per photograph for a three or more fiducial Camera. Sometimes it can be difficult to see three of the four fiducials due to darkness in the scene. In this case you may wish to use an insert that has many more fiducials so you

- have a better chance of finding at least three to mark. Eos Systems sells an insert with 9 fiducial crosses. If you are interested give Eos a call.
- You may have access to a metric camera that has built in fiducials or a reseau grid. In this case you will want to use the camera to your best advantage and set up all the fiducial positions in your Camera definition.
 - You may want the highest possible accuracy from your photo measurements and having multiple redundant fiducials marked can improve accuracy, especially with medium format or large format photography.

Building a Camera Description

Once you have a camera in mind, you will need to build a Camera Description. This description gives PhotoModeler the information it requires to figure out how 3D objects are imaged - whether it be a *CCD* or a piece of film. Without this information, PhotoModeler cannot build 3D models from photographs.

Cameras can be created by typing in parameters into the *Camera Viewer Dialog* or by getting a camera from the camera library or from another project.

A calibration should be done when possible. Calibration is not a difficult process and is almost fully automated. Please refer to the *Camera Calibration* section for information on the steps.

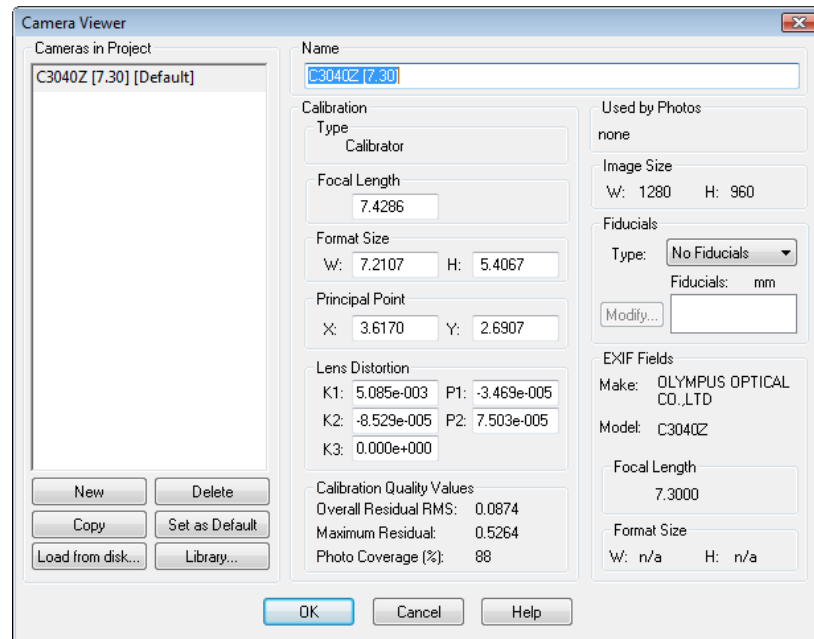
Do I need to calibrate my camera?

If you want the highest accuracy and the most reliability we strongly suggest that you calibrate your camera.

Camera description required

PhotoModeler always needs a 'description' of the camera, e.g. focal length of the lens, format size of the image, and the image center. PhotoModeler may work with approximate values given by the camera manufacturer, or *EXIF* data if available, and the 3D data produced may look reasonable. But if you calibrate the camera using the Camera Calibration, the camera values used by PhotoModeler will be much more accurate. The Calibrator also calculates and compensates for lens distortion. When the camera and lens are more accurately described, the models you produce will also be more accurate.

Camera Viewer Dialog



The Camera Viewer Dialog is used to view and manipulate the cameras used by the current project, and also provides access to the *Camera Library*. You can create new approximate cameras, delete a camera, copy a camera, modify camera parameters, load cameras from disk, and access the camera library from this dialog. This dialog is accessed through the "Cameras..." menu item, and *Photo Properties* from the "Open Camera Viewer..." hyperlink.

A PhotoModeler project can have many different cameras or just one. A project can also have cameras of different types (video, digital or film). As long as the proper camera description is loaded into PhotoModeler (and appears in the above list) and is assigned to the correct Photographs then it will be used to compute 3D data.

For a camera to be used by a Photograph it must first be stored internally in the project. All cameras stored internally in the current project show up in the Cameras in Project list on this dialog. If this list is empty, there are no cameras used anywhere in this project (which should not happen).

The dialog shows information about each camera in the project. When a camera is selected in the Cameras in Project list, its parameters are shown in the fields to the right of the list. Each of these parameters is explained below.

When you are finished viewing or manipulating Cameras you click the OK button. Click Cancel to close the dialog without changes to modified cameras in effect.

Camera Parameters

The *Camera Viewer Dialog* displays a Camera's parameters. It can be used to modify a Camera or to define new approximate camera parameters. The parameters need to be set to reasonable default values before calibration or when building an *Approximate Camera*.

The following list describes each of the parameters:

Parameter	Description
Name	Provide a name for the camera to help you identify it. The name is used when storing the camera to the camera library so do not include characters such as ":" or "\".
Calibration Type	The type of calibration. This will show either "Full", "Field", "Self", "Exif Estimate", "Inverse Estimate", "Idealized", "pre-V6" or "None", depending on the type of project and processing used to 'solve' the camera..
Focal Length:	The focal length of the lens of the camera being calibrated. A PhotoModeler Camera can have only one focal length. Set this to the figure printed on the lens or in the camera specification sheet. See note below regarding macro lenses.
Format Size:	The size of the imaging area in millimeters. For example, 35mm cameras have format size of approx. 36x24mm. This is not the print size. See the section " <i>Determining Digital and Video Camera Format Size</i> " for a quick way of determining format size.
Principal Point:	The reference point in the image to which all marks and lens distortion parameters are related. In a fiducial camera the principal point is in the same coordinate system as the fiducials; in a CCD camera the principal point is relative to the upper-left corner of the image. Set this to be in the middle of the image for a CCD camera.
Lens Distortion:	Parameters that describe two non-linear functions of radial and decentering lens distortion. These can be set to zero for approximations. Also see <i>Lens Distortion Formulation</i> .
Calibration Quality Values:	If the camera was calibrated in Version 6 or later, a few 'quality' indicators are stored with the camera and displayed here. These include "Overall Residual RMS", "Maximum Residual", and "Photo Coverage". See <i>Quality Review Points-Based</i> for more information on these quality indicators.
Used by Photos:	The photos to which this camera has been assigned, listed by photo number.
Image Size:	The resolution of the images created by this camera.
Fiducial type:	If this is a film camera with <i>fiducials</i> the type of fiducials is shown/set here and the fiducial values are set in the box below. Click the Modify button to edit the type of fiducials used by this camera (see <i>Fiducials Dialog</i>).

EXIF fields:	When a camera is created, <i>EXIF</i> information is extracted from its images and stored with the camera. EXIF information is used when matching photos with cameras in the library (see <i>Camera Matching</i>). These fields list the camera Make, Model, Focal Length, and Format Size as obtained from the information stored in the image's EXIF header. If a photo does not contain EXIF information, "n/a" is shown in these fields.
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Note 1: If your camera has a macro lens you should be aware that the focal length can change a lot as the focus changes. All lenses change their principal distance (what we call focal length above) a bit as they focus but it can be extreme in a macro lens. For example, a Nikon 50mm macro lens could become a 100mm lens if focused at only a few inches. It is the 100mm value you need to enter in the dialog.

Note 2: Lens distortion values are shown in scientific notation. This notation makes it easier to compare small values. The last three digits are the power of 10. For example, 2.34e-004 is the same as 2.34×10^{-4} or $2.34 \times 0.0001 = 0.000234$. So 1.2e-006 is a smaller number than 3.4e-005. Positive numbers can be used in the exponent too but you will not see that with lens distortion parameters ($1.53e+005=153,000$).

Creating a new Camera

To create a new 'approximate' camera in a project, click on the "New" button. You will then need to select an image that the camera took to set the camera resolution. A camera with basic default parameters will be created. You can then set it up as needed, e.g. parameters based on known camera specifications, as described below). You can also copy a Camera by selecting it and pressing the Copy button and adjusting where applicable. A new camera will appear in the camera list and this camera can then be assigned to a Photograph(s).

Setting the Default Camera

There is always one Camera in the project that is the "Default Camera". This Camera is the one that is assigned to all newly imported Photographs (unless *Camera Matching* has taken place). This camera has the "[Default]" text after its name in the list. To change which is the default Project Camera, select the Camera in the list and press the "Set as Default" button.

Modifying a Camera

To modify a Camera in a project select it in the project cameras list and adjust the parameters as needed and when finished click OK.

Loading a Camera from disk

To load a Camera from disk into the current project, click the "Load from disk..." button. A standard Windows file dialog will appear. Locate the .PMR or .CAM file on disk, select it and click OK. The chosen Camera file will be loaded into the Project and will appear in the list of Project Cameras. If you choose a .PMR file, the default Camera of that Project is loaded. You can also drag and drop a .cam file into PhotoModeler to add the camera to a project (See *Drag and Drop*).

Note: once a .CAM file has been loaded into a Project it becomes stored internally in that Project and the .CAM file is no longer associated with the internal copy. The .CAM file on disk can be changed and even deleted and it will not affect the Camera loaded into the Project.

Adding Cameras to/Getting Cameras from Camera Library

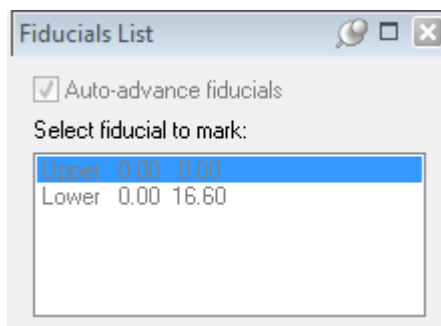
To access cameras in the Camera Library, click the "Library..." button. See *Camera Library*. The Camera Library dialog allows you to move cameras between the project and the camera library on disk. For example, if you have a well solved camera from a Field Calibration and you want to add to or update the camera library, you could use this dialog to move a camera from the project to the camera library. See also *Application Data and File locations*.

Removing a Project Camera

To remove a Camera from a Project first select it from the project camera list, then click the "Delete.." button. A Camera cannot be removed from a Project if it is being used by a Photograph. Note that if this Camera has not been saved to disk then all record of this Camera will disappear.

Fiducials Dialog

When clicking the "Modify..." button in the "Fiducials" section of the *Camera Viewer Dialog*, the Fiducials Dialog is displayed and is used to add, remove or modify *Fiducials* associated with a film camera.



Adding a Fiducial to a Camera

To add a Fiducial to a Camera, click the "Add" button on the Fiducials Dialog. A default Fiducial will be added with the name "Unnamed" and a position at 0.0,0.0.

Once it has been added, the Fiducial should be modified. See *Modifying a Fiducial*.

Fiducials cannot be added to the Camera types, "35mm film w/ Eos Insert" or "35mm film w/ frame edge fiducials". These Cameras always have predefined fiducials.

Removing a Fiducial from a Camera

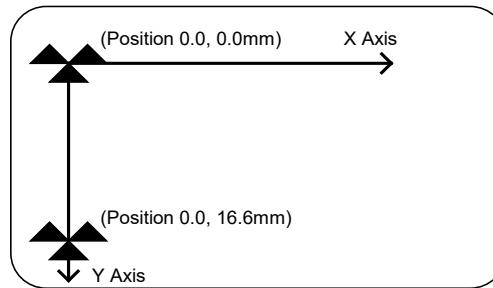
To remove a Fiducial from a Camera select it from the fiducial list. It will appear in the edit boxes below. Click on the "Delete" button and it will be removed.

Fiducials cannot be removed from the Camera types, "35mm film w/ Eos Insert" or "35mm film w/ frame edge fiducials". Fiducials also cannot be removed if they have been marked on any Photograph in the project. If you wish to remove a fiducial that is marked, track it down on all Photographs and delete the *Fiducial Marks* first and then come back into this dialog to remove it from the Camera.

Modifying a Fiducial

To modify a Fiducial, first select it in the Fiducials list of the Fiducials Dialog. Its name and x,y position will appear in the three edit boxes below. Simply modify or retype the text in any of these three boxes to effect a change on the name or the position.

Fiducials in PhotoModeler are defined by an x,y position in millimeters in a coordinate system placed on the film image plane. This fiducial coordinate system must be positive x from right to left and positive y from bottom to top on the image surface. Because a lens flips the picture, this will be positive x from left to right and positive y from top to bottom in the final image as seen in PhotoModeler. The following figure shows this coordinate system with an example of a 35mm camera with the Eos Film Plane Insert.



Fiducial coordinate system as seen on an image in PhotoModeler.

If the distances of the fiducials are known, just set the upper left one to be at 0,0 and then calculate the coordinates of the remaining ones. If they are unknown you will have to measure them in the Camera. It is best to measure them precisely and especially important to get them in their correct relative positions. Be careful not to add any skew or rotation to the fiducial coordinates.

Setting Pixel Squareness

Fiducials and fiducial marks define the mapping from pixel markings on images to the physical space of the camera. Cameras that have only two fiducials cannot compensate for non-square scanner or digitizer pixels because the mapping is defined in only one direction not two as with 3 or more fiducial cameras.

To get accurate results and/or good calibrations from film cameras that have only two fiducials, the squareness of the scanner's pixel should be entered. The best way to set this value is to set it to 1.0, set the "calibrate" check box and use the Camera Calibration to solve for the squareness.

To calculate the value without calibration, find the size of the digitizer or scanner pixel in both directions and divide to get their ratio. For example, a scan of 1536 pixels across and 1024 pixels down over an area of 35mm by 24mm would have a pixel size of $x=22.7$ microns by $y=23.44$ microns for a results squareness of $x/y = 0.972$.

Normally when using cameras with three or more fiducials you would set the squareness to 1.0 and turn calibrate off. Fiducials that span both the x and y direction can compensate for non-square pixels without using squareness.

Occasionally with a 3 or more fiducial camera where the fiducials have not been set up perfectly, calibrating for the pixel squareness can improve a calibration. If you do calibrate a 3 or more fiducial camera and the value for pixel squareness comes out to a value other than 1.0 you should check to make sure the correct fiducial values have been entered.

Note: It is very important when defining the physical positions of fiducials that they be as accurate as possible. Inaccurately defined fiducial positions can cause camera calibration to fail and can cause large errors in 3D processing.

Determining Digital and Video Camera Format Size

It can be quite difficult sometimes to find the correct format size of a video or digital camera's imaging chip. Only some cameras list the imager size and even then the nominal sizes vary between cameras and between manufacturers.

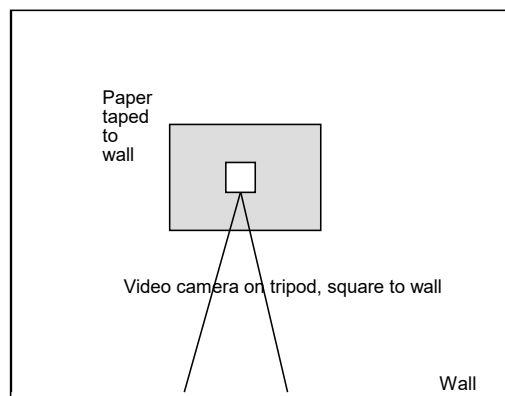
The best way to set up digital and video cameras is to use the *Camera Calibration*. If you want to do the format size calculations yourself you can follow the method below.

You will need

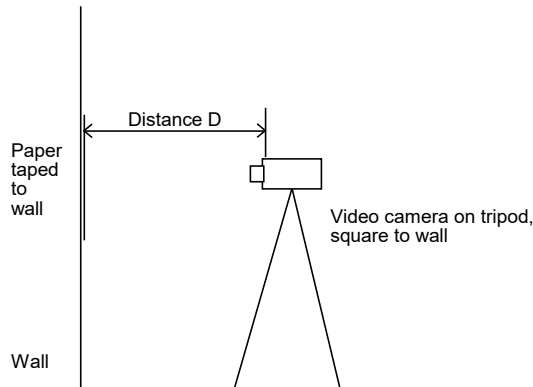
- the video or digital camera
- a tripod (or camera support of some form)
- a sheet of 8.5"x11" paper (or A4 sheet)
- a measuring tape
- a small portion of a flat wall
- a good estimate of the focal length of the camera (the focal length you are going to use)

Setup

1. Set camera on top of the tripod. Make sure the camera is level and square to the wall.
2. Tape a piece of paper to a wall at the height of the camera on the tripod - as shown in the next two figures.



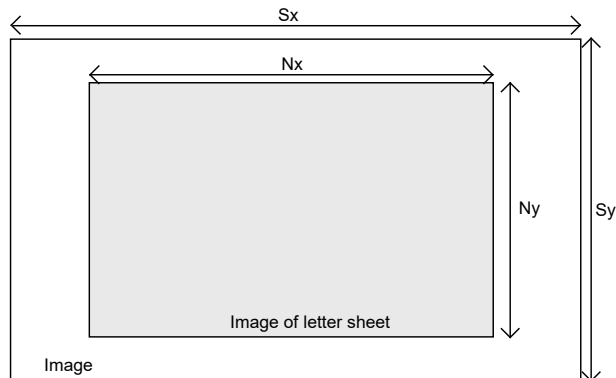
Back view of camera setup



Side view of camera setup

3. Look through the video camera viewfinder and center the paper in the viewfinder. Move the camera such that about 3/4 of the image is taken up. Make sure the camera is in focus and the camera is still level and square to the wall.
4. Take a picture of the paper.
5. Measure the distance from the paper to the location of the focal node (usually half way through the lens) and record this distance as D .
6. Find the focal length of the lens being used. Record this as f .
7. Digitize the image of the paper and load onto your hard-disk.
8. In an image processing program (such as PhotoShop) or in PhotoModeler measure the number of pixels taken up by the paper in the image. See next figure. Record these values as N_x and N_y .

You can find pixel positions in PhotoModeler by loading an image and marking points. When a point is selected its pixel position appears in the status bar. N_x and N_y can be computed as the difference between these values.



Digitized image of wall and paper

9. Determine the number of pixels in the whole image. Record these values as S_x and S_y .
10. Perform the calculations shown below to get an estimate of format size. The more carefully you do the setup and the measurements, the better your result will be.

Formula

The x format size (W) is calculated as:

$$w = P_x / D * f / N_x * S_x$$

where P_x is the size of the paper in the x direction (e.g. 11").

The y format size (H) is calculated as:

$$h = P_y / D * f / N_y * S_y$$

where P_y is the size of the paper in the y direction (e.g. 8.5").

Example

Logitech Fotoman Plus, Digitized image size: 496x360, Focal length $f = 8.3\text{mm}$.

The measurement made were $D = 27.5"$, $N_x=361$ pixels, $N_y=272$ pixels, $P_x=11"$, $P_y=8.5"$, $S_x=496$, $S_y=360$.

Therefore $w = 11" / 27.5" * 8.3\text{mm} / 361 * 496 = 4.56\text{mm}$

and $h = 8.5" / 27.5" * 8.3\text{mm} / 272 * 360 = 3.39\text{mm}$

Notice that we measure the distance D and the size of the paper P_x, P_y in the same units (inches) so they cancel and the focal length is expressed in mm so the answer comes out in mm.

The numbers for the format size come out very close to the final calibrated values for this camera. It is important to have a good focal length and good D , P_x , P_y measurements for this formula to work.

Note: if you are doing this with a macro lens and your distance D is quite small you need to be more careful with the calculation. If you measure the distance from the paper to the location of the imaging surface (where the CCD or film is located) and call this D_1 , then subtract off the focal length (note also which varies quite a bit in macro lenses as you focus) you will get a better estimate for $D \rightarrow D = D_1 - f$.

Lens Distortion Formulation

PhotoModeler uses a standard lens distortion formulation with four parameters as seen in the *Camera Viewer Dialog*. The following formulas describe how PhotoModeler applies the distortion corrections. You do not need to follow nor understand this section unless you are trying to convert a PhotoModeler camera calibration for use with another program or convert another calibration for use with PhotoModeler.

Lens distortion causes a point's image on the imaging surface (film or ccd) to be shifted from its true position as if it had been imaged by an ideal pin-hole camera. The compensation for any point (x,y) on the image surface (given the principal point is $(0,0)$) is given by:

$$x_c = x + dr_x + dp_x$$

$$y_c = y + dr_y + dp_y$$

where x_c, y_c is the corrected image point,

dr_x is the x component of the radial lens distortion correction,

dr_y is the y component of the radial lens distortion correction,

dpx is the x component of the decentering lens distortion correction, and
dpy is the y component of the decentering lens distortion correction.

Radial lens distortion

There are two common formulations for radial lens distortion: balanced and unbalanced. They are mathematically equivalent and make no difference to the algorithm. The balanced distortion formulation "looks" prettier and makes the distortions seem smaller so is commonly used by camera and lens manufacturers. PhotoModeler use the unbalanced form.

The radial lens distortion is radially symmetric about the principal point. A marked point at a radial distance of "r" from the principal point has to be compensated by a factor drb. The correction is applied to the x and y components in this way:

$$xc = x * (1 + drb / r)$$

$$yc = y * (1 + drb / r)$$

If you pre-divide the radial distortion formulas by r you have:

$$dr = drb / r$$

$$xc = x * (1 + dr)$$

$$yc = y * (1 + dr)$$

The formula used by PhotoModeler for dr is given by:

$$dr = K1 * r^2 + K2 * r^4 + K3 * r^6$$

where $r^2 = x^2 + y^2$ (r^2 means r to the power of 2)

where K1, K2 and K3 are the parameters shown in the *Camera Viewer Dialog*. This unbalanced form takes into account the "calibrated" focal length which is found in the same dialog.

The standard balanced form for radial lens distortion is:

$$dr = A0 + A1 * r^2 + A2 * r^4 + A3 * r^6$$

To convert this balanced form to PhotoModeler's unbalanced form you use:

$$s = (1 - A0)$$

$$f = f2 / s$$

$$K1 = A1 / s$$

$$K2 = A2 / s$$

$$K3 = A3 / s$$

where f2 is the focal length (principal distance) given in the original calibration with the balanced distortion and f is the focal length to be used in PhotoModeler.

Do note that some other photogrammetric programs apply K1, K2 and K3 with a different sign than PhotoModeler. If you are not getting good results with the above try changing the sign of K1, K2 and K3. Changing the sign of A0 might also help.

To convert PhotoModeler's unbalanced form to the balanced form is a bit trickier because you need to decide on the balancing point (i.e. where the radial distortion equals zero).

$$A0 = - (K1 * r0^2 + K2 * r0^4 + K3 * r0^6)$$

$$s = (1 - A0)$$

$$f2 = f * s$$

$$A1 = K1 * s$$

$$A2 = K2 * s$$

$$A3 = K3 * s$$

where r0 is an arbitrary radius chosen so the radial distortion curve is balanced with equal negative and positive distortion over the extent of the format's radius.

Decentering lens distortion

Decentering distortion is often not modeled because its contribution is much smaller than radial lens distortion. It is necessary only for the highest accuracy measurements. Many metric cameras come with the radial distortion parameters only and the P1 and P2 decentering parameters can be set to zero.

The formulas used by PhotoModeler for decentering distortion are:

$$dpx = P1 * (r^2 + 2 * x^2) + 2 * P2 * x * y$$

$$dpy = P2 * (r^2 + 2 * y^2) + 2 * P1 * x * y$$

These corrections are applied to the x,y marked point as shown above.

Controlling Calibration of Lens Distortion

You can tell the Camera Calibration program to calibrate for only certain forms of distortion. If you do not want to calibrate for decentering distortion it is best to set the P1 and P2 values to zero before calibration and make the following changes to the ini file (see [Application Data and File Locations](#) for information on where the ini file is stored on disk):

[Process]

...

P1Dev=-0.001

P2Dev=-0.001

When these are set to negative numbers the Camera Calibration will not change P1 and P2 and will keep them equal to zero. Any lens distortion will be compensated by the radial distortion terms only.

Sometimes when you are using the camera with an outside program that does not understand lens distortion (such as most animation and rendering packages) you will want to calibrate it with no radial or decentering distortion compensation. Set all the lens distortion parameters to zero in the [Camera Viewer Dialog](#) and also edit the ini file to turn off radial also:

K1Dev=-0.001

K2Dev=-0.001

After making these changes to the ini file save it to disk and process the Camera Calibration normally.

Camera Calibration

Camera Calibration is the process of determining the characteristics of a camera so it can be used as a measurement device.

PhotoModeler can use photographs taken by different types of cameras. For PhotoModeler to use the image information in a photograph, it needs values for some specific parameters of the camera. Generally we need to know the focal length of the lens, the digitizing scale (which is the CCD format size of a scanner or digital camera) and the principal point (where the optical axis of the lens intersects the photograph). To get improved accuracy, we also use parameters that describe the distortion characteristics of the lens.

Camera calibration is a method for accurately determining values for these camera parameters. Once a camera is calibrated, it will provide accurate measurements.

Cameras calibrated in Version 6 or later store additional information to help gauge the quality of the calibration result. The Overall Residual RMS and the Maximum Residual provide useful feedback about the success of the calibration and are especially useful when comparing two calibrations of the same camera/lens. The Photo Coverage (%) (see *Visibility Settings*, Point Coverage setting in the Camera station section) indicates what portion of the lens has been calibrated. A calibration can only solve for the part of the lens on which are referenced points, so the boundary is a way to gauge visually how much of the lens is calibrated. You'll want all of your points in your model projects within this boundary. The *Camera Viewer Dialog* shows these quality indicators.

Note: the Camera Calibration calibrates both the camera and the device used to convert the photographs to digital form (scanner or digitizer) as one unit. If the scanner or digitizer is changed then the calibration should be redone (applies to film and video cameras but not digital cameras).

Once a calibration is completed, if it is successful and the images have sufficient *EXIF* data, you will be prompted to add the camera to the *Camera Library*. Cameras in the camera library are automatically searched when adding photos to a project as part of the *Camera Matching* feature. It is a good idea to store your well calibrated camera in the library, but it is still possible to load cameras (in the new project wizard or manually) by browsing for project (.pmr) or camera (.cam) files on disk.

Do I need to calibrate a camera?

PhotoModeler needs to know the focal length, principal point and digitizing scale of a camera before it can produce 3D models from that camera. If you know these parameters relatively well, and you are not concerned with the highest measurement accuracy, you may achieve a reasonable result. However, a calibration strongly recommended.

Certain paths in the *New Project Wizard* allow you to select a camera source. If you do not have a calibration for the camera, there are ways to set up an approximate camera, either with 'standard' default settings, or using the *EXIF* information stored in an image.

You can create an approximate (non-calibrated camera) directly in PhotoModeler using the Add button on the *Camera Viewer Dialog*. You will not get the most accurate measurement results but it may be all you need. Often the results with an approximate camera can be quite good but sometimes the results are un-usable – it depends on the quality of input information.

If you find your estimates for the camera parameters do not produce good 3D models in PhotoModeler or if you are interested in the highest measurement accuracy, you will need to calibrate your camera.

You usually need to calibrate a camera:

- before the first time it is used in PhotoModeler,
- when you use a different lens on the camera,
- when you switch between two different focal settings on the camera (i.e. a camera with a zoom lens has multiple focal lengths - you need separate calibrations for this camera if you wanted to use different focal settings). Note that you cannot normally calibrate a camera with a zoom lens at an intermediate setting because it is not exactly reproducible. For zoom lenses only calibrate at most-wide angle, or most telephoto.
- when you change the film scanner you use,
- when you replace the Film Plane Insert or change the fiducials used with a film camera, and
- when the camera or lens has been badly damaged and has been rebuilt.

If you use just one camera and one fixed focal-setting lens for all your projects, you will need to do only one calibration and perhaps never have to calibrate it again. If you use several lenses then you will need to calibrate each of the lenses.

When using Kodak PhotoCD, you will need to calibrate the film, lens, PhotoCD scanner combination at one particular resolution. If you intend to use PhotoCD at different resolutions you will need to calibrate at each resolution. You only need to take one set of calibration photographs, though, since all PhotoCD resolutions are stored at once by the PhotoCD scanner at your local film developer.

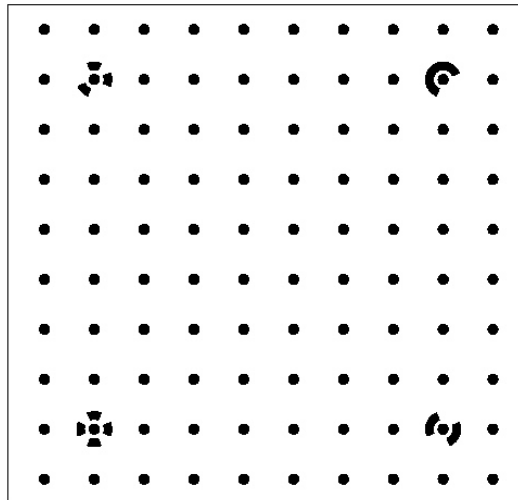
Steps in Camera Calibration

1. Decide on which camera and focal length you will be using in your PhotoModeler projects.
2. Decide on the size and type of *Calibration Grid* you will use.
3. Take the 6 or more photographs of the grid. See *Taking the Calibration Photos*.
4. Start PhotoModeler and start a new Project (toolbar or menu).
5. Choose the "A PhotoModeler Calibration project" option on the first New Project Wizard pane.
6. Follow through the wizard as with other new projects, and give the camera a unique name, specify its type, provide any requested information, add the photographs of the grid, and finish the Wizard.
7. If this is a film camera with fiducials, close Camera Calibration Dialog that has opened, open your photographs and mark your fiducials. See sections later in this document for more information: *Viewing Photographs* and *Marking Fiducials*.
8. Press the Execute button on the *Camera Calibration Dialog*.
9. If the calibration succeeds, you can then close the dialog and save your project (.pmr) and/or camera file (.cam) for use in future projects. Once a calibration is completed, if it is successful and the images have sufficient *EXIF* data, you will be prompted to add the camera to the *Camera Library*. Cameras in the camera library are automatically searched when adding photos to a project as part of the *Camera Matching* feature. It is a good idea to store your well calibrated camera in the library (it is always possible to

load cameras (in the new project wizard or manually) by browsing for project (.pmr) or camera (.cam) files on disk).

10. If the calibration fails see *Camera Calibration Troubleshooting*.
11. In some circumstances (calibration of very wide angle or telephoto lenses) you may need to decide which camera parameters to calibrate. See *Choosing Camera Parameters to Calibrate* for more information. Note, you would make the changes to Preferences before step 8 in this case.

Calibration Grid



The Calibration Grid is a pattern of dots specifically designed for the Camera Calibrator. There are a number of ways to set up the grid for photography depending on the size you need and the available equipment.

Eos supplies two versions of the grid in PDF format:

12. PhotoModelerCalibrationGrid.pdf
13. PhotoModelerCalibrationGrid-36x36sd.pdf

These files are stored in the install directory. The first can be printed at 8.5"x11" and the second is suited to large format (36"x36") printing and has smaller dots suited to high resolution cameras. The 8.5"x11" sheet is suitable when your projects have small objects or for quick/rough calibrations. The larger sheet is more appropriate if modeling larger objects or scenes. Optionally you can also purchase a 35mm slide version and/or a plotted sheet (approx. 1 meter square) from Eos or your dealer.

Ideally you calibrate your camera at the same focus setting (so the same distance from camera to object) as you use it for your project work. In many cases this is impractical because the biggest you can usually make the grid is about 2m across. While this is the ideal, for practical purposes and to moderate levels of accuracy you can calibrate the camera at one distance and use it at another. If you are modeling smaller objects/scenes (or you just want a quick way to test calibration) you can print the grid on a standard piece of paper. If you are modeling large objects/scenes try to make the calibration grid as large as is practical. Note that you can use *Field Calibration* if the model/scene size is much different than your calibration grid size.

There are some advanced ways to use the Camera Calibrator that do not use this exact grid. Contact Eos Support for more information or see the *Field Calibration* section.

Once you know the size of the grid you can decide how best to set it up.

If you need a large grid and you have slide projector and dark room with flat wall you can use the projection method with the 35mm slide (which can be purchased separately).

If you need a larger grid, do not have a room suitable to projection and a size of 1m is suitable, you can plot the larger PDF file on a large drawing sheet or buy the plotted grid from Eos or your dealer.

If a small grid is fine (e.g. you are using a macro lens, a telephoto lens, and your projects will be small (less than 1m in size)) then you can print the PDF on a standard piece of paper (8.5"x11" or A4).

For extremely small grids (extreme close up work of 50mm or smaller objects) you can use a 35mm slide itself with a white background (i.e. without projection just photograph the slide directly).

Taking the Calibration Photos

A little planning of the calibration photography will make the task much easier and give you better results. If you are using a paper form of the grid, placing it on the floor is probably the easiest. It is easy to take photographs from above with a tripod.

Note: Be sure to affix the grid to the floor or smooth surface so that the grid doesn't move between shots. Even the slightest movement of the grid between taking photos can throw the calibration off and can easily degrade the quality of the calibration, sometimes substantially. Also, affix the grid and move around it when taking photos, i.e. do not fix the camera position and rotate the grid.

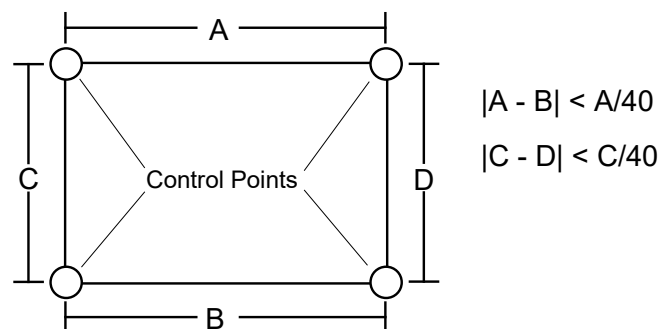
Taking Photos of the Slide

If you are using the 35mm slide and projection there are some additional items to take into account as you set up the room and the camera to take the photographs:

Consideration	Description
Room size	The room should be large enough to accommodate the slide projector and a large blank wall for projection. See discussion below.
Type of wall	If you use a wall to project the calibration pattern on or to paste up a grid poster, then the wall should be flat. Normal wall-board or gyproc wall should be fine. The wall should not have patterned wall paper nor should it be rough or bumpy.

Room lighting	Control the lighting of the room to provide the maximum contrast for the calibration slide. If using the Film Plane Insert in your camera, make sure the room is light enough so the fiducials will image on the film but dark enough to not wash out the projected slide. See further information below.
Use of a tripod	A tripod is recommended but is not completely necessary if the shutter speed is high enough. We have often hand-held cameras for calibration photographs.
Use of a flash	Do not use a flash if using a slide projector. It will wash the grid out. If you cannot turn the flash off in your camera, try covering it with some paper or tape. You can use a flash if you are using a printed calibration poster but beware of excessive bright hot-spots.
Len Focus	The whole calibration slide should be in focus. When using wide angle lenses, the camera tends to be closer to the wall and there is a greater chance there will be a depth of field problem. The lens should be stopped down (large f-stop) to ensure a good depth of field. This might require the use of a tripod.
Projector warm-up	If you are using a slide projector, let it warm up for five minutes before shooting pictures or measuring the scale.

When projecting the grid make sure it is square and does not have keystone distortion. For example, if your projected calibration grid is one meter wide, the difference between length A and length B should be less than 2.5 centimeters or 1/40th of the width.



Another squareness check you can do is to measure the diagonal and compare it to a computed diagonal using Pythagoras. That is $A^2 + C^2 = \text{diagonal}^2$. Try to get this equality within 1%.

Note: Setting the exposure of calibration photographs can be tricky with Film Plane Insert cameras. Take experimental shots first, get them developed at a 1 hour lab, and study the negatives with a magnifying glass before going to PhotoCD or other scanning. Also try bracketing your exposures ± 3 f-stops. Another trick is to shine a spot light on the left side of the grid so just the wall is illuminated and none of the grid. This way the fiducials of the Eos Insert will be, for the most part, illuminated by the brighter wall.

Ideally, you need to calibrate your camera and lens combination at the focus setting you will be using to take measurement photographs. That is, if you are measuring a large building the camera will probably be focused at infinity. Ideally, you should calibrate the camera when the lens is focused at infinity (some cameras do not have a focusing setting). See the section below on what compromises to make when you cannot use the correct focus setting when taking calibration photographs.

Positioning Compromises

Taking calibration photographs can sometimes involve compromises. For example, you might not have a large enough room, or your camera might not achieve perfect edge-to-edge focus in your setup. The following list shows, in order of priority, considerations for calibration photography. The most important considerations are at the top of the list. If you have to make some compromises, start breaking the rules at the bottom of the list first.

1. All four Control Points must appear on all calibration photographs.
2. The calibration pattern should be flat with no sharp bumps or creases. In the case of a paper grid some small creases between the dots is usually OK.
3. The calibration pattern should fill as much of the camera view finder as possible.
4. The pattern should be clean. No shadows or strong marks should appear in the area of the calibration pattern.
5. The camera positions should be close to 45 degrees from the horizontal and vertical as needed.
6. [For film cameras only] Most fiducials should show in the photographs. If you have a two fiducial Camera (such as the Eos Film Plane Insert) all photographs must show both fiducials. If you have a Camera with three or more fiducials then at least three must appear on all photographs.
7. The photographs should have good focus across the pattern (a small amount of blur due to insufficient depth of field is acceptable).
8. All photographs should be taken with the same focus setting.
9. The photographs should have good contrast and not be washed out. There should be a distinct edge between the black and white areas of the pattern.
10. The camera should be focused at the distance that will be used for most measurement projects.

Camera Positioning

To obtain the data needed to calibrate a camera, six or more photographs taken from different angles of a dense point grid are needed. The camera calibration software works with a specific calibration grid which is discussed in the *Calibration Grid* section. We suggest using the eight photographs of a paper grid placed on the floor taken in the positions described below. Additional photographs can be added if desired. The calibration

can have trouble though with a large number of photographs (over 12) when the lens is wide angle and has high distortion. If you are projecting the slide on the wall the photographs are similar but a few positions will be different. It is very important in this case to get at least two photos with a roll of 90 degrees (camera in portrait orientation).

It is very important to note that the grid should fill as much of the photograph as possible. The four control point locations must all appear in each photograph and must not be cut off by the edge of the photograph. The four control points are the coded targets (the dots with partial rings around them).

In the figures below (starting with *Position 1 - normal*) the left pictures show the image taken by the camera and the right pictures shows a 3D view of the camera position and the projected calibration grid. Note that the control points come close to the edge of the image, but are never cut off.

Important note 1: Ensure you do not cut off the control points in the photos. Ensure the grid fills as much of the frame as you can. Ensure you have at least two photos with roll angles of 90 degrees (portrait orientation) - we recommend four rolled (90 degree) photos.

Important note 2: Certain digital cameras perform automatic sharpening on the images they take. This is done because humans like looking at sharp pictures even if they are artificially sharp. On the other hand, image processing algorithms like the Auto-marker in the Calibrator do not work well with sharpened images because they tend to have additional unwanted noise and extra false edges. Images that are sharpened or "unsharp-masked" may not mark accurately and the calibration results will be poor. First try to turn this feature off with your camera (pick the "soft focus" or "lowest sharpness" settings). If the sharpening is very strong (on some consumer digital cameras) you may need to blur your images in an imaging program like Adobe PhotoShop before using them in the Calibrator.

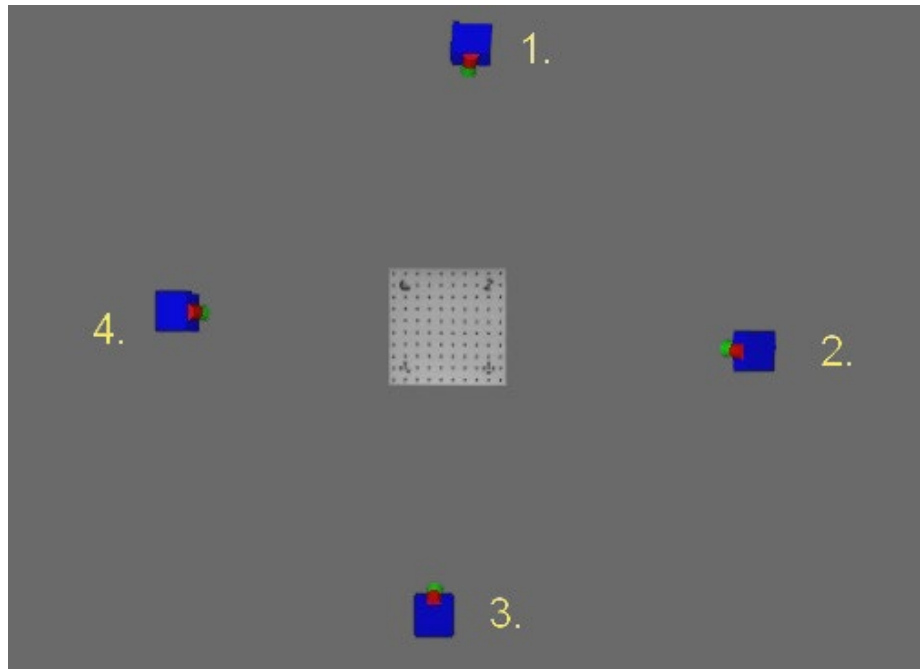
Important note 3: If your camera has a monochrome or black and white setting we recommended using it for calibration photos as it reduces noise and artifacts introduced by the color conversion algorithms of the camera.

Important note 4: Certain digital cameras perform automatic image rotation when they detect the camera in a portrait (rotated 90 degrees) orientation. The images are stored on disk rotated. PhotoModeler and the Calibrator need all images to be in the same orientation (usually all landscape) so it is best to turn this feature off on your camera when taking pictures for PhotoModeler.

Important note 5: Some digital cameras have Image Stabilization features. This feature should be turned off when doing PhotoModeler project work, both when Calibrating and when taking project photos. Image stabilization alters the camera internals and makes it less reliable for use with PhotoModeler.

The following figures depict a suitable eight photo calibration photo set. There are four camera positions and one landscape and one portrait shot at each position. The first figures show 3D views of the camera positions (first from the top and then a perspective view).

Overview Layout



There are four main positions around the edge of the grid. Position 1 may be replaced by other photos when using the slide projected version of the grid - see *Additional Positions and Slide Grid* below.

In the following 8 photos (2 at each position) we strive to cover the image area so that dots appear in all locations. Since in the rotated photos the grid covers only a portion we slide it to one end of the image. We then alternate so two are taken with grid at one end and two with grid at the other. The section *Additional Positions and Slide Grid* talks about adding 4 more photos to make this a bit more comprehensive.

The figures shown of the camera positions can be thought of this way:

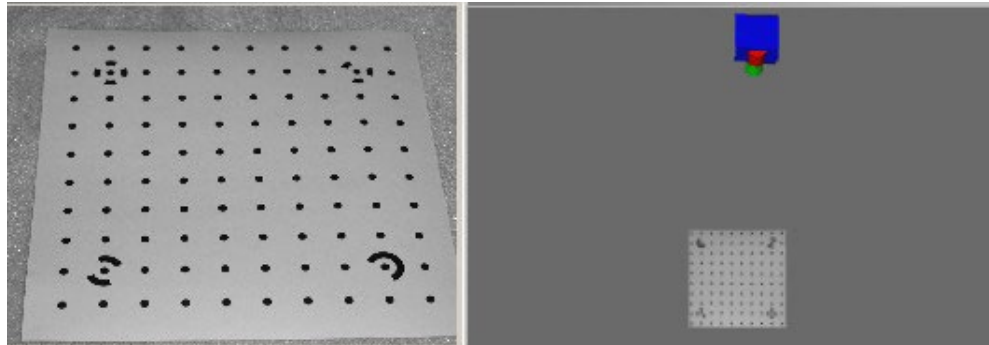
- if you are photographing a grid lying on the floor, then these are top down views (viewer is above grid looking down at floor),
- if you are photographing a grid projected on the wall, then these are front views (viewer is in front of wall looking straight at it).

“ccw” in the section titles below means rotation counter clock-wise and “cw” means rotation clock-wise.

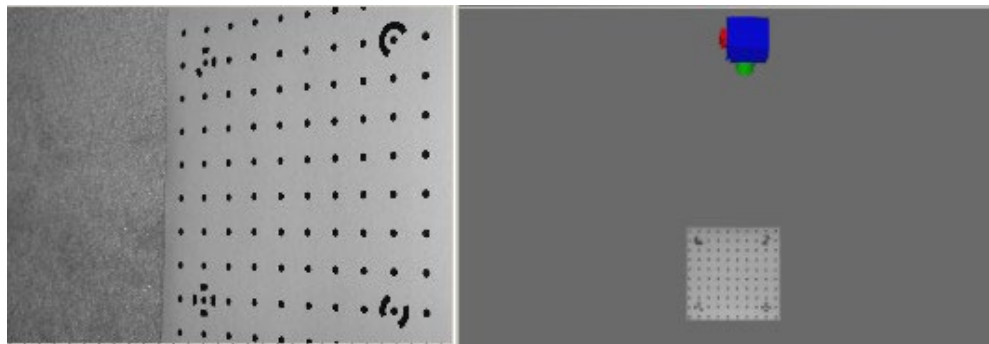
Note 1: the actual orientation of the calibration grid is not important. These illustrations are solely to guide the photography relative to the edges of the grid.

Note 2: the calibration grid should not be moved but instead should be static and rigid - move the camera instead.

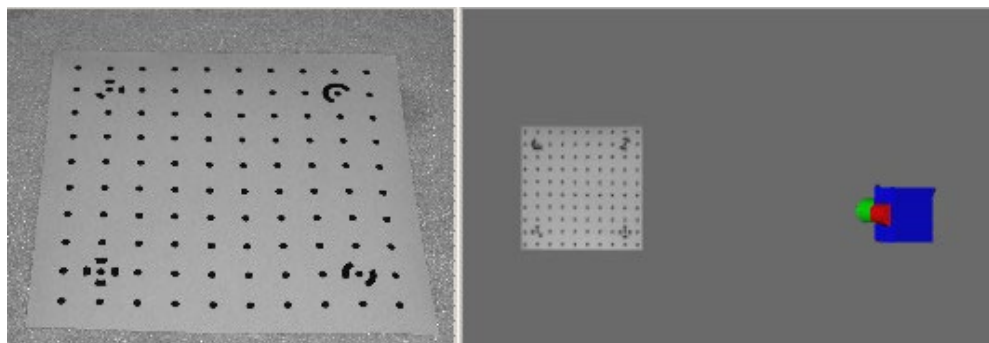
Position 1 - normal



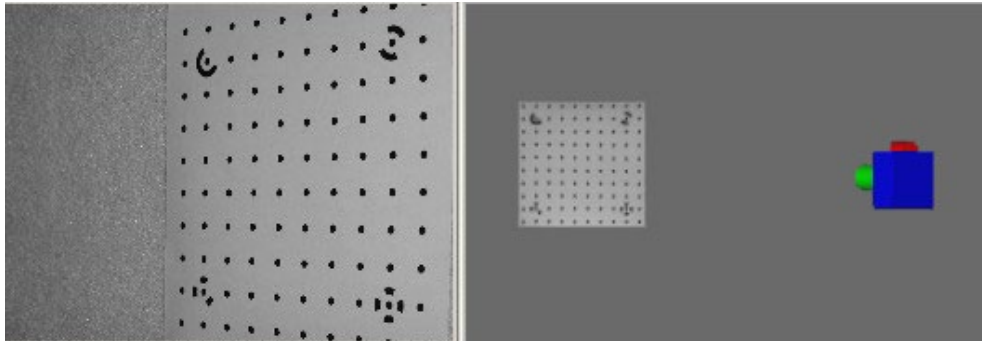
Position 1 - Roll 90 degrees cw



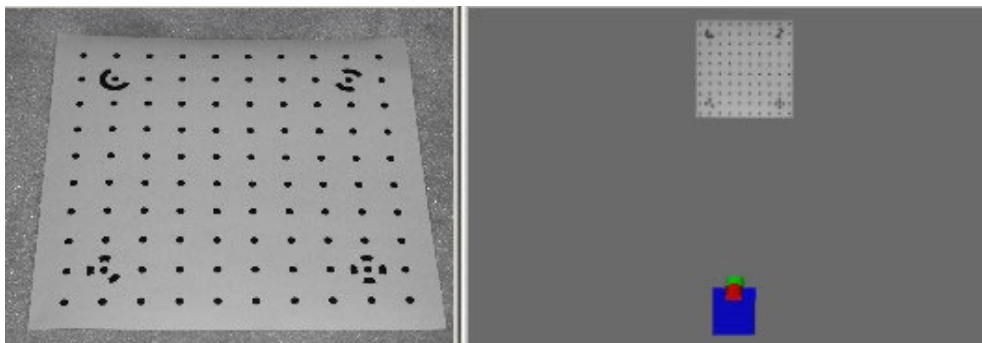
Position 2 - normal



Position 2 - Roll 90 degrees cw



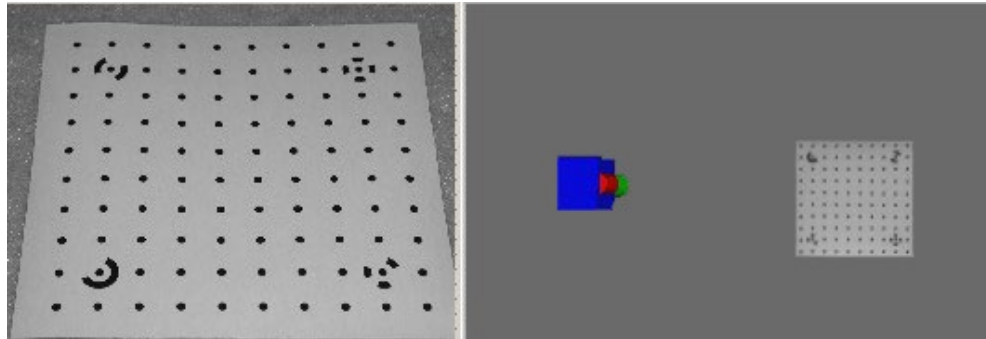
Position 3 - normal



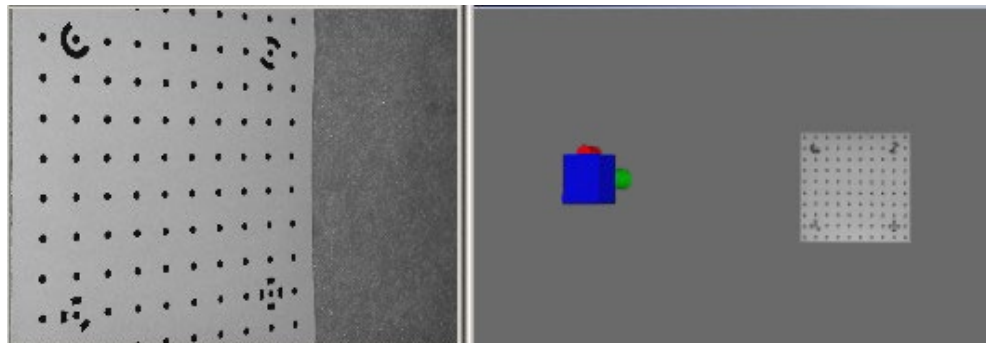
Position 3 - Roll 90 degrees ccw



Position 4 - normal



Position 4 - Roll 90 degrees ccw



Additional Positions and Slide Grid

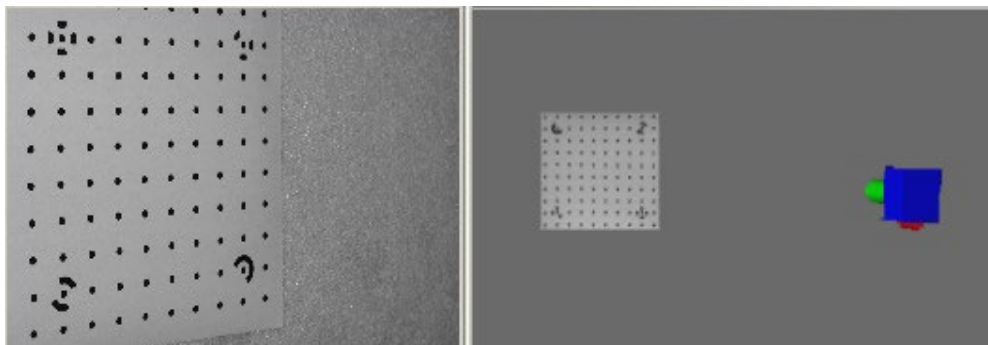
In addition to the eight positions shown above you may want to add one more roll angle at each position bringing the total to 12 photos. These four additional photographs ensure a better coverage and a complete set of roll angles. While they are not necessary, if you are striving for the highest accuracy you may wish to take them. They are shown below in *Position 1 - Roll 90 degrees ccw*, *Position 2 - Roll 90 degrees ccw*, *Position 3 - Roll 90 degrees cw*, and *Position 4 - Roll 90 degrees cw*.

When projecting the grid using a slide projector the position 1 photographs may be difficult to take (because getting above the projected grid is difficult without blocking the projection). In that case we replace all position 1 photos with at least two taken off to the side and from above as shown in *Position 5 - angled* and *Position 6 - angled*.

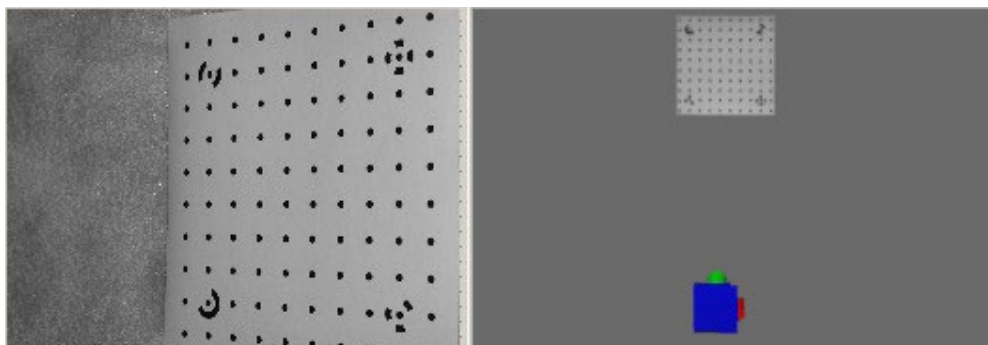
Position 1 - Roll 90 degrees ccw



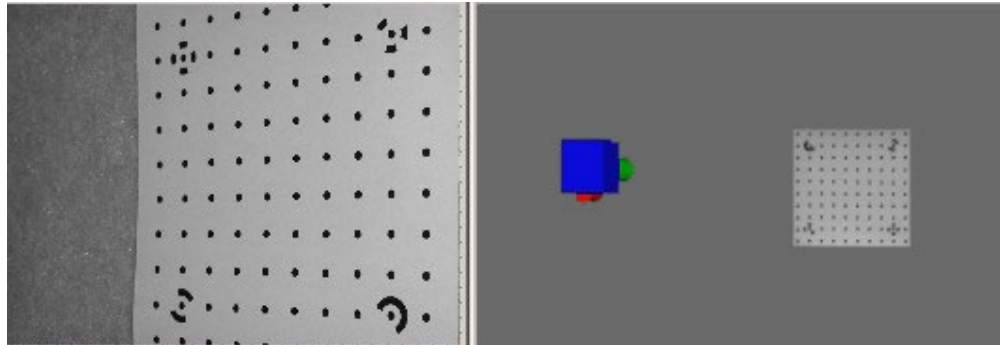
Position 2 - Roll 90 degrees ccw



Position 3 - Roll 90 degrees cw

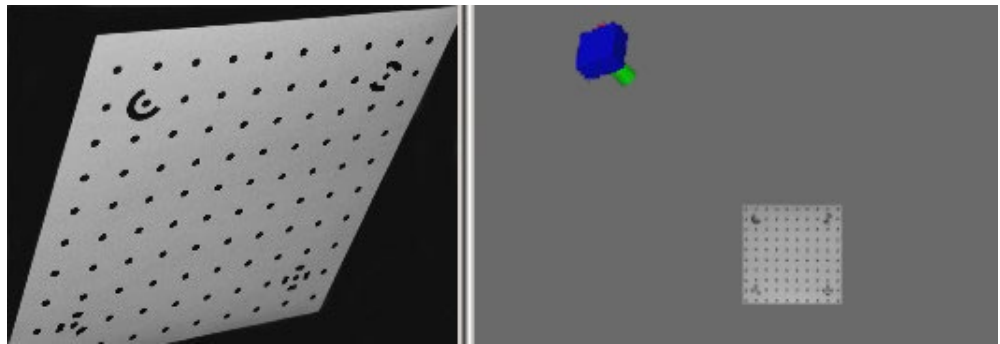


Position 4 - Roll 90 degrees cw



Position 5 - angled

Alternate for slide project grid.

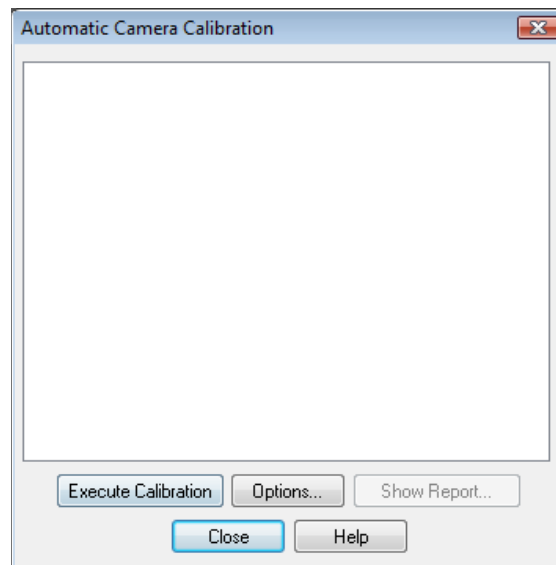


Position 6 - angled

Alternate for slide project grid.



Camera Calibration Dialog



The Camera Calibration Dialog opens after the Camera Calibration Setup Wizard is complete or when the Camera Calibration toolbar button is pressed. It can only be accessed and used when an appropriate *Camera Calibration* project has been set up in the *New Project Wizard*.

If you are calibrating a film camera with fiducials there may be a warning message that appears in this dialog when it is opened. If that appears then there are no fiducials (or an insufficient number) marked on the photographs of the *Calibration Grid*. Close the dialog, mark the *Fiducial* Marks and then reopen.

To start the calibration (after all the appropriate photographs of the grid have been loaded in the Wizard), press the Execute Calibration button. The calibration will run automatically carrying out these steps:

1. Automatic target marking and identification of four 8 bit coded targets in each photograph.
2. Estimation of the camera's focal length.
3. Initial approximate *orientation* of all photographs that have sufficient marks.
4. Automatic references of as many targets as possible with the approximate orientation and approximate camera model.
5. First stage camera calibration processing.
6. Second stage of automatic referencing (remaining marks should be correctly referenced).
7. Second stage camera calibration processing.
8. Automatic deviation and correlation checks and processing parameter adjustment.

When the process is complete one of the *Processing Finished Dialogs* will appear on the screen. You can access the *Project Status Report* from this dialog if you wish to review the calibration. When you close the Calibration dialog, the calibration will be complete and if it was successful and the images have sufficient *EXIF* data, you will be prompted to add the camera to the *Camera Library*. Cameras in the camera library are automatically searched when adding photos to a project as part of the *Camera Matching* feature. It is a good idea to store your well calibrated camera in the library, but it is also possible to load cameras (in the new project wizard or manually) by browsing for project (.pmr) or camera (.cam) files on disk.

You can save the resulting project and/or camera for use with your standard PhotoModeler projects. To check the quality of the Camera Calibration review the next section.

Calibration Checks

There are a number of ways to review the results of the camera calibration and check to see if the results are accurate.

Make note of the final error when calibration is complete (the size of the very last bar or the number on the bottom of the *Total Error Dialog*). A value less than 1.0 indicates a good calibration. A digital camera should have a final error under 0.7. Very good calibrations can have a *Final Total Error* smaller than 0.4. Note these depend on the input marking precision (*Preferences - Processing and Cameras*, Process page) and these values here assume the default values (0.1 pixels for sub-pixel marked points).

If you have a good calibration according to the error bars you might want to do some further checks on the quality of the calibration. The *Project Status Report* is a good way to check for reported problems and to review marking residuals. The largest Marking Residual should be 1.0 pixels or less.

Use the *Marking Residual Display* (see *Visibility on Photos*) to check for any systematic problems. Set the exaggeration until you can see all error vectors. The directions should look random. If they do not look random (all point in one direction or toward center, etc), then something has gone wrong. A lens with very high lens distortion that PhotoModeler cannot compensate for may cause problems like this. Improperly positioned fiducials in the Camera definition can also cause this.

The *Camera Viewer Dialog* also shows some calibration quality values, including Overall Residual RMS, Maximum Residual and Photo Coverage (%).

Choosing Camera Parameters to Calibrate

The default settings in PhotoModeler are to calibrate and solve for the K1, K2, P1 and P2 lens distortion parameters. Some lenses will not require all these parameters to be solved and some lenses may require the addition of the K3 radial distortion parameter. This section describes how one determines the best set of lens distortion parameters.

- A wide angle lens (fisheye or high distortion) may require K3
- Good quality non-distorting lenses may not need K2 or K3, and
- Some telephoto lenses may not require P1 and P2.

The general approach is to calibrate the camera using the standard and default settings with the *Automatic Processing Parameter Assignment* and 'Deviation and Correlation Check' options turned on and then study the results:

- if the calibration processing fails and the lens is non-standard (telephoto or very wide angle) one should try reducing the parameters and rerun the calibration.
- if the deviation value for a parameter is larger than the parameter itself (see *Project Status Report*) then that parameter should be removed and the calibration rerun.
- if the camera parameters are very correlated (over 90% or 95%) (see *Project Status Report*) then they cannot be solved well independently and one or more of them should be removed and the calibration rerun. For instance, if K1 and K2 are highly correlated then remove K2.
- if the marking residuals are large (esp. the RMS residual (over 0.5 pixels)), all other possible errors have been taken into account, and it is a wide angle lens then K3 may need to be added.

Automatic Processing Parameter Assignment will automatically adjust the parameters that are solved if they are causing processing failure. Also, when the Deviation and Correlation check option is on, parameters that have high deviations or high correlations will be removed from the calibration automatically. Processing will be repeated automatically until a suitable calibration is solved. If you have either of these options turned off (or if a calibration fails after automatic adjustments) and if you want to manually experiment with calibration settings you can change which stages are completed and which parameters are solved during a Camera Calibration using the *Camera Calibration Options Dialog*.

Calibration uses two stages of processing. If you have *Automatic Processing Parameter Assignment* turned off, you can set which camera parameters to solve/calibrate in each stage on the *Camera Calibration Options Dialog* by selecting the processing stage in the drop down box at the top of the dialog. It is usually a good idea to allow PhotoModeler to do this automatically, but if you want to experiment with the calibration you should typically solve for the more basic parameters in Stage 1 (e.g. Focal Length, Format Size Width, Principal Point and K1) and the rest in Stage 2 (e.g. Focal Length, Format Size Width, Principal Point, K1, K2, P1, P2, and sometimes K3). Once these changes have been made, the calibration can be run or rerun.

When comparing calibrations to determine which is better you will study values found in the *Project Status Report* and compare:

- Parameter deviation values - the calibration with smaller values is better
- Parameter correlations - the calibration with no correlations between parameters is better (or significantly lower correlation values)

- Marking residuals (largest and RMS) - the calibration with significantly lower RMS marking residual is better.

If you need further assistance do not hesitate to contact your seller for support.

Camera Calibration Troubleshooting

This section lists some common problems with camera calibration. Each problem is stated and followed by suggestions for correcting it. In most well photographed calibration projects, few, if any of these problems occur. If problems persist and the project is setup correctly, manually adjusting some parameters and rerunning certain stages of the calibration can improve your results (see *Camera Calibration Options Dialog*).

The Calibration Automarker misses many of the targets or some of the coded targets.

The Camera Calibrator can handle some loss of targets and still provide a well calibrated camera. The grid has 100 points and if 80 or more are marked per image then that is sufficient. If one or two images do not get used because not all four control points were found then that will generally be OK as well, but it is recommended that all 4 control points are clearly visible in each photo.

If too many photographs are dropped due to problems you will want to investigate. Marking problems may be due to: lack of sharp focus on the image, too much of the grid cropped off, the grid shot at too shallow an angle, or undue sharpening done by a digital camera.

If targets in the background are missed (ie the smallest ones), it may be that they are too small to be recognized, based on current preference settings. There is a threshold setting on the Preferences dialog that can be adjusted so that smaller targets are detected. See the "Ratio of smallest target in image to image size" setting in *Preferences - Processing and Cameras*.

Resolve the problem, reshoot the photos and try again.

The Calibration Automarking stage takes a long time and sometimes with little perceived progress or there are many false targets in the background

When the background behind the calibration grid is "busy", has many edges, or has many circular shapes (as sometimes happens when grid is lying on a patterned carpet), the automarking can slow down considerably. This is because the automarker needs to study every edge in the background to see if it might be a target. In some cases it will actually mark these "false" targets.

In most cases this slow down or the extra false targets do not cause problems with the calibration. There are two methods for resolving the problem.

The first method is to retake the calibration photographs ensuring that the background is clean and noise free. In the "busy" carpet case, putting down a white sheet or large pieces of paper to cover the whole background around the calibration grid would help.

The second method involves changing some values in the program's Preferences. The idea is to narrow some of the search settings so only the high contrast dot targets are found and not the false targets. The settings to change are: 1) Target Marking - Edge Strength High Threshold: try a higher number - perhaps 0.4 - if it is too high proper targets

will get dropped also, 2) Target Marking - Edge Strength Low Threshold Ratio: try a slightly higher number - perhaps 0.2 - if it is too high proper targets will get dropped also, and 3) Camera Calibrator - Ratio of smallest target in image to image size: try a higher number - perhaps 0.01 - if it is too high small targets on the grid (those far from the camera) will be dropped. With some experimentation you can find the parameters that will give quick, error free marking in the calibrator.

The Calibration stops after the first Automatic Referencing stage.

The first stage automatic referencer has a very difficult task. It has to reference at least 10 points on each photo but at this stage the camera parameters are only rough estimates and the camera station orientations are rough also. The biggest problem usually results from cameras with high levels of lens distortion (common on wide angle lenses) because lens distortion is not yet solved for in this first stage referencing. Sometimes this problem can be resolved by using fewer photographs in the calibration. You can also reduce the number of photographs that every mark must be referenced on in stage 1. See the Camera Calibrator section in *Preferences - Processing and Cameras*, "Required number of photos to be referenced for each point in stage one". In extreme cases a field calibration can be used to replace the calibration.

It is difficult to mark a fiducial on a photograph because of low contrast.

If the fiducial you are trying to mark is visible but not very clear because of a dark background, use "*Enhance Image Pane*" from the View Menu to adjust the brightness and contrast of your image. If you wish to permanently modify the image around the fiducial you might want to read the photograph into an image-processing program like Adobe PhotoShop and pick a small region around the fiducial mark and enhance the contrast or brightness. Do not move the region around the fiducial. You may however modify the intensity and contrast of the region.

The Calibration processing stage fails.

It will be uncommon for the processing to fail and not complete. Some possible reasons for failure are: the automatic referencing stages mis-referenced some points, the camera parameters are set up incorrectly due to EXIF content fault, the calibration grid changed shape, there are not enough photographs at the correct angles, or the calibration is over-parameterized. Occasionally calibrations have problems because of unusual or difficult lens-camera relationships. For example, cameras with long focal lengths are more prone to failure. These are some considerations for long focal length calibrations:

1. Lenses with long focal lengths can be problematic. First, what is a "long" lens? A long lens has a narrow field of view and allows you to zoom-in on distance objects. A lens that is long, as far as the calibration is concerned, might have a focal length over 150mm on a 35mm camera. A digital camera with smaller format size would have a shorter focal length to be considered long. For example, a digital camera with an imaging chip that is 18mm by 12mm would have a long lens if its focal length was over 75mm long.
2. Second, what sort of errors does one see when calibration fails with long lenses? For very long lenses the calibration often fails during second stage processing. For calibrations that succeed you might have large post-processing precision errors on the

- parameters or large correlation values (as seen in the Project Status Report) and marking residuals over 1.0 pixel.
3. Third, why are long lenses hard to calibrate? As a lens gets longer, you move farther away from the calibration sheet during photography. This combination reduces the perspective and makes the light rays close to parallel. This reduces the stability of the mathematical solution and makes it especially difficult to solve for lens distortion parameters.
 4. Fourth, what can I do about it? Depending on the length of the lens there are a few different approaches. If the lens is not excessively long (unfortunately hard to determine this before hand), you retry the calibration and reduce the parameters that get solved. If the camera is properly set up and has square pixels we suggest reducing the solution to just solving for focal length. This is controlled by the Calibration Options Dialog in Pro 5.2.1 or the Preferences and ini file in earlier versions (contact us at support@eossystems.com for further information - see *Application Data and File Locations* for information on where the ini file is stored on disk). If it solves and errors are small you can try to add the solution of principal point, and then perhaps K1 lens distortion. Also ensure that a) there are good angles and roll angles for the camera station positions, and there is good frame fill for the targets.
 5. If the lens is quite long the above may not produce a result (or the result will have error values that are too high). The next step is to move away from the flat calibration sheet and go to a 3D field of targets. You will need to build this set up yourself. Coded targets make it easier but it can be done with normal targets too. Using the corner of a room, or a wall and some posts in front of the wall, form an N by N by N cubic area of targets. 25 to 75 targets will suffice. Take angled and rolled photos as you would with the flat sheet. This project will need to be marked and perhaps hand referenced (if coded targets are not used). Then Global Optimize with field calibration option is used to calibrate the camera. Even with a 3D field of targets you may still only be able to solve for focal length, and principal point. Use the error metrics (largest residual under 1.0 pixel, no correlated parameters over 95%, and no precision warnings) as indication the calibration is successful. Contact Technical Support for further guidance.

Another reason for failure is the automatic referencing error might occur with cameras with high levels of lens distortion - try increasing the number of photos each point must be referenced on (See Camera Calibrator section in *Preferences - Processing and Cameras*). An EXIF focal length error encoding may be gotten around by removing the EXIF information (load images into an imaging program re-save without the EXIF data). A grid that changes shape or insufficient number of photographs can be remedied by retaking the photographs of the grid.

Over-parameterization of the camera means that one or more of the camera parameters are not needed. See *Choosing Camera Parameters to Calibrate* for more information. Calibrations of cameras with long focal lengths often fail due to over-parameterization. If you allow PhotoModeler to automatically parameterize and the deviation and correlation checks are completed during Calibration, the most stable and accurate set of parameters will be solved (see *Automatic Processing Parameter Assignment* and *Camera Calibration Options Dialog*).

The final Total Error in Calibration processing is higher than 1.0.

A good camera calibration will have a *Final Total Error* of less than 1.0 and very strong calibrations can have values under 0.4. Note this depends on the input marking precisions (Preferences / Process). This value is shown in the *Total Error Dialog* during processing or

in the *Project Status Report* after processing. High error may be due to referencing errors, marking imprecision, a calibration grid that changes shape (i.e. between shots, perhaps due to it not being firmly affixed to the ground or other flat surface), or the calibration is over-parameterized.

The automatic referencing error might occur with cameras with high levels of lens distortion - try increasing the number of photos each point must be referenced on (See Camera Calibrator section in *Preferences - Processing and Cameras*). Imprecision by the marker may be due to undue sharpening by a digital camera (turn it to softest setting if possible), or color artifacts from the digital camera (try the camera's monochrome/black-white mode if it has one). A grid that changes shape can be remedied by retaking the photographs of a rigid and static grid. See *The Calibration processing stage fails*. for more information on over-parameterization.

The Marking Residuals are high after Calibration processing.

A good calibration will have marking residuals all under 1.0 pixel. If you have a few points over 1.0 residual but less than 2.0 pixels then one would generally not worry. If a large number of points (more than 10) have residuals over 1.5 then there is a more serious problem. Imprecision by the marker may be the result of undue sharpening by a digital camera (turn it to softest setting if possible), or color artifacts from the digital camera (try the camera's monochrome/black-white mode if it has one).

Some digital cameras and some office flat bed scanners perform an automatic operation called "unsharp masking". This makes photographs seem sharper to us visually. Unfortunately this operation can greatly increase the noise and false edges in a scene like the calibration grid. It will be worse if the lighting is not strong and the contrast is low. The added image noise and false edges throw off the Camera Calibrator's automatic marking algorithm because it does not see smooth black to white transitions in the image. This can cause the auto- marked points to be poorly marked, which in turn can cause a poor calibration or a calibration that fails altogether.

The solutions are:

1. Try turning down the sharpness setting on your digital camera or scanner.
2. If your digital camera has a monochrome (black and white) mode try that as it may reduce artifacts.
3. Pull the images into an imaging program like PhotoShop and do noise filtering and blurring. The images can look very blurry to a human and be quite acceptable to the Calibrator.

The Status Report shows high correlations or high deviation values for camera parameters.

A good calibration will have no errors reported in these areas. The parameters that are being solved might need to be changed. See *Choosing Camera Parameters to Calibrate* and *Automatic Processing Parameter Assignment* for more information.

A high correlation between some of the camera parameters does not necessarily mean a problem with the calibration, especially if the correlation is less than 95% and if between a lens distortion parameter and some other parameter.

It is common to see correlation warnings between the P1,P2 (decentering lens distortion) and Xp,Yp (principal point) parameters. For some lenses you will also see them between

the K lens distortion parameters. A quick background: A correlation of 100% between two parameters (e.g. P1 and Xp) means that the adjustment algorithm cannot decide between adjusting P1 or Xp to get the same result. 100% correlation means that a change in P1 or an equivalent change in Xp gives the same final error - in this way the adjustment algorithm does not know which one to adjust. In the end it does not mean the final solutions for P1 or Xp are wrong, it just means the values are quite uncertain.

Often when parameters are highly correlated we suggest removing one of them from the solution (in the case above remove P1 and let it stay at zero) so the adjuster can choose a good value for the other parameter (Xp in case above). Very high correlations and correlations on many parameters often indicates more fundamental problems with the calibration setup though. You should look at the positions of the cameras - ensuring there are rolled positions (camera rotated to portrait orientation at a few locations) and ensuring strong angles. Also look for good fill of the view finder with the grid.

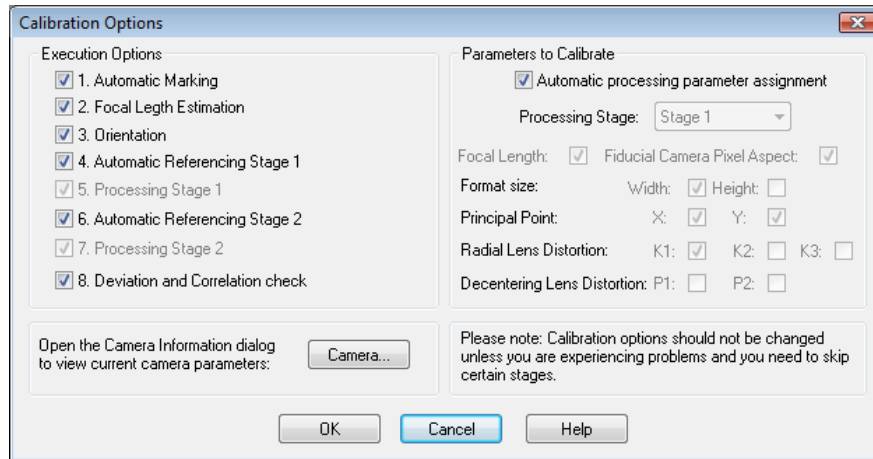
Correlations between parameters is a fact of life for such adjustment solutions. In fact all parameters are correlated to other parameters to some degree. It is only when parameters are highly correlated that we need to take action. Generally we would not be worried until a correlation is over 95%. In fact in future versions of PhotoModeler we will increase the threshold for that warning to 95%. You can do the same now by opening the *Preferences* dialog's Process page (see *Preferences - Processing and Cameras*) and changing the "Only report parameter correlations over this %:" setting in the Project Status Report section to "95":

PhotoModeler Pro 5.2.2 and later have an automated method for removing parameters with high deviations and high correlations. This method uses a 95% threshold for correlation. If the automated parameter system can remove a parameter without significantly increasing the total error then it will - otherwise the parameter will remain and the warning will appear again.

These warnings may also appear during a field calibration ('field calibration' option during a normal processing). In this case there is no automated method for deciding which parameters are appropriate. You can use the same method as the automated technique though. You remove the parameter that is highly correlated (starting in this order K3, K2, K1, P2, P1, Fw). I.e. if P1 and Xp are highly correlated, set P1 to zero and remove it from the adjustment (see *Preferences*). Take note of the total error and rms residual error before and after parameter removal. If it does not change or only increases a small percent then P1 can be removed. If the error increases significantly then P1 should perhaps be added back. It can be a difficult decision sometimes and if you are unsure please do not hesitate to email your pmr file to support@photomodeler.com and we can provide more feedback.

To summarize: a) do not be overly concerned with correlations under 95%, b) if you have parameters correlated over 95% or many parameters with deviation and correlation warnings then consider improving the photography, and c) you can experiment with parameters removal in field calibrated projects by comparing pre and post total error and rms residual.

Camera Calibration Options Dialog



The Camera Calibration Options Dialog is displayed when pressing the “Options...” button on the *Camera Calibration Dialog*. The “Options...” button becomes enabled only when re-calibrating (i.e. after opening a calibration project and after a full calibration has been attempted).

If your calibration fails (and your project setup is good – see *Camera Calibration Troubleshooting*), there are a number of options available that allow certain stages of the calibration to be skipped, and certain camera parameters (see *Choosing Camera Parameters to Calibrate*) to be removed from calibration. A stage or parameter is skipped when its checkbox is unchecked.

Note: When the *Automatic Processing Parameter Assignment* is turned on the controls for the various parameters (and Processing Stages) are disabled. This allows PhotoModeler to automatically remove parameters that are causing processing failure in one or both stages of processing.

With most standard calibrations, this dialog is not used as calibration will have succeeded on the first attempt. However, some calibrations can be more problematic (e.g. long focal length lenses) and may require manual adjustments on this dialog)

You can also view and edit the camera’s parameters manually in the *Camera Viewer Dialog* by clicking the “Camera...” button.

Note: When the Deviation and Correlation check option is checked, PhotoModeler analyzes camera parameters and checks for high deviations and correlations; if deviations and/or correlations between parameters are found, PhotoModeler automatically removes the offending parameter(s) from the calibration. This helps strengthen calibrations, especially in projects that are prone to over-parameterization.

Skipping certain stages can help when troubleshooting a difficult calibration and also can help reduce the time required for a re-calibration by skipping stages that are clearly completing satisfactorily.

Note: Calibration options should not be changed unless the calibration process is failing and your calibration project setup meets all of the requirements described above. When a calibration is first attempted the Options button on the Calibration dialog is disabled - you need to attempt a full calibration at least once. Remember to check the success of the calibration (i.e. total error, marking residuals, point tightness, etc.) after the calibration attempt to make sure it is reliable.

You may wish to skip certain stages when :

- Automatic Marking: Skip this stage if your calibration grid is clearly being automatically marked without any problems, or you have manually adjusted or marked points to be included in the calibration.
- Focal Length Estimate: Skip this stage if you manually adjust the starting focal length (see *Camera Viewer Dialog*) after a failed calibration and you do not want PhotoModeler to estimate it again. This is useful especially when recalibrating a camera with a long focal length, where manually increasing the focal length starting estimate can sometimes improve the calibration result.
- Orientation: Skip this stage if orientation is succeeding. Note though that if you are re-estimating or manually entering a new focal length, it is usually best to re-orient and not skip this stage.
- Automatic Referencing Stage 1: Skip this stage if your project is clearly being automatically referenced correctly in this stage, or if you have manually adjusted or referenced points and do not want automatic referencing to make changes.
- Processing Stage 1: Skip this stage if your project is processing in this stage or if you want to experiment with different settings.
- Automatic Referencing Stage 2: Skip this stage if your project is clearly being automatically referenced correctly in this stage, or if you have manually adjusted or referenced points and do not want automatic referencing to make changes.
- Processing Stage 2: Skip this stage if your project is processing in this stage or if you want to experiment with different settings.
- Deviation and Correlation check: Skip this stage if you do not want parameters automatically removed from the calibration despite having high deviations and/or high correlations.

A rule that should generally be followed is this: a stage should not be skipped if a preceding stage is set to run. For example, if you are estimating Focal Length, it is usually best to not skip the remaining stages as the Focal Length estimate can have an effect on the result of the next stages.

Automatic Processing Parameter Assignment

When this option is turned on PhotoModeler automatically finds the optimal set of parameters to solve during calibration based on an iterative processing approach. The default set of parameters is used in the first stages of processing, and if processing fails, certain parameters are removed and processing is repeated. Processing is repeated until the optimal set of parameters is found and calibration processing is successful.

This feature works well when in tandem with the Deviation and Correlation check (see *Camera Calibration Options Dialog*) where parameters that have high deviations and/or correlations are removed from the calibration automatically. Calibration processing is repeated automatically until a suitable calibration is solved.

If no suitable combination of parameters is found with automatic processing parameter assignment and/or the deviation and correlation check, calibration can fail (this will rarely happen unless there are problems with the calibration project setup, photography factors etc. see [Camera Calibration Troubleshooting](#)). You will then want to review your setup, perhaps manually adjust parameters and stages (see [Choosing Camera Parameters to Calibrate](#)) and try calibration again.

Note: If the images in the calibration have **EXIF** data, PhotoModeler uses this data when estimating the Focal Length as a starting point for calibration. PhotoModeler will attempt to verify that the EXIF Focal Length information from the images is valid (it is not correct on all cameras). If the data does not produce reasonable results a warning will appear that will allow you to choose an alternate form of focal length estimation. Also note that PhotoModeler uses other internal checks when EXIF information is not available, so the calibration will also work with images that do not have EXIF information.

Camera Matching

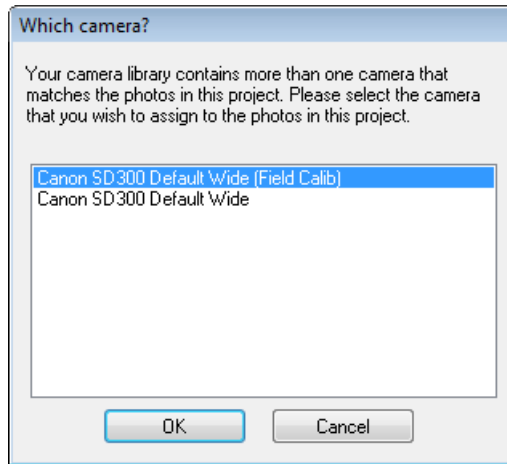
When adding photos to a project (via the [New Project Wizard](#) or the [Add/Remove Photographs Dialog](#)), PhotoModeler tries to automatically find the camera that took those photos using a camera matching process. Camera matching can only be done with photos that have **EXIF** information (and with cameras that are stored in the Camera Library that were calibrated (or field calibrated in PhotoModeler using images with EXIF information). When adding photos, each photo's EXIF information is analyzed and compared to the EXIF information stored in the camera description file (.cam) associated with cameras in the Camera Library.

Cameras calibrated using PhotoModeler version 6 or later will have EXIF information stored in the file if the calibration was done using images with EXIF information.

Note: when opening a project saved in PhotoModeler version 5 or earlier, the EXIF information is added to a camera based on the first photograph assigned to the camera, as long as the photographs contain EXIF data. This allows you to load a previous version project, and copy the updated camera to the library using the [Camera Library Dialog](#).

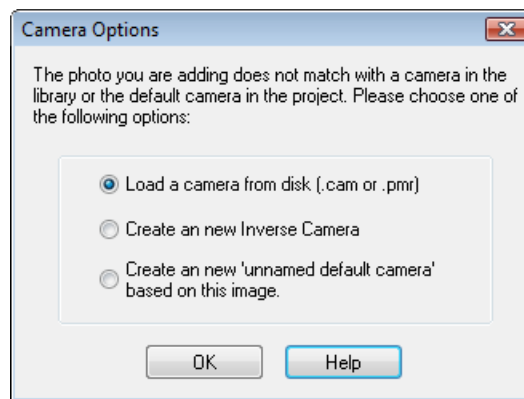
When adding a photo to the project, PhotoModeler scans all cameras in the [Camera Library](#) and checks the EXIF information. If the photo has EXIF data and that data matches the camera's EXIF data (comparing Focal Length, Make and Model), a copy of the camera is added to the project and assigned to that photo.

If multiple matches are found (ie you have multiple calibrations of the same camera at a specific focal length), a list (see below) will appear from which you can select the appropriate camera for the project:



Note: if a camera and/or a photo do not have EXIF information or there are no EXIF matches, the project's default camera is assigned to the newly added photo. If the project's default camera is an Inverse camera, a copy of the camera is made and assigned to the new photo. If the default camera is not an inverse camera, and the new photo is not automatically matched, and the photo does is not assigned to the default camera the *Camera Options Dialog* appears showing various options for camera assignment.

Camera Options Dialog

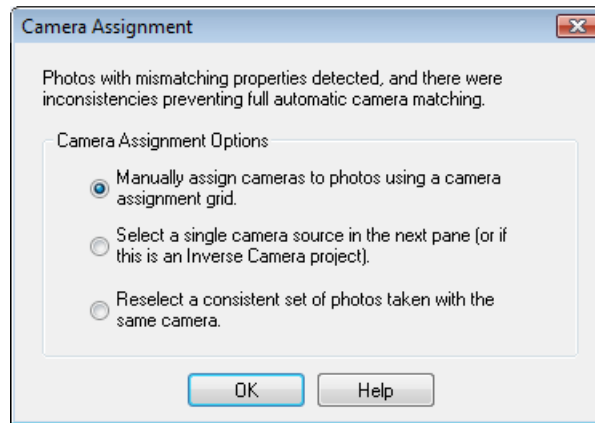


The Camera Options dialog appears when you attempt to load a photo into an existing project (ie not during the wizard) that does not match the default camera or any of the existing cameras in the project (i.e. mismatching image resolution and aspect ratio, mismatching EXIF information). The options are:

1. Load a camera from disk (.cam or .pmr): Browse to a .pmr project containing the camera that took the photo, or the .cam file if stored in this format (see *Camera Viewer Dialog*).

2. Create a New Camera: Select this if the source of the photo is unknown and you intend to use the *Inverse Camera* approach to solving the camera.
3. Create a new 'unnamed default camera': Select this if you want PhotoModeler to create a very basic camera and assign it to the photo. This would be suitable for photo review only as the camera would be one with very approximate parameters.

Camera Assignment Options Dialog

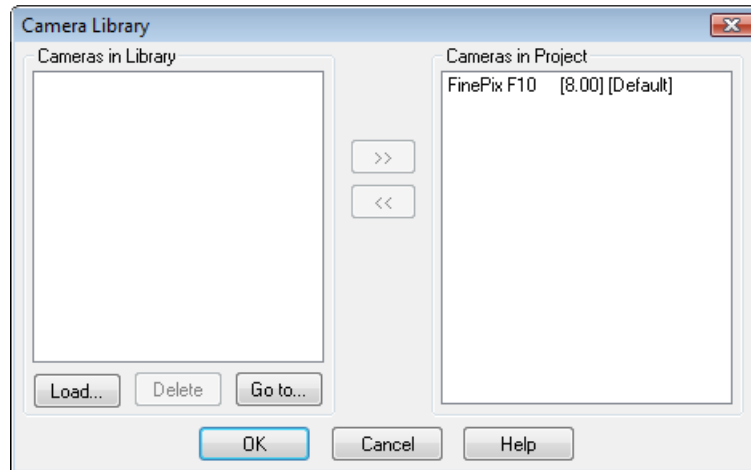


During project setup in the New Project Wizard, the Camera Assignment Dialog appears when you try to import a series of photos that do not all match. There are 3 options:

- Manually assign cameras using the camera assignment grid. This allows you to go through all selected photos and assign a camera manually, either from the library, or from disk.
- Select a single camera source. The next pane will allow you to select a single camera that will be assigned to all photos. Select this option if this is an inverse camera project.
- Reselect photos. This returns you to the previous pane so that you can reselect your photos.

Camera Library Dialog

The Camera Library provides a way to manage camera files stored in your camera library.



You move selected cameras from the library to your project and/or from the project to your library by using the ">>" or "<<" buttons.

Pressing the "Load..." button brings up a familiar file selector that you use to browse your disk for cameras (by either .cam or .pmr) and load into your library. If you select a .cam file, then a copy of the camera is made and it is stored in your camera library. If you select a .pmr file, the camera is first extracted from the file, then a copy is made. If the .pmr file has multiple cameras, you will be asked to select one. Cameras are stored in the library by using the camera name as the file name on disk. Camera files won't appear in your library until you press OK on the dialog.

Note: characters such as ":" cannot be used in file names, so if a camera is to be stored in the library, its name should not include invalid characters. If a camera cannot be saved to disk because of an invalid character a warning message will appear. You then need to rename the camera in the *Camera Viewer Dialog* before trying to save to the library again.

Pressing the "Delete" button will permanently delete the camera file from your library. The file won't actually be deleted until you press OK on the dialog.

Pressing the "Go to..." button opens a Windows File Explorer window providing access to the .cam file so that you can backup, copy or send etc.

Press cancel if you do not want to keep changes made in this dialog.

Camera Library

PhotoModeler uses a central repository (.cam files) to provide easy access to often used cameras. Cameras in the Library are also included in the search for camera/photo matches when adding photos to a project. See *Camera Matching* for information on how photos are matched with cameras from the library when adding photos to a project.

There are two ways to store camera files in your camera library:

- After a successful calibration (or Field Calibration), you will be prompted to store the camera in your library. If you decide to store your camera, the camera will then be included in any camera matching searches when adding photos to a project.

- Using the *Camera Library Dialog*. This dialog can be accessed by pressing the “Library...” button on the *Camera Viewer Dialog*.

See also *Camera Calibration* and *Application Data and File Locations* for information on the specific location of camera files on disk.

Camera Background

This chapter discusses some background theory of camera use in PhotoModeler and in measurement in general. It then discusses specifics about different types of cameras that can be used with PhotoModeler and their characteristics.

Using a Camera for Measurement

There are three central tenets that PhotoModeler depends on to do three dimensional measurement:

1. PhotoModeler assumes that a ray of light coming from some point through the focal node of the lens of a camera and hitting the film can be described by a perfectly straight line.
2. By knowing where the camera was at the time of exposure, PhotoModeler can use the location of where the ray of light hit the film to calculate the equation of that ray of light in three dimensions.
3. Each point that is to be measured is imaged in at least two photographs, and preferably in three or more. These points are used to compute light ray positions and their intersections for determining positions in three dimensional space.

How these assumptions may be upset

There are a number of factors that can cause the above assumptions to be false or partially incorrect:

1. particles and turbulence in the air between the object and the camera bend the light ray,
2. an imperfect camera lens distorts the path of the light ray,
3. the film or imaging sensor (a CCD in a video camera perhaps) does not image the light ray perfectly (it tends to blur it or to shift it),
4. we do not know precisely where the imaging surface (film or CCD) was positioned relative to the camera at the time of the exposure, and
5. the camera characteristics, such as focal length and lens distortion change from photograph to photograph thereby interfering with the repeatability of the light ray measurement.

The following sections address the five points above and discuss the implications on camera choice.

1. Air Effects

When we use PhotoModeler to measure objects up to perhaps 1000 meters in size, our camera positions are close enough to the object to make the light ray distortion by the air negligible. In aerial photography the object being measured might be very far away and air caused distortion can have a significant effect. In astronomy, objects are viewed through

the whole depth of the Earth's atmosphere and sophisticated techniques are needed to model the effects of air turbulence and other air effects.

2. Lens Distortion

All camera lenses distort images to some extent. Lenses found on non-industrial cameras and consumer 35mm cameras range from quite low quality to quite high quality. PhotoModeler can compensate for the lens distortion through a calibration procedure thereby making even consumer-quality lenses reasonable choices for doing measurements.

3. Imperfect Imaging

PhotoModeler makes an assumption that the imaging media is a perfectly flat plane. This is very close to being true with small CCD chips found in video cameras and in some of the digital cameras. This is not usually true in a film camera. Large-format cameras (such as an 8x10 film camera) can have a lot of problems with film flatness. Careful photographers will use vacuum platens that hold the large pieces of film flat during exposure. In a good 35mm camera, the film will be relatively flat but might still bow a bit. Typically, CCDs have better flatness characteristics than film.

All imaging devices have limits of resolution. The light ray coming from some feature on the object and intersecting the imaging media will be blurred. It will be blurred by both the lens and by the media itself. In a CCD, this is due to a finite size of the image sensors and in film this is due to a finite grain size. The higher the resolving power of the imaging system (lens and media), the more precisely we will be able to identify where that light ray hits the media. The more precisely we can identify the location of the light ray, the more accurate our measurements will be.

Therefore, a high resolution CCD is better than a low resolution CCD and fine-grain low-speed film is better than coarse-grain high-speed film. Most CCDs have lower resolving power than most film but the technology is advancing quickly and soon this will no longer be the case. The Kodak DCS 660 digital camera comes very close to the same resolving power of a 35mm camera if one considers the whole optical chain.

When using film, you must take into consideration how the film is digitized for computer use. There are four different scanning technologies available to the consumer today:

- Kodak PhotoCD,
- Flat bed scanner,
- Hand held scanner, and
- Slide scanner.

All of these scanners involve mechanically scanning a sensor or mechanically shifting the film. All scanners add further distortion to the image captured on film. Making mechanical movements precise can be expensive and so many consumer-grade scanners are not very precise.

The PhotoCD format is useful because a roll of 35mm film can be scanned inexpensively but with very good quality and resolution. Many of these PhotoCD scanners are accessible through retail film processing outlets. The PhotoCD format for 35mm film is also very high resolution (up to 3072 by 2048 pixels).

The other three scanner types can scan between 100 and 3000 dots per inch. A good office flat-bed scanner can capture up to 600 dots per inch. If you scan the 35mm film negative directly you can get up to 850 by 560 pixels. This is comparable to a good broadcast quality video camera. If you print and blow-up the negative and then scan it, you can get very high resolutions (up to 5000 by 3000 pixels on an office flat-bed) but you would have introduced another distorting step (printing the negative on photographic paper). We suggest that a flat bed scanner not be used with enlarged prints with PhotoModeler; the accuracy and distortions effects are too unpredictable.

4. Imperfect Point Location

PhotoModeler needs to know where the imaging medium (film or CCD) is placed relative to the camera lens and body at the instant of the exposure. With a digital camera or CCD video camera, the imaging sensor is fixed onto the body of the camera and as long as the lens position is fixed to the body also, you have a rigid and highly repeatable means of locating any individual CCD pixel in the lens / camera / media system.

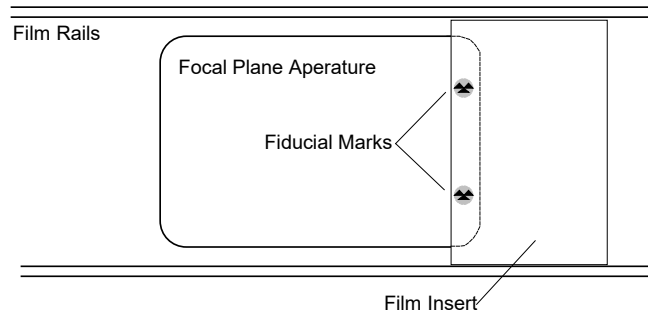
On the other hand, in a film camera, the film is removed from the camera for processing and digitization. By the time we are locating points on the film image in PhotoModeler, we have little idea where that point was relative to the lens / camera body at the time of the exposure.

We can reconstruct the position of the film at the time of the exposure using fiducials. Every photograph has a rectangular border which is the image of the rectangular hole in the camera body between the lens and the film. In a 35mm camera this hole is approximately 36mm by 24mm. This hole is part of the camera body and hence does not move relative to the camera from exposure to exposure. That means that the image of this hole does not move relative to the lens and body. In some film scanners when you scan the negative you also scan the border (right up to the film sprocket holes).

We can use film cameras and scanners for doing 3D measurement in PhotoModeler as long as we use a reasonable quality camera, lens and scanner, and if we scan the whole negative frame or use added fiducial marks so that PhotoModeler can determine where the image was relative to the camera at the time of the exposure.

At this time, the scanner used in the Kodak PhotoCD workstation (2000 series) does not allow your film lab to capture the border of the photograph. Without a frame reference we cannot tell where the image was at the time of exposure. Kodak produced a scanner that has good color accuracy, good within frame geometric accuracy but poor positional accuracy between frames. They did not intend the PhotoCD to be used the way we wish to use it.

The only way to use the PhotoCD system then is to modify your 35mm camera so that fiducial information is imaged directly onto the inner part of the negative or slide. The following diagram shows the back of a 35mm camera with the back open and no film installed. It shows how a stiff piece of plastic has been glued to the side of the camera focal plane opening to act as a reference for PhotoModeler.



Video cameras also have a positioning problem. Most modern video cameras use CCDs for the imaging sensor but then immediately convert the image into an analog NTSC compatible video signal. This video signal is then turned back into a digital signal by a video capture board in the desktop computer. The horizontal resolution of the camera's CCD gets degraded in this multi-step conversion.

In low quality video cameras and low quality video capture boards, the NTSC signal is not handled very well either and one gets a problem called line jitter. That means that if you were to take a video photograph of a perfectly straight vertical line and then view it on your computer monitor after digitization you would see a wavy line caused by imprecise locating of the horizontal position of each horizontal video line.

5. Camera not repeatable between photographs

PhotoModeler depends on the fact that the internals of the camera do not change from photograph to photograph. The internals are focal length, lens distortion characteristics and lens position relative to the imaging media (film or CCD). For this reason, the user:

1. should not use a zoom lens on the camera unless the focal length can be locked securely,
2. should not use interchangeable lenses unless one lens is left securely on the camera during the shoot for one Measurement Project,
3. should not refocus the camera because in many consumer cameras, the lens focal length and lens distortion characteristics change as the lens is focused, and
4. should not depend on autofocus cameras since the lens is focused out of user control.

The user must follow dictates 1 and 2 above and should take care with 3 and 4 but not be unnecessarily worried about focus effects unless the focusing is changing considerably (i.e. some shots are focused at 1 foot and some at infinity).

Note: When using a macro lens, adjusting focus usually causes relatively large focal length changes, which should be kept in mind when taking photographs.

Importing and Using Photographs

Typically, the first step in creating a project using the *New Project Wizard* is to add photos (see *Project Wizard: Select Photos*). After a project has been created, the *Add/Remove Photographs Dialog* is used to add or remove photos to a project.

Getting Photographs into Your Computer

Photographs must be converted to a digital representation that can be stored on a computer's disk system. PhotoModeler works with digital photographs in many formats. The accepted formats are: TIF, BMP, PCX, TGA, JPG, PNG, PCT, PSD (PhotoShop), PPM, MAC, CAL, SGI, RBG (SGI) and PCD (Kodak PhotoCD).

Note: PhotoModeler can read images in many bit depths (1 bit black and white, 4 bit color, 8 bit monochrome, 8 bit color with palette, and 24 bit full RGB color) but some processes (like automatic target marking and *sub-pixel target marking*) only work on 8 bit monochrome (no palette) or 24 bit full RGB images.

The following sections describe how to convert your photograph to digital format depending on what type of camera was used.

For All Cameras

The following suggestions and directions apply to photographs from all types of cameras:

1. Obtain your digital images in the highest possible resolution provided by the camera or scanner while taking into consideration the amount of disk space and RAM you have on your machine.
2. Do not rotate the digital images in an imaging program (e.g. PhotoShop) and specifically do not rotate some of them without rotating all of them. Do note that some digital camera automatically rotate portrait photos and this feature should be turned off.
3. If you rotate all your photographs (for example 90degrees to convert portrait photographs into landscape photographs) you should rotate all the photographs assigned to one Camera the same way and in the same direction. The camera information will need to be rotated also unless the camera calibration was done with similarly rotated photographs. Note that it is easier to import them all landscape and use the Photograph Property dialog and the view rotation setting.
4. Make sure you pick the matching camera for all or each of the photographs used by PhotoModeler. I.e. if you are using photographs from an Olympus 300DL camera make sure you assign a camera matching that camera's parameters as the project default or to those particular photographs. If the camera parameters used do not match the actual camera you will get poor results. *Camera matching* helps solve camera/photo mismatch problems, but this is only possible when using images with EXIF information and a camera with matching information is stored in the Camera Library.

5. If you have calibrated a camera with PhotoModeler's Camera Calibration, the images used in projects and in the calibration should be digitized/captured in exactly the same manner.
6. It is a good idea to put all the images for one project in their own separate hard disk directory. The PMR file from PhotoModeler can be stored there also making it easier to keep all the project data together.

Now study the appropriate sections below for directions particular to your camera type.

From Digital Cameras to PhotoModeler

Most digital cameras come with software for communication between computer and camera an interface cable (USB, serial, parallel, or SCSI). This software can download the pictures from the camera to the hard-disk. Some cameras have removable memory-cards, flash-cards, or disk-cards that can be inserted in a PC Card or other reader and then the images are just copied off the card onto the hard disk.

Using a digital camera is a just matter of loading all the desired images from the camera into one directory on your hard-disk. Follow the generic guidelines above regarding rotation and resolution, etc.

From Video Cameras to PhotoModeler

Using a video camera will require a digitizer board (sometimes called a frame-grabber board). Set up the board to capture images of approximately 512 pixels across by 400 down. Most video cameras do not resolve any better than this. Capture each of the frames you want from your motion or still video and place them in one hard disk directory.

All frames should be captured at the same resolution and digitizer card settings. If capturing from motion video try to capture frames where the camera is not moving much or the objects in the scene are mostly stationary - this is because a video frame is composed of two video fields which are 1/30th of a sec apart and if the camera or object was moving there will be blurring in the frame caused by inter-field movement.

Follow the generic guidelines above regarding rotation and resolution, etc.

From Film Camera to PhotoModeler

Handling photographs from a film camera is a bit more complex because of the loss of position frame-of-reference. The frame-of-reference tells PhotoModeler where the picture was relative to the camera lens at the time of exposure. The frame-of-reference can be computed by PhotoModeler when the user: 1) marks Eos Film Plane Insert fiducials, 2) marks frame corner fiducials, 3) marks metric camera fiducials or reseau, or 4) uses InverseCamera for photographs from unknown cameras. Your photographs should fall into one of the four categories above. See the sections below for further directions based on the category.

Eos Film Plane Insert was used

Photographs taken with a 35mm camera with an Eos two point or nine point insert can be scanned by almost any scanner. Kodak PhotoCD, a negative/slide scanner or a flat bed office scanner from prints can all be used successfully. Simply scan your photographs as consistently as possible and if you do any cropping do not crop off any fiducial marks.

When the photographs are loaded into PhotoModeler you will need to mark the fiducials before using the photographs for modeling or measurement. Follow the generic guidelines above regarding rotation and resolution, etc.

Full Frame scans or prints available

Full frame scans or prints show the whole 35mm frame (the 36mm x 24mm black frame around the picture). If the scan or print shows the sprocket holes then you have full frame prints. Prints are normally not made this way. See the section "*Using Film Negatives without the Film Plane Insert*" for more information on full frame prints.

Full frame photographs are handled the same way that Eos Film Plane Insert photographs are handled as described in the section above. Note that Kodak PhotoCD and some other slide/negative scanners are not full frame scanners and so they cannot be used in this case.

Metric camera with fiducial or reseau was used

Photographs from metric cameras are scanned in the same manner as Eos Film Plane Insert photographs as described above.

Photographs come from a 3rd party unknown camera

Photographs from unknown cameras are handled by the Inverse Camera feature of PhotoModeler. Inverse Camera requires known 3D control points in the photographs. See the *Inverse Camera* section for more detail.

Usually unknown photographs come as prints and not in negative/slide form. If you do have negatives you can perform a combination of full frame scanning with full-frame fiducials and InverseCamera for maximum accuracy. We will talk about the more common prints-only case. With prints you will need to scan them on your flat bed scanner. You should:

1. scan one photo at a time and place each photo in exactly the same spot on the scanner-bed each time (usually up against the top right edges),
2. set the cropping of the photographs so it always exactly matches the outside border of the print or leave a small border around the print (cropping and border should be the same for every photo used by one Camera), and
3. do not rotate the photographs on the scanner bed - that is, make sure they are all placed with the same orientation (usually landscape).

You should end up with images that all have exactly the same pixel dimensions (e.g. 1525 pixels wide by 978 pixels high).

The Wizard will guide you through setting up the correct camera parameters for this case.

Photo prints come from your camera but they are not full frame and there are no fiducials

In this situation we assume you do not want to carry out InverseCamera on each of your photographs (perhaps you have no Control Points or you do not have the time) and you want to use these photographs to carry out a normal PhotoModeler project.

You will notice that this situation is not one of the four categories listed above in the *From Film Camera to PhotoModeler* section. This is because PhotoModeler cannot properly

reconstruct the frame-of-reference in this case. You may get less accurate projects in this case. There are a few things you can do to maximize the possibility of getting an accurate result.

First of all, follow all the directions in the "*Photographs come from a 3rd party unknown camera*" above. Secondly, use the "35mm" camera type in the Wizard and with no fiducials, and pick the appropriate scanner. Once you have entered your print size and indicated the photo dimensions PhotoModeler can estimate appropriate camera parameters.

Adding Photographs to Your Measurement Project

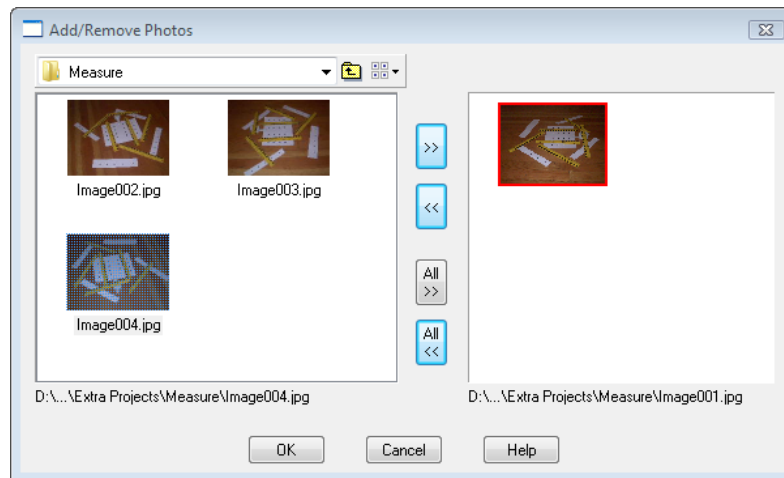
The photographs for your Measurement Project are now stored in your computer in one of the acceptable formats.

If you have already started a project for this measurement, open your previously saved project file. See *Opening an Existing Project*.

If you have not started a project see *Creating a New Project*.

You can also add images by dragging and dropping image files from Windows Explorer onto the PhotoModeler application window (see *Drag and Drop*).

Add/Remove Photographs Dialog



The Add/Remove Photographs Dialog is used to import Photographs into and to remove Photographs from the current Project.

The dialog has a small toolbar, and two regions that show a *chip* or description (depending on the view style) of each photograph in the current directory (on the left) and in the current project (on the right). Only photos of the supported formats (see *Getting Photographs into Your Computer*) will appear. The region at left also shows any subdirectories in the current directory allowing you to navigate deeper into the directory structure (by double clicking the directory symbol). Shortcuts to other directories are also shown and can be used to navigate.

Below each of these areas are text boxes that show the location and file name of the currently selected photo chip above. a section showing photos on disk, a series of buttons to move photos in/out of the project, and a section showing photos in the project.

The toolbar has a drop down control from which you select a directory on disk (you can also type a path in this text box). The "Move up" button moves to the parent of the current directory. The "View Style" tool changes the display of photos (in both the disk and project) between either 'thumbnails' (chips) or 'details' (showing file names, sizes etc.), and behaves much like the file explorer in Windows.

This dialog can be resized by dragging the dialog border which helps when viewing photo details (this feature is not available when add/removing photos in the New Project Wizard).

Note: PhotoModeler can read images in many bit depths (1 bit black and white, 4 bit color, 8 bit monochrome, 8 bit color with palette, and 24 bit full RGB color) but some processes (like automatic target marking and sub-pixel target marking) only work on 8 bit monochrome (no palette) or 24 bit full RGB images.

Loading Photographs into a Project

On the *Add/Remove Photographs Dialog* change to the directory where the images that you wish to use in the project are located.

Select a photo chip to see its file name at the bottom (if thumbnail view style is selected). When you have found the photograph you want, click on the ">>" button to move it into the Project. You can move multiple photographs this way one at a time or you can move multiple photographs at once by using the shift-key to do multiple selection and then pushing the ">>" button. All photographs in the source directory can be moved at once by using the "All >>" button. Note that you will want to use this button only if you are confident all photos can be processed together at startup. For new projects it is often best to start with just a few photographs.

Images from different directories can be loaded into a Project by going to one directory, moving the required images into the project and then going to the next directory (using the "Move up" button or via directory shortcuts) and moving some more images. Repeat this as necessary.

Any photograph additions to the Project can be canceled by hitting the "Cancel" button on this dialog.

You can also add photos to a project by dragging images from Windows File Explorer onto the PhotoModeler application window. If there is a matching camera in the project or in your camera library, it will be assigned to the new photos.

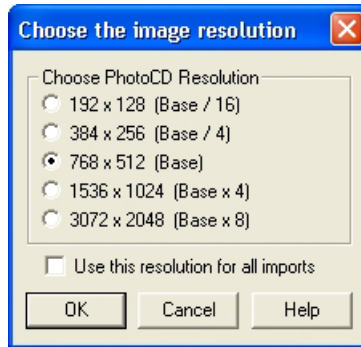
Removing Photographs from a Project

To remove a Photograph from a Project first select the photo (chip or description), its file name will also appear at the bottom of the dialog, then click the "<<" button. The photograph will be removed from the Project. If this Photograph has any marks on it, you will be asked if you want to remove it. If you say yes, the Photograph and all its marks will be removed from the Project permanently (unless you cancel out of the dialog using the "Cancel" button). The "All <<" button removes all photographs in the project at once.

Note: Removing a photo(s) from a project does not remove the photo(s) from disk.

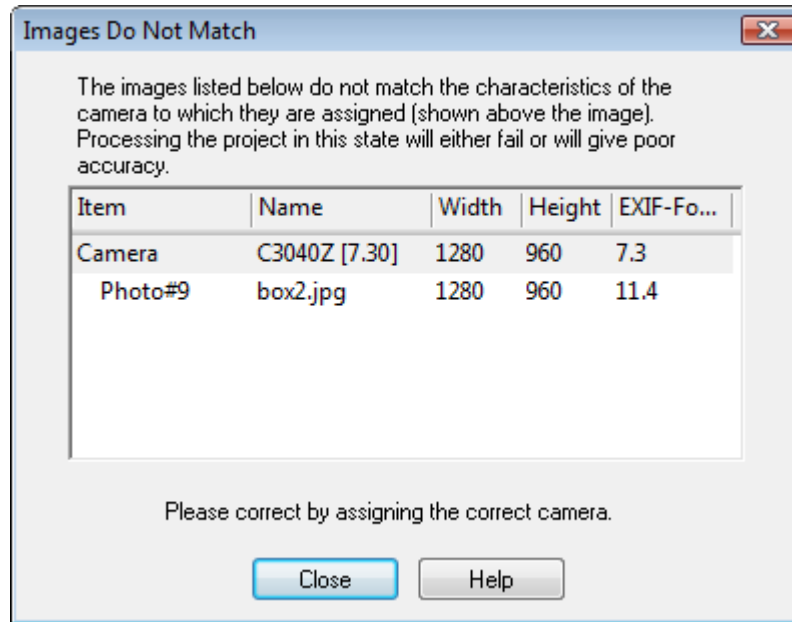
Note: if you want to remove a Photograph and its marks from processing only and do not want to delete them permanently from the project use the Photograph property called "do not use" described in the *Processing Action* section.

Image Resolution Dialog



Whenever a Kodak PhotoCD image (extension PCD) is imported into PhotoModeler this dialog appears to request which size/resolution is required. The base 768x512 pixels is the default. The highest resolution images are 18MB each so beware that you will need a fast computer, fast hard-disk and lots of RAM to use these successfully. If you check the "Use this resolution for all imports" box, all PhotoCDs image being imported in this session will be imported at the chosen resolution. You can mix resolution images in your project but once they have marked points on them you cannot change the resolution without losing all your markings.

Image Check Dialog



The Photographs and their assigned Camera must be consistent in terms of image aspect ratio and **EXIF** Focal length (if available). This dialog appears only when there is a mismatch. **Camera Matching** helps prevent camera/photo mismatches, however a mismatch can occur when manually assigning cameras and photos.

Image aspect ratio: The dimensions of the image in pixels (expressed as X by Y). The Photograph's image size is read from the image file on disk and the aspect ratio is calculated. The Camera's image resolution is stored by PhotoModeler when the Camera is first created. The image aspect ratio must be the same for the photo and the camera, otherwise, it will be listed in this dialog, and will likely cause problems.

EXIF Focal Length: When a digital camera (using EXIF .jpg image format) takes a photo, various data are stored in the image's header that can be read by software known as an EXIF reader. One item of this data is the EXIF Focal length of the camera that took that image. The Camera's EXIF Focal length is stored by PhotoModeler when the camera is first created (calibration or on photo import for an approximate camera). For example, if the focal length stored with the image was 7.6mm, the Camera's focal length must also be 7.6mm or this dialog will appear. Note: if you are using an image format that does not store EXIF information, the EXIF focal length parameter is not used or checked.

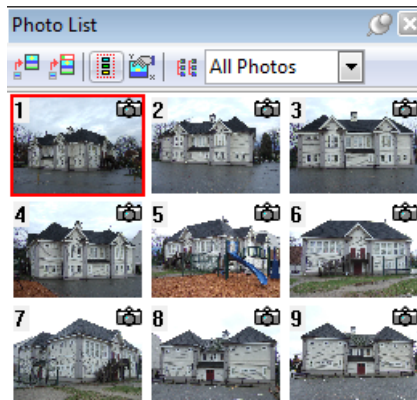
If there is an inconsistency between either of these two parameters, your project will not be in a reliable state. An inconsistency indicates that the camera assigned to the photograph in PhotoModeler was not the camera that took the photograph. This must be fixed. Either remove the offending image from your project or assign the correct camera to this image.

Viewing Photographs

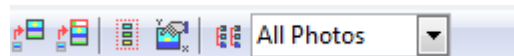
This section describes how to view and use photographs once they have been imported. See *Adding Photographs to Your Measurement Project* if your project does not have photographs yet.

The easiest way to view a photograph is to double click on its *photo chip* in the *Photo List Pane*. Photographs can also be opened by double clicking the photo's row in the *Photo Table*.

Photo List Pane



The Photo List pane contains the photo chips representing the photos that have been added to the project as well as a small toolbar to perform actions on the photo chips:



The toolbar contains five controls:

- **Open Photo(s)** – opens the selected photo or photos in the Photo Windows pane, in the position immediately adjacent to the Photo List. Press Esc on the keyboard to abort opening the photos.
- **Open Photos Tabbed** – opens the selected photo or photos in the Photo Windows pane, brings it to the top of other photos in the pane and 'tabs' the other photos in the pane. Press Esc on the keyboard to abort opening the photos.
- **Select All button** – selects all photos in the Photo List. This will be used in combination with the Open Photo(s) or Open Photos Tabbed tools.
- **Properties of Selected Photo(s)...** - shows the *Photo Properties* dialog box for the selected photos. It is the same Properties tool that appears on the right click menu when right clicking a photo chip.
- **Edit Photo Sets** – displays the *Edit Photo Sets Dialog*, in which you can add, delete or edit *Photo Sets*. Only the photo chips for the photographs in the Photo Set shown in the Photo Set list will be shown in the photo chip area. This is very useful for projects with many photographs when navigating between them becomes troublesome. A smaller set of photos can be more manageable.

- Photo Set selector – lists all photo sets currently stored in the project providing a way to show only photos in the photo set in the Photo List pane. This is very useful for projects with many photographs when navigating between them becomes troublesome. A smaller set of photos can be more manageable.

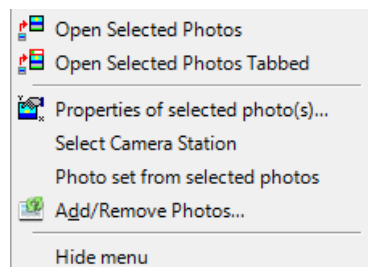
Below the toolbar is the Photo Chip area which displays the chip (small) versions of the photographs in the project.

If you click on a chip it will get a red border to indicate it is “selected”. You can then press the Open button to have the photograph open in the *Photo Windows pane*. Double clicking on a chip is a short cut to using the Open button. The photo will open immediately to the right of the Photo List pane. When holding down the Alt key, the photo opens tabbed.

You can select multiple chips by using the shift key (extend) or ctrl key (disjoint) during mouse selection. Then when the Open button is pressed all selected photographs are opened. If the Select All button is pressed then all chips currently shown in the Photo Chip area will be selected. So pressing Select All and Open buttons in sequence is the fastest way to open all the photographs in the project.



These chips can be used to open photos (i.e. double click) or get information or perform other actions through a right click menu:



This menu provides access to commonly used tools to perform various actions on the selected photo(s): Open Selected Photos and Open Selected Photos Tabbed open photos into the Photo Windows pane (see toolbar description above); Properties of selected photo

shows the *Photo Properties* dialog box; Photo set from selected photos creates a photo set from selected photos, and Add/Remove Photos brings up the *Add/Remove Photographs Dialog*.

Also when the mouse cursor is hovered for a few moments over a photo chip, a tooltip window appears showing information about the photo:

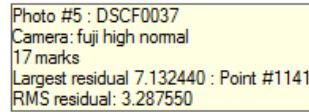


Photo #5 : DSCF0037
Camera: fuji high normal
17 marks
Largest residual 7.132440 : Point #1141
RMS residual: 3.287550

The photo tooltip shows the photo number, name, the name of the camera that took the photo, the number of points marked on the photo, the residual and id of the point mark with the highest residual, and the overall photo RMS.

Each chip shows two pieces of graphical information. The photograph number (which uniquely identifies a photograph in a PhotoModeler project pmr) is shown on the top left of the chip. The status is shown as an icon on top right of the chip. The icons are:

- Blank - photograph has marks but is not yet processed / *oriented*.
- Red "X" - photograph will not be processed (has no marks or has been set to "do not use")
- Green "X" - photograph has been set to "use but no adjust"
- Camera - photograph is *oriented*.

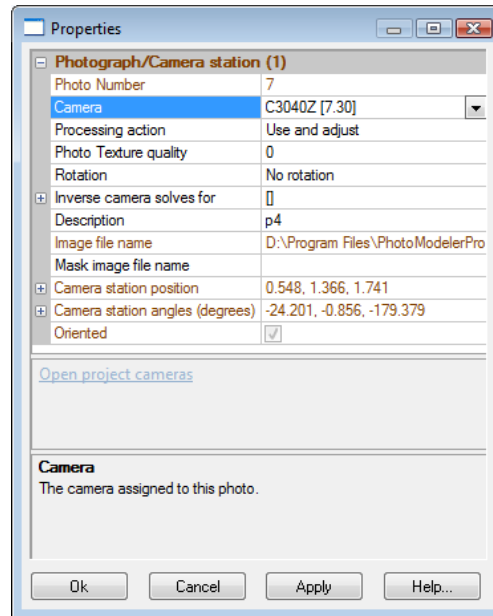
There can be combinations of these such as a red "X" on top of a Camera bitmap means the photo is oriented but has been set to "do not use".

If the photograph you wish to open is not in this list see *Adding Photographs to Your Measurement Project*.

Note: PhotoModeler has an automated mechanism for creating smaller versions of each image. These smaller versions are used in the Photo List pane, the Photo Table and, the Add/Remove Photographs Dialog. These smaller images are cached in ".cch" files in the directory where the images are. This approach makes PhotoModeler more efficient but if the images come from read-only media there will be problems. You will get error messages when the cache is created. To fix, move the image files onto read/write media. This does not apply to read-only PhotoCD disks as these images are handled differently.

Note: If you try to open photos and your system is low on memory, a "Low Memory" warning will appear. The warning box will give you the option to continue opening photos or to cancel opening photos. If your system gets too low on memory, it can become unstable, causing abnormal behavior in PhotoModeler. You can control whether this warning appears and at what level of memory usage by adjusting the Memory Check settings in the Photo Control section of *Preferences - User Interface*.

Photo Properties



The Photo Properties Dialog displays properties of one or more photographs in the project and provides the facility for modifying these properties in a *Property Grid*. This dialog is accessed from the Properties button on the *Photo Table* or on the right click menu when in select mode and the cursor is on a photograph window or a photo chip.

See also the *Photo Table* section for information on the display of photo and camera information in a table.

The dialog can show the properties for one or more Photographs at a time. If you select multiple photographs in the Photo Table and press properties button, this dialog will appear showing all common properties to those selected photos. Where the properties are not the same, the dialog will show blank, or be tristate checkbox or use the word "varies". The properties of all photos can be changed at once. For instance, you could select four photographs and switch them all to use a different camera by using one invocation of this dialog.

The dialog contains properties of the Photograph, the Photograph's image and Photograph's associated Camera Station. These are described in the sections below:

Photo Number

The Photo Number is assigned by PhotoModeler when added to the project. A photo's number is shown in this field and also in the top left corner of the "image chip" shown in the *Photo List Pane*. You can renumber photos using the *Renumber Dialog* (from the Project menu).

Camera

When the Camera property is clicked a down arrow appears to access a drop down menu of cameras in the project. The Camera drop-down list will show the selected photograph(s)' Camera. To change the photograph(s) so it uses a different camera, press the down arrow and pick a new camera. If the Camera does not appear it means it is not loaded into the project. In this case press the "Open project cameras" hyperlink to bring up the *Camera Viewer Dialog*. This dialog will allow you to load, save, create and modify Cameras. On reassigning a camera and hitting OK on the dialog in some cases you may see the *Image Check Dialog* which indicates that a camera and photo do not match.

Processing Action

The Processing Action is a powerful Photograph property that allows you to easily remove from or freeze a photograph in the 3D processing (Orientation and Global Optimization). The three options (which appear when you select the property and a down arrow appears and then clicking the down arrow shows the options) are described here with explanations of when they might be used:

Processing Action	What it does	When to use
Do not use	The photograph and its points will not be oriented and processed. It is as if the photograph was not in the project at all.	Use when you want to experiment with removing a photograph from contributing to model production or to processing. Useful for troubleshooting.
Use and adjust	This is the normal and default setting for processing. The photograph and its points will be oriented and processed.	Use when a photograph has not yet been processed.
Use but no adjust	The photograph and its points contribute to the 3D model but during processing it will not be adjusted (moved or oriented).	Use when you are adding a new photograph to a set of photographs that are well processed and have had a lot of work done on them. Set this attribute on all the solved photos. Also useful for troubleshooting.

Note: When a Photograph is first imported into a project it is automatically set to "Do not use". This means new photos will not be processed or counted by Audit and other tools. As soon as something is marked (fiducial, marked point, cylinder, etc.) on a Photograph it is automatically set to "Use and adjust". This allows you to have many unused photos in a project without worrying about how they affect processing and audit etc. Then as soon as you start to use them (by marking on them) they are automatically included in processing etc. The processing action can still be manually overridden whenever you want by using the radio buttons described above.

Photo Texture Quality

The Photo Texture Quality setting is an arbitrary integer number that defines the relative quality of the photograph for texture extraction or auto-coloring. The photograph with the highest quality setting is used first for photo-texture extraction when a Surface appears on more than one photograph. If one or more of the photographs have the same quality value (which is the default) then the photograph with the lowest number is chosen first.

The Photo Quality is a positive or negative integer value. It is only the relationship between the photos' individual qualities that makes a difference. A photo with a higher quality gets chosen first as a texture source if the face being textured appears on that photo.

For example, if one face/Surface appeared on photo 1, 3 and 4 and the photo qualities were set to:

photo 1: quality -1

photo 3: quality 0 (which is the default setting)

photo 4: quality 2

the face would be textured from photo 4 as the search order is 4,3,1.

When the photo quality is the same on two photos, the photo with the lower photo number gets used. So for these five photos:

photo 1: quality -2

photo 3: quality 0

photo 4: quality 2

photo 5: quality 0

photo 7: quality 1

the search order for choosing a texture source would be: 4,7,3,5,1.

You can override the assignment of photo to textured face by using Materials defined as PhotoTexture from photo N. See the *Materials Dialog* for more detail.

Rotation

All photographs taken by the same camera should be imported with the same rotation (either all portrait or all landscape). The standard is to define cameras with landscape orientation (i.e., the format width is larger than the format height) but if you take some photographs with the camera rotated clockwise or counter-clockwise 90 degrees you will have a portrait photograph. This photograph must still match its camera and be imported in landscape rotation. This means you would have to view the photograph with the scene lying on its side (i.e., not upright).

The Photo Rotation setting fixes this. You import all your photographs in landscape (more pixels wide than they are high), and use the rotation on the photo to give you a view that is upright and easier to work with.

When the Rotation property is selected a down arrow button is shown which provides access to the available rotation options.

Each photograph has its own rotation setting and this setting is saved with the pmr so each time you open this photo it will open rotated the same way.

Inverse Camera solves for

See the *Working with Unknown Cameras and Photographs* manual/help section for details on when and how this is used for dealing with photographs taken with unknown cameras. To use this feature you require control points (or Axes Constraints) to be marked on the photograph in question. If you turn these options on and have insufficient control points, the photograph will not be processed.

A small "+" or "-" button to the left of the property heading is can be clicked to contract or expand the Inverse Camera settings. When expanded, three properties are shown: focal length (click the down arrow for this setting and choose TRUE when you want to solve for the focal length of the camera that took this photo), principal point (click the down arrow for this setting and choose TRUE when you want to solve for the x,y principal point of the camera that took this photo), and format aspect (click the down arrow for this setting and choose TRUE when you want to solve for the aspect ratio of the format size of the camera/scanner that took this photo).

If you are using Control Points to do Inverse Camera processing you must meet some minimum requirements. If you are solving just focal length in Inverse Camera (most common) then each photograph, that has InverseCamera focal length turned on, must have four or more Control Points with a good spread. If you have asked for principal point solution also you will need an additional two Control Points and for format size an additional one Control Point. So if you have all three Inverse Camera parameters turned on for solution you will need at least seven Control Points on that photo.

See the above mentioned section for information on when and when not to turn on the solution for various camera parameters. Note that if you get a solution it could be wrong or inaccurate if you solve for the wrong set of camera parameters.

Description / User Name

The Photograph / Camera Station is named automatically based on the associated image file name on first export. But you can change this name to whatever you want. Perhaps you prefer "Left Front" as a name instead of "crt0004". This name also appears:

- in the caption of the open Photograph window, and
- in the *Photo Table*.

This can help you keep track of your photographs.

To edit this property, click the text in the field and make your edits. Once OK is clicked, the changes will be stored with the photo.

Image Filename

This is a non-editable field that shows the full disk path name of the image associated with this Photograph.

Mask image file name

An optional mask file can be assigned to each photo to indicate areas not to include for texturing. An example is where a car or tree obstructs the model object or scene and you do not want that obstruction to appear in a photo texture. In a multi-photo texture, the areas masked in one image will be textured by other images where available. In a single photo texture, the areas masked will appear grey.

This is one way to create a mask image:

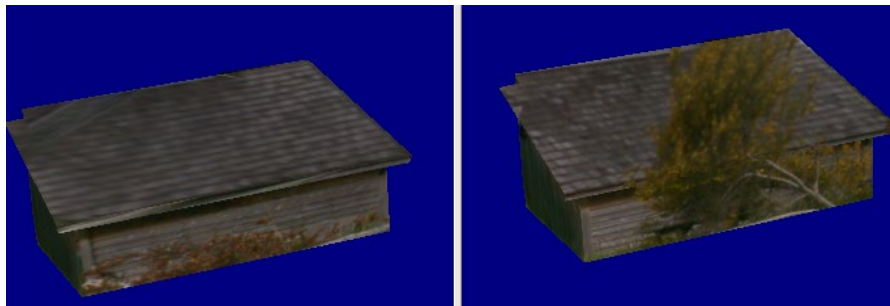
1. Open an image editor that supports layers.
2. Open the photo to which you want to apply a mask.
3. Save the file with a new name as a duplicate so that you do not accidentally overwrite the original.
4. Create a new layer and paint it solid white, and adjust the layer transparency so that you can see the underlying image.
5. Paint in black over the areas that you want to mask out. You may wish to fade the edges or use anti-aliasing so that you have a smooth mask border. Any areas painted black will be masked, areas painted white will be transparent and shades in between will be graduated (i.e. the darker the mask, the more opaque it will be).
6. Save the mask layer as a separate image on disk (usually the folder with the project images is the best location). Only the gray information in a mask image is used, so typically the mask image should be saved as an 8 bit grayscale image.

This explains one way of creating a mask image but there are several other ways to do it (some image editors have a dedicated masking feature so consult your documentation for more information).

Note: The masked photo texture will only take effect in the 3D Viewer when Quality textures are enabled.

Also Note: Make sure the mask image is the same resolution as your photo image so that the mask is aligned correctly with appropriate areas in the photo.

When you click on the Mask property, the “Browse for mask file” hyperlink appears. Click the hyperlink and browse to the mask image that you saved to disk. Once you click OK, the mask is assigned to the photo, and when you next open a 3D Viewer with Surfaces and Photo Textures turned on, you should see that the areas that were masked no longer appear in the photo texture, as shown in the example below:



This shows a screen capture of a model in two 3D Viewers. The one on the left shows a photo texture with a mask assigned to one of the photos, while on the right the model is shown without the mask.

Camera Station Position

This property gives information on the position component of orientation of the Photograph's Camera Station (i.e. the position of the perspective center of the camera at the time the photo was taken).

When this property is expanded (i.e. by clicking the small + next to the property title), the position is given in the x,y,z coordinate system of the project. Note these orientation numbers are in the rotated coordinate system as defined by Scale/Rotate.

You can also see the scaled and rotated Camera Station information in the *Photo Table*.

Camera Station Angles

This property gives information on the angles component of orientation of the Photograph's Camera Station (i.e. the angles of the camera station at the time the photo was taken).

When this property is expanded (i.e. by clicking the small + next to the property title), The Omega (deg.) is the rotation about the X axis, the Phi (deg.) is the rotation about the Y axis, and the Kappa (deg.) is the rotation about the Z axis.

Note: the values for orientation of the Camera Station can be changed here - you should be quite confident in your coordinate systems before you do this. When any of these values are changed, the Camera Station will be set to be "oriented". In other words, this is a method of manually orienting a Camera Station. This might be useful when you know the photo positions before hand (such as a stereo camera setup on an ROV).

Oriented

The Oriented property shows a checkmark when a camera station's position and angles have been solved, that is when the photo has been successfully processed and oriented.

When the property is selected, the "Force Unoriented" hyperlink appears. Clicking this link (and then subsequently the OK on the dialog) will force the Photograph's Station to be unoriented (as if it was not processed). This is very useful when doing Inverse Camera work or when troubleshooting orientation problems. This can be used in combination with the *Processing Dialog* to force the reprocessing for *Inverse Camera* and reorientation of a single photograph.

Photo Windows Pane

The Photo Windows Pane contains photos that have been opened in the project. When a photo is opened from the Photo List, it will always appear in the Photo Windows Pane, but there several options for the layout of photos within the pane. As in other panes containing multiple views or windows, photos can be tiled, tabbed, or split horizontally or vertically using the tools on Windows menu.

Photos can also be dragged (click and drag the photos title bar to move) into many different configurations, by using the "*Docking Context Stickers*" which appear while the photo is being dragged into position (i.e. mouse is down and a window is being moved). Photos can also be resized by clicking and dragging the photo window borders.

The Photos Pane itself can be placed anywhere within the PhotoModeler application window or can be floated anywhere on the desktop. The pane can also be pinned.

The Photo Zoom/Pan Tools Toolbar also provides tools to interact with photo windows, such as zoom in, zoom out, zoom area etc. The Pane Tools Toolbar contains various tools to interact with active panes, such as tiling, splitting etc. See *Toolbars* for more information.

See *Paned Interface* for general information on panes, visibility, configurability and user interaction.

Photograph Window

Photographs are displayed in a Photograph Window, and will always be displayed within the *Photo Windows Pane*. The Photograph Window is user-sizable but the Photograph will remain the same size unless it is zoomed. This preserves an accurate mapping of photograph pixels to screen pixels. If you make the window larger than the photograph at current zoom, a diagonal line hatch area will surround the photograph. This hatched area is dead and no work can be done in it. If the window is smaller than the photograph at current zoom, scroll bars will appear around the edges of the window allowing you to change what part of the photograph can be seen.

A Photograph Window can be closed at any time using the "X" button in the upper right of the window. Photographs can be moved by dragging the caption bar, and can be resized by dragging the window borders.

See *Paned Interface* for general information on panes, visibility, configurability and user interaction.

The Photo Zoom/Pan Tools Toolbar also provides tools to interact with photo windows, such as zoom in, zoom out, zoom area etc. The Pane Tools Toolbar contains various tools to interact with active panes, such as tiling, splitting etc. See *Toolbars* for more information.

Photograph Windows are used to mark and reference features. Any features you have marked, are displayed in the Photograph Window they were marked on. To learn about marking features see *Marking*.

Closing a Photograph Window does not delete any of its markings (points, lines, cylinders etc.). They are stored with the project permanently until deleted by the user.

To learn how to create a Photograph Window see *Viewing Photographs*.

Changing the Magnification of a Photograph

PhotoModeler allows you to magnify the image of any open photograph so details can be better seen and marked. The Zoom In and Zoom out tools also work in the 3D Viewer (in addition to the usual controls at bottom right of the viewer or mouse controls).

There are a number of ways to access tools to magnify (or "zoom") or manipulate the display of a photograph:

- Window menu has several tools to manipulate the photo, including the Zoom In and Zoom out tools, and the various tools on the Photo Windows sub-menu.
- there is a toolbar dedicated to photo manipulation, called the Photo Zoom/Pan Tools (see *Toolbars*),
- an action button on the Open View Tools toolbar (see *Toolbars*),
- actions available through right-mouse menus,
- actions available through a wheel mouse, and
- actions available through keyboard commands.

Zoom Menus

The Window menu and its Photo Windows submenu and many of the right-click menus provide access to magnification functions. The zoom tools that appear on various menus and toolbars are described below:

Zoom In Mode

To magnify a photograph or a 3D Viewer:

1. Pick up the Zoom-In tool from the toolbar (the magnifying glass with a "+").
2. Click this tool on the Photograph or 3D Viewer Window you wish to magnify.

PhotoModeler will magnify this window each time you click the mouse button. The photograph or 3D Viewer will magnify about the point specified by the cursor position. I.e. if you wish to study some feature more closely, click the zoom-in tool on top of it and it will be magnified and placed in the center of the window.

Zoom To Area Mode

To magnify a photograph in a user specified area:

1. Pick up the Zoom-Area tool from the toolbar (the square-dotted magnifying glass with a "+").
2. Click and hold this tool on the Photograph Window you wish to magnify.
3. Drag the mouse until the desired rectangular area is shown.
4. Release the mouse button.

PhotoModeler will magnify this photograph to best fit the chosen rectangle into the current window. This tool is not accessible when the 3D Viewer is active. If in this mode and a 3D Viewer becomes active, the mode will switch to a valid mode for 3D, such as Zoom In.

Zoom Out Mode

To decrease the magnification of a photograph or 3D Viewer:

1. Pick up the Zoom-Out tool from the toolbar (the magnifying glass with a "-").
2. Click this tool on the Photograph or 3D Viewer Window you wish to zoom out.

PhotoModeler will unmagnify the photograph one level. Each mouse click will decrease the magnification down to the original magnification.

Zoom To Fit/Zoom to Fit All

To return quickly to default magnification, select "**Zoom To Fit**" from the window menu, use the Zoom To Fit tool from the toolbar or use the zoom default keyboard short-cut (F). Zoom to fit makes sure the whole image is visible at once in the current window no matter what the window size. The Zoom to Fit All tool performs this action on all open photos.

Once the photograph is zoomed-in only part of a photograph will be visible. To change the part of the photograph that is visible when it is magnified you may use the scroll bars or one of the "panning" tools.

This tool is not accessible when the 3D Viewer is active. If in this mode and a 3D Viewer becomes active, the mode will switch to a valid mode for 3D, such as Zoom In.


Pan Mode

To pan the photograph:

Adjusting the vertical scrollbar will pan the photograph up or down. Adjusting the value of the horizontal scroll bar will move the photograph from side to side. The setting in the Preferences dialog 'Real-time image pan update' (under the Image page, see [Preferences - User Interface](#)) allows you to choose if the image is panned during scrolling in real-time or not. If this preference is checked, when you move either of the scroll bars, the image is panned in real-time. Otherwise the image will be refreshed in its new position only after you stop scrolling and release the mouse.

Note: Depending on the speed of your machine you may want to change the time delay setting. You can balance the speed of panning versus the quality of the pan. The Preference setting that controls this speed vs. quality trade off is "The number of milliseconds the mouse should be stationary before redrawing the image during pan" in the Image page. If you have a fast machine try lowering the setting (perhaps to zero) to get high quality, smear-less panning or if you have a slow machine, and panning is too slow or not interactive enough, try increasing this setting.

To pan the photograph in both directions at once:

1. Pick up the "panning" tool from the toolbar .
2. Press the mouse button down and drag the photograph with the "panning" tool.

Part of the photograph is updated as you move the mouse. When the photograph has been dragged to the correct location release the mouse. PhotoModeler will redraw the photograph.

Additionally see the [Temporary Zoom / Pan Mode](#) section below for a method of panning without leaving the current mode.

This tool is not accessible when the 3D Viewer is active. If in this mode and a 3D Viewer becomes active, the mode will switch to a valid mode for 3D, such as Zoom In.

Zoom 1:1

Set the active photograph's magnification such that one image pixel is displayed for each screen pixel.

This tool is not accessible when the 3D Viewer is active. If in this mode and a 3D Viewer becomes active, the mode will switch to a valid mode for 3D, such as Zoom In.

Zoom Previous

Makes the active photograph return to the most recent zoom and pan settings. This tool is not accessible when the 3D Viewer is active. If in this mode and a 3D Viewer becomes active, the mode will switch to a valid mode for 3D, such as Zoom In.

Zoom Keys

There are a number of keys that provide direct access to zoom functions. They keys can be pressed in most modes. These are:

+ or = or numeric keypad +	Makes the active photograph (or the active 3D Viewer) zoom-in under the current cursor position.
- or _ or numeric keypad -	Makes the active photograph (or the active 3D Viewer) zoom-out under the current cursor position.
F	Makes the active photograph fit completely within the current window.
Shift+F	Does Zoom-to-Fit on all open photographs.
ALT	Brings up the Zoom Window. See next section.
CTRL	Enters the temporary Zoom-Area and Pan mode. See the section after next.

Zoom Window

In all modes, when the cursor is over the active photograph window, you can press and hold the ALT key to bring up the temporary Zoom Window.

The temporary Zoom Window zooms the image under the cursor to a fixed magnification and specified size. These are user set in the *Preferences* dialog.

You can carry out most actions in the Zoom Window, such as selection, moving by dragging, marking points, marking lines, marking curves, etc.

When you are finished the desired action release the ALT key and the Zoom Window will go away.

When the ALT is held down and the cursor moves outside of the Zoom Window, the contents of the window will pan in the direction of the cursor. The speed of the panning is controlled by settings in the *Preferences* dialog.

Note that the Zoom Window displays all those model items that the user has specified in the *Visibility On Photos* pane.

If you find the Zoom Window is too slow to appear you may try 1) reducing its size, as specified in Preferences, or 2) changing model visibility for those types of objects that you do not need visible for the current work.

The Zoom Window is especially useful when you are dealing with large images (for the whole image to be visible you need to use a zoom factor such as 1:4). If the Zoom Window magnification is set to 200% (2:1) in Preferences then you can easily get an overall view of the photograph while staying at 1:4 and doing detailed work (marking, moving, selection etc.) by using the Zoom Window at 2:1.

Temporary Zoom / Pan Mode

In all modes, when the cursor is over the active photograph window, you can press and hold the CTRL key to enter the Temporary Zoom / Pan mode.

When the CTRL key is pressed, the cursor will change to show the two possible actions.

When the CTRL key is held, the left mouse button pressed and held, and the mouse dragged, a region box will draw on the photograph. When the left mouse button is released a Zoom-Area command will be executed. See the section above for Zoom Area.

When the CTRL key is held, the right mouse button pressed and held, and the mouse dragged, the photograph will pan just as if the pan mode was being used.

You can think of this CTRL temporary mode as a quick way to get into Zoom-Area or Pan mode without ever leaving the mode you are in.

Note: short-cuts that use the CTRL key are still accessible in photograph windows. For instance, to access Undo one would press Ctrl and Z. If the cursor is over a photo the cursor will change to show the Temporary Zoom / Pan mode but when Z is then pressed the Undo function will be carried out.

Wheel Mouse Zoom

If your mouse has a wheel control (usually between the left and right buttons), you can use this to change the zoom or magnification of the photograph window (works with 3D Viewer also!). Activate the photograph window, place the cursor over the photograph and roll the wheel. Rolling up increases the magnification and rolling down decreases it. The point about which the zoom takes place is the current cursor position. .

On some systems this wheel-based zoom may stop working when the scroll bars appear in the photograph window. This is a result of the mouse driver over-riding PhotoModeler. This happens only on some systems. If this behavior is annoying you can turn off wheel zoom altogether by adding this line:

WheelMouseZoom=FALSE

to the [Image] section of the PhotoModeler .ini file (see [Application Data and File Locations](#) for information on where the ini file is stored on disk).

A Common Set of Zoom and Pan Tools

There are many photograph magnification and panning tools in PhotoModeler. As a result it can be difficult to determine which are the best to use.

First of all, there is no right or wrong. There are so many of these tools because people operate the program differently and have different tastes for keys vs. toolbars vs. menus etc.

A PhotoModeler expert might use this set of tools often:

+ key	to zoom in quickly while in any mode
F key	to fit whole photo to the window
Fit toolbar button	to fit whole photo to the window
Ctrl right mouse button	to pan while in any mode

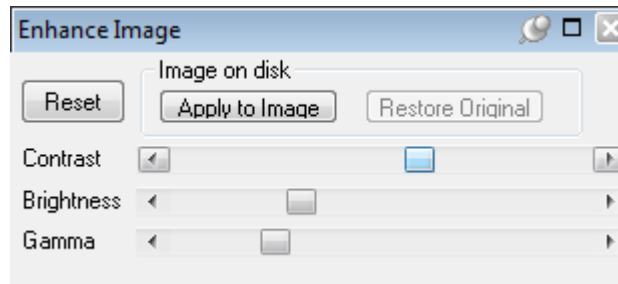
Right click menu	to access zoom 1:1
Alt key	to access zoom window to get quick magnify
Mouse wheel	to make rapid changes in zoom level without a mode change
Zoom area toolbar	to get precise area to view
Ctrl left mouse button	to get precise area to view while in any mode

Changing the brightness and contrast of an image

While viewing a photograph or doing marking and referencing operations it can be helpful to change the brightness or contrast of the photograph. This can help bring out some features that are hard to see otherwise.

To change the brightness or contrast of a photograph, make the photograph window active and choose "Enhance Image" from the Edit Menu (see *Enhance Image Pane*). Modify the values in the Brightness and Contrast Dialog.

Enhance Image Pane



This pane is made visible by clicking the Enhance Image tool on the View menu. As with other panes, the pane will be displayed in its most recent location within the PhotoModeler application window. The purpose of the pane is to make visual changes to a photograph so you can better do marking, or view certain features. It also allows you to make changes to the actual image on disk, which can be useful for photo texturing and cleaning up images for use with the automatic marking.

The currently active Photograph will be the one modified.

There are three controls:

- Contrast - adjusts the difference between the bright and dark. When the control is centered the difference is close to zero and the image will look a constant gray. When the control is to the left the image will go negative (which you will not use much but can be useful in some situations).
- Brightness - adjusts the overall intensity of the image by shifting all gray levels in one direction. When the control is to the left the image will be very dark and when it is to the right the image will be very bright (whitish even).
- Gamma - adjusts a non-linear function that is used to correct the inherent non-linearities in cameras and monitors. This is one of the more useful controls for making parts of the image visible that were hidden in shadows or overly bright areas.

These settings are saved with the pmr file so each time you open the photograph they will be displayed with the last settings. Note that the actual image data on disk is not changed, just how you view the image data. If you want to reset the view back to the default, or unmodified setting, click the Reset button.

The image enhancement happens dynamically as you adjust the slider controls. While this happens the model data (points, lines, etc.) are not drawn. This is to speed up the adjustment process. If you wish to see the model data, check the "Model" checkbox. The updates will be slower but you will be able to see the relationship between the model data display and the underlying image data.

You can also apply the settings directly to the image on disk by clicking the "Apply to Image" button. Applying the display enhancements to the image file will adjust the pixel data on disk. This can be useful for photo texturing (e.g. balancing multiple images for use across several photo textures), or for reducing 'noise' in images when Automatic Target Marking (e.g. images can be enhanced to increase the contrast of targets) because both of these methods access the disk image file directly.

Note: When applying the enhancements to an image on disk, the changes will affect the use of the image when texturing, creating ortho photos or use in other applications. A back-up of the original image is stored in the current image directory when you click "Apply to Image" so you can revert to the original image at any time. The "Restore Original" button becomes enabled when a back-up image is saved to disk. The back-up image file is stored in the same directory as the other images with ".bim" appended to the file name.

Photo Sets

A Photo Set is a collection of photographs in a PhotoModeler project.

Photo Sets are especially useful in projects with large numbers of photographs. Photo Sets are also used in photo-texturing (see *Materials Dialog*) and *Automatic Target Marking*.

Every project has three default Photo Sets: 'All', 'Oriented' and 'Unoriented'. The 'All' set contains all photographs in the project. The 'Oriented' set contains all photographs that are *oriented* and the 'Unoriented' set contains all photographs that are not oriented (and hence cannot be used for various operations).

A photograph can belong to any number of Photo Sets.

Outside of the three default sets, the user can create their own Photo Sets in a number of ways:

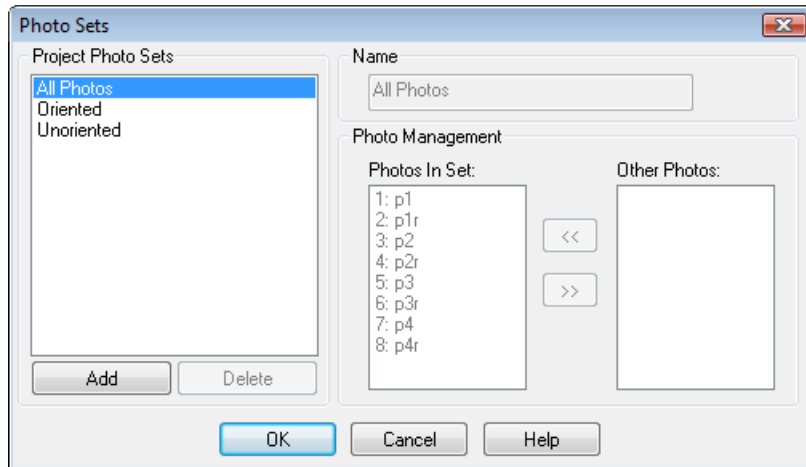
- By selecting one or more Photo Chips in the *Photo List Pane*, pressing the right mouse button and selecting the item "Create Photo Set From Selected Photos". The chips that are selected (have red borders) will be formed into a new set with the name "n:photos" where n is a sequence number starting at '1'.
- By selecting one or more Photo Chips in the *Photo Table*, pressing the right mouse button and selecting the item "Create Photo Set From Selected Photos". The photograph rows that are selected will be formed into a new set with the name "n:photos" where n is a sequence number starting at '1'.
- By selecting one or more objects in any view (3D View, Tables, Photograph), pressing the right mouse button and selecting the item "Create Photo Set From Photos Showing Selected". All photographs in the project are searched to see if they have a mark of one of the selected objects. If so that photograph is added to the set. This set has the name "n:selection" where n is a sequence number starting at '1'. Note, this is very similar to the

“Open Photos Showing Selected” operation but instead of opening all the photos, a Photo Set is created.

- By adding a new Photo set in the Edit Photo Sets Dialog.

The *Photo List Pane* can be set to show only those photos in a set. These are also set automatically when sets are created by the right click menus. This is helpful to reduce the project to manageable size when there are many photographs.

Edit Photo Sets Dialog



The Edit Photo Sets Dialog is used to create, delete and modify *Photo Sets*. It is opened from the *Photo List Pane*, or the File menu.

The dialog has a list of all Photo Sets currently in the project (including the three default sets). The three default sets cannot be modified or deleted.

To add a new Photo Set:

1. Press the Add button.
2. Select and modify the name of the set in the Name box.
3. Select the photographs to be in the set and press the << button. Photographs can be added one by one or in a group by using group selection.

To modify an existing Photo Set:

1. Select the Photo Set in the list.
2. Change the name if desired.
3. Select photographs in the right list to add to the set, or select photographs in the left list to remove from the set and use the << and >> buttons respectively.

To delete an existing Photo Set:

1. Select the Photo Set in the list.
2. Press the Delete button.

If you want to keep the changes you have made to the sets, press the OK button to exit the dialog.

Photos Missing Dialog



PhotoModeler stores the absolute path names of all image files imported into the Project PMR file. When the images are moved to a new directory, renamed, format changed (new extension), or deleted then PhotoModeler cannot find the images to display them or show the Project Photographs dialog.

Whenever you open the Project Photographs dialog or the 3D Viewer PhotoModeler checks to see if all the photo image files are still at the locations defined by the absolute paths (e.g. d:\Projects\Car 1\img1.tif). If it cannot find one or more images the dialog above appears.

You have three options:

1. Point PhotoModeler to the new directory where the images have been moved - select the first radio button, press OK and then find any one of the missing images in the new directory and press Open in the file dialog. If all the images are not found in the specified directory the file dialog will appear again so you can pick a second directory etc.
2. Point PhotoModeler to each renamed photograph image one by one - select the second radio button, press OK and then indicate each replacement file name as listed in the caption of the file dialog. If you click Cancel in the file dialog for an image file then it is just skipped and assumed permanently missing.
3. Tell PhotoModeler to ignore the missing files for now and continue with the current operation - select the third radio button and press OK.

When you indicate a photograph is no longer available, PhotoModeler uses a place-holder image-chip in the Project Photographs dialog so you can still select it and view its information.

Examples

Here are some examples of how this dialog functions and how you can use it to effect changes in the project.

You have a PMR but none of the images

You have a PMR on disk or a PMR someone sent you but you do not have any of the images used in the Project but you still want to study the project and view the 3D model. You open the PMR file in PhotoModeler and then bring up the 3D Viewer. The Photos Missing Dialog will appear. You pick option 3 "are no longer available" and press OK. The 3D Viewer will display normally with the only difference that any materials that are photo-textured or auto-colored will appear as a solid color only.

You want to switch a project from TIFF to JPEG images

You have a project that was done with TIFF images or some other non-compressed format. You now want to send that project and images to a colleague or to Eos technical support and want to switch to JPEG images. You create a new empty directory. You copy just the PMR into that directory. You then convert all your TIFF files to JPEG files keeping the same file names but using JPG file extension. You open the PMR in the next directory with PhotoModeler and open the Project Photographs dialog. When you get the Photos Missing Dialog you choose option 2 "have been renamed or format changed". A file dialog will appear asking for the replacement for the first image in the project. The image being replaced is listed on the file dialog title bar. You then choose the corresponding JPEG file and press OK. Repeat this for each image in the project. Save the PMR (perhaps with a new name so you can distinguish it). This new PMR now uses the JPEG files instead of the original TIFF files.

You want to move the images to a different directory from the PMR

You want to separate the images and PMR which are in one directory into separate directories. Create the new directory and move all your image files there. Open the PMR in PhotoModeler and open the Project Photographs Dialog. The Photos Missing dialog will appear. Choose the first option "all have been moved to a new directory". When the file dialog appears change to the new directory and select any one of the images files and press OK. If all the images are found in the new directory you are done. Save this PMR that now points to images in the new directory.

Building a 3D Model

This chapter describes how to build a 3D model in PhotoModeler. Before building the model, the user must create a project, and add photographs to it. See the sections *Creating a New Project*, and *Importing and Using Photographs*.

Building a 3D model is a three stage process:

1. Mark the locations of features on each photograph.
2. Possibly reference the points common to more than one photograph.
3. Process the information you have entered.

This chapter is broken down into the following sections:

- *The Objects That Make Up A Model* - Describes the various types of 3D objects that are used to make up a 3D model in PhotoModeler, the properties of each object type and how each object has its 3D position computed.
- *Marking* - Describes the basics of marking points, edges, curves, cylinders, silhouettes and fiducials on photographs.
- *Selection and Visibility* - Describes the basics of selecting objects so you can later manipulate them.
- *Referencing* - Describes the basics of referencing marks between photographs so they can become 3D.
- *Creating and Modifying Objects* - Describes, in more detail, the marking, referencing, and editing of specific types of objects. Builds on the Marking, Referencing and Selection sections.

The Objects That Make Up A Model

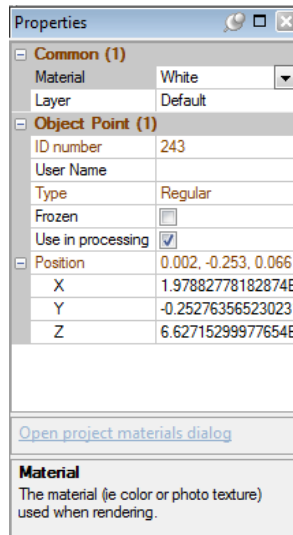
A 3D Model in PhotoModeler is composed of different types of objects. These objects are used to capture certain 3D characteristics of the real-world scene or item you are modeling.

These objects are: *2D Marked Points*, *3D Object Points*, *Lines*, *Curves*, *Silhouettes*, *Edges*, *Cylinders*, *Surfaces*, *Shapes*.

Properties of each these objects can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Tables* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected objects.

Properties of Selected Dialog

The Properties of Selected dialog shows various properties based on what is selected using a *Property Grid*.



The Common section will show the materials and layers common to selected objects. See *Materials and Layers* for more information on these types of properties. The number of items selected is shown in parentheses next to the headings (e.g. the “(4)” next to the Common heading indicates four objects have been selected in total and the properties shown apply to these 4 items). Information in the Common section applies to each of the selected objects. The sections below Common show the properties specific to that type of object. In the example above, one point is selected and its various property data are shown.

Information on the properties specific to certain object types can be found in the following sections: *2D Marked Points*, *3D Object Points*, *Shapes*, *Lines*, *Curves*, *Silhouettes*, *Edges*, *Cylinders*, *Surfaces*.

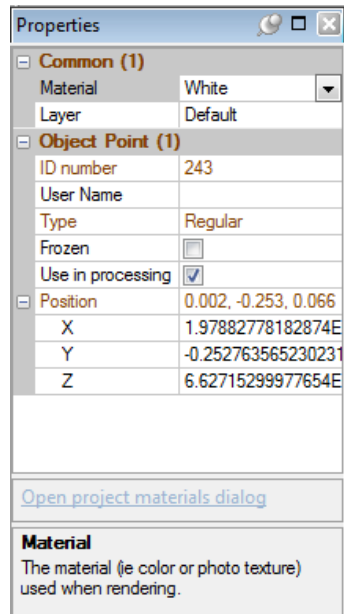
The Properties dialog shows the same information as the *Properties Pane* except the dialog version is accessed from the various menus (e.g. right click, edit menu etc), it appears in the centre of the application window, and the dialog is only up while properties are being edited. Once changes are made, the dialog must be closed by pressing OK before carrying on with other work. The Properties dialog allows you to cancel any changes by pressing Cancel button, whereas the Pane requires that you use Undo after a change is made.

Properties Pane

The Properties Pane is one of the panes that make up the *Panled Interface* in PhotoModeler. This pane shows the same information as the *Properties of Selected Dialog* (also in a *Property Grid*), only the pane version can be displayed at all times (if activated) while the dialog version is only up while using it. Changes made in the Properties Pane can be done using the Undo tool.

Property Grid

The *Properties Pane* and the *Properties of Selected Dialog* both display data using a Property Grid. A property grid is a hierarchical list of properties (many are editable) and is capable of displaying many different data types or sub-items consistently.



Property grids are comprised of data panels (i.e. a “Common” section and other object type sections depending on what is selected), a hyperlink panel, and a help panel.

- The data panel(s) contains the property data of selected items. The Common section contains the properties that are common to all selected objects, which generally are the Material and Layer properties. Below the common area are the properties specific to the objects selected, separated by headings for each type. The property fields will show data applicable to the selected item. If multiple items are selected and they share the same property, the field will show the common property. If multiple items are selected and they have differing properties, the field will show “varies”. Note that if you edit a “varies” field, the change will apply to all selected items.
- The hyperlink panel shows text that can be clicked that cause various actions (text is known as a hyperlink, and works similarly to web browsers). When certain property fields are clicked and selected, a hyperlink will appear in this area providing quick access to relevant areas of the application. For example, when the Material property is selected an “Open project materials dialog” hyperlink appears and when clicked the Materials Dialog is opened.
- The help panel shows a brief description of the selected property. For example, if the Material property is selected, the help panel shows “Material – The material (i.e. color or photo texture) used when rendering”.

The various components of the property grid can be expanded or contracted by clicking the small “+” (when contracted) or the “-” (when expanded) next to the panel heading. Double clicking the panel heading toggles the panel contracted or expanded.

Panels can also be sized. When placing the mouse cursor over the border of the panel, the cursor changes to a sizing cursor which enables you to click and drag the panel border.

The grid shows various data types:

- check boxes for true (checked) or false (unchecked) properties.
- text properties like names

- numerical, for value properties
- dropdowns for properties with a preset list of options.

Properties shown in red text can be edited in the grid. To edit a value, click on the property to select it, then click on the edit variable field hyperlink in the hyperlink panel. The field can then be edited as required. After a property is edited, the change takes effect once you select another property, hit enter on the keyboard or click on another window or pain. Hitting Esc on the keyboard while editing will cancel the change.

2D Marked Points

2D Marked Points are the point markings made on a photograph. Each 2D Marked Point has one associated Object Point (while each Object Point can have many associated 2D Marked Points, i.e. a marked point for each reference on a photo).

2D Marked Points get referenced to each other to provide PhotoModeler the light ray information it needs to solve the *3D Object Points*. See also *How Object Points become 3D*.

2D Marked Point Properties

A 2D Marked Point

Properties of 2D Marked Points can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *2D Point Table* and the *Status Bars*.

3D Object Points

Object Points are one of the most important items in PhotoModeler. Most projects will contain Object Points. An Object Point is a 3D location (X,Y,Z).

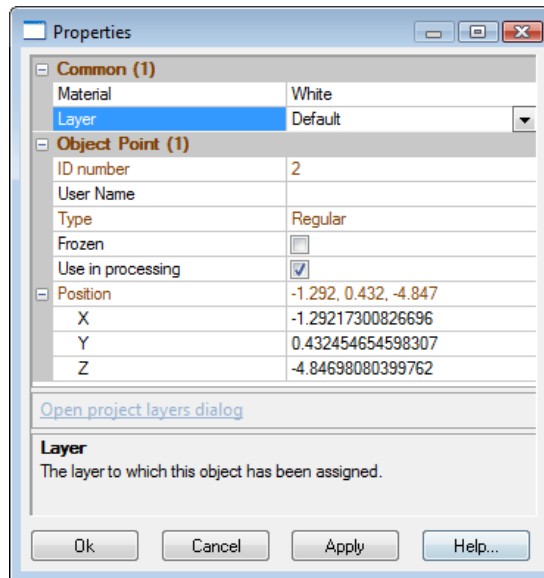
Object Points are central to camera station orientation and overall processing. The only type of project that may not have any Object Points is a single photo constrained project using Edges.

Object Points are created by placing Marked Points on Photographs. These Marked Points are then referenced together (in a multi-photo points-based project) to define the 3D location of the Object Point.

There are three classes of Object Point:

- Normal Object Point: created during marking. Referred to as "Object Point" and sometimes "3D Point" in the User Manual.
- Surface Draw Point: created during *Surface Drawing* for obtaining a 3D location in a single photograph by placing it on a 3D surface.
- Control Point: imported and marked through the *Imports Explorer*. A user defined XYZ location that aids in orientation, scaling, and improving accuracy.

Object Point Properties



The Object Point Properties Dialog can be accessed by selecting an Object Point (in Point Table or 3D Viewer), or a Marked Point (in a Photograph) and using the right-click menu item "Properties of Selected...". You can also use the Properties button on a Point Table. When opening the properties dialog for a point, the User Name field has focus by default which allows you start typing the name without first clicking on the name field.

The dialog will display information from one or more Object Points. If the information is the same for all selected points, then the information will appear in the dialog. If the information differs then the field in the dialog will be blank or will say "varies". Even if multiple points are selected a property value can still be modified. When the Apply or OK button is pressed, all the points will be changed to that value. The number in brackets shows how many objects have been selected.

An Object Point has these properties:

- a unique identifier number called an ID (which will indicate also if the point is a coded target) – you can renumber your points using the *Renumber Dialog*,
- a User Name (any text string the user desires, or blank) - user names appear on photos when Point ID Visibility is on, and user names are used in *Merging Projects*,
- an X,Y,Z position,
- an optional Offset Point which is a 3D point associated with the Object Point based on various parameters. Offset Points have sub-properties of Type, Offset Distance, Offset point material, Offset point layer and Offset Axis End Point, see *Offset Points* for more information.
- a "Do not process" flag - if set the Object Point will not be used in Orientation or Global Optimization (useful if the point is a guess) and the point will not be included in point audit totals,

- a "Frozen" flag - if set the Object Point's xyz position cannot be modified by any process. This also makes a normal Object Point act like a Control Point (useful for Inverse Camera),
- a Material, and
- a Layer.

In addition to the above properties there is an 'Uncode' button which when pressed will convert *Coded Target* points back into normal points without changing any of their marks or 3D positions. The button is disabled when no selected points are coded. The actual change to 'uncode' the point(s) happens on the OK or Apply button presses.

Properties of 3D Object Points can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Point Table* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected objects.

How Object Points become 3D

Object Points can have a 3D position computed in many different ways. They are probably the most complex and flexible in this regard.

How a point can get a valid 3D location:

- it is a Control Point: the user provides the xyz.
- it appears on two or more oriented photographs: it is computed by intersection math or by global optimization math.
- it is a surface draw point that is drawn on a surface that has known 3D position and the point is marked on an oriented photo: it is computed by the surface draw plane intersect math.
- it is attached to a surface that is constrained by one of the coordinate plane constraints (horizontal, vertical front, vertical side) where one or more other points in that surface have known xyz: it is computed using the known points and the coordinate plane information.
- it is part of a "surface is planar" constraint where three or more other points in that surface already have known xyz position: it is computed using the known points and a computed plane equation (from the plane's known points).
- it is attached to a line that is constrained by one of the coordinate axes constraints (vertical, horizontal front/back, horizontal left/right) where the point at the other end of the line has known xyz position: it is computed using the known point at other end and the coordinate axis information.
- it is PhotoModeler's chosen origin point in a single photo constrained project when there are no control points (this is usually the point that is part of the most coordinate plane or coordinate axes constraints): PhotoModeler sets it to be 0,0,0.
- an offset point can be associated with an object point and, as long as the object point has a valid 3D position and the offset parameters are properly defined, the offset point will appear as a 3D point on photos or in the 3D Viewer.

Note: the situations where a point will not have a 3D position are: a) it is not a control point, nor part of a constraint and it appears on fewer than two oriented photographs, or b) it is not a control point, nor part of a constraint, it appears on two or more oriented photographs but the maximum angle of its light rays is smaller than the Bad Angle Threshold (as shown in the Audit Page of the *Preferences* dialog – see *Preferences - Processing and Cameras*).

When you combine these you get a very powerful set of capabilities. Examples:

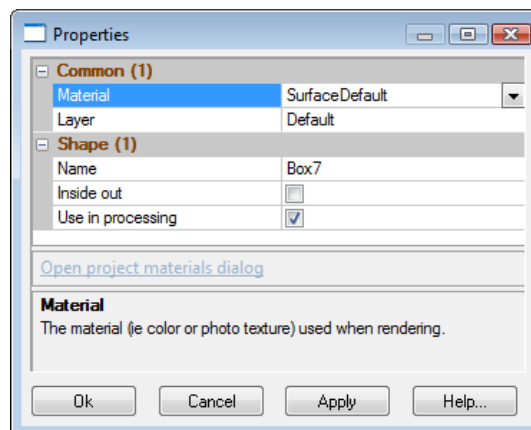
1. One photo, no control, lines and points with coordinate axes and plane constraints: All points attached to the chosen origin point with a constraint and all points attached to those points by a constraint will have computable xyz coordinates
2. One photo, one control point, lines and points with coordinate axes and plane constraints: All points attached to the control point with a constraint and all points attached to those points by a constraint will have computable xyz coordinates
3. One photo, some coordinate axes constraints plus a surface planar constraint: All points are computed similar to above and then for any coplanar constraint that contains three or more already computed points (i.e.. they define a plane that is not necessarily one of the coordinate planes (i.e. can be at an angle)) the remaining points in that constraint can be computed.
4. Two photos, referenced points, and some coordinate axes constraints: All points imaged on two or more photos are computed by orientation and global optimization and then all points on one photo but attached to the other points by constraints are also computed.
5. Two or more photos with no control points and no constraints: All points imaged on two or more photos are computed by orientation and global optimization.

For more information on Constraints see the section, *Working with Constraints*.

Shapes

Shapes are described fully in the *Shapes Modeling* section.

Shapes Properties



A Shape has these properties:

- a Material, and
- a Layer.

Properties of Shapes can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected objects.

How Shapes become 3D

Shapes get their 3D position by marking shape vertices and/or shape edges on key associated features in photographs.

Lines

Lines are connections between Object Points. They make up the "wire frame" of a model.

Lines are created between points and are not marked and referenced.

Line Properties

A Line has these properties:

- a Material, and
- a Layer.

Properties of lines can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Line Table* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected lines.

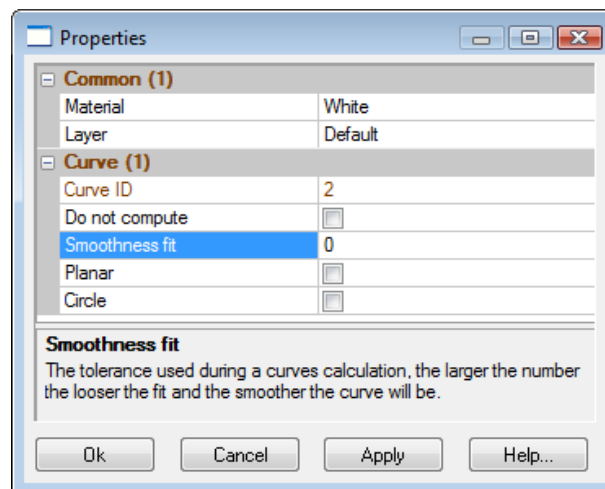
How Lines become 3D

Lines get their 3D position solely from the 3D positions of their end Object Points.

Curves

A Curve is a 3D Non-Uniform Rational Bezier Spline (NURBS). They are used to describe the edges of an object in the model when those edges are not straight.

Curve Properties



The Curve Properties Dialog can be accessed by selecting a Curve (in a 3D Viewer), or a Curve Mark (in a Photograph) and using the right-click menu item "Properties of Selected...".

The dialog will display information from one or more Curves. If the information is the same for all selected Curves, then the information will appear in the dialog. If the information differs then the field in the dialog will be blank or will say "varies". Even if multiple Curves are selected a property value can still be modified. When the Apply or OK button is pressed, all the Curves selected will be changed to that value. The number in brackets shows how many objects have been selected.

A Curve has these properties:

- a unique identifier number called an ID – you can renumber your curves using the *Renumber Dialog*,
- a type - an "open" curve has a distinct start and end point, a "closed" curve is periodic and has no start or end. A circle is an example "closed" curve,
- a "planar" flag - when set the curve is projected onto the best fit plane so as to make it perfectly flat,
- a "circle" flag - when set the curve is projected onto the best fit plane and then fit to a circle,
- a "Compute 3D shape" flag - when set the curve will be computed in 3D (if possible). Default is on. Uncheck this to stop a curve from having a 3D representation without getting rid of its marks, etc.
- a smoothness setting - a setting to define how smooth the curve is - used for filtering out bumps and blips caused by inaccuracies in marking, camera parameters, and station orientation. This setting is not required when the curve is a circle,
- a Material, and
- a Layer.

Properties of curves can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Tables* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected curves.

How Curves become 3D

Curves get their 3D position:

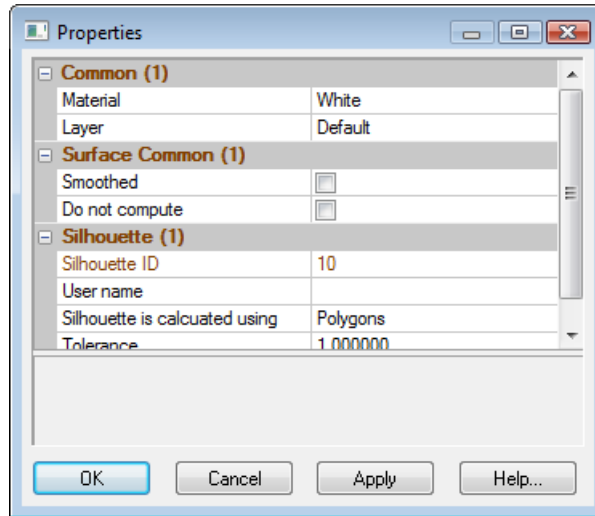
- from the curve projection algorithm when the curve is referenced on two or more oriented photos
 - fires when a curve has marks referenced/unreferenced
 - fires when a curve point is added/removed/moved in a curve mark
 - fires when one of the photos its mark appears on is oriented, reoriented or forced unoriented
 - fires when the user changes camera parameters or camera station parameters for that photo
 - fires after global optimization

Note that there are special requirements for photography to properly create curves. See the Quick Start Guide section Photography for Curves, Edges and Cylinders.

Silhouettes

Silhouettes are.

Silhouette Properties



A Silhouette has these properties:

- a Material, and
- a Layer.
- a “smoothed” flag – when set the silhouette surface will appear smooth shaded in the 3D Viewer (and some export formats),
- a “Compute 3D shape” flag – when set the silhouette will be computed in 3D (if possible). Default is on. Uncheck this to stop a silhouette from having a 3D representation without getting rid of its defining objects, etc.
- a unique identifier number called an ID
- a User Name (any text string the user desires, or blank)
- Calculation method – the silhouette can be solved using either Poly or NURBS format. Generally the Poly format will be more successful but you have the option to use the NURBS form, which is useful if you intend to export your project and the other application only supports NURBS surfaces.
- a Tolerance setting – the tolerance used during silhouette calculation, where a higher tolerance results in a smoother but more approximate surface, since the surface can use more ‘flexible’ defining silhouette marks. Increase this setting if your silhouette is ‘jaggy’ or ‘lumpy’ or is not solving well or at all.

Properties of Silhouettes can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Silhouette Table* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected silhouettes.

How Silhouettes become 3D

Silhouettes get their 3D position much like a curve:

- from the silhouette projection algorithm when the silhouette is referenced on two or more oriented photos

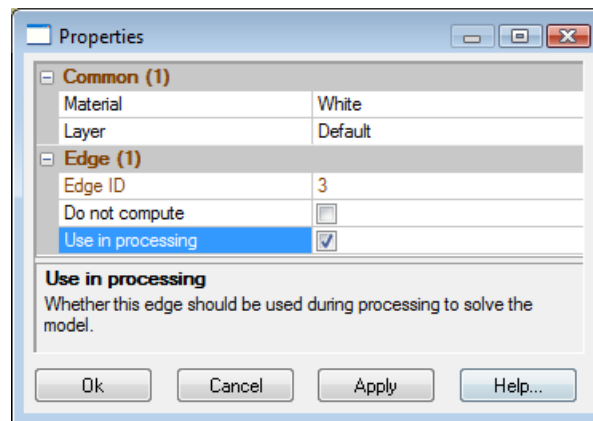
Edges

An Edge is a line segment between two 3D positions. The most important aspect of Edges is that when referenced their end points do not need to match across photographs. What is being marked and referenced is the edge or line on an object and not the end points of that line or edge.

An Edge is a "first-class" object like Object Points are. That means Edges are computed by Global Optimization and affect Global Optimization results. In PhotoModeler only Object Points and Edges are used in Global Optimization.

One typically uses Lines (which connect Object Points) when there are well defined points in the photo and which can be matched across photographs. When there is a "line" or "edge" in a photograph that does not share distinct end points with other photographs (or they are not visible in other photographs) then Edges are more appropriate.

Edge Properties



An Edge has these properties:

- a unique identifier number called an ID – you can renumber your edges using the *Renumber Dialog*,
- a "Compute 3D shape" flag - when set the edge will be computed in 3D (if possible). Default is on. Uncheck this to stop an edge from having a 3D representation without getting rid of its marks, etc.
- a "Do not process" flag - if set the Edge will not be used in Orientation or Global Optimization (useful if the edge is a guess or is not solving well) (it can still have a 3D position computed by intersection),
- a Material, and
- a Layer.

Properties can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Tables* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected objects.

How Edges become 3D

Edges are assigned 3D position:

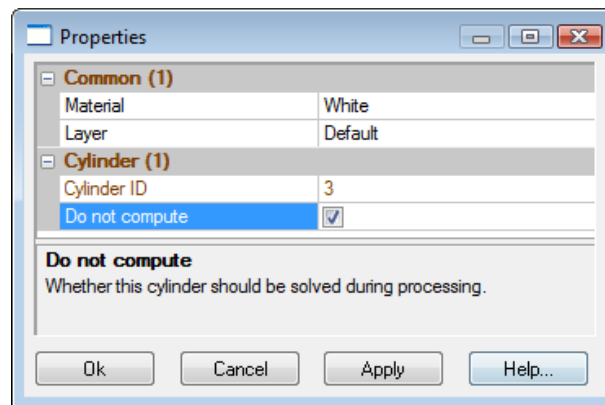
- during global optimization
- from intersection math when the edge is referenced on two or more oriented photos
- *fires when an edge has marks referenced/unreferenced*
- *fires when an edge point is moved*
- *fires when one of the photos its mark appears on is oriented, reoriented or forced unoriented*
- *fires when the user changes camera parameters or camera station parameters for that photo*
 - from constraints computation when the edge is used in one of the *Axes Constraints*

Note that there are special requirements for photography to properly create edges. See the Quick Start Guide section Photography for Curves, Edges, and Cylinders.

Cylinders

A Cylinder is a solid of revolution of a straight line of specified length and radius. It is used to model objects that are cylindrical and have the same radius along their whole length (e.g. pipes).

Cylinder Properties



A Cylinder has these properties:

- a unique identifier number called an ID – you can renumber your cylinders using the *Renumber Dialog*,
- a “Compute 3D shape” flag - when set the cylinder will be computed in 3D (if possible). Default is on. Uncheck this to stop a cylinder from having a 3D representation without getting rid of its marks, etc.
- a Material, and

- a Layer.

Cylinders do not have their own property sheet.

Properties of cylinders can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Tables* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected cylinders.

How Cylinders become 3D

Cylinders get 3D position:

- from the cylinder intersection algorithm when the cylinder is referenced on two or more oriented photos
- fires when a cylinder has marks referenced/unreferenced
- fires when a cylinder point is moved
- fires when one of the photos its mark appears on is oriented, reoriented or forced unoriented
- fires when the user changes camera parameters or camera station parameters for that photo
- fires after global optimization

Note that there are special requirements for photography to properly create cylinders. See the Quick Start Guide section Photography for Curves, Edges and Cylinders.

Extracting Cylinder Information

The information for cylinders is calculated on the fly immediately after a cylinder is referenced. The cylinder algorithm is computed when:

- cylinders are referenced,
- a cylinder mark is moved,
- a cylinder mark is deleted, and
- the project is reprocessed.

Note: Cylinders will not compute until the photos they appear on are oriented and processed.

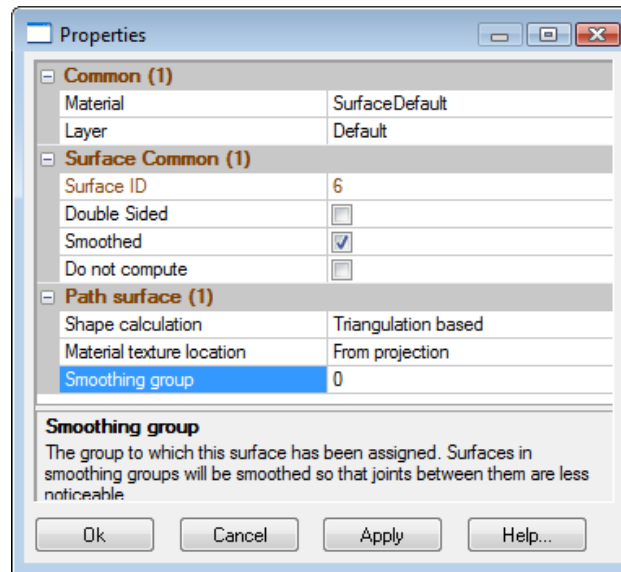
Since cylinders are computed on the fly one can get information on them right away. This information can be in the form of an export to a 3D CAD file, a DDE program inquiry, or by reading the information on the *Status Bars*.

Surfaces

A Surface is a an object that helps make the 3D model look "solid". Surfaces are applied Materials such a colors and photo-textures to make the model look more realistic and have trims and holes applied to help refine their shape. Surfaces are the only object in PhotoModeler that can be photo-textured.

Surfaces can be created as paths, triangles, lofts, sweeps, revolutions, silhouettes and Fit NURBS Surfaces. See the *Creating Surfaces* section for details.

Surface Properties



The Surface Properties Dialog can be accessed by selecting a Surface (in a Photograph , 3D Viewer or *Surface Table*) and using the “Properties of Selected” tool, the “Properties of Selected...” item on the Edit menu, or the right-click menu item “Properties of Selected...”.

The dialog will display information from one or more Surfaces. If the information is the same for all selected items, then the information will appear in the dialog. If the information differs then the field in the dialog will be blank or will be a shaded check box. Even if multiple Surfaces are selected a property value can still be modified. When the Apply or OK button is pressed, all the selected items will be changed to that value. The number in brackets shows how many objects have been selected..

All Surfaces have these properties:

- a unique identifier number called an ID – you can renumber your surfaces using the *Renumber Dialog*,
- a “smoothed” flag – when set the surface will appear smooth shaded in the 3D Viewer (and some export formats),
- a “Compute 3D shape” flag – when set the surface will be computed in 3D (if possible). Default is on. Uncheck this to stop a surface from having a 3D representation without getting rid of its defining objects, etc.
- a Material, and
- a Layer.

All surfaces except Silhouettes also have these properties

- a “double-sided” flag – when set the Surface will be visible from both sides in the 3D Viewer (and in some export formats),
- Four extend percentages (displayed in the Extend property), and
- Trim/hole settings (displayed in the Trim & holes property).

Path & Triangle:

- a “shape calculation” setting – when set to “Triangulation based” the Surface will be calculated using planar triangulation, when set to “NURBS based” the Surface will calculate as a NURBS Surface.
- A “smoothing group” – an integer value between 0 and 255 the defines which group this path surface belongs too. All path surfaces (which includes triangles (which are 3 sided paths)) in the same smoothing group and share an edge are smooth shaded in the 3d Viewer. Some export formats (notably 3DS and OBJ) also support smoothing groups. A smoothing group of 0 means this surface belongs to no group and hence is not smoothed against any other surface.
- Path Surface’s can optionally acquire their textures based on the mark’s position in a photo as opposed to the projected position. The “Material texture location” buttons on the Path Surface Properties section controls this. Using the mark’s location allows you to ‘tweak’ some cases where the projected location does not match the image exactly. (E.g. bits of sky mapping to the peak of a roof). This setting only applies to path surfaces defined by marked points and not to path surfaces defined by curves or edges.

Lofts:

- a “closed” flag – when set the Surface will start and end at the same object.

Revolutions:

- a “Degrees of Revolution” setting. Controls how far around the axis of revolution the surface should go.

Silhouettes:

- a “silhouette calculated using” setting – when set to “Polygons” the Surface will be calculated using polygons, when set to “NURBS” the Surface will calculate using NURBS. The NURBS form is slower but more accurate.
- silhouettes have a tolerance setting which controls the silhouette surface intersection algorithm. Increasing the tolerance results in a simpler but more robust silhouette surface.
- silhouettes have an optional user name.

Fit NURBS Surface to selected points:

- Max Spans U and V – Controls how well the surface fits to a set of points.

Properties of surfaces can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *Surface Table* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected surfaces.

How Surfaces become 3D

Surfaces get their 3D position solely from the 3D positions of their defining objects. So if one of the objects (a point, line, curve or edge) is not 3D, the Surface will not include that object in its 3D shape calculation. When the number of objects, with valid 3D shape, fall below the minimum needed to define a particular surface type then that surface will no longer be 3D (no display in the 3D Viewer or projections and will not export but will show up in the Surface Table still).

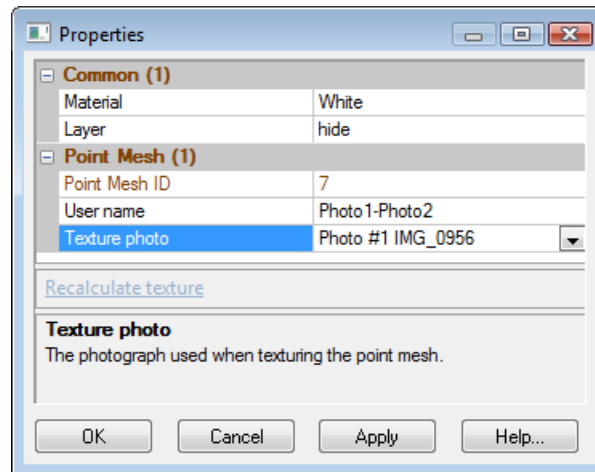
PointMeshes

A PointMesh is an object created using DSM (Dense Surface Modeling) tools that is made up of a large number of points that generate a point cloud for a textured surface and

optionally triangulated using various meshing stages. For detailed information on the DSM process, see *Dense Surface Modeling / PhotoModeler Scanner*.

As part of the PointMesh creation process, DSM Trims are used to define the extents of the point mesh. Please see *DSM Trims*.

PointMesh Properties



The PointMesh Properties can be accessed by selecting a PointMesh (in a 3D Viewer or *PointMesh Table*) and using the “Properties of Selected” tool, the “Properties of Selected...” item on the Edit menu, or the right-click menu item “Properties of Selected...”.

The dialog will display information from one or more point meshes. If the information is the same for all selected items, then the information will appear in the dialog. If the information differs then the field in the dialog will be blank or will be a shaded check box. Even if multiple PointMeshes are selected a property value can still be modified. When the Apply or OK button is pressed, all the selected items will be changed to that value. The number in brackets shows how many objects have been selected..

All PointMeshes have these properties:

- a Material, and
- a Layer.
- a unique identifier number called a PointMesh ID,
- a User name which is automatically generated depending on how it was generated (but can be edited),
- Texture photo from which the pointmesh extracts color information to generate a mapped photo texture (applies to the point cloud points and triangles). When this setting is selected, the Recalculate Texture verb appears which allows you to remap the color data from the selected photo onto the point mesh.

Properties of surfaces can be viewed using several features in the PhotoModeler user interface, including the *Properties of Selected Dialog*, *Properties Pane*, *PointMesh Table* and the *Status Bars*. Also note that the *Measurements Pane* shows various data about one or more selected point meshes or points within the point mesh.

How PointMeshes become 3D

PointMeshes are created using the DSM tools typically from stereo photo pairs. For information on creating DSM/point meshes, please refer to *Dense Surface Modeling / PhotoModeler Scanner*.

Materials and Layers

All 3D Points, Shapes, Lines, Curves, Silhouettes, Edges, Cylinders, Surfaces, PointMeshes and Surface Drawing have a Material and a Layer. The Material is used to assign color and texture for export and 3D Viewer display and the Layer name for grouping the objects logically.

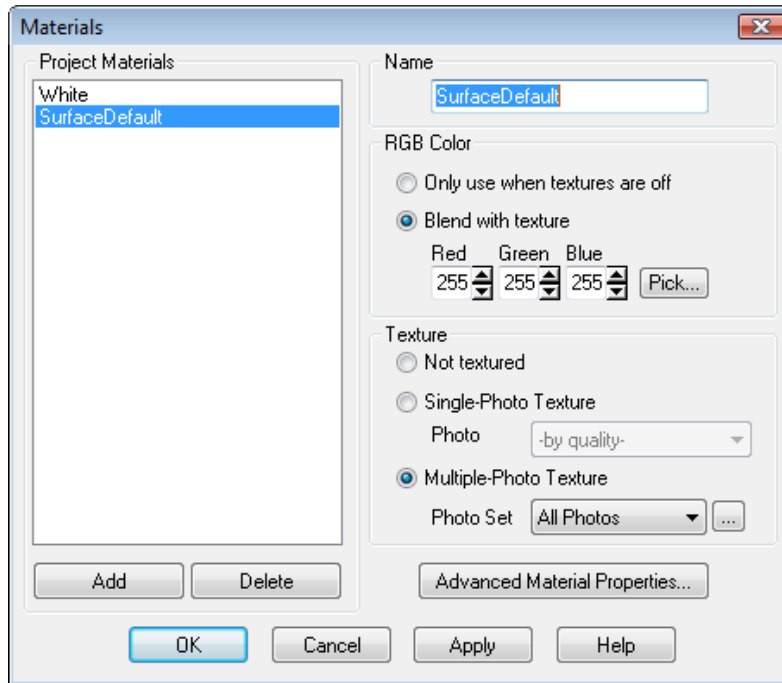
Material/Layer Properties

When *Properties of Selected dialog* (or *Properties Pane*) is shown there will be a Common section that contains the Material and Layer properties. These fields show the name of the Material and the name of the Layer assigned to the currently selected objects.

If all selected objects have the same Material then the Material's name will be shown in the top list box. If there are two or more selected objects and they have different Materials then the list box will be blank. Similarly for the Layer name.

All the currently selected objects can have their Material or Layer changed here by selected a new choice from the drop down lists. Alternately when a Material property is selected, a hyperlink appears in the area below the grid, and when clicked they provide quick access to the *Materials Dialog* (when the material property is selected) or Layers Dialog (when the layer property is selected).

Materials Dialog



The Materials Dialog is used to create, delete and modify Materials. A Material is an attribute of a surface that describes how it will be rendered.

This dialog is accessed through the Material Toolbar button, via the “Materials...” menu item in the Edit menu, or from the “Open project materials dialog” hyperlink on the Properties pane. See also *Current Material Tool*.

All projects have a material called “White” which cannot be modified or deleted. It is a non-textured diffuse white material.

Most projects will have a material called “SurfaceDefault”. This is added to every new project and assigned to all newly created Surfaces as long as the default material for all new objects is White or SurfaceDefault. SurfaceDefault is set up as a multi-photo textured material but can be changed or deleted.

To add a new material, press the Add button. A new material with a default name will be added. You can change this name by typing in the Name edit box.

To delete a material, select it in the project materials list and press the Delete button. Note when you delete a material, and only if dialog is exited with OK, any objects that have this material assigned will be set back to the Default material.

To modify a material, select it in the list of project materials, its name will appear in the Name edit box. Then adjust any of the attributes found on the right of the dialog.

Note: If the Material is an existing one you might find the “Apply” button on this dialog useful. You can have the 3D Viewer open and be in this dialog and apply changes and see the results immediately – all without closing and reopening the dialog.

Material Attributes

A Material in PhotoModeler defines how the surface interacts with light. Textbooks on computer graphics go into much greater detail on these standard settings but we will give a brief introduction here.

The ambient portion of a material describes what the surface looks like under ambient illumination only (that is the light not coming directly from light sources). The area of an object away from a light or in shadow is typically lit only by the ambient light. In PhotoModeler there is no setting for ambient light. When a material is exported the ambient portion is set to a 33% grey level (a standard value in computer graphics).

The diffuse portion of a material describes what the material looks like when lit by a directional light. This is the properties that we most readily associate with an object's perceived color. This will be the most important setting for a material.

The specular portion of a material describes what the material looks like in the areas of highlights or specular reflections. This is the area where a directional light bounces directly to the viewer's location. We most readily identify specular areas by bright white spots on an object. The size and strength of the specular reflection area is controlled by the shininess of the material. You will need to change the shininess setting to get the specular effect to show up (esp. in the 3D Viewer).

The emissive portion of a material describes how a surface emits light. For example, a lit sign or a light bulb have surfaces that emit light. This portion is not affected by lights in the scene.

The shininess of a material describes how smooth the surface is. We associate small strong highlight area with very shiny materials and large weak highlight areas (or no highlights at all) with dull materials.

The diffuse setting is controlled from this dialog and the others from the *Advanced Materials Dialog*.

Diffuse Color From

The "Diffuse Color From" setting in a PhotoModeler material defines where the diffuse portion of the material comes from. If set to "RGB setting below" then the diffuse color of the surface is set to the red, green and blue values from the Diffuse spin controls. If set to "Single-Photo Texture" or "Multiple-Photo Texture", the diffuse color for the surface is set to the Diffuse RGB setting modulated by a texture derived directly from the photographic data under a Surface. For this reason, only Surfaces can have a "photo-texture" diffuse setting. Note, if another object type (such as a point or a line) is set to photo-texture it will be overridden by PhotoModeler and changed back to "diffuse from rgb setting only". See the sections below for a description on how photo materials are derived.

Diffuse RGB

These three spin controls define the diffuse color of the material. Setting all three controls to 0 would give a black color and setting all three to 255 would give a white color. The RGB values can also be set using the Windows Color palette control by pressing the Pick button beside the controls.

Single-Photo Drop-down List

This drop-down list controls from which photograph the diffuse texture is derived from. Surfaces typically appear on multiple photographs and so there is a question of which photo should be used to photo-texture that element. The default setting for this control is “by quality-” and this means that the photograph on which this Surface appears with the highest quality setting (see *Photo Properties*) will be used for texture extraction. This is typically the easiest setting to use and provides most of the flexibility to get the desired result.

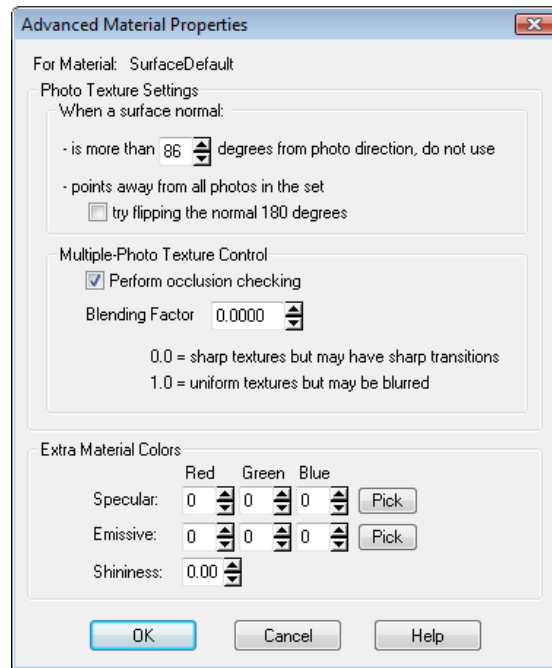
In some cases you will want to specify a specific photograph for a particular Surface or set of Surfaces. This is accomplished by defining a photo-texture Material with the Photo list set to the number of the desired photograph. Using this manual override gives you the flexibility when the “by quality” setting will not give the required results.

Multiple-Photo Photo Set List

There are a number of cases where a complex shaped surface cannot be adequately textured from one photograph. By choosing the multiple-photo setting you can apply more than one photograph to a surface. PhotoModeler decides which photograph will be applied to which part of the photograph based on the angle of the surface relative to the photo and the distance. See the *Advanced Materials Dialog* for more information.

The photographs to be applied to the surface are defined by a Photo Set. For example, if the “All” Photo Set is chosen then any photograph in the project can be used for photo-texturing that surface (it does not mean that all photographs will be used just that any one or more of the set can be used). The Photo Set is then used to restrict the photographs you may not wish to have texture a particular surface. For example, if photo 5 is of poor quality, you can create a Photo Set with photo 5 missing and then use that set in this drop down list.

Advanced Materials Dialog



The Advanced Materials Dialog is opened from the *Materials Dialog*. The dialog has two main sections: the Photo Texture Settings section and the Extra Material Colors section both of which are described below.

Photo Texture Settings

The first texture setting controls when a photograph is valid as a source of texture for a particular part of a surface. These values apply when the Texture setting in the *Materials Dialog* is set to Multiple-Photo Texture.

A surface normal angle setting of 80 degrees says this, “if a part of a surface has a normal (the perpendicular direction away from the surface) that subtends an angle with the light ray from the photo to that part of the surface that is 80 degrees or less, then that photo is a valid source of texture for that part of the surface”. So for example if you had two surfaces in the model and one pointed towards photo 1 (an angle of 20 degrees let’s say) and the other was at a very sharp angle to photo 1 (an angle of 90 degrees (so the photo 1 camera is seeing the surface edge-on)) then photo 1 will be used as a source of texture for the first surface but not the second.

If a surface does not face any photo within this angle tolerance then it will get no textures. If a surface faces more than one photo within this tolerance then the photo textures will be blended based on the Multiple-Photo Texture Blending Factor control.

The setting “When a surface normal points away from all photos in the set _ try flipping the normal 180 degrees” controls what to do when there is no appropriate photographic data to texture a surface or part of a surface. This would happen when no photographs were taken at a suitable angle to that part of the model. If no texture is available then the surface

normal is rotated 180 degrees and the photos are checked again as possible sources of texture. This can produce some strange results but in some cases with symmetric objects and simple textures the result can look better than no textures.

Multiple-Photo Texture Control

The Multiple-Photo Texture Control section has two controls.

The 'Perform occlusion checking' check box determines if the texture algorithm during quality texture creation determines if another surface is between the surface being textured and the source photo under consideration. If there is a surface that obscures this part of the surface then that photo will not be used for texturing. The remaining photos that are valid source material for this part of the surface will be used instead. If there are no remaining valid photos for this part of the surface, then the surface will get the non-texture pixel color (see *Preferences - Exports and Output*).

The 'Multiple-Photo Texture Blending Factor' controls how multiple photographs are blended when a part of a surface has more than one valid source photo for texturing. This factor is based on the angle between the surface and the particular photos. When the blending factor is zero, every part of the surface will get pixel data from only one of the valid photos. The photo chosen is the one which would have the largest projected pixel (see note below). When the factor is non-zero then the photo with the smallest angle is chosen up to a threshold and then that photo is blended with other photos of similar angles. Once the factor is close to 1.0 all the valid photos will be blended together based on their angle. This gives smooth transitions between photos (photos can switch on a surface) but can cause more blurring if the photo data does not line up.

Note: what is the largest projected photo pixel on a surface? Imagine that a pixel on a photograph covers a small rectangle area - small but still a definite area. Imagine now four light rays that go from the center of the camera station position through the four corners of this pixel and out into space. When these four light rays hit a surface at a distance from the camera they will form an area (much larger than the original pixel if the camera and surface are typically separated). This is the projected area of the pixel. Two things affect this area - the distance of the camera from the surface and the angle of the surface to the camera. A good pixel for texturing is close to rectangular when projected and large. Poor pixels are small or with extreme skewed shape due to perspective.

Extra Material Colors

The Extra Material Colors section controls some material properties for rendering.

Specular RGB

These three spin controls define the specular color of the material. Setting all three controls to 0 would give a black color and setting all three to 255 would give a white color. The RGB values can also be set using the Windows Color palette control by pressing the Pick button beside the controls. See the *Material Attributes* section for more information.

Emissive RGB

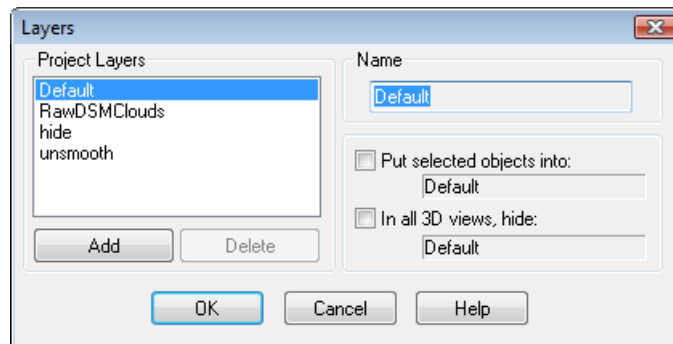
These three spin controls define the emissive color of the material. Setting all three controls to 0 would give a black color and setting all three to 255 would give a white color.

The RGB values can also be set using the Windows Color palette control by pressing the Pick button beside the controls. See the *Material Attributes* section for more information.

Shininess

This spin control varies between 0 and 1 and defines the strength of the specular highlight region. A setting of 0 is a perfectly dull material and a setting of 1 is a very shiny material. This setting is used by the 3D viewer and the exporters as scale for a factor that is used as a power in the lighting equations. The factor can be varied for each type of exporter with a setting in the ini file (see *Application Data and File Locations* for information on where the ini file is stored on disk). See the *Material Attributes* section for more information.

Layer Dialog



The Layer Dialog is used to create, delete and modify Layers. A Layer is grouping of a set of objects in a project. These groupings are used to sub-divide the objects in a project into logical entities (for example, "frontDoor", "backWall", "Roof" might all be layer names for a house project). These Layers can be used to control what is displayed on Photographs and in the 3D Viewer. They are also useful during export of your project data to external graphic packages. In 3D Studios they are called "Objects", in Wavefront they are called "Groups", in DXF they are called "Layers", in VRML they are set up as DEFed Separator or Transform nodes, and in IGES as "Levels".

This dialog is accessed from the "Layers..." button on the Layer toolbar, and the "Open project layers dialog" hyperlink on the *Properties Pane* (or dialog box). See also *Current Layer Tool*.

All projects have a Layer called "Default" which cannot be modified or deleted. Unless otherwise set all objects get placed in the Default layer.

To add a new Layer, press the Add button. A new Layer with a default name will be added. You can change this name by typing in the Name edit box.

To delete a Layer, select it in the project layer list and press the Delete button. Note when you delete a Layer, and only if dialog is exited with OK, any objects that are assigned to this Layer will be placed back in the Default Layer.

To modify a Layer, select it in the list of project layers, and its name will appear in the Name edit box. In this dialog all you can change is its name.

The two checkboxes on the dialog allow you to perform actions based on the selected layer:

- “Put selected objects into” – If any items (points, lines, curves etc.) are selected while this dialog is up, you can assign the selected items to the currently selected layer. The selected layer will be shown in the text box below the checkbox. The layer assignment happens when you press OK.
- “In all 3D views hide” – When you have one or more 3D views open, you can hide the selected layer on all open 3D views. The layers are hidden in 3D views when you press OK.

Marking Points-based

Marking is the process of creating and positioning an object on a photograph. Points, edges, curves, cylinders, silhouettes, fiducials and shapes are items marked on photographs.

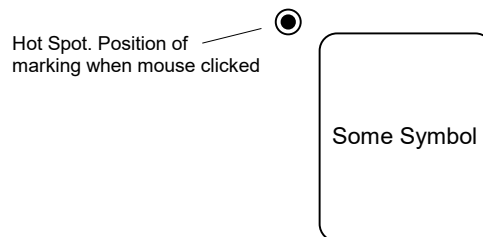
Once points, edges and curves are created you can add lines and surfaces between them. Lines and surfaces can be created in photographs, 3D viewers or in the Point Table.

Note: We strongly recommend that when starting a project, that only a few points and few photographs be marked. Once you have perhaps 10 to 15 points marked and referenced on three or four of your photographs, do the 3D processing. When you have confidence in that result, add new markings and new photographs in stages, doing 3D processing in between. Carrying out PhotoModeler projects this way minimizes the chances that you will make an error that is difficult to find or fix.

If you have *automatic processing* turned on, the model may solve while you mark points. Keep an eye on the *Alert Poppers* that appear in the bottom right of the application window for information on the status of your project as it processes, especially if a message appears about high residual points.

All marking is done by putting PhotoModeler into a particular mode, and then using the mouse, position the cursor over the location you wish to mark. You click the left button of the mouse to place the mark.

When in these modes, PhotoModeler changes the cursor so that you will know what mode you are in and so you have a precise location to mark. The cursors are large enough to see without straining and yet they also have a small dot for precise point positioning. All the cursors have the following form:



Marking Cursors

When you are marking a feature such as a line end point, you place the small dot of the cursor over the feature of interest in the photograph and click the mouse button.

You can also use the arrow keys on the keyboard for fine marked point adjustment. Select the mark with your mouse then use the arrow keys to adjust the position on the photo. This works when a single point (marked point, curve point, cylinder point, shape vertex, etc.) is selected on a photo.

Generic Marking

To Mark Objects on Photos:

1. Open the photograph you need by double clicking on the photo chip in the *Photo List*.
2. Pick up the desired tool (point, edge, curve, etc.) from the toolbar or select the appropriate mode from the Marking menu.
3. As the mouse is moved over a photo, the cursor will change to show the mode you are in. Also, while in a marking mode, the cursor will change if you move over an existing photo mark. For example if you are in point marking mode and you move the cursor over an existing point mark, the cursor changes to indicate that a point cannot be re-marked at that location; as you move off the existing point the cursor changes to indicate that a point can be marked. These 'context sensitive' cursors apply in each marking mode and provide useful feedback about the current mode and what to expect when pressing the mouse button.
4. Click the mouse in the desired location in the photo to start the object. A point requires one click, an edge requires two (a click at each endpoint), a cylinder four, and curves, silhouettes, and shapes require a variable number of clicks.
5. For specifics on marking edges, cylinders, curves, silhouettes and shapes see the sections below.
6. Once one object is complete you will remain in that mode so the next object of the same type can be created in the same fashion.

Hint: To increase the precision of your marking you may want to use any one of the zoom and pan tools discussed elsewhere in the manual. For best precision you will want the photograph zoomed to at least the 1:1 or 2:1 level.

See also *Coded Targets*, *Sub-pixel Target Marking*, *Marking Points*.

Marking Targets

If you are using targets (RAD targets, coded targets, dots, or templates), you can use the sub-pixel target marker to quickly and accurately find the center of the target. Accurate marking like this ensures that the exact center of the target is found and marked in each photo.

With the sub-pixel target marking tool, drag a region around the entire target (around the outer ring for RAD or coded targets, or the dot for non-coded targets). When you release the mouse the centre of the target will be marked very accurately.

See also *Targets - Do's and Don't's*, *Coded Targets*, *Sub-pixel Target Marking*, *Marking Points*, *Automatic Target Marking*.

Marking Fiducials

If you are using a film camera with PhotoModeler, you may need to mark fiducial points on each photograph. These "fiducials" are reference-frame marks that tells PhotoModeler where the film was in the camera at the time of exposure. Digital and video camera images do not need fiducials. If you do not plan on using a film camera, you can skip this section.

To Mark Fiducial Points:

1. Select "Fiducials List" from the Marking menu (this tool is enabled only when Fiducials exist in your camera, based on the camera set up during project creation).
2. The Fiducials List pane will appear.
3. Choose the name of the Fiducial you wish to mark on the Photograph from the list on the Fiducials List pane. Fiducials that have not been marked will be enabled in the list.
4. Click the mouse in the center of the fiducial imaged on the Photograph. Zoom in on the fiducial first if you need higher precision.

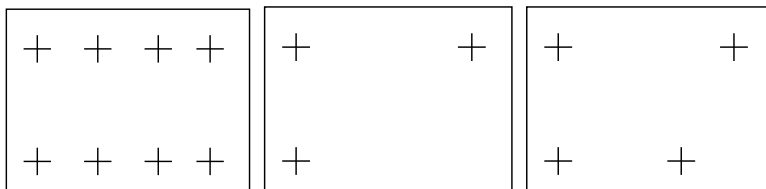
Hint: It is important to mark each fiducial as precisely as possible. Zoom the photograph in and be as careful as possible when marking fiducials.

Fiducial points can be moved and deleted the same way that Marked points can. You cannot, however, use them as end points in lines or surfaces, or reference them to other points.

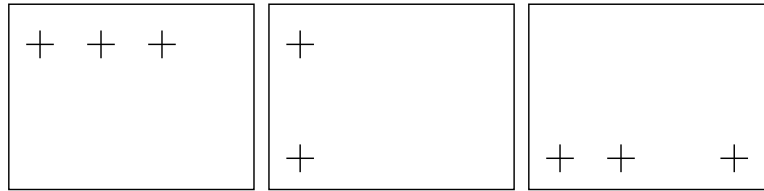
On some photographs it may not be possible to see each fiducial mark. This may be the case if the fiducial mark was positioned over a dark object in the scene you photographed. If this is the case, mark only the fiducials you can see. You must mark both fiducials if you are using a two fiducial camera (such as the Eos Film Plane Insert) or at least three if you are using a camera with three or more defined. Sometimes using Image enhancement can reveal the fiducial on the photo (see *Enhance Image Pane*).

The requirement for sufficient fiducials depends on the type of camera. If the Camera being used has only two fiducials (i.e. Eos Film Plane Insert) then both fiducials have to be marked on every photograph. If the Camera being used has three or more fiducials then a minimum of three fiducials must be marked on each photograph. These three fiducials must also cover more than 1/3rd the image in both height and width to be sufficient.

For example the following marked fiducial configurations are good for an eight fiducial camera:

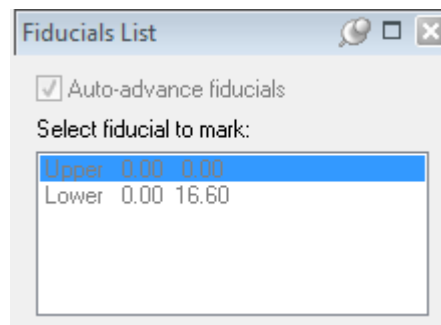


but these are not:



Fiducials List Pane

When Fiducial Marking mode is entered, the Fiducial List Pane appears:



The list contains each fiducial defined in the camera associated with the current photograph. The check box above this list is the Auto-advance button.

When the mouse cursor is in the Photograph Window the cursor will change to the Fiducial Marking Cursor. To mark a particular Fiducial, use the list in the pane to choose the required fiducial and then click on the Photograph at the location where this Fiducial appears. The photograph window must be activated first before the first mark can be placed. Always make sure to look at the list to see which is the current selected fiducial to be marked.

You should zoom up the Photograph to mark the Fiducial to get as much marking precision as possible. When you select any of the zoom modes you will automatically exit Fiducial Marking Mode and the Fiducial List pane will disappear. To get back to marking the Fiducial, reenter Fiducial Marking Mode by using the menu item.

If the "Auto-advance" check box is checked, as each Fiducial is marked, the list will automatically advance to the next unmarked Fiducial on this Photograph. If you activate another Photograph while in Fiducial Marking Mode and when Auto-advance is set, the list will enable the first unmarked Fiducial on this Photograph and will be disabled if none are to be marked.

During marking you can also skip over a fiducial and advance the list to the next available fiducial by clicking the right-mouse button to bring up the menu and then choose "Next Fiducial"..

To leave Fiducial Marking Mode select any other application mode (such as Select, Point Mark, Zoom etc.).

Selection and Visibility

Selection Overview

Many operations in PhotoModeler work on "selected" items. You select these items and then perform the operation on the selection set. Move, delete, scale, rotate and measure are some of the operations that work with selected items.

Items can be selected in Photograph windows, Table windows, 3D Viewer windows, and the Shapes and Imports Explorer windows.

Mouse selection

To select an item with the mouse, move the cursor to the item in a window; the mouse cursor will change to indicate the type of object over which the cursor is positioned, which helps identify what is about to be selected. Click the left mouse button without changing the mouse position. Once an item is selected, its color or highlight will change.

If you want to move the item in a Photograph, do not release the mouse button - simply drag the item to its new location by moving the mouse and then releasing the mouse button. Items cannot be moved in Tables or 3D Views.

Multiple selection

To select more than one item with the mouse, hold down the shift key while making the second and subsequent selections with the mouse.

To clear the selection of one item in a set of multiply selected items hold down the shift key and select it again.

To clear the selection of all selected items in a window, click the mouse in the window anywhere but on top of a selectable item (without holding the shift key down).

Multiple-select in Tables follows the Windows standard of shift-click is an extend select (all objects between first selected item and clicked on item are selected) and ctrl-click is a specific extend select (the item clicked on it added to the list of items selected).

Box selection

To select all items in a rectangular region on a photograph, press the left mouse button while the arrow cursor is over a region where there are no selectable items, then drag the mouse while holding the mouse button down. A rectangular region is swept out by the starting location and current location of the mouse and is displayed on the screen by a box. When the mouse button is released, all items within the region are "selected". Lines and Surfaces must be completely within the rectangular region to be selected. Multiple select also works with box selection in that you can add to any current selection by holding the shift key while doing a single, multiple or box select.

Region selection

To select all items in a polygonal region on a photograph or in the 3D Viewer, use the *Region Select (Temporary)* mode (Edit menu or "D" short-cut key). When in this mode click the left mouse button anywhere in the photograph to begin. Then move the mouse to the next vertex of the polygonal area and click again. You will see a "rubber-band" line to

guide you. Repeat this to surround the objects to be selected. Click within ten pixels of the starting point, or double click anywhere in the photo and the region will close and the objects will be selected. Hitting the ESC key during the region definition will cancel it. This mode is a 'temporary' one in the previous mode is activated as soon as the region is closed. This mode also works in the 3D Viewer.

Lines and Surfaces must be completely within the polygonal region to be selected. Multiple select also works with region selection in that you can add to any current selection by holding the shift key while drawing a new region.

Menu selection

Global Selections can be done by using either the Edit Menu or the right-click menus.

Choosing "Select All Marks/Objects in Active View" in the Edit menu or from the right click menu (when cursor is in a photograph, 3D Viewer or table), will select all visible objects in the view (photographs, table, and 3D view) that is currently active in the workspace. When chosen it will select all visible objects in the view where the menu was activated.

These select-all capabilities are quite useful when married with appropriate use of the *Visibility Settings*.

Universal Selection

Universal Selection is a powerful set of tools for selecting and comparing objects in all the three main views of a project (Photographs, 3D Views, and Tables).

You can select, by using the mouse, points, edges, curves, lines, surfaces and cylinders in photographs and in the 3D Viewer. In the Point Table you can select only Object Points.

An important notion to understand when dealing with Universal Selection is the difference between an Object and a Mark. A Mark is something that appears on a photograph only and must be referenced between photographs. The types of Marks in PhotoModeler are the Marked Point, the Edge Mark, the Curve Mark, the Cylinder Mark, the Silhouette Mark, and the Shape mark. An Object is something that exists globally to all photographs. The Objects in PhotoModeler are Object Point, Edge, Curve, Cylinder, Line, Silhouette, Surface and Shape.

Every Mark is associated with one Object (for instance every Marked Point on a photograph has one underlying 3D Object Point). Some Objects are not associated with Marks (Lines and Surfaces) and appear on all photographs and some Objects are associated with multiple Marks (Object Point, Edge, Curve, Silhouette, Cylinder, Shape).

Photographs display these Marks: Marked Point, Edge Mark, Curve Mark, Silhouette Mark, Cylinder Mark, Shape Mark and these Objects: Line and Surface (3D projections). All of these can be selected.

3D Viewer windows display these Objects: Object Point, Edge, Curve, Cylinder, Line, Silhouette, Surface, Shape. All of these can be selected.

Point Table windows display Object Points only. Object Points can be selected. Point Mark Table windows display Marked Point (also indicate their associated Object Point).

A special menu item in the Edit menu works with Universal Selection to move selections around. It is called "Expand Selection to all windows". When you select Marks in photographs, this menu item moves the selection to all marks associated with the same underlying Object on all open photos and the Object in the 3D Viewer and Table. When

you select Object Points in the 3D Viewer or Point Table this menu item will select all associated Marked Points on all open photographs. The same applies to edges, cylinders, curves, and silhouettes.

For example, if you have a Photograph, 3D Viewer, and a Point Table open and you select one Marked Point in the photo and then choose "Expand Selection to all windows", the associated 3D Point/Object Point will be selected and will appear red in the 3D Viewer and outlined in the Point Table.

Another example: if you have a Photograph and a 3D Viewer open and you select one Cylinder in the 3D Viewer and then choose this menu item, the associated Cylinder Mark will be selected in the Photograph (if the cylinder appears on this photo).

Features:

- When you select an Object (Object Point, Edge, Curve, Line, Surface, Silhouette or Cylinder) in a 3D Viewer or Point Table the selection automatically appears in all other open 3D Viewers, Point Tables, and Photographs as appropriate. This is a great way to do auditing on your Lines and Surfaces to make sure they appear in the photographs you expect.
- When you select a Mark (Marked Point, Edge Mark, Curve Mark, Silhouette Mark or Cylinder Mark) the selection (red color) appears only in the photograph that it was selected on because Marks are associated with one photograph only.
- Operations that act on selected objects (e.g. measure, delete, layers, materials, tag, point audit, etc.) can be done by selecting objects in 3D Viewer, Table and Photograph windows.
- You can create new Surfaces and new Lines by selecting points in 3D Viewer, Point Table and Photograph windows.
- You can mark new Surfaces and new Lines across photographs and between photographs, 3D Viewers and Point Tables (for example you could create a new triangular Surface by marking one point in a Photo window, one point in a Point Table window, and the last point in a 3D Viewer window).
- During referencing only Marked Points, Edge Marks, Curve Marks, Silhouette Marks and Cylinder Marks select in the Reference View. You can select a Line but it is immediately converted into its end points.
- You can select Lines and Surfaces in a 3D Viewer or other photograph and when going into reference mode all Marked Points associated with those features will be selected in the reference view.

Selection Details

Objects that are selected are highlighted in a different color in the open windows as appropriate. The default selection color is red but this may be changed in the *Preferences* Dialog.

Objects may be selected in Photographs, Tables or 3D Viewers:


Type	Select in a Photograph	Select in a Table	Select in a 3D Viewer or Photo (as 3D/projection)
Point Mark	yes	Yes (2D Point Table)	

Object Point		Yes (Point Table)	yes
Offset Point		Yes (Offset Point Table)	yes
Edge Mark	yes		
Edge		Yes (Edge Table)	yes
Curve Mark	yes		
Curve		Yes (Curve Table)	yes
Cylinder Mark	yes		
Cylinder		Yes (Cylinder Table)	yes
Silhouette Mark	yes		
Silhouette		yes (Silhouette Table)	yes
Line	yes		yes
Surface		yes (Surface Table)	yes
Shape Mark	Yes		
Shape			yes

To select an object in a Photograph it must be visible. See *Visibility and Selection Control*.

To select an object in a photograph, open the photograph and make this photograph the active window by clicking on the title bar or anywhere on the photo (off a mark).

To select one object in a photograph:

1. Pick up the Select tool from the toolbar  or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Select the object by clicking the mouse on or close to the object.


PhotoModeler will highlight the object, by coloring it in red. The Status Bars will also update to show you information about the selected object.

Note 1: There is a priority for the selection for objects (for instance if you have a thin surface beside a line, it will be hard to select the surface because lines have higher priority). Using the ALT Zoom window or some other zoom so that the objects are farther apart on the screen will make it easier to select such objects.

Note 2: Some marks (curve marks, edge marks, cylinder marks, silhouette marks) are composed of two pieces: points and the connecting mark. You can select both or either of the pieces. The operation you wish to carry out will decide which piece to select. For instance if you wish to move

one point of an edge or a curve, you would select just the one point but if you wished to delete the whole mark, you would select the mark between the points.

To select more than one object in a photograph:

1. Pick up the Select tool from the toolbar  or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Select the first object by clicking on it with the mouse.
3. Holding down the shift key, click the mouse on the second and subsequent objects.

PhotoModeler will highlight any additional objects.

To select all objects within a rectangular region:


1. Pick up the Select tool from the toolbar or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Click the mouse button when the cursor is not over any selectable item.
3. Holding down the mouse button, drag the mouse to highlight a rectangular region.
4. Let go of the mouse button when the region is the correct size.

PhotoModeler will highlight all marks, lines and surfaces that fall completely within the rectangular region.

To select objects in a 3D Viewer:

1. Pick up the Select tool from the toolbar  or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Select the first object by clicking on it with the mouse. You may need to change the size of the 3D symbol size or change the view zoom to make the object selectable as when the object (esp. point, line, edge, curve) is thin it will be hard to select.


The object will highlight in red in the 3D Viewer (and possibly other open windows).

3. Holding down the shift key, click the mouse on the second and subsequent objects.

PhotoModeler will highlight any additional objects.

- Note: You can also use the Region Select tool in the 3D Viewer.

To select Objects in a Table:

1. Pick up the Select tool from the toolbar  or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Select the first object by clicking on it with the mouse.

The object will highlight with a black border around the row in the table.

3. Holding down the control (Ctrl) key, click the mouse on the second and subsequent objects. You may also select a range of points by using the shift key as you click (then all points between the first selected object and the current click will be selected).

PhotoModeler will highlight any additional objects.

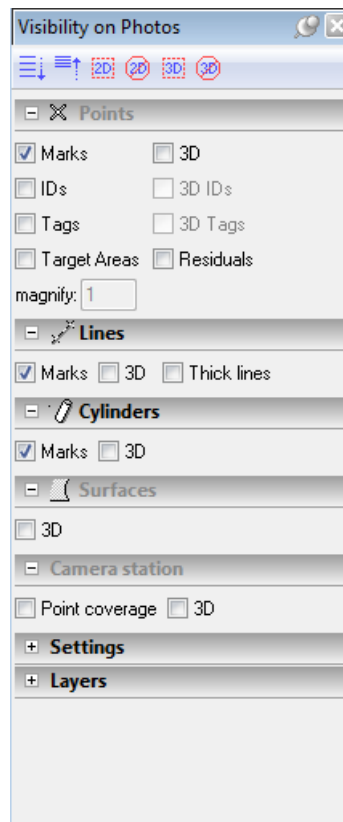
Visibility and Selection Control

When you have many marks on your photographs with possibly many lines and Surfaces also, things can get a bit cluttered. The photo update can get slower (especially when 3D items are visible on a photo), certain objects get harder to select, and it can get harder to see the photographic data under all the markings.

All the photographic marks can be turned off and on. This is done with the *Visibility Settings*.

Visibility Settings

The Visibility Settings are part of the *Visibility on Photos* pane. They have controls for setting what and how various items are displayed on Photograph Windows:



When a check box is “on” in one of these sections then that particular type of object will be visible on the photographs. An object has to be visible to be selectable.

The pane has sections for each object type, and only items that are currently in the project are shown (i.e. once an object has been added to the project, settings to control visibility of

that type will be shown on the pane). Each section can be expanded/contracted using the small +/- symbols to the left of the section titles.

The following describes each of the sections this pane.

Visibility on Photos Toolbar

This pane has a small toolbar to facilitate various common actions. These tools are described (from left to right):

Expand: Expands all object type sections that were contracted.

Contract: Contracts all expanded object type sections in the pane.

Select 2D: Enables the visibility of all 2D marked items on photos.

Deselect 2D: Disables the visibility of all 2D marked items on photos.

Select 3D: Enables the visibility of all 3D (projected) items on photos.

Deselect 3D: Disables the visibility of all 3D (projected) items on photos.

Points Photo Visibility

The Points section of the Visibility on Photos pane controls whether 2D objects (marks on photographs) and 3D objects (or projections) are visible on the open photographs. It also has controls to show or hide offset points, point id's (2D and 3D), tags (2D and 3D), Target Areas, and Residuals (with magnification factor). If an item is not available (e.g. a photo does not contain corresponding object types, the checkbox will be disabled).

When a check box is empty the corresponding item type is hidden from view in a photo. The type will also not be selectable. For example, if 'Marks' were off then they could not be selected by any means (single click, box area select or Select All menu item). This can be useful if you wish to select a number of features of one type in a window.

When PhotoModeler is in point marking mode then Marks visibility is forced on and cannot be turned off until a different mode is activated (e.g. selection).

Point ID Visibility Photo Visibility

When Points are visible as Marks or 3D projections on a photograph, the Point ID's Visibility option becomes available. Control Points have a similar setting in Projections.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Point IDs (short for Point Identifier Text) provides feedback on which point you are seeing. The ID text appears right beside the point in question. This text can take on different forms:

Point Type	ID Format
Normal Point	Idn - unique ID number of 3D Point
Tagged Point	T idn - 'T' denotes it is tagged

User Named Point	idn:user name - 'user name' is text entered in 3D Point properties for that point
Marked Control Point	idn: (cpm:name) - 'name' is the name of the imported control point that is marked here - 'cpm' stands for Control Point Mark
Projected Control Point	(icp:name) - 'name' is the name of the imported control point that is projected here - 'icp' stands for Input Control Point

A Marked Point or projected 3D Point can have combinations of the top four. So for example, point #34 that is a mark of the control point called "CP12", with a user name of "my first", and is tagged would have the displayed ID text, on the photo beside the point, of "T 34:my first (cpm:CP12)".

The display of user name and control point name (for normal points) can be turned off using a setting in *Preferences*. See Image section in *Preferences - User Interface*.

Note: You can renumber the points in your project using the *Renumber Dialog*.

Residual Errors Photo Visibility

The visibility of marking residual errors is controlled by the "Residuals" check box. See *Marking Residual Display* and *Marking Residual* for more detail. You can control the exaggeration factor of the displayed Residual Error by entering an exaggeration amount in the 'magnify' text box below the check box.

Note: Residual Errors are not displayed on a photo when that photo is set to 'Do Not Use in Processing' or when that photo is not oriented.

Target Areas Photo Visibility

When sub-pixel targets are manually marked, the 'target area' is displayed as a red boundary around a target. It shows what bounding area was used in the target marking algorithm and provides feedback on the likelihood of an accurate mark. Unless the Target Areas checkbox is checked this boundary will disappear when the display is updated. You can control whether the target area is shown at all times for all sub-pixel marks (including automatically marked targets) by checking this checkbox. See also *Sub-pixel Target Marking*.

Note: Target Areas are not displayed on a photo when that photo is set to 'Do Not Use in Processing' or when that photo is not oriented.

Note: Target Areas are deleted when a project is idealized due to the changes in image pixel data.

Offset Point Photo Visibility

When a 3D Object Point has a defined offset point (see *Offset Points*), you can enable the visibility by checking the 3D offsets checkbox. The visibility of these items will use the same settings as other 3D items on photos, such as Transparency and Point Size.

Note: 3D offsets are not displayed on a photo when that photo is set to 'Do Not Use in Processing' or when that photo is not oriented. A model must also have a coordinate system defined by either a scale/rotate or control points.

Lines Photo Visibility

The Lines section of the *Visibility on Photos* pane controls whether 2D lines (marks on photographs) and 3D lines (or projections) are visible on the open photographs. There is also a checkbox to control whether Thick Lines are shown as Line marks on photos. Lines, Edges, Cylinders and Curves can be hard to see sometimes because they are drawn as single pixel wide lines on the screen. When the "Thick lines" check box is checked all these items displayed on all open photographs will be redrawn with a wider black background to make them easier to see. The width of the thick drawing is settable in *Preferences*.

Note: The Thick lines setting applies to all photo marks that use a straight line graphic, i.e. lines themselves, edges, cylinders, and shapes.

The Lines section will only appear on this pane if at least one line has been marked in the project.

When PhotoModeler is in Line marking mode the line mark type is forced to be visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Curves Photo Visibility

The Curves section of the Visibility on Photos pane controls whether 2D curves (marks on photographs) and 3D curves (or projections) are visible on the open photographs.

The Curves section will only appear on this pane if at least one curve has been marked in the project.

When PhotoModeler is in Curve marking mode the curve mark type is forced to be visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Cylinders Photo Visibility

The Cylinders section of the Visibility on Photos pane controls whether 2D cylinders (marks on photographs) and 3D cylinders (or projections) are visible on the open photographs.

The Cylinders section will only appear on this pane if at least one cylinder has been marked in the project.

When PhotoModeler is in Cylinder marking mode the cylinder mark type is forced to be visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Silhouettes Photo Visibility

The Silhouettes section of the Visibility on Photos pane controls whether 2D silhouettes (marks on photographs) are visible on the open photographs. To show the 3D silhouette (or projection) on a photo, you need to enable 3D surfaces in the Surfaces section (see below).

The Silhouettes section will only appear on this pane if at least one silhouette has been marked in the project.

When PhotoModeler is in Silhouette marking mode the silhouette mark type is forced to be visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Surfaces Photo Visibility

The Surfaces section of the Visibility on Photos pane controls whether 3D surfaces (or projections) appear on a photo. Surfaces are unique in that the only way to view surfaces on photos is via the 3D representation (which can only appear if the surface is valid and solved), that is, surfaces do not have 2D photo marks. Setting 3D surface visibility to on also enables 3D silhouettes to appear on photos since a silhouette is effectively a type of surface.

The Surfaces section will only appear on this pane if at least one surface (or silhouette) has been marked in the project.

When PhotoModeler is in one of the Surface marking modes the Surface section becomes visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Imported Objects Photo Visibility

The *Imported Objects* section of the Visibility on Photos pane controls whether 3D imported points (and point id's), 3D imported lines, and 3D imported surfaces are visible on open photographs.

After an Imported Object has been added and its 3D position calculated (by marking control, pinning or as a static) it's 3D visibility can be turned on and the imported object will be projected onto the photos.

The Imported objects section will only appear on this pane if at least one import has been added to the project.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Shapes Photo Visibility

The Shapes section of the Visibility on Photos pane controls whether 2D edge marks (marks on photographs) and 3D edges, 3D faces and 3D face names are visible on the open photographs.

The Shapes section will only appear on this pane if at least one shape has been added to the project.

When PhotoModeler is in Cylinder marking mode the cylinder mark type is forced to be visible.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Camera station

The camera station section of the Visibility on Photos pane has two controls.

The first is the Point Coverage control which sets whether the point coverage boundary is shown on photos. A camera that has been calibrated in version 6 or later stores the extents of the calibration coverage as a 'rectangle' in each photo frame. A calibration can only 'solve' for the parts of the lens that contain 3D points, so the lens is essentially uncalibrated outside of this 'frame'. Viewing the point coverage boundary provides an indication of whether points are marked within the calibrated region of the lens.

The 3D checkbox allows you to view projected 3D camera stations in photos (i.e. only oriented camera stations for photos that were taken at angles that are visible from the current photo). This helps visualize camera angle differences in photos.

Note: 3D items are displayed on oriented photographs only. See the section on *Photo Projections* for more information.

Settings

The Settings section has settings that control the appearance of 3D objects in photos.

The Transparency slider controls how transparent a 3D object appears in photos. Adjusting the transparency is useful items are not clearly visible or when you want to view photo contents 'through' the projected item. If the slider is to the left (solid) then the 3D model will look solid and will hide the photograph behind it. If the slider is to the right (clear) then the projection will not be visible at all (but note it will still be selectable and this is not the same as turning projections off). Other in between settings let you see the projected 3D model and the photograph at the same time.

The sizes settings control the relative size of various 3D items in photos. These are identical to those in the *3D Viewer Options Dialog* except they apply to the 3D model projected onto the photos. Note that surface type applies to Cylinders, Silhouettes and Surfaces.

The Surfaces and cylinders drop down list controls how 3D surfaces and cylinders are displayed in photos. The options are the same as in the 3D Viewer options dialog: Shaded, Wireframe, Dots, Fast Textures, Quality Textures.

Layers

The Layers section has settings that control the visibility of layers. Objects can be placed in layers to help reduce clutter in the photo windows. See [Layer Dialog](#) for more information on layers.

Referencing

Referencing is the process of telling PhotoModeler that marks on two or more different photographs represent the same physical object in space.

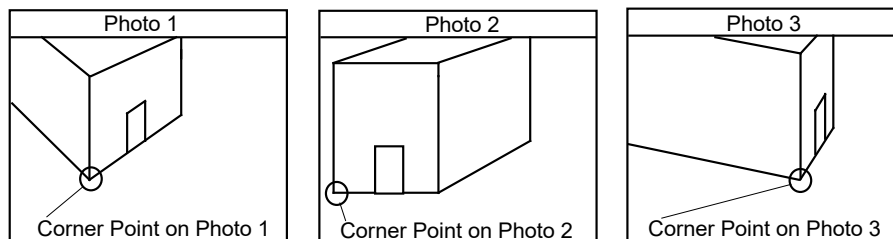
Photograph Marks (user identified positions on photographs) such as Point Mark, Edge Mark, Curve Mark, Cylinder Mark and Silhouette Mark, should be marked and referenced in each photograph that the object appears in.

Referencing is not used in single-photo projects.

In a multi-photo points project, referencing is the key step needed to ensure the project will process properly and to ensure objects get computed with 3D positions. In a multi-photo shape project referencing can be used to add details and define points that can not be identified as a vertex of a mark-able shape.

Marks must be referenced on at least two photographs, but can be referenced on as many photographs as there are in the project.

In the example diagrammed below, the user must tell PhotoModeler that the corner point shown on Photo 1 is the same point as the corner point shown on Photos 2 and 3.



Example of referencing 3 views of the same point.

Three different strategies exist for doing Point Referencing:

1. Mark all points first and then reference them as a second step.
2. Combine the marking and referencing steps. Choose one photograph and mark all of the points that are visible on it. Choose a second photograph that has many points in common with the first one. Make the first photograph the Reference Source Photograph, and select all of its Marked Points. Mark points on the second photograph as they are highlighted on the first photograph. This approach can be more difficult than marking and referencing separately but is also more efficient.
3. Do single point marking/referencing while in Reference mode. Enter Reference mode, click on an image to create a new mark and select it as the source photo, then

immediately mark same point on a different photo. Note you can also hold the shift key while marking points in the source photo and then you can reference them together in the destination photo.

Edges, Curves, Cylinders, and Silhouettes must be marked before being referenced so only option 1 is available. Option 1 can be carried out using Reference Mode or the Quick Referencer (see below).

Note: Marks are objects that are drawn only on **Photographs**. Multiple marks, referenced together, are used to form the **3D Object**. So a 3D Point is created from two or more Marked Points; a 3D Curve is created from two or more Curve Marks; a 3D Cylinder is created from two or more Cylinder Marks; a 3D Edge is created from two or more Edge Marks; a 3D Silhouette solid is created from two or more Silhouette Marks.

Referencing Colors

A color coding system is used to quickly identify items in photos that are referenced and those that are not referenced. This applies to point, curve, edge, cylinder, and silhouette marks. Marks on photos that have not been referenced are displayed in gray. Once the item has been referenced on at least two photos its color changes to white on photos.

During referencing mode additional colors are used to illustrate a point's referenced state. Objects selected for referencing on the source photo are displayed in the red selection color. When over a destination photo points already referenced on the source photo are yellow. The active point on the source photo has its ID displayed yellow if it has not yet been referenced on the destination, if the active source point has already been referenced on the source it will be purple.

Representative colors can be selected on the Colors page of *Preferences - User Interface*.

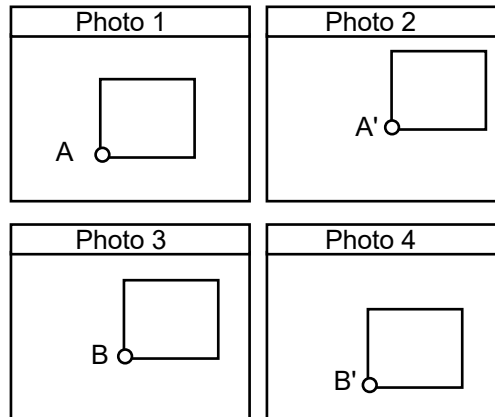
Referencing is Additive

- If a Mark on one photograph is referenced to a Mark on a second photograph, and
- If this Mark on the second photograph is referenced to a Mark on a third photograph,
- Then it follows that, the Marks on the first and third photographs will be referenced to each other.

For example, in the diagram below, Marked Points A and A' have been referenced to each other, and Marked Points B and B' have been referenced to each other. If you do the following:

1. select Marked Point A,
2. make Photo 1 the Reference Photograph,
3. make Photo 3 the Active Photograph,
4. reference Marked Point B to Marked Point A

then Marked Points A, A', B and B' will all refer to the same location in your 3D model. This point will show as having "4 references".



Additive referencing.

While the example shows Marked Points, this also applies to Edge Marks, Cylinder Marks, Curve Marks and Silhouette Marks.

Note: When properties (such as Material and Layer) of the objects being referenced differ, the property of the item with the most references will take precedence (e.g. if the layer of one Curve is different from the layer of the other Curve(s) being referenced, the layer of the Curve with the most associated Curve Marks becomes the final Curve's layer).

Referencing Marks

There are two methods for referencing Marks. There is the Reference Mode which is entered into using the *Reference Mode and Pane* and there is the *Quick Reference* command.

Quick Reference is used when only a one or two objects need to be referenced, whereas the Referencing Mode is more useful when a number of marks have to be referenced together. Referencing Mode can also drive you through referencing (mark by mark) so there is less chance a mark will be missed (i.e. remain unreferenced). Quick Reference though does have the advantage of being able to select objects from Tables, Projections, and the 3D Viewer for referencing.

Quick Reference

The "Quick Reference" tool allows you to quickly reference any number of same type of item on photographs (marks or projections), in tables, or in the 3D Viewer.

To use this tool, you select the items that represent the same object on any open photographs, tables or 3D Viewers, and then click the Quick Reference tool on the toolbar (or the menu item under the Reference menu, or by pressing the SHIFT-Q key). If your selection contains items all of the same type, and satisfies the requirements for referencing (e.g. selection does not contain two or more items marked on the same photograph, etc.) then the items will be referenced.

Note: Although you cannot Quick Reference two 2D items marked on the same photograph, you can select and Quick Reference a marked item and a 3D (projected) item on the same photo as long as that projected item does not already have an associated 2D mark on the photo. Using 3D

items allows you to do single photo referencing! The item must have had its 3D position solved already for the 3D item to appear though (and that 3D item visibility has to be on).


If the Quick Reference succeeds, the selected items are all referenced together and are unselected.

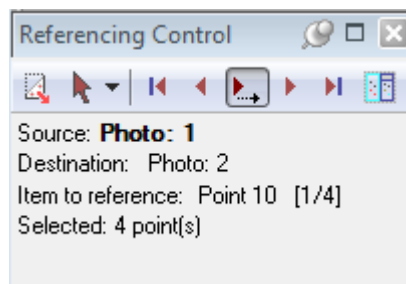
If Quick Reference fails, a warning message will appear displaying the reason for failure and the items will remain selected.

Note: When properties (such as Material and Layer) of the objects being referenced differ, the property of the item with the most references will take precedence (e.g. if the layer of one Curve is different from the layer of the other Curve(s) being referenced, the layer of the Curve with the most associated Curve Marks becomes the final Curve's layer).

Reference Mode and Pane

The Referencing Mode is used to provide more assistance with Referencing than the *Quick Reference* command.

When Reference mode is entered by selecting "Reference Mode" in the Referencing menu, or by pressing the Reference Toolbar button  , the Referencing pane will appear.



The Referencing Pane has tools to control how referencing acts and displays information about its current state

While objects are usually referenced across multiple photographs, all referencing actions take place between two views. These two views are called the "Source " and the "Destination". Although 3D views and tables can also be used as the reference source or destination, typically it is done between two photos. We will describe reference between two photos but the same actions could apply to 3D views or tables.

In the Source Photo you select marks (Marked Points, Edge Marks, Curve Marks, Cylinder Marks or Silhouette Marks), and in the Destination Photo you identify which marks there are the same as the ones in the source.

When you first start referencing mode no source or destination will be selected. To choose a source select one or more objects to reference. Once an object is select a blue line will paint around the border of the photo, the title bar will update to include "REFERENCE" and the referencing pane will indicate that view is the source.



Once a source is selected when the mouse is brought over a new view it will be selected as the destination. You can have multiple photographs open at once and in effect have multiple Destination Photographs as will be described below.

The current Source Photo and Destination photo are shown on the referencing pane along with information on the selected items.

Source: **Photo: 2**
 Destination: Photo: 1
 Item to reference: Point 59 [1/3]
 Selected: 3 point(s)

Above this text is the referencing toolbar.



From left to right the button functions are as follows (note that the tooltip that appears when you mouse over the tools provides a brief description of the purpose) :

- Clear source: Unselects all objects on the source view and clears it as the reference source. You can then select an object on a different view causing it to become the new source.
- Choose sub-mode: Allows you to switch between select, mark and target mark referencing sub modes. While in select sub-mode you can only select existing points to reference from and to. When in mark sub-mode (the default) you can create new marks on the source and destination photo, or if you point to an existing mark the cursor will change allowing you to select it. Mark target sub-mode is similar to mark sub-mode but allows you to mark circular targets in the same way as *sub-pixel target marking* mode.
- Navigate selected list: When more than one object is selected for referencing on the source these controls allow you to 'scroll' through which item is currently being referenced.

- Go to first object moves to the first item in the selected group of items.
 - Go to previous object moves to the previous item in the selected group of items.
 - Auto-advance: When this button is depressed if an item selected for referencing has already been referenced on the current destination view it will automatically be by-passed and the next object selected for reference which has not yet been referenced on the current destination will be selected.
 - Go to next object: moves to the next item in the selected group of items.
 - Go to last object moves to the last item in the selected group of items.
- Auto Arrange Photos: When this button is depressed, the source photo (this only applies to photos) is repositioned so that it always appears in the left-most part of the Photos pane, while other open photos including the destination photo are tabbed to the right. When the source photo changes, it will get automatically repositioned to the left when in this state. If the button is not depressed, the source photo will not be repositioned and can be anywhere within the Photos pane.

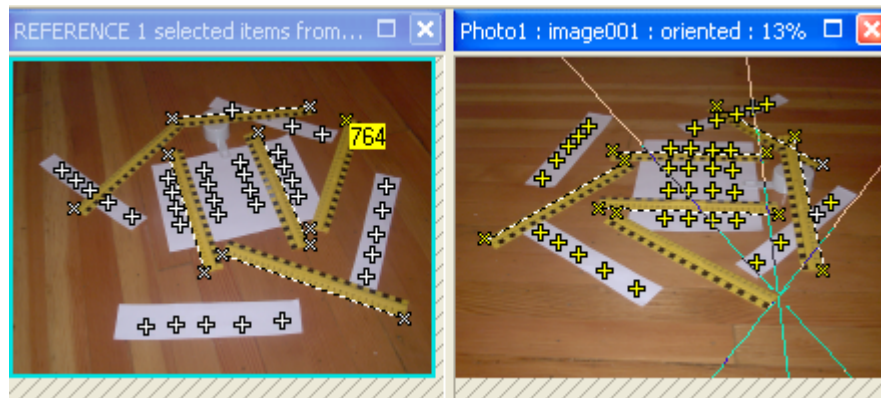
Reference helper lines

When referencing Marked Points between oriented photos a 'ghost' helper line will be displayed for each photo the selected mark has been referenced on. The technical term for this line is the epi-polar line. The matching location on the destination photo should lie somewhere along these lines, likely near the intersection of them if multiple are shown. The better the orientation of the source and destination photos the closer the lines will be to the true location. You should always mark and reference the points at their true location on the photo even if this location conflicts with the helper lines, since the reference helper lines are just a guide to help locate the general area on the photo to mark.

A source and destination photo showing a source mark that has not been referenced yet (i.e. is only marked on that one photo so produces a single reference helper line):



A source and destination photo showing a source mark that has been referenced on 3 oriented photos, the point location should be where the reference helper lines intersect:



When referencing points or silhouettes, if a mark already exists near the reference helper lines the potential matches are highlighted (see *Reference Helper Highlight*).

Auto-drive Referencing

When a Marked Point, whose underlying Object Point is 3D, is highlighted in the Source Photograph, the cursor and image in an oriented Destination will automatically jump to the expected location of the point. You can then find the point (which should be close by) and click on it to reference. Because the image moves also you can be zoomed and the image will re-center to the expected point location.

To use this mode, your Source and Destination Photographs must be oriented/processed. If this mode is on when one of the Source or Destination are not oriented then you will see no effect.

Auto-drive operates for Marked Points and Curve Marks only.

Reference Helper Highlight

During Referencing Mode when a point or silhouette is selected on an oriented source photo, the best potential match(es) will highlight in the destination photograph. The color of the highlight can be set in *Preferences - User Interface* on the Color page with the "Potential Reference" color setting.



The light blue mark is the potential reference on the destination image:

Referencing Steps

To reference objects across photographs:

You can have multiple photographs open at once, but if you need to open a photo to mark or select additional points, you can open (or close) photos while in referencing mode.

1. Start Reference mode by selecting "Reference Mode" in the Referencing menu, or by



pressing the Reference Toolbar button .

The Reference Control Pane will appear.

2. Open the photograph which will act as the source of objects that you will be referencing from, and select the items you wish to reference (selection of items can be done before or after you enter Reference mode).

The source photo will be listed on the Referencing Control pane, along with the number of items selected. The selected objects will become highlighted. A blue outline is painted around the source photo image and the photo window title bar shows that it is the source photo and lists the number of selected items.

3. Open the photograph which has the associate unreferenced marks (Marked Points, Edge Marks, Curve Marks, Cylinder Marks, or Silhouette Marks) that you wish to reference. If they are not marked already, you can mark them while in Reference Mode. If the destination photo is open already, simply move your mouse cursor over it and it becomes active.

You are now ready to select the associate point mark(s) or mark points on the destination photo if not marked already.

*PhotoModeler will highlight all marks on this photograph, that have already been referenced to the marks on the source photo. The first mark encountered on the source photo, which has not yet been referenced, is highlighted in yellow. PhotoModeler changes the cursor to indicate what type of object is being referenced (a double "X" for Marked Point, a double line for Edges, or a double curve for Curves etc). When referencing points or silhouettes, PhotoModeler also highlights the most likely match using a **Reference Helper Highlight** color. If the mouse cursor is over a point that has already been referenced, the cursor changes and you are prevented from selecting it.*

4. If the object that is highlighted in the Source is visible in the destination, click the mouse on it. If you are referencing a point and it has not yet been marked on this destination, you may mark and reference it simultaneously with one click.

PhotoModeler now knows that this object is the same in both photographs. PhotoModeler will highlight this mark in yellow, on the destination photo. PhotoModeler will advance the highlight, on the source Photo, to the next unreferenced mark that is selected.

5. If the object that is highlighted in the source is not visible in the current destination, click the right mouse button and pick "Skip Object" in the menu, or press the "Escape" key to move on to the next mark.

PhotoModeler will advance the yellow highlight, to the next unreferenced mark on the source photo.

6. Continue the previous step, until all the marks that are highlighted on the source photo and are visible on the destination photograph, have been referenced.
7. Repeat steps 3 through 6 for different destination photographs. Simply move the cursor over any open photo (or open a photo) and the activated photo becomes the destination.

Note 1: To change to a different source photo, click the Clear Source Photo button on the Referencing toolbar to deselect all points. Then simply reselect points in a new photo. This new photo becomes the source photo for referencing.

Note 2: PhotoModeler will not allow a referenced object to appear more than once on a photograph. An attempt to do this will result in a warning message and the reference will not be

done. If you think two marks should be referenced but PhotoModeler will not let you, a mistake has been made. To fix referencing errors see [Correcting Referencing Errors](#).

Note 3: Some referencing preference settings can be found in [Preferences - Marking and Referencing](#) including settings for auto-focus photo window, auto-drive, auto-photo-advance etc.

Referencing cursors

During referencing mode the following cursors can appear.



- The mark referencing sub-mode is selected and the mouse is over the source photo or no source photo has been selected yet. Clicking will create a new mark and select it for referencing.



- The mark referencing sub-mode is selected and the mouse is over the source photo or no source photo has been selected yet and the cursor is over an existing mark. Clicking will select the mark for referencing.



- The mark referencing sub-mode is selected and the mouse is over a destination photo. Clicking will create a new mark on the destination photo and reference it to the selected mark on the source photo.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo and over an existing mark that is not already referenced on the source photo. Clicking will select the mark on the destination photo and reference it to the selected mark on the source photo.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo and over an existing mark that has already been referenced on the source photo. Clicking will produce a warning message explaining why this reference is invalid.



- The select referencing sub-mode is selected and the mouse is over the destination photo or source photo or no source photo has been selected yet but the mouse is not over a mark so nothing can be selected. Clicking will do nothing.



- The select reference sub-mode is selected and the mouse is over the source photo or not source photo has been selected yet and the mouse is over a mark. Clicking will select the mark as the source object.



- The target mark while reference sub-mode is selected. Clicking will switch to target mark mode where you must hold the button down and drag a box around the target region. Releasing the mouse button will create a new mark. If you are over the source photo this mark will then be selected as the source mark, if you are over the destination the new mark will be selected and referenced to the source.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a curve is selected as the source and the mouse is over a curve on the destination. Clicking will select the curve on the destination and reference it to the source.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a curve is selected as the source but the mouse is not over a curve on the destination. Clicking will do nothing.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a cylinder is selected as the source and the mouse is over a cylinder on the destination. Clicking anywhere on the cylinder photo mark will select the cylinder on the destination and reference it to the source.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a cylinder is selected as the source but the mouse is not over a cylinder on the destination. Clicking will do nothing.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, an edge is selected as the source and the mouse is over an edge on the destination. Clicking will select the edge on the destination and reference it to the source.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, an edge is selected as the source but the mouse is not over an edge on the destination. Clicking will do nothing.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a silhouette is selected as the source and the mouse is over a silhouette on the destination. Clicking will select the silhouette on the destination and reference it to the source.



- The select or mark referencing sub-mode is selected and the mouse is over a destination photo, a silhouette is selected as the source but the mouse is not over a silhouette on the destination. Clicking will do nothing.



- The mouse is over a destination photo and you are at the end of the set of objects selected on the source (i.e. all the selected items have been referenced or skipped over). Clicking will open the next photo in the project tabbed on top of the current destination.

What Referencing Means for Lines

- When two Marked Points are referenced they represent two different views of the same Object Point in space.
- Lines are created by connecting two or more Object Points.

When the two end points of a line on the Source Photograph are referenced to two points on the Destination Photograph, the line that connects them is drawn on the Destination

Photograph. This line appears on the Destination Photograph, because its end points on the Destination Photograph are referenced to end points on the Source Photograph. There is just one line, but it is visible in two places.

In addition, Lines marked on the Destination Photograph become visible on the Source Photograph, when appropriate referencing is done.

If two Lines are marked, one on the Source Photograph and one on the Destination Photograph, and if the end points of these Lines are referenced to each other, PhotoModeler will replace these two Lines with one Line. This Line will still be visible on both photographs.

Correcting Referencing Errors

If two Marked Points are referenced to each other, but they do not mark the same physical feature on the object, they will not generate a correct 3D point. Similarly for Edges, Curves, Cylinders and Silhouettes.

To correct a referencing error:

1. Select the mark that is incorrectly referenced.
2. Select "Unreference Selected" from the Referencing menu.

PhotoModeler will remove all references from this mark to any other marks. You may need to do this in more than one photograph to completely unreference any particular object.

Or,

1. In select mode, right-click on a mark in a photograph. You can also do this on the source photo while in reference mode.

The right click menu will appear.

2. Select the "Unreference Selected" menu item.

PhotoModeler will remove all references from this mark to any other marks. You may need to do this in more than one photograph to completely unreference any particular object.

To examine the references that exist between points, use the Point Audit feature. Select "Point Audit Selected..." or "Point Audit All..." from the Referencing menu.

See also [Point Audit](#) and [Referencing](#).

Point Audit

Point Audit provides a way to examine specific information about each 3D point in your project.

When you mark a project, you are identifying 2D locations of features on each photograph. When you reference these points you are telling PhotoModeler how to combine these points to form a set of 3D points. Point Audit is a way of checking your work to determine if any of your points are likely to be poorly located in 3D space.

Point Auditing may be performed on all the points in your project at once or on a group of selected points.

To Point Audit all of your points:

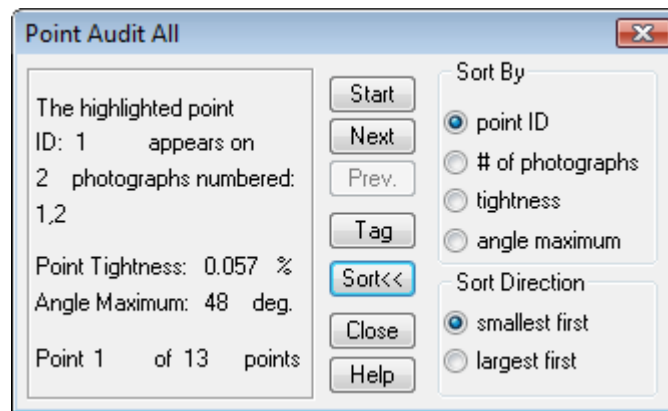
1. Open all or some of your photographs.

2. Select "Point Audit All..." from the Project menu.
3. Study each point as shown by the yellow highlights and the Point Audit Dialog.
4. Press the "Next" button to examine the next 3D Point. Use the "Prev." button to step backward in the list of 3D Points.

To Point Audit some of your points:

1. Open all or some of your photographs.
2. Select the points to audit.
3. You can use single point select, multiple select or rectangular selection. See *Selection and Visibility*.
4. Select "Point Audit Selected..." from the Project menu.
5. Study each point as shown by the yellow highlights and the Point Audit Dialog.

Point Audit Dialog



The Point Audit Dialog displays information about one 3D point. To view information about the next point, press the "Next" button. To view information about the previous point press the "Prev." button.

The order in which points are presented by the Point Audit Dialog is controlled by the sorting option. The order can be ascending or descending by the Point ID, the number of photograph references, the point tightness and the point angle maximum.

To sort the points in Point Audit:

1. Press the "Sort>>" button to expand the Point Audit Dialog.
- The dialog will expand to show the sorting options*
2. Select the type of sort and the sort direction in the two radio button group boxes on the right of the dialog.
 3. Press the "Start" button.

The points will be resorted and the first one will appear on the left.

Point information is presented in two ways. First the current point is highlighted on each photograph it has been marked on. In addition, the Point Audit Dialog displays numeric information about the highlighted point.

The first line, "Appears on N photographs", refers to the number of photographs this point appears on. A point appears on one photograph when it is marked. When it is referenced to another point this point will now appear on two photographs. PhotoModeler achieves best results with points that appear on three or more photographs, but it can also use points that appear on two photographs. Points that appear on only one photograph will not appear in the 3D model.

The second line, "on photographs numbered: N,M,P...", refers to the photo numbers of the photographs that this point appears on. These numbers can be used to locate this point on the visible photographs.

The fourth line: "Point Tightness: N %", refers to the precision with which this point has been marked on all photographs and the precision with which the Camera Stations for these photographs have been oriented. Low numbers are better here. A value of "n/a" means the point has no 3D position and hence no tightness.

The third line: "Angle Maximum: N degrees", refers to the maximum angle between light rays that image this point on each of the photographs this point appears on. In general, the closer this number is to 90 degrees the more accurately the location of this point can be determined. Better angle maximums are obtained by taking your photographs from widely separated positions. A value of "n/a" means the point has no 3D position and hence no angle maximum. Points with very low angles (see Audit section of *Preferences - Processing and Cameras*) may not compute in 3D.

The fifth line: "Point ID N", shows the unique identification number that each 3D model point has. This ID is the same number shown on the *Status Bars* when a point is selected, and same as the ID written out by Export.

The sixth line: "Point N of M points", is used to let you keep track of how far along you are in your Point Audit. "M" is the total number of 3D points in the project if you used "Point Audit All" or it is the number of selected 3D points if you used "Point Audit Selected". Points that have their "do not use in processing" property set are not counted in the totals.

To use Point Audit to find problems, study how each point is highlighted on the photographs. If the highlighted points mark different physical features, then a referencing error has been made. You should unreference these points and reference them to points that mark the same features. If a point appears on just one photograph, you should mark it on the other photographs it is visible on and reference these points. See *Correcting Referencing Errors* for more information.

When you have found a point that needs correction and you do not want to stop and correct it now, you can tag it for future use. Tags are saved when the project is saved and can be viewed or changed at any time.

The "Next" or "Prev." buttons will become inactive (gray) when the end or beginning of the list of points being audited has been reached.

Creating and Modifying Objects


Object Points

Object Points are created, deleted and modified by manipulating Marked Points.

Marking Points

To mark a point, first open or activate the desired photograph.

To mark a point:

1. Pick up the Point Marking tool , or select "Mark Points Mode" from the Marking menu.
2. Click this tool on the location to be marked.

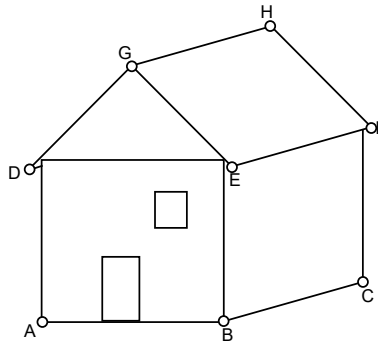
A Marked Point symbol will appear at the location marked. Each additional click will produce a new Marked Point symbol. The photograph being marked may be magnified to allow more precise marking.

3. Repeat step 2, until all of the points you require on this photograph have been marked.

Note: If the Point Marking tool is clicked on top of or very close to an existing Marked Point symbol, the position "snaps" to that Marked Point and a new point is **not** created.

Hint: To increase the precision and ease of marking it is a good idea to maximize the size of the Photograph Window and to zoom-in on the point being marked. See *Changing the Magnification of a Photograph*.

The user should mark each point that is required in the 3D model. For instance if you are modeling the house shown below, the points A through H, at the very least, will be of interest to you. They should be marked on each photograph on which they are visible.



Marking the corners of a house.

Editing Points

The editing operations you can carry out on a Point Mark are:

- move it,
- delete it.

Moving Marked Points

If you are unhappy with the location of a Marked Point you have marked, whether it be a single Marked Point or part of a line, you can move this point instead of re-marking it.

To move a Marked Point with the mouse:

1. Click the mouse on the Marked Point symbol.

This Marked Point becomes highlighted in red.

2. Holding the mouse button down, drag the point away from the current location.

If lines connect this point to other points, temporary lines are drawn to these other points. During movement the Marked Point symbol is hidden and only a Move Cursor along with any attached lines are shown. Move does not active until the cursor has moved three to five pixels from the point. To move a Marked Point a small distance, first drag it away some distance and then drag in back to the desired spot.

3. Release the mouse button when the cursor is in the correct location.

PhotoModeler will redraw any lines or surfaces connected to this Marked Point, so that they connect to the new location.

Deleting Points

To delete a point, open the photograph containing the point you wish to delete. Make this photograph the active photograph.

To delete a point from a photograph:

1. Pick up the Select tool from the toolbar or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Click the mouse on the point you would like to delete.

The point you select becomes highlighted. If you want to delete more than one point, hold down the shift key to extend your selection, and click on additional points. Rectangular selection will work also.

3. Select "Delete" from the Edit menu, or press the "Delete" key on your keyboard.

PhotoModeler will remove the selected point or points from your photograph.

To reverse the deletion of a point, select "Undo" from the Edit Menu. PhotoModeler will replace the deleted point or points, and any deleted lines or surfaces. Only the last delete operation may be reversed. To redo the delete operation, select "Undo" again.

Offset Points

Offset points are 3D point positions that are defined based on the position of one or more existing **Object Points**. Offset points create a 'shadow point' of their associated object point, moving and updating their positions as the Object Point changes.

There are several types of offset points:

- **RAD offset** - a point offset from two RAD target points. RAD offsets are set up when generating/printing RAD coded targets (see **Create Coded Targets Dialog**), and when applying the offset range to your project (**Coded Target Offsets Library**). A RAD offset point is generated from two RAD target points in the offset range as set using the **Offset Point Range Dialog**. Only those RAD targets within the defined range will generate offset point. The vector, defined by the first odd numbered target ID and the next consecutive (even) target ID is used as the direction, while half the distance between the two target id's is used as the offset distance from the even target ID. In other words, the RAD offset point is placed $\frac{1}{2}$ the distance between the two targets beyond the even coded target ID along the vector defined by the two target points.

- Axis offset - a point offset from another along a vector parallel to the X, Y or Z axis. An axis offset point is defined on the Object Point properties dialog.
- 2 point offset - point offset from another using two points as the vector defining the offset direction. A 2 point offset is defined in the Object Point properties for the first point. The ID of a second point that defines the direction is also entered. These offsets are useful for defining corners or other places where dot targets would be hard to place. 2 point offsets are also used when setting up your *Coded Target Offsets Library*.
- Custom offset - an offset point defined by a set of saved properties that can be reused in all your projects - for example when using offset points with Evidence Markers. You define a custom offset using *Edit Custom Offset Types* (a link visible in the Object Point Properties dialog when the 'Offset type' field is chosen).

Offsets are set up using the Object Point Properties dialog or pane. You can also set up groups of offset points that can be reused from project to project using the *Coded Target Offsets Library*.

To create an individual offset point you first select an object point and use the *Properties Pane* or dialog box to define the parameters for the offset. You must define an offset type and distance (unless you are using RAD offsets).

Properties	
Common (1)	
Material	White
Layer	Default
Object Point (1)	
ID number	3
User Name	
Type	Regular
Frozen	<input type="checkbox"/>
Use in processing	<input checked="" type="checkbox"/>
Position	4.765, 15.673, -5.161
Offset type	Z axis offset
Offset point	
Offset distance	2.000000
Offset point material	From associated object point
Offset point layer	From associated object point
Edit custom offset types	
Offset type	
The type of offset point associated with this object point	

In the screen capture shown above, Point #3 has been assigned a Z axis offset type. Once the type is selected, the parameters of the offset are shown in the expandable Offset point section. The *Edit Custom Offset Types* hyperlink shows when the offset type is selected. A distance of 2.00 (in project units, can be positive or negative) has been entered and the material and layer are selected. By default the offset point uses its associated point's material and layer, but an offset can have its own distinct material or layer.

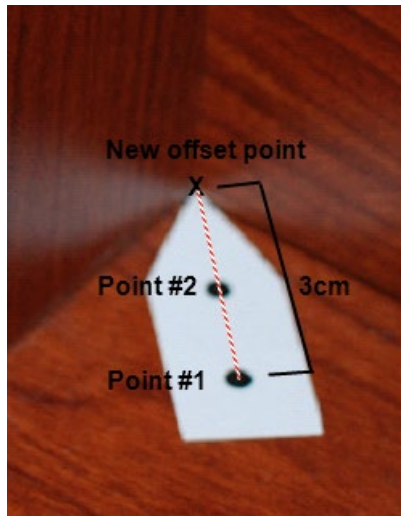
Once the offset has been defined, it will appear in the *Offset Point Table*, the 3D Viewer (if the "Offset Points" option is checked on the Vector Types page of *3D Viewer Options Dialog*), and as a 3D point on photos (if the "3D offsets" option is checked on the Visibility on Photos pane, see *Visibility Settings*).

Note: The project's coordinate system must be defined (either Scale/Rotate or Control Points) for the offset points to calculate their 3D position, and an offset point's associated object point must have a 3D position.

For example, if you had a target as shown in the examples below, and you are interested in the point on the road surface (eg to create a surface on the road plane), you could use an Axis Offset and define an offset point to be created down the Z axis using the height of the target off the ground (as long as you know the exact distance from target center to the road surface, and you define the model's rotation such that the ground is the XY plane and the Z axis is vertical):



A 2 point offset is a point offset from another using two points as the vector defining the offset direction. You define an offset direction based on the vector between two points, this is called a 2 point offset. For this type of offset you enter the ID of a second point that defines the direction of the offset, which can be useful for defining corners like this:



In this example, the point in the foreground (Point #1) would be assigned a 2 Point Offset type using the point in the background (Point #2) as the second point ID. You would use the known distance between Point #1 and the tip of corner as the distance or value of offset (e.g. 3cm). As long as Point #1 and #2 have valid 3D positions (and the model's coordinate system has been defined, this offset setup would create a 3D offset point at the tip of the corner using the line between the points as the direction vector (red dashed line shown above).

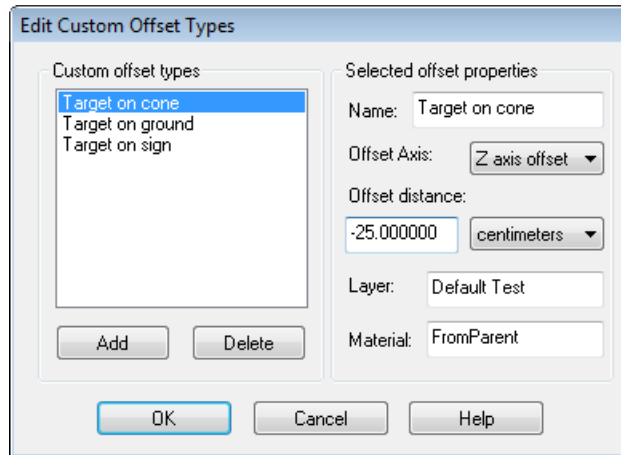
This allows highly accurate point marking, using targets, where normally a target could not practically be placed. Offset points can be used like regular points for creating lines, surfaces, curves through points, measurement, etc.

By default offset points will use the same material and layer of the object point they are offset from but you can set specific values for the offset point.

If you repeatedly use a specific offset distance and axis, you can create a custom offset type using the *Edit Custom Offset Types* dialog and assign this to the appropriate object points. A custom offset has a preset distance and axis type, which means you do not have to define the type of offset for each point.

You can also automatically setup a series of reusable two point coded target offsets (or RAD target offsets) using the *RAD and Coded Target Offsets* command (on the Project menu if the Coded Target module is installed).

Edit Custom Offset Types



This dialog is accessed from the Object Point properties dialog using the Edit Custom Offsets hyperlink when the Offset Type is selected. This is the dialog that allows you to create custom offset types. These custom offsets will be listed in the *Object Point Properties* offset type drop down enabling you to simply select the offset type for each point, without having to re-define it from scratch each time. Selecting the custom offset type will apply the settings to the selected object point.

For example in the screen shot shown above, selecting the “Target on cone” offset would create *offset points* that are 25 centimeters down the Z axis. Note that the sign of the distance will depend on the setup of the rotation’s direction. Typically, to move down the axis, the value in the example above would be -25cm.

Use the Add button to create a new custom offset, and the Delete button to remove any offsets you no longer need.

If you had a series of pre-cut target targets such as this, you could set up a series of Coded Target Offset pairs that could be reused whenever you need.

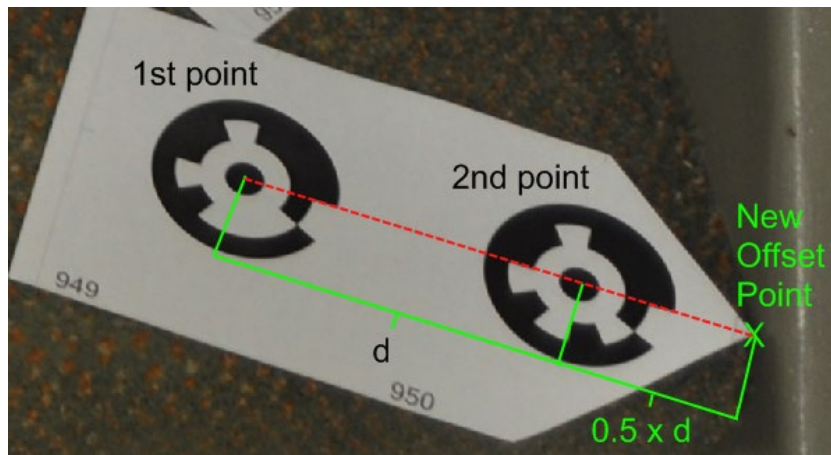
RAD and Coded Target Offsets

Coded target offsets are 2 point *Offset Points* created between 2 coded target or RAD target points. The Coded Target Offsets... command (on the Project menu if the Coded Targets module is installed) brings up the *Coded Target Offsets Library* dialog.

There are two types of Coded Target Offsets: RAD offsets and old-style coded target offsets.

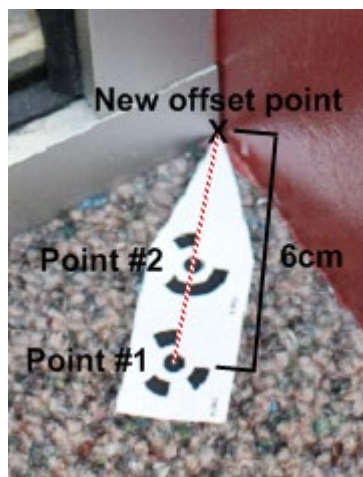
RAD offsets are set up when generating/printing RAD coded targets (see *Create Coded Targets Dialog*), and when applying the offset range to your project (*Coded Target Offsets Library*).

The following shows an example of 2 RAD targets (in the defined range) being used to create a RAD offset:

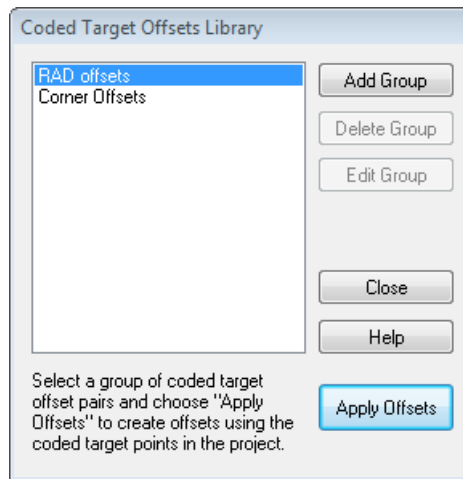


The offset point at the green X will be created at $\frac{1}{2}$ the distance between the two targets in the direction of the vector defined by the two targets. The absolute offset distance will be determined by the scale applied to the project. Note how the 1st point (#949) is odd and the 2nd point (#950) is even. RAD offsets always use an odd first point in the pair. In this example, Point #949's properties will show a RAD offset type, with an Offset Axis End Point property of 950.

If you are not using RAD targets, you can use the old style coded targets to define a coded target offset. The following shows an example of 2 coded target points that can be used to define an offset:



Coded Target Offsets Library



This dialog also allows you to add, remove, edit and apply 'groups' of coded target offsets. This is a different way of applying offsets than by using the offset settings on the Object Point properties dialog. Here, you can set up re-usable offsets and apply this range to the existing points in the project.

Once you have printed and set up your coded target offsets (e.g. the two coded targets in the example shown above), you can set up your coded target offset library here, where you define the coded target pairings. These settings can apply to all projects, so in whatever project you open, your offset library will be available.

This dialog also allows you to apply RAD offset settings to the currently open project. You cannot add, remove or edit RAD Offsets as the pairs are set up based on how they were created (see *Create Coded Targets Dialog*) and on the range as defined on the *Offset Point Range dialog* which appears when you click Apply Offsets.

When you click Add Group, you will be prompted to name the offset group. The group will then appear in the list at left. An example of when you would want multiple groups in your library is when you want to have a group for each Coded Target Bit Set (note though that a project can only contain coded targets from one bit set).

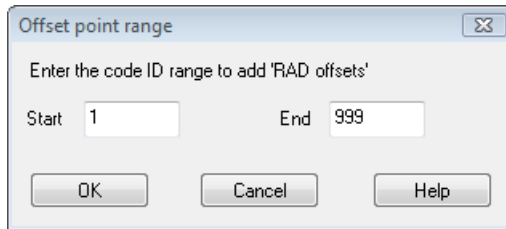
To populate a coded targets group, select it in the list at left, and click Edit Group, which will open the *Edit Coded Target Offset Pairs* dialog.

To remove a group from your library, click Delete Group.

Once a group of coded target offset settings has been created and populated with a set of offsets, you select it in the list, and click Apply Offsets. Your project will be scanned, and for each ID of a point in the offset group that is found, an offset will be created as specified by the coded target offset parameters. If you have multiple groups in your library that apply to the current project, you need to select each group and click Apply Offsets.

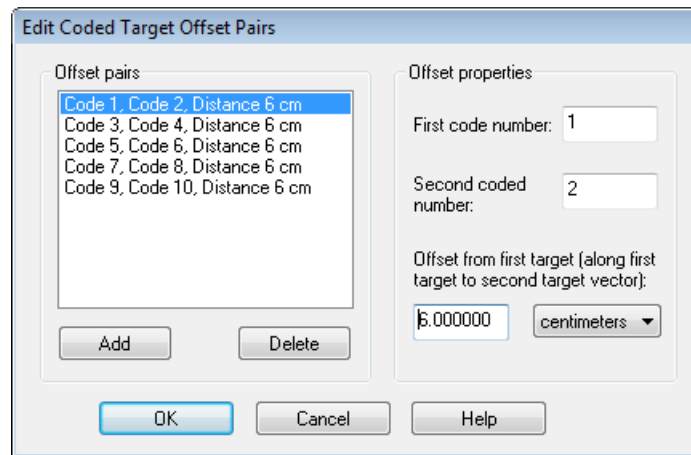
Offset Point Range Dialog

This dialog appears when you Apply RAD offsets to the project, by clicking the Apply Offsets button:



Select the range of your RAD offsets based how you created the RAD targets (see [Create Coded Targets Dialog](#)). The Start and End values bound the range of codes of the 1st point in the RAD target pair.

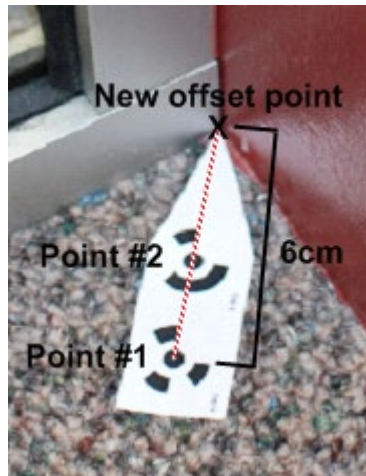
Edit Coded Target Offset Pairs



This dialog allows you to add, delete and change pairs of coded targets used to create offset points, when setting up groups of offset points for your [Coded Target Offsets Library](#).

Here you choose the 2 coded target IDs and the distance along the vector defined by these 2 points. Define the offset for each pair of points that has been prepared in your set of targets.

In the example shown in the dialog box screen capture above, the first coded target ID (#1) is the ID of the point to which the offset is applied (i.e. when the Properties of the Point #1 are displayed, the offset parameters will be shown). The second coded target ID (#2) is the ID of the point that defines the vector direction. The Offset distance (6cm) is the distance from the center of Point #1 to the new 3D offset point. That is, the vector starts at Point#1, passes in a straight line through Point#2 and ends at the new offset point, 6 cm from Point #1. This is shown in the following example:



This offset point will be shown in the Offset Point table and in #1's point properties as a 2 Point offset, with Point #2 as the second point, and a value of 6cm.

When a series of these pairs are made, their parameters can be set up and added to the library to be used in multiple projects.

When 'Apply Offsets' on the *Coded Target Offsets Library* dialog is clicked these settings will be used to create offset points.

Sub-pixel Target Marking

There are a number of factors that contribute to the overall accuracy of a project. One of the large factors is the precision of the point marking and the referencing of like points across photographs. With most types of points marked the user has to zoom in, and click to mark the point location. There is a fair amount of inaccuracy in this operation. Even on high contrast good targets, a human operator is accurate to only one to three pixels. When you then take into consideration that many points look different in photographs taken at different angles, the overall precision of identifying exactly the same point in object space is usually around three to ten pixels at photo scale.

One way to overcome this limitation of manual photogrammetry is to make the software mark the points in an accurate and consistent manner. It is difficult to do this on any type of natural point (e.g. corner of a window frame or other distinguishable feature) but if we know a priori what the target is going to look like, the software can do quite a good job of marking it by studying the digital image data. This is what the sub-pixel target marker does.

Note that there is a manual sub-pixel target mode which we will describe here and an automated method described in the *Automatic Target Marking* section. Sub-pixel target marking also applies to *Coded Targets* and *Automated Coded Targets Project*. Much of the background covered here applies to these other areas also.

Targets - Do's and Don't's

The following list outlines issues to keep in mind when using targets in a project:

DO:

- Ensure the center dot of a target is large enough on all photos. The dots should be at least 8 pixels diameter in all photos. If in doubt use a larger center dot. Plan dot size based on the target that will be farthest from any camera.
- Place targets on locally flat areas, or apply a stiff backing so the targets don't bend.
- Fasten targets on the object or in the scene so that they do not move between photos - even the slightest movement between photos can throw the solution off.
- Each target should appear on 2 or 3 photos (more is better) with minimal perspective (i.e. between 50 and 90 degrees where 90 degrees is straight on to target). This is to ensure that the target will be detected and marked with a high degree of confidence.
- Ensure at least 8 to 10 targets are clearly visible with minimal perspective in each photo and that there is overlap of targets between photos.
- Targets should have a good spread across a reasonably large area of the image.
- Targets should be in focus and not blurry. Ensure there is good exposure of all photos.
- Targets should be high contrast (i.e. avoid dark targets on a dark background) - the dot and code regions of targets should have a strong contrast and crisp edges.

DON'T:

- Don't trim printed targets too closely. You need to leave a reasonable amount of white space around the edge of the code rings or dots.
- Don't warp or bend targets.
- Don't use the same target number more than once.
- Don't mix target bit sets (i.e. don't use 12 bit targets along with 8 bit and / or RAD targets).
- Don't move targets between photos.
- Don't lay out targets so they are only in a line (spread them out in a wide area).
- Don't use targets that are larger than 200 pixels across in photos if high accuracy is important.

Target Shape

The Sub-pixel Target Marker works with Circular Targets (both coded and non-coded targets) and Template Targets. See also [Using Targets](#).

Circular Targets are solid circles or dots of contrasting color to the background (white dot on dark background for example). **Coded Targets** are circular targets with a code ring used for implicit referencing between photos. Template Targets are user defined shapes that can include shapes like crosses, grids, edges, corners, rectangles and even circles.

The Circular Target marker tends to be more consistent, more precise and faster than the Template Target marker so if you have a choice of target type, we recommend circles.

There are two methods of sub-pixel marker in PhotoModeler: the centroid method and the Least-Squares Matching (LSM) method. The centroid method is for circular targets only but works with any blob shape that is similar to a filled circle whereas the LSM method works with filled circles and Template Targets.

The target should be a consistent brightness and color and may be a light color on a dark background or a dark color on a light background. You can make your own physical targets with a laser printer or for an object with constant color you can use the removable sticky dots available at stationary stores.

Note: PhotoModeler only “sees” monochrome images when doing target marking (manual or automatic *sub-pixel target marking*). Color images are converted to monochrome / grayscale first before the sub-pixel algorithm is run. One has to be aware that targets that might look high contrast in a color image (dark yellow target on blue background for example) might not be high contrast when converted to grayscale. Color targets can be used with PhotoModeler as long as one ensure the “brightness” of the target differs considerably from the background.

The next sections deal primarily with Circular Targets. Circular Targets are the default in PhotoModeler and if no Template Targets are imported, then only Circular Targets will be marked manually or automatically. To find out more about how to load a Template Target and how to mark them, please see the *Template Target Marking* section.

Circular Target Size

There are some limits to target size. You do not want the targets to be too large or too small.

Circular targets that are photographed at a large angle to the camera appear as ellipses. This is not a problem unless the target is very large in the photograph because it is close to the camera. In this case, the center of the ellipse (which is what PhotoModeler sub-pixel marker finds) is not the projection of the center of the circular target. Usually you only need to be concerned if the target image is larger than an 1/8th the size of the photograph.

Note that if using *Coded Targets* the requirement for size of the center dot is similar to what is described here but see the Coded Targets section, *Target Size and Appearance* to verify your sizing. Note also that the sizes computed below are diameters where Coded Targets uses radius. They differ just by a factor of two.

The sub-pixel marker will accept a target down to five pixels in diameter in the digital image, provided they are very high contrast (eg retro-reflective). However if you do not take into account targets that appear in the distance, and/or the camera angles, you may end up with background targets that are too small to be marked. For good accuracy you will usually want the target to be eight or more pixels across, and higher if the images are ‘noisy’ (ie contain high contrast items that are not targets).

The chart below shows typical target size minimus for various target types, for use in the formula below when printing targets.

Target Type	Minimum Target Diameter (in pixels)
High contrast / retro-reflective	6
Circular Targets, naturally lit	10
Coded Targets (center dot portion)	12
Manually Marked (eg Survey targets)	10

You will need to plan how big to make the physical targets. Here is a calculation you can do to get an estimate:

$$\text{Target Diameter} = \text{Minimum Target Diameter in pixels (see chart)} * \text{maxDistance} * \frac{\text{formatSizeWidth}}{(\text{imageSizeWidth} * \text{focalLength})}$$

Where:

- "Minimum Target Diameter in pixels" is from the chart above
- "maxDistance" is the farthest a target will be from the camera
- "formatSize" is the horizontal size of the image format
- "imageSize" is the number of pixels in the image
- "focalLength" is the focal length of the lens.

Making sure your units are consistent, let us do two examples:

I. Laser Printed Targets (naturally lit) on a Building using a Digital camera

- maximum distance from camera: maxDistance = 15m = 15,000mm
- target diameter = 10pixels
- formatSize = 12mm
- focalLength = 15mm
- imageSize = 1200 pixels

therefore minimum target diameter = $10 * 15000 * 12 / (1200 * 15) = 100\text{mm}$. Print out a 16cmx16cm black area with a 10cm diameter white circle in center for the target. Note this is really the smallest the target should be and if you can use bigger targets, do so.

II. Removable coded targets on a Car using a Film Camera and PhotoCD

- maximum distance from camera: maxDistance = 7m = 7,000mm
- target diameter = 12pixels
- formatSize = 36mm
- focalLength = 50mm
- imageSize = 3600 pixels

therefore minimum target diameter = $12 * 7000 * 36 / (3600 * 50) = 16.8\text{mm}$. So print coded targets such that the center circular dot is 16.8mm (using contrasting color to the car).

Note: The suggested sizes shown are starting points. You might find for highest accuracy you need the targets to be a bit larger than shown here. When a target is viewed at a shallow angle it will need to be bigger to be marked correctly. The numbers above are for targets that are perpendicular to the camera. For this reason, erring a bit on the larger size might be advisable.

Sub-pixel Accuracy

The sub-pixel circular target marker is accurate to 0.05 of a pixel for very high-contrast, low-noise circular targets down to about 1 pixel accuracy for lower-contrast, noisier targets. Generally the LSM method is more accurate and especially on small targets.

The actual final improvement in the accuracy of your project is hard to determine because it depends on the number of sub-pixel targets, where they are located on the objects, and how well they appear in the images etc. Generally for a project that is mostly circular targets and done with a calibrated camera you can expect from five to twenty times improvement in accuracy. So for a three mega-pixel digital camera you could expect about 1 in 15,000 to 1 in 60,000 accuracy. For a project that is a mix of natural, human-marked points and some sub-pixel points you can expect from two to ten times improvement in accuracy for the sub-pixel marked points.

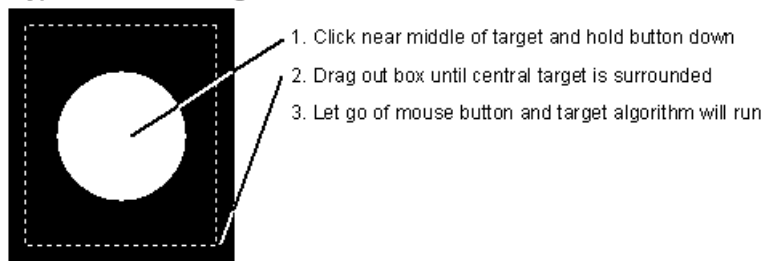
How to use the Sub-pixel Target Marker

There are three methods for manually marking of sub-pixel targets. The first is the Sub-pixel Target Mode found on the Marking menu the second is the Target Mode on the *Imports Explorer Pane*, and the third is the Mark Target mode while Referencing (see *Reference Mode and Pane*). The Sub-pixel Target Mode is described here but much of this applies to how target marking in other modes works also.

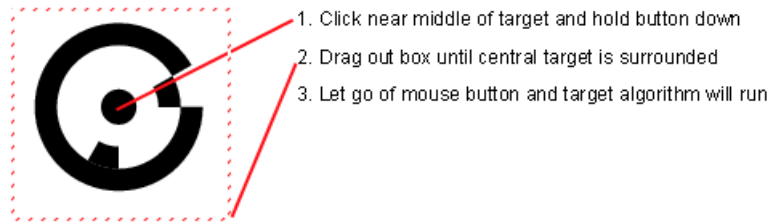
When in Sub-pixel Target Mode the marking cursors will look different.

To use these sub-pixel tools, click down near the center of the circular target in the image and while still holding the mouse button down, drag the centered box out until the target and its surrounding background are all enclosed. Try not to enclose too much background clutter as that might confuse the sub-pixel marker. All of the target itself and a bit of background must be enclosed inside the region. When manually marking a coded target, you must enclose the entire code ring in the drag region (note that manual sub-pixel marking of a coded target only works when the *Coded Target* module is installed).

Typical Circular Target



Typical RAD Target



Note that RAD targets can only be detected if you have the *Coded Targets* module installed .

When you let go of the mouse button, the target marker will automatically study the selected area of the image and extract the target boundary. Within the target boundary a weighted centroid calculation is done and the point (marked point or control point) will appear at the computed sub-pixel location. The boundary of the target will also be drawn in red. This boundary will disappear on the next display update unless the Target Areas check box control in the Points section of the *Visibility on Photos* has been turned on. If the boundary seems wrong you can select Edit/Undo and try with a larger or different region. If the boundary seems spiky (not ellipsoid) you do not need to worry as long as the whole target is enclosed inside the red boundary.

Points that have been marked by the sub-pixel tool look different on the photo. The sub-pixel Marked Point (whether done during marking or referencing mode) looks like a plus sign (+) and the sub-pixel Import Point looks like plus sign with a surrounding triangle.

If you select and move a sub-pixel point, it will lose its "sub-pixel" characteristic and turn back into a normal point unless you are using the *re-sub-pixel marking mode*. This also occurs when using the arrow keys on the keyboard for fine marked point adjustments.

During the 3D Processing, points with "sub-pixel" characteristics have a tighter precision set (smaller standard deviation errors). The precision used for these marks is defined on the Preferences Dialog ("Process" page of *Preferences - Processing and Cameras*, "Default Point Standard Deviation" section, "Sub-pixel Targets" fields).

LSM vs Centroid Methods

PhotoModeler automatically decides which of the two sub-pixel markers to use based on a Preference setting ("General" page, "Sub-pixel method threshold size" field). When the detected target has a diameter, in pixels, smaller than this number, LSM is used and conversely if it is larger than this size, centroid method is used. You can force LSM always by making this number very large (300 pixels for instance) or you can force centroid method always by making this number zero.

Note that LSM is used always for Template Targets. Centroid is used for Circular Targets only.

LSM uses an iterative template matching process that is more robust, handles smaller and lower contrast targets better, and tends to be more accurate than the centroid method. The reason it is not used all the time is because it is slower and its speed falls with the square of the size of the target. It can be very slow with big targets and that is why we have the preferences setting described above.

Note: You can set what RGB channel to use for sub-pixel marking using this ini setting (default is 1 which means all sub-pixel marking is done on the green channel for color images):

[General]

SubPixelMarkingColourChannel=1

(where 0=RED, 1 = GREEN, 2 = BLUE, -1 = convert color to grey scale)

Marking in just one channel may improve marking precision because there will be less negative effects of chromatic aberration of the lens. Most digital cameras have more green sensors than red or blue and this is why the green channel is the default.

Re-sub-pixel marking mode

Re-sub-pixel marking mode will allow you to move an existing mark (sub-pixel or regular) and have its location sub-pixel marked again.

1. Pick up the Re-sub-pixel Marking tool, or select "Re-sub-pixel Target Mode" from the Marking menu.

The select point to re-sub-pixel mark cursor will appear when the mouse is over a photograph.

2. Move the dot on the cursor to the mark you want to move, click and hold the left mouse button.

The move point cursor will appear.

3. Drag the dot on the cursor to the location of the target you want to move the point to and release the left mouse button.

The select target region cursor will appear.

4. Move the cursor so the target region selection box encloses the target.

*As with regular **Sub-pixel Target Marking** this will create a sub-pixel point mark.*

Note: When you use the arrow keys on the keyboard for fine marked point adjustment the point will revert to its non-sub-pixel state.

Template Target Marking

Template Target Marking is a type of sub-pixel marking for (typically) non-circular targets. See the **Sub-Pixel Target Marking** section for background on sub-pixel marking and for more detail on Circular Targets.

Like circular targets these Template Targets can be marked, auto-marked, and PMV tracked. The templates can be any arbitrary image, and the targets can appear at arbitrary angles and with arbitrary perspective in the photos. These template targets are marked to sub-pixel precision with an LSM (least squares matching) algorithm.

Types of Template Targets

The program ships with some predefined targets but you can define their own. There are three classes of target: 1) ideal isolated targets, 2) ideal infinite extent targets, and 3) natural targets. Each of these targets has different capabilities and different restrictions.

An ideal target is an abstraction. For example a cross target is defined with perfectly sharp and straight edges although the target will never look like this in a real image. An isolated target is one where the target sits alone with background surrounding it. An infinite extent

target is one where the target is matched to only a part of object and the target will not be surrounded by background (i.e. target's edge(s) extend to the edge of the template image). Natural targets are pieces of imagery as they would look in a real image - they do not have a uniform background but are not infinite in extent.

Templates are defined by a bitmap image file (bmp, tiff, jpeg, etc.) but for the ideal targets a loss-less format like bmp or tiff is preferred. Ideal targets are defined as white targets on a black background. They can be either sense in the photographs (i.e. white targets or black targets).

The different target types are described below and the *Importing Target Templates* section has an image of the examples described.

Ideal Isolated Targets

Ideal isolated targets are defined by templates that are not blurred, have perfect edges, and have a black border of at least one pixel all around the targets in the template image file. These are used to mark isolated targets in photos (that is targets that are surrounded completely by a uniform background). The targets in the photos can be any size and any orientation and they are marked to sub-pixel precision. Distinct targets with a uniform, high contrast background will generally provide better solutions.

The program ships with two cross-shaped ideal isolated targets.

The program ships with two different cross targets to point out an issue to be considered with some types of targets. The ratio of the width of the arms to the length of the arms is important for getting good solutions. Another way to think about it is that the shape of the cross matters but the overall size does not. The target template should have similar arm width to arm length ratio as in used in the project's photographs. For example, a cross with short, thick and stubby arms would not work well if the crosses in the photograph had slender and long cross arms. You can create your own cross template to match the crosses uses in your imagery.

The two provided templates are named "Cross 3/29" and Cross 5/23" to denote the ratio of cross arm width to its length. The Cross 5/23 is a "stubbier" cross as the ratio of the width of its arms to the length of its arms (in this case the height of the whole cross target) is 5 to 23.

When manually marking an Ideal Isolated target, it is important to outline a region around the target that is similar in size proportionally to the border of pixels in the template target. Marking may fail if the region outlined around the target is too tight on the target. It is better to err on a larger region, but it is best to avoid including too much 'noise', or other high contrast shapes.

Ideal Infinite Targets

Ideal infinite-extent targets are defined by templates that are not blurred, have perfect edges, and have no border (that is, at least part of the white target touches the edge of the template image). These are used to mark targets in photos that are part of a larger object and usually do not have a clear surrounding background. These targets are not sized to match the region being marked in the source image but instead they are extended. The pixels at the boundary of the target are replicated at infinitum as needed to match the source region being marked.

The program ships with a survey target (looks like two squares touching at one corner), an edge target, a corner target, and infinite cross. These infinite-extent targets cannot be used in auto-marking or tracking but still make useful tools in manual sub-pixel marking of corners, edges, etc.

When marking an infinite target it is important to choose an area that resembles the target template. If the template is infinite but the object being marked has a boundary the region selected should not include this boundary. For example when marking a survey target only the center portion of the target should be selected, extending to include the outside border of the squares may cause the target marking to fail.

A good use of an infinite target is the infinite cross. This target is well suited to marking grids of lines. In a grid the intersections are not isolated crosses but instead are part of larger lines. The infinite cross template can mark the intersection of these lines to high accuracy.

Natural Targets

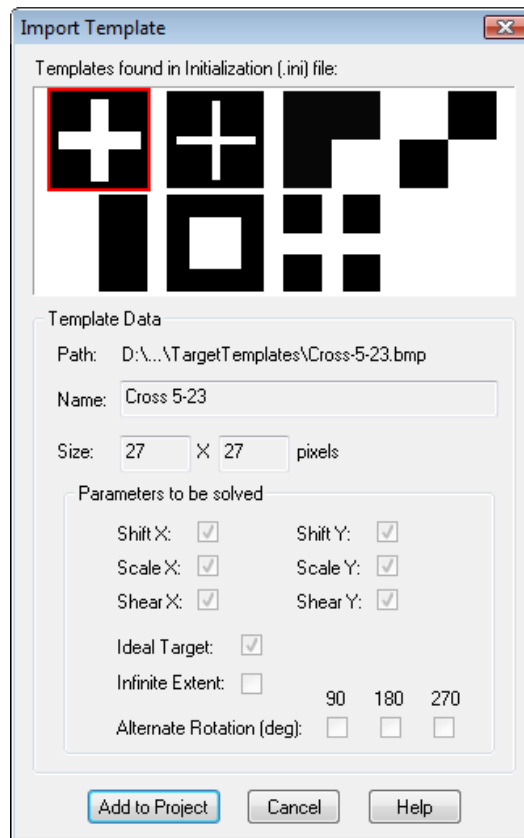
Natural targets are assumed to be already imaged by a typical camera. That is they have blur and maybe a bit of noise. In other words they are not ideal. The program marks natural targets a bit differently as it does not need to solve for the amount of blur nor will it solve for large changes in size from the template. Some rotation, skew and small scale change is solved for but the freedom of orientation may not be the same as with ideal targets. They cannot be auto-marked but they can be tracked in PMV.

How to Use Template Targets

The basic steps for using Template Targets are:

1. Creating your own templates (optional). See *Creating Your Own Target Templates*.
2. Importing one or more templates into the project. See *Importing Target Templates*.
3. Define the template parameters. See *Defining Target Templates*.
4. Mark the targets with manual sub-pixel marking (see *Marking Template Targets*), or automatic marking (see *Automatic Target Marking*).

Importing Target Templates



The Import Target Template Dialog is opened by clicking the “Import Template...” button on the *Defining Target Templates* dialog.

This dialog shows template images and their parameters as defined in the program’s .ini file. Note that none of these parameters can be edited on this dialog. They are shown for reference only.

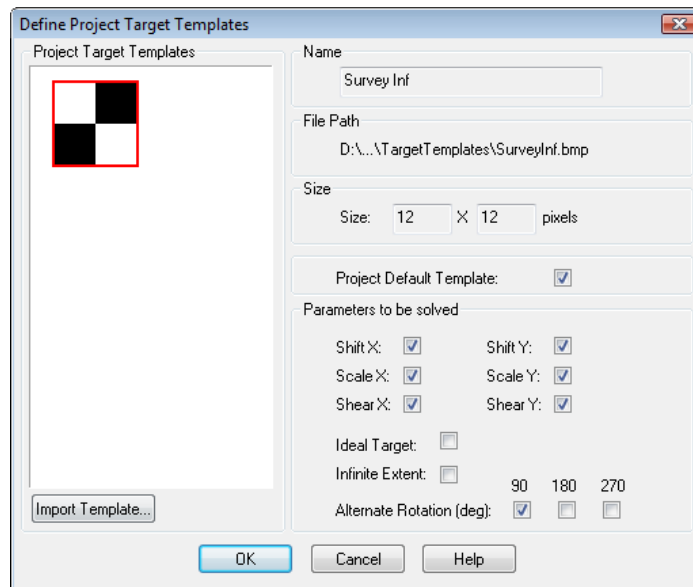
To import a template into a project, select a template image and click “Add to Project”.

Also note that if the correct image path is not defined, the template’s image cannot be shown (a blank image saying “No image on disk” will be displayed in its place). You will not be able to import a template without a valid template image. A warning will appear when you click “Add to Project” if your image is invalid.

Target Templates are identified in PhotoModeler (i.e. on the Toolbar and in the *Automatic Target Marking* dialog) by the name as defined in the .ini file. Therefore, a Target Template’s name must be unique so that it can be differentiated.

Once a valid template is imported into your project, it becomes the default template and can be used for sub-pixel template target marking. It will remain the default template until another template is imported, or a template is selected on the Sub-Pixel Marking Mode sub-toolbar (see *Marking Template Targets*).

Defining Target Templates



The Define Target Templates Dialog is brought up by the Define Targets... tool. The dialog shows all target templates loaded in a project.

Note: This is an advanced tool and is not visible on the toolbar or menu until you customize your toolbars and add it manually (see [Toolbar Customization](#)). The tool can be added to a toolbar from the Customize dialog by clicking the “Commands” tab, selecting the “Template Targets” category, then dragging the tool from the “Commands” window onto a toolbar or into a menu. Once the tool has been added, close the Customize dialog and click it to add Templates to your project.

When this dialog is opened, no templates will appear until one or more templates are imported into a project. The Import Template dialog can be accessed by clicking “Import Template...” button. Once imported, templates are stored with the project and they do not need to be redefined or re-imported when the project is re-opened.

At the top of the dialog are the template images (note these images are resized for viewing purposes to be the same height within the viewing area). When a template is selected at the top, its parameters are shown below. First the file name and path of the bitmap file that defines the template is shown beside “Template Path”. The name of the template is listed next (this is the name the user picks when choosing which target type to mark in the drop lists). Next is the size of the template bitmap image in pixels. The box at the bottom shows some parameters for each template relating to how it is solved.

These parameters control how the marking algorithm adjusts or warps the template when matching a target in the photo:

- The Default Template setting controls whether the selected template is the default. The default template will be automatically selected in the Sub-Pixel Marking Mode sub-toolbar drop list, or the drop list in the Auto-marking dialog. Once a template is imported, it automatically becomes the default template, but a template’s default setting can be toggled on and off. If no template is set as the default, Circular Target [non-template] will be used automatically.

- The two “Shift” parameters control whether the template is shifted/moved in the X and Y directions within the target marking region;
- The two “Scale” parameters control whether the template is scaled/sized in the X and Y directions within the target marking region;
- The two “Shear” parameters control whether the template is skewed in the X and Y direction within the target marking region.
- Ideal Target – this indicates the target is defined as ‘ideal’ and during the marking process the amount of blur in the source target gets solved (this increases the accuracy significantly).
- Infinite Extent –this indicates the target is not to be sized and the border pixels repeat ad infinitum. Infinite Extent targets cannot be auto-marked or tracked in PMV.
- The “Alternate Rotation” parameters control whether the template is rotated if a marking attempt fails (e.g. if marking fails, the template is rotated X degrees and a match is reattempted – this is repeated after each failure for each of the selected rotation parameters). This is useful in that it allows a single template to be used in any orientation (e.g. an edge could be left, right, up or down facing and still be marked using a single template).

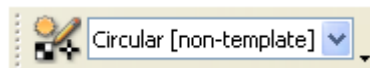
Some target shapes do not need to solve for all parameters. For example the Infinite Edge does not solve for any parameters in the direction of the infinite shape (e.g. the Y direction on a non-rotated infinite vertical edge template) because its shape does not change if you adjust it (i.e. scale or shift) in the Y direction.

Note that these settings (other than Name and Filename) can be edited from within the program in the “Define Project Target Templates” dialog box. This is useful if you need to adjust a setting to help improve marking results.

The above parameters are optimally set for the targets that ship with the product. If you add your own template and are not sure which parameters are correct please contact Technical Support for assistance.

Marking Template Targets

Template targets can be marked with the manual sub-pixel marker. When the user enters sub-pixel marking mode (Edit Menu/‘Sub-pixel Target Mode’ or the ‘Sub-pixel Target Mode’ toolbar button) the Target Sub-toolbar may appear. Note that it only appears if at least one Template Target has been imported.



A setting on the Preferences dialog (Target Marking page of *Preferences - Marking and Referencing*) controls whether this toolbar appears if at least one template has been imported. If this toolbar is not visible, and a template has been defined as the ‘default’ template, the default template will be used when target marking (see Define Project Target Templates dialog for information on the Default template). If no default template has been set, the traditional circular target marker will be used when marking.

The first target type in the list is the Circular Target (non-template). This is the proven method for marking isolated circular targets. The other templates (once they are imported) are in the drop list, and their names correspond to the names shown in the Define Project Target Templates dialog. The target type is selected in this list before marking. Note that the default template will be automatically selected. Once a template is selected in the drop

list, it becomes the 'default template'. The default template can also be set on the Define Project Target Templates dialog.

Marking a template target is similar to manual circular target marking as described in the Sub-Pixel Marking section. Click the cursor down in the center of the target area and drag out the box to surround the target. Release the mouse button to have the target sub-pixel marked. For more complex target types (e.g. cross) a better match is usually found when the first click (i.e. the mouse down) occurs inside the cross region, and the region selected adequately surrounds the target (i.e. includes enough background around the target).

For infinite extent targets, only the area to be matched should be selected (i.e. the target region should not be extended beyond the edge of the target in the image in whatever direction the target's is 'infinite'). For example, with an edge template, outline that region of the edge the matcher is to study.

Some Considerations in Template Target Marking

The process of marking a template target is fairly complex, has its limitations and cannot be used in every project. Limiting factors include:

- The amount of 'noise' in an image. Competing, relatively high contrast artifacts on or around a target can confuse the template target marker, especially when trying to mark idealized targets. Best results will be achieved when targets are very distinct on a clean background.
- The amount of distortion of a target. Although the target marker is robust enough to compensate for targets that are distorted due to perspective, if the target is too distorted, the target marker will have trouble matching the shape with the template.
- Target size variances. The target marker will compensate for changes in target size due to perspective. However, if the target size varies too much between images, target marking may not be consistent. It is best to use templates of a size that will at least somewhat resemble the target sizes in your image.

The *Targets - Do's and Don't's* section mainly refers to circular target marking, but also has information that applies to template target marking.

Creating Your Own Target Templates

There are two steps to adding a target template to PhotoModeler. First the template image must be created in an image editing program. Next the template must be described in terms of a series of settings, which are stored in the programs initialization file (see *Application Data and File Locations* for information on where the ini file is stored on disk).

Creating the Template Image

For most accurate marking results, the template image should have the following characteristics:

- Square N by N pixels
- Centered. If the template image has an odd number of pixels in width and height, the center pixel of the target should be at $\text{width}/2 - 0.5$, $\text{height}/2 - 0.5$. If the template has an even number of pixels, there will be no center pixel and so the target center should be at $\text{width}/2$, $\text{height}/2$.
- White target (value 255) on a black background (value 0), if the target is "ideal".

- Sized proportionally to the targets appearing in your project.

The templates that are installed with the program can be used as a guide for creating other templates. Template images can be any image format that is compatible with the program although a .bmp or .tif file works best for 'ideal' targets.

Describing the Template Image

Each template needs to be described in the program's .ini file in terms of a series of settings. Changing or adding settings requires that you open the file in a text editor and add/edit the settings manually (see *Application Data and File Locations* for information on where the ini file is stored on disk). The ini file will already have the default installed template settings near the end of the file. Each template must have the following settings (note that punctuation and spelling must match):

```
[TargetTemplate_1]
Filename = Cross-5-23.bmp
Name =Cross 5/23
ShiftX =1
ShiftY =1
ScaleX =1
ScaleY =1
ShearX =1
ShearY =1
IdealTarget =1
InfiniteExtent =0
Rotate90=0
Rotate180=0
Rotate270=0
```


The heading for each template is in square brackets. Each template must be numbered in sequence with the last template number equaling the "NumTemplates" setting in the [TargetTemplates] section. These settings correspond to the settings shown on the Define Project Target Templates dialog box (described above) and can be edited there (except for the Filename and Name), but you must first add these settings to the ini file so that the program can locate them on your hard drive and set them up for importing into the project. Note that a template must have a unique name; duplicate named templates cannot be used as they will not be distinguishable on the toolbar. A warning will appear when defining the template if you have duplicate names, and you will be forced to redefine the name in the ini file.

Edges

Edges are created, deleted and modified by manipulating Edge Marks. In other words they are not directly accessible.

Marking Edges

To mark an Edge on a photograph:

1. Pick up the Edge Marking tool  , or select "Mark Edges" from the Marking menu.
The Edge cursor will appear when the mouse is over a photograph .
2. Move the dot on the cursor to a place on the edge and click the left mouse button.
An Edge Point will be placed on the photo and a dynamic line will extend from it to the cursor.
3. Move the dot on the cursor to another point on the edge and click the left mouse button.
The Edge Mark will be drawn.

Note that when marking Edges you are marking along a linear feature in a photograph and you should not be marking sharply defined features that are easily seen in other photos (use Marked Points for that). The key here is when you reference an Edge between photos, their end points do not need to match.

Editing Edges

The editing operations you can carry out on an Edge Mark are:

- move the two end points, or
- delete it.

Moving the end points of an Edge is very similar to moving a Marked Point. The only difference is that the Edge Mark will follow the cursor as a dynamic line during the move. See the section above for more detail.

Deleting an Edge Mark involve selecting the mark, and pressing the delete key. See the Marked Point Delete section for more detail.

Edge troubleshooting

If the Edges you have drawn and referenced (or constrained) are not appearing in the 3D Viewer or in a 3D Export then some of the requirements may not have been met. See the following sections for more information: in the Troubleshooting chapter - *A Curve or an Edge does not appear 3D* or in the Quick Start Guide section - Photography for Curves, Edges and Cylinders.

Curves

There are two forms of NURBS Curve. The first is a 3D object created by marking and referencing Curve Marks. . The second is *Curve from Points*.

Curve from Marks

One method for creating 3D curves is by marking and referencing Curve Marks on Photographs.

Marking Curves

To mark a curve on a photograph:

1. Pick the Curve mode tool from the toolbar:

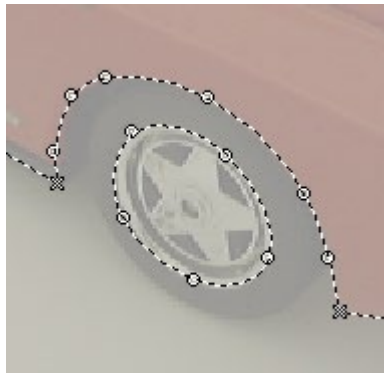


C The application will go into NURBS Curve marking mode and the cursor will change.

2. Click the mouse at the start of the curve. For an open curve (where first and last point in curve are different) you should click on a Marked Point (to be referenced an open curve must share a common Marked Point). For a closed curve you can start at any location.

A curve point will be placed on the photo or if you clicked on an existing Marked Point, no new point will be placed. A dynamic line will connect the first point to the cursor.

3. Move the cursor a short distance along the curve and mark a second point.
4. A curve point will be placed on the photo, a line will be drawn between the first and second point and a dynamic curved line through the first two points and the cursor will appear.
5. Move along the curve in the photograph placing points so that the curve mark (and dynamic curve line) line up with the curve in the photo. The better the line matches the curve data in the photo the better the results will be. In other words, you need to make sure that not only do the points you place lie on the curve in the photo but the curved spline drawn between the points must also lie on the photographic curve.
6. When the curve is complete, you can mark the last point as a curve point, on top of a Marked Point, or join to the first point in the curve to make a closed curve. A curve can also be closed by using the right-click menu "Close curve" item. See the [Curve Properties](#) section for more information on open vs closed curves.
7. The curve drawing will stop automatically if you close the curve, otherwise you click the right mouse button to bring up the menu and pick "End Draw" to end the current curve. The ESC key will also end curve drawing at the last marked point.



Examples of an Open Curve (top curve)
and a Closed Curve (curve on the wheel rim)

Editing Curves

The editing operations you can carry out on a Curve Mark are:


- move any point,
- add a new point,

- delete a point,
- remove a Marked Point, or
- delete it.

To Change Curve Shape by Moving Points

1. Go into Select mode (arrow cursor).
2. Place the tip of the arrow cursor over a Curve Point and click the left mouse button and hold it down.
3. Drag the mouse watching the shape of the dynamic spline line. You can drag the point along the curve or perpendicular to it. When the mark has achieved the desired shape release the mouse button.

To Extend an Existing Curve


1. Go into Curve mode .
2. Move the dot in the curve cursor over one end point of an open Curve Mark and click the left mouse button (as you would when starting a new curve).

If the curve is referenced and this is the common shared point among the referenced curves you will not be allowed to do the extension. Otherwise a menu will appear with these options: "Extend curve from selected point", "New curve starting with selected point", and "Cancel".

3. If you choose "Extend..." the existing curve will be added to as if you were continuing to draw the existing curve.
4. If you choose "New curve..." a new curve will start with a new point (not shared with other curve) that is at same x,y as the clicked on point.
5. End the new curve draw or extend as you would a new curve draw.

Note that if the point clicked on to perform the extend is part of two curves the *Which Curve Dialog* will appear. You pick the curve and that curve will be the one extended.

To Change Curve Shape by Adding Points

1. Go into Curve mode .
2. Move the dot in the curve cursor over a Curve Mark. Place the cursor approximately where you want the new point inserted (any location between the start and end point of the curve but not close to the ends (or that would be an "extend" as described above)).
3. Click on the right mouse button.

The Curve Right Menu will appear.

4. Pick "Insert point in curve".

A point will be inserted in the curve at the current mouse position temporarily. Move the mouse until the curve achieves the desired shape.

5. Click the left mouse button.

A new curve point will be drawn at the location of the mouse and will be added to the curve. Note that you can click on an existing Marked Point and that Marked Point will be added to the curve. A curve can have Marked Points at any location (not just the two ends).

To Change Curve Shape by Deleting Curve Points


1. Go into Select mode (arrow cursor).
2. Place the tip of the arrow cursor over a Curve Point and click the left mouse button to select the point.

The curve point will highlight.

3. Press the Delete key on the keyboard or use the "Delete Selected Items" menu under the main Edit menu.

The curve point will delete and the curve will redraw to take that into account. Note you can also use the right-click menu and use "Remove point from curve".

To Change Curve Shape by Removing Marked Points

1. Go into Curve mode .
2. Move the dot in the curve cursor over a Marked Point that is part of a Curve.
3. Click on the right mouse button.

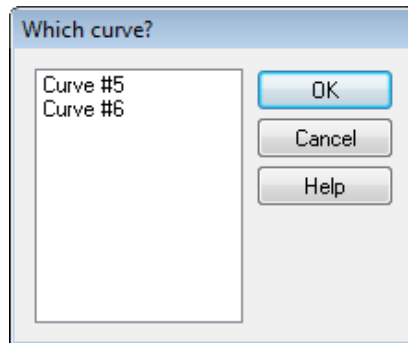
The Curve Right Menu will appear.

4. Pick the "Remove point from curve" entry.

The Marked Point will not be deleted but will be removed from the curve. The curve will redraw to take that into account.

Note that if a point being removed is part of two curves the *Which Curve Dialog* will appear. You pick the curve and the point is removed from that curve only.

Which Curve Dialog



This dialog appears automatically in these situations:
when removing a point that belongs to two or more curves
when extending a curve from a point that exists in two or more curves.

You simply pick the curve you want by its ID and press OK. The particular operation then continues. You can see Curve ID's by selecting a Curve Mark and looking at the *Status Bars*.

Deleting a Curve Mark

1. Go into Select mode (arrow cursor).
2. Place the tip of the arrow cursor over a Curve Mark but not over a Curve Point and click the left mouse button to select the Mark (selecting Curve Mark is different than selecting a Curve Point).

The Curve Mark will highlight.

3. Press the Delete key on the keyboard and the Curve Mark and all its Curve Points will delete.

Curve troubleshooting

If the Curves you have drawn and referenced are not appearing, in whole or in part, in the 3D Viewer or in a 3D Export then some of the requirements may not have been met. See the following sections for more information: in the Troubleshooting chapter- *A Curve or an Edge does not appear 3D* or in the Quick Start Guide section - Photography for Curves, Edges and Cylinders.

Curve from Points

One method for creating 3D curves is by joining a number of 3D Object Points using the "Curve from Points" mode.

To create a Curve from Points:

1. Open a photograph or 3D view window that shows all the Object Points you want the curve to pass through.
2. Go into Curve from Points mode.
3. Select the points in order that the curve should pass through. At least two points must be selected for the curve to be created. It is a good idea to have a 3D Viewer open or projections turned on so you can see the curve being created.

If a Curve from Points is draw between two points it is a linear curve (degree 1) (i.e. a line), if between three points it is a quadratic curve (degree 2) and for four or more points it is a cubic curve (degree 3).

Curves created with this method are pure 3D objects (much like Surfaces) and in this fashion do not appear on photographs. They appear in the 3D Viewer and in photo projections when they are properly defined. They are also listed in the Curve Table. In a Curve Table they are shown with no photographs.

If any of the points in this type of Curve lose their 3D position the Curve will reinterpolate though the remaining 3D points. When the point positions update the Curve will be reinterpolated to pass through them.

Cylinders

Cylinders are created, deleted and modified by manipulating Cylinder Marks. In other words they are not directly accessible.

Marking Cylinders

Marking most curved surfaces in PhotoModeler requires that the surfaces have targets placed on them before the photography. This requirement makes modeling a large number of cylindrical pipes and vessels cumbersome.

PhotoModeler has an advanced algorithm for determining the position, orientation and diameter of a cylinder/pipe given edge markings in two or more oriented and solved photographs without any targets.

To mark cylinders:

1. Open one or more photographs that show cylinders you wish to model.
2. Go into cylinder marking mode by either selecting "Mark Cylinders" from the Marking menu or selecting the cylinder toolbar button.

The cylinder marking cursor will appear to show you are in Cylinder Marking mode.

3. Find the cylinder you wish to mark and click down on the edge between the cylinder and its background.

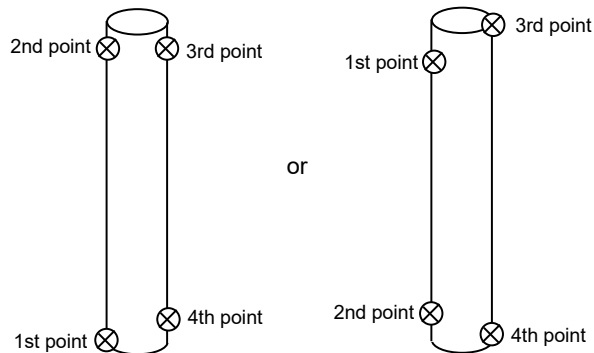
One cylinder point will be drawn and you will get a rubber band line.

4. Mark a point along this same edge of the cylinder as far down the cylinder as you can see in this photograph (or as far as you want to model).

The second cylinder point will draw and the rubber-band line will disappear.

5. Mark a point anywhere along the second edge of the cylinder and then similarly a point further along the same edge.

The order you mark the cylinder points does not matter as long as the first two points are on one edge and the second two points are on the other.



Editing Cylinders

The editing operations you can carry out on a Cylinder Mark are:

- move any of the four end points, or
- delete it.

Changing the position of a Cylinder Mark is very similar to editing an Edge Mark. You select and drag any of the four end points and then release the mouse button. During the drag you will see just the one curve edge being dynamically drawn.


To delete a Cylinder Mark you select it and press the Delete key.

Lines

Creating Lines

Lines are used to join Object Points. When marking on a photograph you can create lines and Marked Points simultaneously. Lines can be created in photographs, 3D Viewers or Point Tables.

To create a line in a photograph:

1. Pick up the Line Marking tool , or select "Mark Lines" from the Marking menu.
2. Click this tool on the location to be marked for the start of the line.
A Marked Point symbol will appear at the location marked. A temporary line is drawn, from the current mouse location, to the Marked Point symbol that was marked.
3. Move the mouse to the location of the second point of the line.
4. The temporary line will follow the movement of the mouse.
5. Click the line tool on the location of the second point.
A second Marked Point symbol will appear. A permanent dotted line will be drawn between the first and second Marked Points. A new temporary line will be drawn, from the second Marked Point, to the current mouse location.
6. Repeat steps 3 and 4.
PhotoModeler will continue to create connected lines and new Marked Points.
7. Click the right mouse button to bring up the menu and choose "End Draw", or press the ESC key, when all of the connected lines have been marked.

When using the Line Marking tool, line connections as well as points are recorded. Choosing "Undo" from the Edit Menu after a multi-point line has been drawn, undoes the whole line with all its points, not just the last point of the line.

The temporary line drawn during line marking disappears when the cursor leaves the photograph window. When the cursor is outside the window, you can scroll, move and resize the window and then return to marking the same line just by putting the cursor back inside the window.

Note: If the Line Marking tool is clicked on or close to an existing Marked Point symbol, the line end is "snapped" to that Marked Point and a new Marked Point is **not** created. Also, if a line is drawn on top of an existing line, a new line is **not** created.

See also *Marking Points*.

Creating Lines using 3D Viewer or Point Table

To create lines from existing points using the 3D Viewer or Point Table, use the Line tool as with photographs and just click on the points visible in either type of window. You can draw lines between points in one type of window or between window types. I.e., start the

line drawing in a photograph, continue with point in a Point Table and then finish on a 3D Viewer.

Note: Line drawing is a continuous mode that keeps on adding line segments for every point you click on. In a photograph you get out of this mode by either hitting right mouse (and picking End Draw from the menu) , by hitting ESC key or by going into a different mode. In the 3D Viewer and the Point Table, the right mouse button option is not available. So to stop drawing lines and to start a new set of lines, press the ESC key.

Deleting Lines

To delete a line, open the photograph containing the line you wish to delete. Make this photograph the active photograph.

To delete a line from a photograph:

1. Pick up the Select tool from the toolbar or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Click the mouse on the line you would like to delete.

The line you select becomes highlighted. If you would like to delete more than one line, hold down the shift key to extend your selection, and click on additional lines. Box selection can also be used.

3. Select "Delete" from the Edit menu, or press the "Delete" key on your keyboard.

PhotoModeler will remove the selected line or lines from all of your photographs. PhotoModeler will not delete the end points of these lines.

To reverse the deletion of a line, select "Undo" from the Edit menu. PhotoModeler will replace the deleted line or lines. Only the last delete operation may be reversed. To redo the delete operation, select "Undo" again.

Note: if you have many lines to delete and you do not want to delete any other points or features you can use the *Visibility Settings* to turn off all items but lines. This makes selection and deleting easier.

Surfaces

The sections below describe how to create the different types of surfaces, how to delete them, how to modify and how to use Surface Draw.

Creating Surfaces

A surface is described by a set of defining objects: multiple points, edges and/or curves. In this sense they are not "marked" but instead "created" from existing objects.

Note: unlike all other object types surfaces are never displayed in a "marked" form on photographs. They are only visible on the surface table, or if they have sufficient defining objects and are able to calculate their 3D shape, they will be visible in the 3D viewer and projections.

Surfaces are required for texture extraction, ortho-photo production, surface drawing and for export to external rendering and animation packages that expect 3D faces, meshes or NURBS surfaces.


Surfaces can be created in eight different ways:

- the path tool
- the triangle tool
- the boundary patch tool
- the loft tool
- the sweep tool
- the revolution tool
- the cone tool
- silhouettes
- the Fit NURBS Surface to Selected Points action

The objects needed to define a surface depend on what type of surface is being created, outlined in the following table:

Surface Type	Minimum objects need to create
Path	3 points, 1 point and a line or an edge, 2 lines or edges, or 1 curve
Triangle	3 points or 1 point and a line or an edge
Boundary patch	2 curves, lines or edges
Loft	2 objects - curves, lines or edges
Sweep	2 objects - curves, lines or edges
Revolution	1 curve, line or edge and 1 line or 1 cylinder
Cone	1 point and 1 curve (open or closed)
Silhouette	2 referenced silhouette marks
Fit NURBS Surface	Minimum of approx. 20 points but depends on the point positions.

To create a Path Surface:

1. Switch into Path Surface Creation mode by pressing the Path Mode Tool  or by selecting "Path Mode" from the Surfaces sub-menu.

The cursor will change to the path surface cursor.

2. Determine what order you will select the points and objects (marked points, object points, lines, edge marks, edges, curve marks, or curves). You will need to make sure the path you define does not cross over itself and will close properly.
3. Select the first object of the path from a photo, 3D view or table.

The selected object will highlight. Note: since by definition a close curve is closed path it can be the only object in a path. Selecting a closed curve will automatically create a path surface using the curve as the defining path.

4. Select the second object of the path from a photo, 3D view or table.

The second object will highlight and a path will be drawn on any open photographs with marks for all items in the path. If the selected objects are 3D and the minimum requirements for a path are met the surface will also display in 3D.

If the line, edge or curve you select is not added to the path in the direction you need you can use the "Reverse Last Object" command, located on the Surface sub-menu, to reverse it.

5. Continue with selecting objects to complete the path.


If you make a mistake when selecting the path if you click on the last object in the path it will be remove from the path.

6. When you are finished you can either click back on the first object in the path, or you can select "Finish Surface" from the right-click or surface menu.

The path outline displayed on any open photos will erase and the surface be added to the project.

Note: the direction a path faces is determined by the direction (clockwise or counter-clockwise) its path is selected. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

To create a Triangle Surface:

1. Switch into Triangle Surface Creation mode by pressing the Triangle Mode Tool  or by selecting "Triangle Mode" from the Surfaces sub-menu.

The cursor will change to the triangle surface cursor.

2. Select the first object (mark point, object point, line, edge mark or edge) of the triangle from a photo, 3D view or table.

The selected object will highlight.

3. Select the second object of the triangle from a photo, 3D view or table.

The second object will highlight and a path will be drawn on any open photographs with marks for all items in the triangle. Once you have selected the minimum objects required to form a triangle the surface will automatically finish.

4. Continue with selecting objects to complete the triangle.

To create a Boundary Patch Surface:

1. Switch into Boundary Patch Surface Creation mode by pressing the tool or by selecting "Boundary Patch Mode" from the Surfaces sub-menu. Note that the boundary patch is similar to the Path Surface but it a) is always a NURBS surface, b) takes only 2 to 4 objects in the path/boundary, and c) creates a bilinear Coons patch.

The cursor will change to the boundary patch surface cursor.

2. Select the first object of the path from a photo, 3D view or table.

The selected object will highlight.

3. Select the second object of the path from a photo, 3D view or table.

The second object will highlight and a path will be drawn on any open photographs with marks for all items in the path. If the selected objects are 3D and the minimum requirements for a path are met the surface will also display in 3D.

If the line, edge or curve you select is not added to the path in the direction you need you can use the "Reverse Last Object" command, located on the Surface sub-menu, to reverse it.

4. Continue with selecting objects to complete the path. Four boundary curves is the maximum. If four are chosen the curves and lines much meet at their corners at common points.


5. Depending on the number of objects chosen the path will close automatically and the boundary patch will be created or if selecting fewer than four boundary objects you can select "Finish Surface" from the right-click or surface menu.

The path outline displayed on any open photos will erase and the surface be added to the project.

Note 1: since by definition a close curve is closed path it cannot be used in a boundary patch.

Note 2: the direction a boundary patch faces is determined by the direction (clockwise or counter-clockwise) its path is selected. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

To create a Loft Surface:

1. Switch into Loft Surface Creation mode by pressing the Loft Mode Tool  or by selecting "Loft Mode" from the Surfaces sub-menu.


The cursor will change to the loft surface cursor.

2. Select the first object to loft through from a photo, 3D view or table. Object types that can be used to define a loft are curves, lines and edges.

The selected object will highlight.

3. Select the second object to loft through from a photo, 3D view or table.

The second object will highlight and if the selected objects are 3D the surface will be displayed in 3D.

If the line, edge or curve you select is not added to the loft in the direction you need you can use the "Reverse Last Object" tool , located on the Surface sub-menu, to reverse it.

4. Continue with selecting objects to complete the path.

As you select more objects for the loft if they are 3D they surface being created will update.

Note: if you make a mistake when selecting the objects to loft through if you click on the last object in the loft it will be remove from the loft.

5. When you are finished you can either select "Finish Surface" from the right-click or surface menu, or to close the loft you can click back on the first object in the loft or select "Close Surface" from the right click or surface menu.

Note: the direction a loft faces is determined by the direction of the objects being lofted through. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

Also note that if you are lofting through curves, the way a curve has been defined will affect how the surface will look, especially when using closed curves. For a smooth loft surface, try to define your curves such that the curve starting points are aligned, and that all curves are defined in the same order and direction. This helps with the surface calculation, starting from the start points of each defining curve.

To create a Sweep Surface:

1. Switch into Sweep Surface Creation mode by pressing the Sweep Mode Tool or by selecting "Sweep Mode" from the Surfaces sub-menu.

The cursor will change to the sweep surface cursor.


2. Select the object to be 'swept' (sometimes called the section or cross-section curve) from a photo, 3D view or table. Object types that can be used in a sweep are curves, lines and edges.

The selected object will highlight. The closest end point of this object will be moved to the start of the next object selected and 'dragged' or 'swept' along it to define a surface. Note: if you do not want to use the closest end point as the connecting end of the two objects you can use the "Reverse Last Object" command, from the Surface sub-menu, and the opposite end will be used.

3. Select the object to sweep along (sometimes called the rail or trajectory curve) from a photo, 3D view or table.

The second object will highlight and the surface will be created. Note: the direction a sweep faces is determined by the direction of the objects being swept along. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

To create a Surface of Revolution:

1. Switch into Revolution Surface Creation mode by pressing the Revolution Mode Tool  or by selecting "Revolution Mode" from the Surfaces sub-menu.

The cursor will change to the revolution surface cursor.

2. Select the object to be revolved from a photo, 3D view or table. Object types that can be revolved are curves, lines and edges.

The selected object will highlight.


3. Select the object (axis) to revolve around from a photo, 3D view or table. Object types that can be revolved around are lines, edges and cylinders.

The second object will highlight and the surface will be created.

Note 1: by default the object is revolved 360 degrees around the axis. This can be adjusted on the properties dialog of the revolution.

Note 2: the direction a revolution faces is determined by the direction of the object being revolved. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

To create a Cone Surface:

1. Switch into Cone Surface Creation mode by pressing the Cone Mode Tool  or by selecting "Cone Mode" from the Surfaces sub-menu.

The cursor will change to the cone surface cursor.

2. Select the end point or the base curve of the cone.

The selected object will highlight. Note: The base curve of a cone does not have to be closed using an open curve will create an 'open' cone.


3. Select the opposite end of the cone (i.e. if you selected a point first, now select a curve. If you had selected a curve now select a point).

The second object will highlight and the surface will be created. Note: the direction a cone faces is determined by the direction of the curve being used. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

Note 1: at any time during surface creation you can abort the surface by selecting "Cancel Surface" from the right-click or surface menus, or by pressing [esc].

Note 2: Object selection behaves differently during surface creation. Multiple objects can be selected without using the shift key to extend your selection. Selection highlights are cleared after each surface is created.

To create a Fit NURBS Surface:

1. Using select mode select the points used to define the point cloud from photos, 3D viewers or tables. Often region select is a useful tool for this.
2. Choose "Fit NURBS Surface from Selected Points" from the Surface sub menu or the Fit NURBS Surface Tool .

The surface will be created. The number of spans used to create the surface can be controlled on its properties dialog. When more spans added the surface will fit to the points better, but will be less smooth..

Note 1: Fit NURBS Surfaces have an automatic trim created from their outer bounding points and are automatically extended by 2% to ensure the outer bound trim lies on the surface.

Note 2: the direction the surface faces is determined by the order the points are selected. If the surface you create does not face the direction you would like you can use the "Flip Surface(s)" command, located on the surface sub-menu. This command will flip the currently selected or, if no surfaces are selected, the last created Surface. Surfaces also have a "double sided" property that will mean a surface 'faces' in both directions. See [Surface Properties](#).

To create a Silhouette Surface:

A silhouette surface is created from referenced marks and not from 3D objects like other surfaces. You draw a mark that defines the *silhouette* of the object in two or more photographs, and reference the marks together. If the photographs are *oriented* the surface will be computed and can be seen in the 3D Viewer or in Projections.

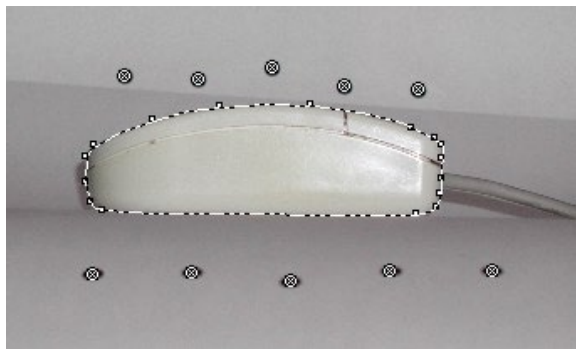
Note that silhouette surfaces are often rough approximations of the true shape of an object. Some objects are well suited to silhouette modeling and others are not. The more complex the surface the more photographs needed to produce a good approximate 3D model with the silhouette method. Also any convex surface cannot be modeled (because it cannot be silhouetted against a background). The advantage of the silhouette method is

that some curves surfaces can be created without targets or without profile curves. It is also quick (for low number of photograph projects).

An example of a two photo silhouette is this mouse. You can see the two views of the mouse and the two silhouette marks.



Top View with silhouette mark



Side View with silhouette mark and point references


You can see in the second photograph there are some circular targets. These were used to setup and orient the two photographs (they are cut off in the top view).

The end result of this simple project (a few minutes work) is this 3D model:



Two 3D Views of Silhouette model of mouse

Steps:

1. Set up the project such that there are enough points to mark and reference (at least six points shared between photos) so that all photographs will orient.
2. Take photographs of the object trying to ensure that every plane of the surface is in a photograph that is perpendicular to that part of the surface. In other words, try to photograph every surface "edge on" in at least one photograph.
3. Start the project with the calibrated camera, load the photographs, do the point marking and referencing, and process the project to orient the photographs. Starting with two or three photographs with the most perpendicular angles is best.
4. Go into silhouette marking mode (toolbar  or menu). Note that you can also import a set of silhouette marks using the *Import Silhouettes* tool (see below).
5. Click down anywhere on the outline of the object (the outline that separates it from its background).
6. Trace out the outline by clicking down points esp. where the outline changes shape quickly.

7. Complete the outline and close by clicking on the start point or by using the right click menu option "Close Curve".
8. Fine tune the curve outline by dragging points (select mode) or by adding and removing points (silhouette mark mode and right click menu). See *Editing Curves* for more information as the operations are very similar.
9. Repeat this process for the other one or two photos to start.
10. Go into Referencing mode and reference the silhouette marks together. You can also use the *Automatic Referencing* tool with silhouettes.
11. Open the 3D Viewer to see the result.
12. Continue to fine tune the marks and also add additional photographs and their silhouette marks until you get the shape you want.
13. Once the silhouette solves and has a 3D position, it can be measured to obtain its volume, and triangulated area using the Measure tool. This data (including the center of mass position) is also shown on the *Silhouette Table*.

Import Silhouettes:

The Silhouette import file(s) can be imported by clicking the "Import Silhouettes" tool. You can select and import one or more silhouette mark text files.

An import text file containing one or more silhouette mark definitions can be selected and the marks will be added to the specified photographs.

The import file must be an ASCII text file in the following format:

```

Number of silhouette marks in file
Silhouette Number (or 'Next')
Photo Number
Number of poly-line segments
Poly-line segment 1 x,y
Poly-line segment 2 x,y
Poly-line segment 3 x,y
...
Silhouette Number (or 'Next')
Photo Number
Number of poly-line segments
Poly-line segment 1 x,y
Poly-line segment 2 x,y
Poly-line segment 3 x,y
...
etc.
```

Lines that start with ; are considered to be comments and are ignored on import. Blank lines are also ignored.

A sample file might look like this:

```

; Number of silhouette marks to add:
3
; id of the first mark to add:
1
; photo to place the first mark on:
```

```

1
; number of x,y points in the first mark:
4
; the x,y points of the first mark:
22,130
106,272
160,150
366,54

;id of the second mark to add:
1
;photo to place the second mark on:
2
;number of x,y positions in the second mark:
5
; the x,y positions of the second mark:
268,444
500,498
1006,450
524,280
386,332

; The third mark (will use the next available silhouette id):
Next
1
4
402.5,234
540,344
700,264.3
548,252

;end of file

```

This sample file would create 3 silhouette marks. The first one numbered 1 on photo 1 would have 4 x,y poly line positions (22,130 106,272 160,150 and 366,54). The second mark would also be for silhouette number 1 (meaning this new mark will be referenced to the first mark created) on photo 2. It will have 5 poly line positions (268,444 500,498 1006,450 524,280 and 386,332). The third mark would be created with the next available silhouette number on photo 1 with 4 x,y poly line positions (402.5,234 540,344 700,264.3 and 548,252). If any of the marks listed in the file conflict with existing marks in the project (e.g. A mark with the specified id already exists on the specified photo) they will not be added.

Deleting Surfaces

To delete a surface, you should open a **3D Viewer**, a **Surface Table** or a photograph that shows the projected surface you wish to delete.

1. Pick up the Select tool from the toolbar or choose "Select Items" from the Edit Menu.

PhotoModeler will change the cursor to the selection cursor.

2. Click the mouse on the surface you want to delete.

The selected surface becomes highlighted. If you want to delete more than one surface, hold down the shift key to extend your selection and click on additional surfaces.

3. Select "Delete" from the Edit menu, or press the "Delete" key on your keyboard.

PhotoModeler will remove the selected surface or surfaces from all views. PhotoModeler will not delete the vertices of this surface.



To reverse the deletion of a surface, select "Undo" from the Edit menu. PhotoModeler will replace the deleted surface or surfaces. Only the last delete operation may be reversed. To redo the delete operation, select "Undo" again.

Note: if you have many surfaces to delete and you do not want to delete any other points or features you can use the Surface Table or using the *Visibility Settings* to turn off all items but projected Surfaces on photographs. This makes selection and deleting easier.

Trims and Holes

You can trim and create holes in surfaces by defining a trim/hole boundary. You can think of these boundaries as cookie cutters applied to the surface. For trims the inside of the cookie cutter is kept, for a hole the outside of the cookie cutter is kept.

To create a trim or hole on a surface:

1. Select the surface you want to trim or add a hole to.
2. Choose "Trim Surface" tool  or "Create hole in surface" tool .

The selected surface becomes highlighted in the alternate highlight color.

3. Select objects to define the outer boundary of the trim or hole.

The objects selected will highlight and if all selected objects display on a photo the boundary outline will be drawn on any open photos. This is similar to creating a Surface Path.

4. When you are finished you can either click back on the first object in the trim/hole, or you can select "Finish Trim" from the right-click.

When the boundary of the trim/hole is 'dropped' on the surface the entire boundary must fall on the surface if it does not the trim/hole will not be applied. Sometimes it is useful to extend a surface before trimming it. Trims can be enabled/disabled and deleted using the Trims & holes setting on *Surface Properties*.

Note 1: surface draw points, lines and curves can be used as the defining objects in a trim. This provides a simple way to create objects to define a trim or hole.

Note 2: you can only apply trims and holes to NURBS surfaces. This means you can not use Path surfaces in polygon form or Silhouettes.

Extend

Surfaces can be extended beyond the edges created by their defining objects using the Extend setting of *Surface Properties*. When the extend equally in all directions option is checked all edges of a surface will be extended. If this is unchecked each edge of a surface can be extended individually. In some cases the extension can not be calculated or the extension can cause the surface to become invalid. When you apply an extension to an existing 3D surface if the surface can no longer calculate its 3D position a warning dialog will appear.

Path surfaces in polygon form and silhouettes cannot be extended.

Note: applying a negative extension will shrink the surface.

Surface Drawing



Surface drawing gives you the ability to create 3D data by marking in only one photograph. This is done by drawing "on" a surface that is 3D. Surface Drawing is useful for drawing/modeling detailed patterns that lie on one plane (such as brick or stone work on the facade of a building). Surface Drawing requires no referencing so detailed patterns and curves are much easier to mark.

Surface Drawing is also useful for drawing curves that lie on planes from a single photograph (such as a skid mark on a road surface).

Surface Drawing requires Surfaces. These Surfaces must project onto an oriented photograph.

You can mark Surface Drawings at any time and they will update automatically when anything changes (such as the orientation of the photo/camera station or the shape of the underlying Surfaces).

To draw on a surface:

1. Make sure you have one or more Surfaces projected in the photograph (they do not need to be visible to be used but you might find it easier if Surface Projections are turned on so the surfaces being drawn on can be seen).
2. Pick up the Surface Draw tool .
3. Decide if you will be drawing straight lines or curves. If curves pick the curve option from the toolbar .
4. Click the first point inside a Surface.
5. Proceed to draw your pattern by drawing Surface Draw points.
6. Whenever you click the right mouse button the menu will appear where you can pick "End Draw" and the line drawing will stop.
7. Once the first point has been drawn inside a Surface, subsequent points in a Surface Draw line can be drawn outside of any Surfaces. These points are called "Extended Surface Draw" points.

Surface Draw points are always assigned to one and only one Surface. It is from this assigned Surface that Surface Drawing computes its 3D planar position. Note that you cannot set a surface draw point's property to "do not use in processing" because a surface draw point's 3D position is based on the surface on which it lies. Individual surface draw points are not used in processing.

Note: if a Surface is in a layer and that layer is set to not be visible then the Surface is not used when doing Surface Drawing. This can be useful if two or more Surfaces appear on top of each other in a photograph where you want to do Surface Draw but on a particular surface.

Surface Draw Curve Differences

The NURBS curves drawn on a surface are similar to the full 3D NURBS curves created with the curve tool and referenced across photographs. They do have some differences

with full 3D Curves and they also have some differences with line-type Surface Draw. Surface Draw Curves:

- cannot be extended,
- cannot go through existing points (Object Points or other Surface Draw Points), and
- because of the method surface draw curves search for their best Surface to associate with, it is recommended that when a curve changes planes at sharp angle that the user place points close to the transition.

Surface Draw Troubleshooting

If you have done Surface Drawing on a photograph that is processed and some or all of the Surface Draw points are not being calculated in 3D (i.e. you cannot measure the points and points/lines do not appear in the 3D Viewer), the problem may be that the assigned Surface may not have a 3D position. Click on the Surfaces defining objects to see if they all have valid positions or use the *Surface Table* to determine if the surface has a 3D position.

Processing Points-Based


To create a 3D model from the Camera and Photograph marking information, PhotoModeler uses a special numerical algorithm. This algorithm uses advanced mathematical techniques to adjust the input data, to create the 3D point data and to minimize errors in order to maximize accuracy.

Processing is an iterative process. It repeats a sequence of steps as many times as necessary to determine the location of each point and edge in three dimensions and to minimize the total error.

Before processing can be started, the following must have been done:

1. Create a project,
2. Add photograph(s) of an object to the project,
3. Mark points on each photograph and reference them to corresponding points on all other photographs, or in a single photo project add Constraints (Axes or Control Points) to the points and edges, and
4. Mark any required fiducials if using a fiducial camera.

Processing is accessed under the "Project Menu" with the menu item called "Process..." or

by using the Process toolbar button . Processing goes through two stages. The first is called an audit and the second is called the adjustment. The audit provides early feedback to the user on how well it is expected the adjustment will proceed. With poor data sets, it is possible that the adjustment will fail and no 3D model will result. The audit stage helps weed out these cases. The auditing function can also be called independently of processing through the "Audit" menu item.

Audit

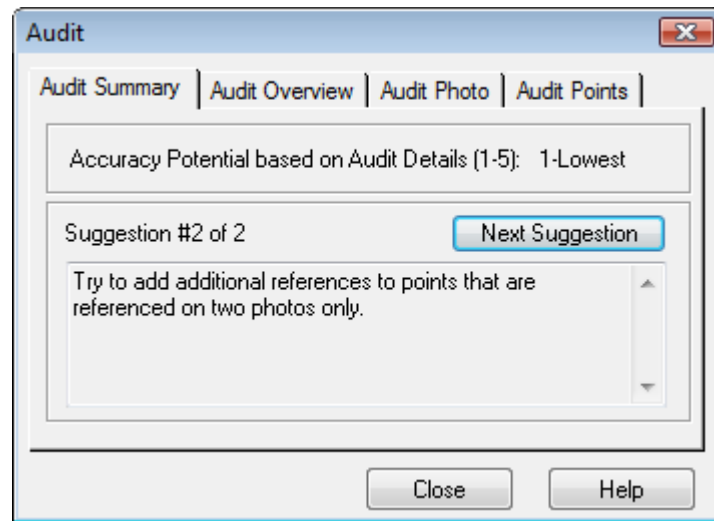
Auditing is the process of reviewing the project data that is important to the generation of the 3D model. The information provided by the Audit step can be instrumental in tracking

down problems and in predicting the success of the processing stage. For identifying error in referencing specific points refer to the *Point Audit* section.

The Audit that is carried out before Processing has two components - Reference Checking and Data Audit. See the *Reference Checker* section for details of the first component. In the Data Audit component PhotoModeler performs a number of calculations with the Camera Station orientations and the marked and referenced points and presents the output in the *Audit Dialog*.

Audit Dialog

The Audit Dialog has four tabs. These tabs are displayed as part of the Audit/Statistics Dialog (Project menu, "Audit/Statistics..." item) and as part of the *Processing Dialog*.



The first tab is the Audit Summary and it provides feedback on how well a project will process. At the top it gives a numeric summary of the potential from 1 to 5 where 1 is the lowest potential for accuracy and 5 is the highest potential for accuracy. Projects that are at level 1 or 2 may still be fine projects for your particular usage. If you want higher accuracy in the project you can try to increase this number (see below).

The bottom part of the dialog shows zero or more suggestions. One suggestion is shown at a time. If there are no suggestions the string will say "No Suggestions", if there is only one suggestion it will display "Suggestion #1 of 1", and if there are N suggestions it will display "Suggestion #1 of N". When there are N suggestions ($N > 1$) you can press the Next Suggestion button to show the next suggestion in the set.

The suggestions are presented as an aid to help you improve the project or to help you get it processed successfully. When there are numerous things wrong with a project (for example, a poorly defined camera and gross referencing errors) the suggestions may start to become misleading. In situations like this PhotoModeler cannot determine the real problem and so makes many suggestions with the hope that it covers the true problem.

One particular suggestion is given by the Reference Checker for potential problems found with referenced points. See the *Reference Checker* section for more detail.

Audit Acceptance

A number of the sub-tabs of the Audit dialog have a column on the right, headed "Acceptable?". It provides feedback from PhotoModeler on what it thinks about the quality of each category. Under "Acceptable?", PhotoModeler places the words "yes", "maybe" or "no". The following table describes what each of these mean:

"Acceptable" Indication	Explanation
yes	This category is acceptable and it should cause no problems in processing.
maybe	This category is marginal and it might cause some problem in processing.
no	This category is not acceptable and it might lead to a bad 3D model or processing that will fail.

The key for the user is to study how many acceptable indications there are of each type. If you scan down the list and see all "yes" entries, then the processing will most probably succeed and a good 3D model will result. If you scan down the list and see all "no" entries, then the processing will most probably fail and if it does succeed, the resulting 3D model will be very poor and inaccurate. If all entries are "maybe", the processing might succeed but the resulting 3D model will be questionable.

When you see a mixture of indications, it is hard to predict what might happen during processing. It is possible to have all "yes" entries, with one "no" entry, and have the processing fail.

If processing does not succeed or the resulting 3D model is poor, the user should take steps to change the "no" entries to "maybe" or "yes" and to change the "maybe" entries to "yes". The section below, called *Fixing Audit Problems*, describes how that can be done.

The auditing process changes the project by flagging points and photographs with quality indications. Choosing Cancel will stop the changes from taking place, choosing OK or Process will leave those changes in place.

The following manual sections describe the Audit Dialog tabs in more detail.

Note: the values shown in the Audit Dialog are affected by the Photograph property "do not use". See *Processing Action* for details.

Audit Overview

Audit Summary		Audit Overview		Audit Photo	Audit Points
Overall Quality		Num.		Acceptable?	
Total Used Points		29		maybe	
Total Photographs		15		yes	

Summary	Good	Weak	Unused	Total
Photos	15	0	0	15
Points	21	2	6	29
Weak data will only be used in second stage processing.				

The second tab of the *Audit Dialog*, as shown above, has two sections.

The Overall Quality section shows information on the number of photographs and the number of points in the Measurement Project.

The "Total Used Points" line shows the number of 3D Points marked on the object. A single 3D Point on the object can be marked on more than one photograph, but as long as the Marked Points are referenced to each other, they will be counted as one point. A non-control-based project must have at least six 3D Points to solve correctly. Often, however, projects with fewer than 10 3D Points will not solve correctly because of other inaccuracies. Points that have their "do not use in processing" property set are not counted in the totals.

The "Total Photographs" line shows the number of photographs to be used in processing.

The Summary section shows what PhotoModeler thinks about the photographs and points overall. It labels each photograph and 3D Point as either "good", "weak" or "unused". For example, a 3D Point with just one light ray is considered to be "unused" and will not be used in processing, but a 3D Point with two light rays is considered to be "weak" and may be used differently by the algorithm. Points with very low angles may be considered to be "unused".

The "Points" line shows the number of good, weak and unused 3D Points in the project. A large percentage of the points should be good. PhotoModeler will allow a small number of *Weak Points* and *Unused Points*.

Note: Normally, points that are weak do not get used in first stage processing. However, if your project is weak overall (e.g. due to a low number of points and/or photos) weak points will be used in first stage processing. Text is shown at the bottom of the dialog indicating how 'weak' points will be used in first stage processing.

If there are many unused or weak points, refer to the *Fixing Audit Problems* section to try to improve this.

The "Photographs" line shows the number of good, weak and unused photographs in the project. Unused photographs are usually those with too few points marked, and with no fiducials marked. PhotoModeler will allow some small number of *Weak Photographs* and *Unused Photographs*. If there are many unused or weak photographs, the user should refer to the *Fixing Audit Problems* section to try to improve this.

Many of these Audit problems are quite easy to fix and you should not be discouraged by poor Auditing results. Fixing the problem usually involves only marking and referencing some more points.

Audit Photo

Audit Summary	Audit Overview	Audit Photo	Audit Points		
		Min.	Max.	Avg.	Acceptable?
Points Per Photo		30	31	30	yes
Photo Coverage (%area)		25	25	25	yes
Fiducials Per Photo (%)		n/a	n/a	n/a	yes

The third tab of the *Audit Dialog* shows information about individual photographs.

Photographs are not considered here if they do not have fiducial marked and they were taken with a fiducial film camera.

The "Points Per Photo" line shows:

- The minimum number of Marked Points any one photograph has marked on it,
- The maximum number of Marked Points on any one photograph and,
- The average over all photographs.

Every photograph must have at least six Marked Points or three Control Points marked on it before it can be used properly.

The "Photo Coverage" line shows the percentage area covered by Marked Points in each photograph. It shows the minimum, maximum and average coverage. For example, a coverage of 10% means that the rectangular region surrounding all points marked on a photograph covers 10% of the area of the photograph. A low coverage means that PhotoModeler cannot accurately determine the true position or orientation of the Camera Station associated with that photograph. If many Camera Stations cannot be placed correctly in three dimensions, the resulting 3D model could be quite inaccurate.

The "Fiducials Per Photo" line shows the minimum, maximum and average number of fiducials marked on the photographs as a percent of total possible. If this is a CCD camera (video or digital) this line does not apply. An Eos Insert Fiducial camera should have all its fiducials marked (i.e. 100%). A frame fiducial camera can work with 3 fiducials marked (i.e. 75%). Other fiducial cameras should have at least 50% marked.

Audit Points

Audit Summary	Audit Overview	Audit Photo	Audit Points	
	Min.	Max.	Avg.	Acceptable?
Rays Per 3D Point	1	2	1	no
Angle Intersection	57	70	66	yes
Ray Tightness (%of size)	0	0	0	yes
	Num.	%		Acceptable?
Points on one Photo only	33	70		no
Points on two Photos only	14	29		maybe

The fourth tab on the *Audit Dialog* shows information about individual 3D Points. Marked Points do not contribute to the calculations on 3D Points if they are imaged on "unused" photographs. Points that have their "do not use in processing" property set are not counted in the totals.

The "Rays Per Point" line shows the number of light rays that define the 3D Point. In other words, this tells you how many photographs this 3D Point has been marked on. Every 3D Point must be marked on at least two photographs and preferably on three. This line shows the minimum, maximum and average number of light rays per point in the project. The higher the number of rays per point, the higher the redundancy and hence the higher the precision of that point.

The "Angle Intersection" line shows information about the angles between the light rays. The values shown are the biggest angle between any two light rays that image a point. Refer to the section of the Quick Start Guide called Guide For Taking Photos for a description of why angles are important. The ideal case is that the angle between the light rays defining a 3D Point are at 90 degrees to one another. It is reasonable to have angle intersections between 30 and 90 degrees. When the angles get too small, PhotoModeler cannot compensate well for errors and this might reduce the 3D model accuracy. Angle Intersection cannot be computed until the photographs have been oriented.

The "Ray Tightness" line shows information about how well all the light rays, that define a 3D Point, intersect. Because of inaccuracies in Camera Station orientation and point marking, the light rays will not intersect perfectly at one point in 3D. The light rays will all miss each other by a bit. The ray tightness number indicates how well they intersect. The smaller the number the better the intersection. This number is given as a percent of the project size. Tightness might appear as "n/a" if the project has a film camera and no fiducials have been marked. Ray Tightness cannot be computed until the photographs have been oriented.

The "Points on one Photo only" line shows the number of 3D Points in the project that have been marked on only one photograph and have not been referenced. PhotoModeler cannot use these points for 3D processing, but it can accept a low percentage of them without failure.

The "Points on two Photos only" line shows the number of 3D Points in the project that have been marked on only two photographs. PhotoModeler will use these points for 3D processing, but if there is a high percentage of two ray only points, the resulting 3D model will be less accurate.

Fixing Audit Problems

The following table outlines what steps can be taken to improve a certain Audit category. Taking the actions on the right should improve the numbers in the category and therefore make the processing successful or improve the 3D model. See the sections above for more detail on what the individual categories mean.

Note: if many of the Audit numbers show "0" or "n/a" perhaps many of the photographs are "unused". Photographs can be "unused" when their fiducials are not marked (for a film camera), when there are too few points marked or when the Marked Points cover only a small portion of the photograph.

To Improve	Do This
Total Points	Mark more points and reference them.
Total Photographs	Add more photographs. Refer to the section of the Quick Start Guide called Guide For Taking Photos for more detail.
Points Per Photo	Add more points to any photograph that has few points.
Photo Coverage	Add points to photographs ensuring that they cover as much of the photograph as possible. Even if you do not require the points, PhotoModeler might. Try to get as best coverage of all photos as possible.
Fiducials Per Photo	Mark more fiducials on the photographs. See <i>Marking Fiducials</i> .
Rays Per Point	Make sure all or most points are marked and referenced on three or more photographs.
Angle Intersection	Make sure the photographs are taken with good angles. Also make sure that the Camera Station positions and angles match the photographs.
Ray Tightness	Make sure that the Camera Station orientations are good.
Points on one Photo only	Decrease the number of points marked on only one photograph. See <i>Point Audit Dialog</i> for a means to identify single unreferenced points.
Points on two Photos only	Decrease the number of points marked on only two photographs. See <i>Point Audit Dialog</i> for a means to identify these points.

Photos - Unused	Mark fiducials on all photographs (if using a film camera), mark more points on the photos and ensure they cover a large percent of the photo. Also check to see if the Photograph has an assigned and oriented Camera Station.
Points - Unused	See above for improving Rays Per Point, Angle Intersection, Ray Tightness.

Reference Checker

The Reference Checker is an automated process for checking the quality of point references. Since the quality and correctness of point references are key aspects in multi-photo projects, this system can considerably improve the overall accuracy, quality and robustness of your projects.

The Reference Checker runs automatically as one of the pre-processing stages (i.e. before the Processing Dialog appears). The Reference Checker even works with unoriented and unprocessed photographs making it ideal for catching referencing problems early.

The Reference Checker depends on the Project Marking Quality setting found in the *Project Information Dialog*. With this setting you tell the program how precisely marked you think the points are. A project with good quality sub-pixel points may have a Project Marking Quality between 0.5 and 1.0 pixels whereas a project of a natural object with some roughly marked points might have a Project Marking Quality as high as 10.0 pixels. A Project Marking Quality of -1.0 turns the Reference Checker off.

The concept behind the Reference Checker is to check photographs pair wise to determine if any points appear to be marked worse than the Project Marking Quality. There are situations where this cannot be determined (for instance if a pair of photos has fewer than 9 correctly referenced points between them).

The Reference Checker has a second stage that runs after Processing is complete. See the *Second Stage Results* section for more detail.

First Stage Results

The results of the first Reference Checker Stage are displayed in the Audit Summary window of the Processing Dialog. If there are no messages that look like these below then no referencing errors were found (which does not mean that there are no referencing or marking errors but just that they could not be found).

The two messages in the Audit Summary take this form:

(1) At the current Project Marking Quality of <p> pixels, these single photo mis-references were identified (point ID, photo ID): <list1> and these possible multiple photo mis-references have been identified (point ID): <list2>

(2) With the current Project Marking Quality of <p>, too many mis-references were found. No points will be removed from processing. Perhaps processing should not be carried out until errors are fixed.

When the (1) form of message appears the <list1> will show the point ID and photo ID of possibly mis-referenced points. These are points that could be identified as being possibly mis-referenced on only one photo. These marked points are "turned off" for this next processing so they will not affect the processing accuracy. The <list2> will show the point

ID of 3D object points that are turned off on all photos and not used in this next processing (these are points which may be mis-referenced on two or more photos).

When the (2) form of the message appears, too many possible mis-references have been detected. In this case, no points are turned “off”. It is probably a good idea to not process though and instead to investigate what might be wrong with the project. In some projects that are properly referenced, the Project Marking Quality has to be increased to remove this warning.

Second Stage Results

The second stage of the Reference Checker renames, unreferences, or sets to ‘do not use’ determined to be worse than the Project Marking Quality. What action the Reference Checker takes depends on the options set in the *Processing Dialog*. This second stage does not run if the first stage did not find any problems or the first stage did not run for some other reason.

When the second stage of the Reference Checker runs, there should be no points remaining in the project with a Marking Residual over the Project Marking Quality.

The results of the second stage are displayed in the Project Status Report and the message looks like this:

“Problem: Points were automatically unreferenced/renamed/set to ‘do not use’ after processing because they had residuals larger than the current Project Marking Quality of <p> pixels. <list of points>

Suggestion: High point marking residuals are a result of mis-marking or inaccurate marking, mis-referencing and/or poor camera orientation. Review problem points and remark and/or re-reference where required. “

If problem points had been unreferenced in this stage you may consider reprocessing the project for maximum accuracy and to see if any other points are identified by the Reference Checker.

Note: To reverse the changes made by reference checker during process, use the Undo Process tool before making any other changes.

Note: For regular multi-photo projects with a calibrated camera the default marking quality is 5.0 and the default action on finding a reference error is to rename the offending point. High accuracy projects (i.e. projects with most points marked using the sub-pixel target marker and Automatic Coded Target projects) use a default setting of 1.0. Other projects that are likely to be less accurate have a default setting of -1 which disables the feature (such as Inverse Camera projects).

While you can change the settings for a project manually on the *Project Information Dialog*, you can change default settings by adjusting these ini settings:

[General]

RefCheckActionDefault= (0-do not run ref check, 1-unreference, 2-set to do not use in processing, 3-rename)

RefCheckRenameDefault=The name to use for re-name

AccurateProjectMarkingQuality=5

OtherProjectMarkingQuality=-1
OldProjectMarkingQuality=-1
AutoProjectMarkingQuality=1.0
SubPixelProjectMarkingQuality=1.0

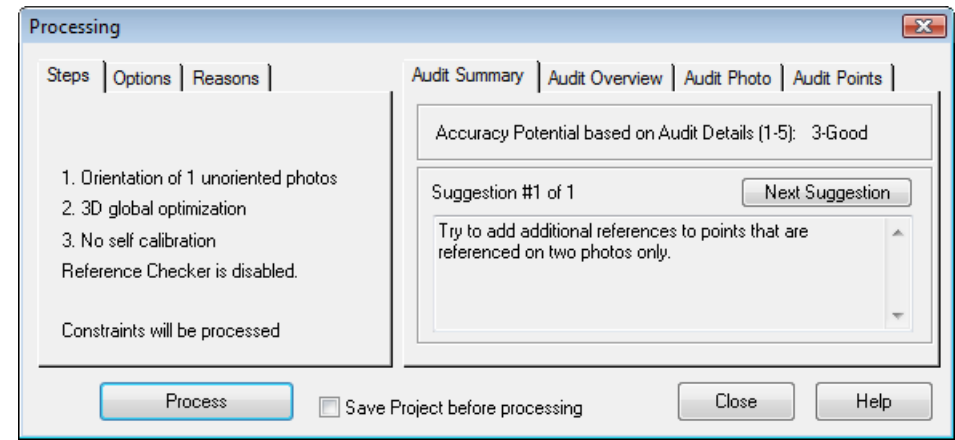
Adjustment and Processing

The second stage of processing is called Adjustment. In this stage PhotoModeler runs a number of algorithms to build the 3D model.

Note: Adjustment is concerned with Marked Points, 3D Points, Edge Marks, Edges, Camera Stations and Cameras only. Objects such as Lines, Surfaces, Cylinders, Surface Drawings, and Curves do not affect the 3D adjustment process in any way.

The processing is divided into three stages: Orientation, Global Optimization and Self-Calibration.

Processing Dialog



The Processing Dialog provides control over the processing stages and provides feedback on project quality.

Processing is started by using the toolbar button, the F5 key or the Project, "Process" menu item.

This dialog is split into two sections. The section on the right contains Audit information and is identical to that found in the *Audit Dialog* so it is not described here further.

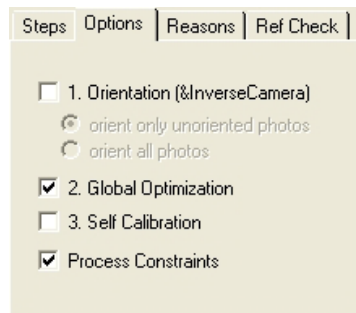
The section on the left is used to control the four main stages of 3D Processing (Orientation, Global Optimization, Self-Calibration,, and Reference Checker Stage 2).

Orientation:	To determine the relative positions in 3D space and the relative rotation angles of the cameras that took the photographs. InverseCamera processing is also run during this stage.
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Global Optimization:	To optimize and minimize the error in all marked points, 3D points, and camera station positions and angles. See <i>Global Optimization</i> section below.
Self-Calibration:	To optimize the results further by performing small adjustments on the parameters of the camera at each photograph to account for changes induced by focus affects etc. This is also optionally "field calibration" as set by the field calibration Preferences settings. See <i>Self-Calibration</i> and <i>Field Calibration</i> sections below.
Reference Checker – 2 (2 nd Stage)	To finalize the decisions on bad references found in the first Reference Checker stage. This second stage of Reference Checker can unreference bad references, set bad references to 'do not use in processing', or name bad references a specified user name. The 'Steps' tab on the processing dialog lists the state of the two Reference Checker stages.

In most normal circumstances you can leave the default settings of this dialog and press the "Process" button to start the 3D Processing. There are various circumstances when you may want to do an Orientation only, a Global Optimization only, or ask for Self-Calibration or Field-Calibration.

The first step in the dialog will tell you how many photographs have to be oriented (in other words how many have not been oriented yet). The first time you process a project , all the photos will need to be oriented. Subsequent processing will need to orient only newly added photographs. You can also force the orientation of all photographs using the second tab described next.



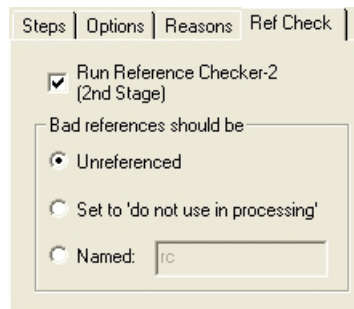
The second tab has controls for the various steps. If orientation is not required (i.e. all photographs have been oriented successfully) then the Orientation can be turned off and on (otherwise it is forced on). With orientation you can set whether only unoriented photos are to be oriented or all photos are to be oriented. The Inverse Camera processing, if required, is done along with the Orientation step.

Global optimization and self-calibration can also be turned on and off. For single photo projects, only the first orientation stage is done so the later two stages will be off and disabled.



The third tab in this section provides more information about what processing will be done and reasons why the options have been set.

There are numbers telling you how many photos cannot be processed (due to insufficient fiducials, insufficient referenced points or insufficient control points), how many photos have been set to "do not use", "use and adjust" or "use and no adjust", how many photos can be processed as a result and how many photos need to be oriented.



The fourth tab provides the ability to control how the Reference Checker 2nd Stage affects points in the project (see *Reference Checker*). The first checkbox enables or disables running of the Reference Checker 2nd Stage. Then if enabled, Reference Checker 2nd Stage will either unreferenced, set to 'do not use in processing', or name (to the name specified) points that have residuals higher than the Project Marking Quality (see *Project Information Dialog*). Note these settings are saved and restored with the project.

When you press the Process button processing will begin (unless certain *Minimums* have not been met). The *3D Process Dialog* will appear when Global Optimization begins. If the "Save Project before processing" box is checked when you click the Process button, the current project will be saved to its named pmr file before processing begins.

Minimums

There are certain minimums that must be met before processing can proceed.

Single Photo Project

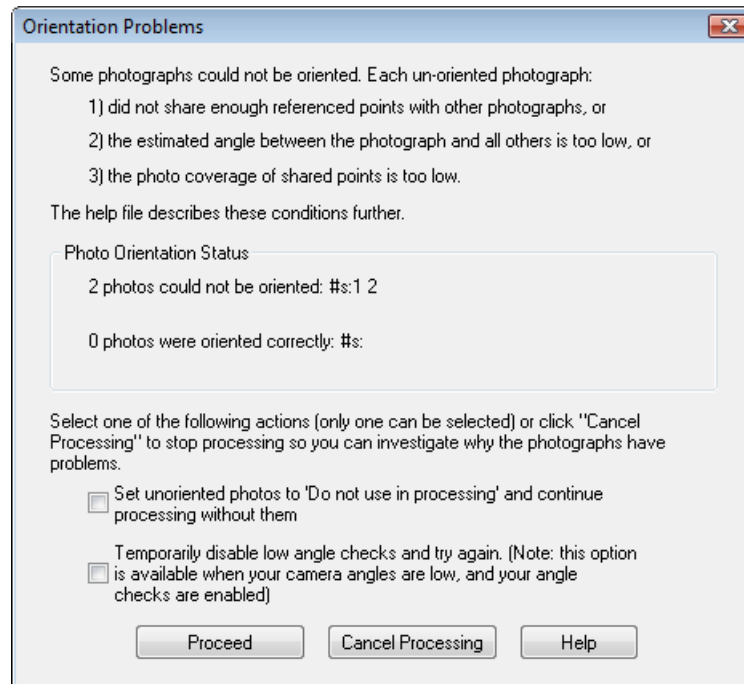
- minimum of one photograph set to "use and adjust" or "use but no adjustment"
- at least three control points or sufficient axes constraints (see *Axes Constraints*). Note these minimums change if Inverse Camera Processing has been requested. See *Inverse Camera solves for* and *Working with Unknown Cameras and Photographs*

- the photograph's points or constrained lines/edges must cover a reasonable area of the photograph (i.e.. cannot be just on a small region in the photo)

Multiple Photo Project

- minimum of two photographs set to "use and adjust" or "use but no adjustment"
- each processed photograph must have at least six referenced points or three control points. Note these minimums change if Inverse Camera Processing has been requested. See *Inverse Camera solves for* and *Working with Unknown Cameras and Photographs*. PhotoModeler will automatically orient photos that have only 4 or 5 referenced marked points, provided the 4 or 5 marks can have their 3D position calculated based on other photos (i.e. those points appear on two or more other photos that are oriented/orientable, or are control). This makes low-point-count projects and auto-projects with a minimum of coded targets more easily completed.
- each processed photograph's points must cover a reasonable area of the photograph (i.e.. cannot be marked on just on a small region)
- if there are three or more photographs each processed photograph must have at least one point that appears on two other photographs or at least one control point

Orientation Problems Dialog



Occasionally a project has trouble orienting when processing, especially when certain conditions are present (as shown in the text in the dialog above):

- There were not enough referenced points shared with other photos. When photos do not share enough referenced points, PhotoModeler does not have enough data to work with. See the *Minimums* section for more information on this.

- The angle between the cameras that took the photos is too low. When the angle between the camera positions is too low, PhotoModeler cannot reliably calculate light ray intersections and therefore has trouble solving camera positions. Thresholds to control the whether orientation fails due to angle problems can be set on the Orientation pane of the *Preferences* (Low Angle Marked Point Fitter Check).
- The point coverage, or the area of a photo covered by points, is too low. When all points are concentrated in a small portion of the photo, PhotoModeler has trouble resolving the camera positions due to the limited spread of the geometry.

Global Optimization

This stage adjusts the positions and angles of the Camera Stations and the positions of the Object Points and Edges on each iteration. At the end of each iteration, PhotoModeler determines whether this set of adjustments will produce a good 3D model. If it will not, it does some more adjustments and so on until a good result is achieved. If the Camera, Camera Station information or the marking and referencing data is poor, then Optimization can fail. Failing does not crash or stop PhotoModeler, it simply does not produce a 3D model.

The main purpose of Global Optimization is to minimize the errors found in the input data and come up with the best solution for Camera Stations and 3D Object points.

No interaction with PhotoModeler is allowed during Optimization other than pausing or terminating. The user may interact with any other Windows program but it will slow the processing down. Optimization can take some time to complete for complex projects. The user can watch the *Processing Dialog* to see how well the Optimization is proceeding.

Self-calibration

When there are sufficient 'good' points and photos in the project, and the self-calibration check box is checked in the Processing Dialog then the self-calibration process will run along with the global optimization.

In self-calibration PhotoModeler attempts to make minor adjustments to the camera parameters to account for changes in focal length, principal point and lens distortion as the camera lens is focused.

When one camera is shared between multiple photographs, self-calibration copies the camera (one for each shared photo) during processing so they can be independently adjusted. After processing is completed you can see the results of the individual calibrations by opening the *Photo Table*. These individualized camera settings will remain until the next processing or until a camera parameter is changed on the original camera for that photograph.

Field Calibration

When there are sufficient 'good' points and photos in the project, the self/field-calibration check box is checked in the Processing Dialog, and the field calibration check box is set in Process section of *Preferences - Processing and Cameras* then the field-calibration process will run along with the global optimization.

Field calibration is very much like the Camera Calibration path of the New Project Wizard in that it is trying to solve the internal parameters of one camera. Field calibration can be a replacement for full Camera Calibration in some circumstances.

For high accuracy projects, Field Calibration (along with appropriate photographs) can be very important to get that extra bit of accuracy.

What projects are good Field Calibration Projects?

Field calibration is much like a *Camera Calibration* project and so has similar requirements:

- there should be at least five photographs,
- the photographs should all be taken with the same camera at one focal length setting,
- the photographs should be at strong angles to the subject,
- the photographs should all be at similar distance to the subject (and hence all at the same focus setting),
- the distance of the camera from subject should be similar to the distance used in your real projects,
- there should be one or two photos that have rolled angles (portrait type shots), and
- there should be at least 25 well marked and referenced points on all photos, with the points having each at least four references.

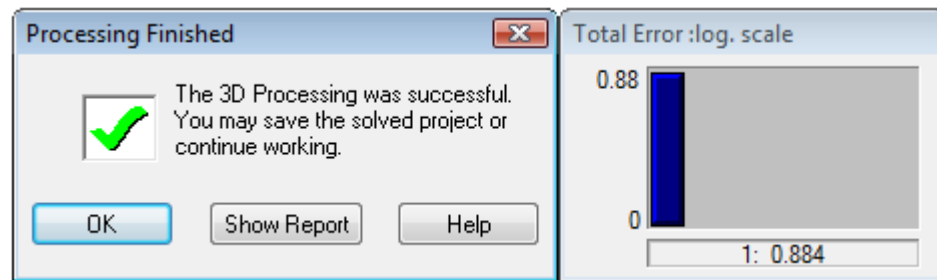
When should Field Calibration be used?

When the highest accuracy is required it is a good idea to calibrate your camera at the distance and focus setting you will be using for your real projects. If your real subjects are smaller than one meter across then *Camera Calibration* software that comes with PhotoModeler can meet that requirement easily. On the other hand if the subjects are bigger than what can comfortably be done with a projected slide or printed calibration pattern then you may want a more accurate calibration than the Camera Calibrator can give you. Field calibration fills this need.

You may wish to first do a standard calibration project with the Camera Calibration choice in the New Project Wizard. You can use this calibration data for smaller subjects. You then find a suitable subject (side of a building for example) that you can take photographs from all angles (side to side and up and down). You photograph the building and set up a normal PhotoModeler project using the previously calibrated camera. You mark and reference as many points as you can (using the sub-pixel target marker if you have circular targets) on these photos and when you process you ask for field calibration as discussed above.

When the processing is complete and you have reviewed the quality of the solution (by reviewing *residual* values, tightness, model shape etc.), you can then save the camera to disk with these updated camera parameters and use in your future projects of similar size.

3D Process Dialog



The dialog that appears after you click the Process button on the *Processing Dialog* is the *Progress Dialog*. After the first processing iteration is complete the *Total Error Dialog* will appear beside it.

Total Error Dialog

The Total Error Dialog appears beside the *3D Process Dialog* during Global Optimization (i.e. it does not appear when orientation-only processing is done) or during *Camera Calibration*. The dialog shows a set of vertical bars where each bar shows the accumulated error within the 3D model in one iteration. A new vertical bar is added to the Total Error Dialog for every iteration of the global optimization solution. The bars should get shorter as processing proceeds (which shows reducing error in the model). See also *Final Total Error*.

The error values shown in this dialog are technically referred to as the 'standard error of unit weight' or the 'a posteriori sigma0'. These values are unit-less and combine information from image *residuals*, camera parameter residuals, edge residuals, constraint residuals and control point residuals. If there are no control points, no constraints and self-calibration or full calibration is not being done these values reflect closely the total weighted residual error in the photo markings.

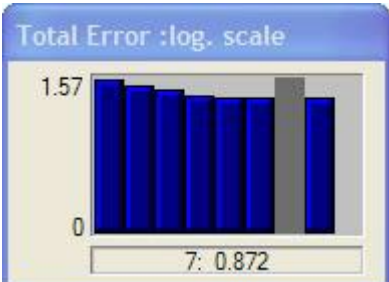
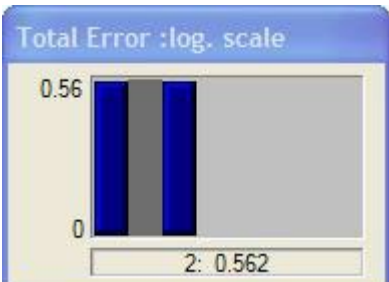
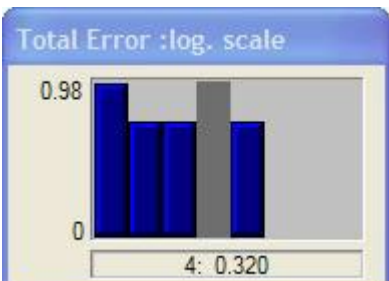
If the bars get bigger instead of smaller or if there are more than ten vertical bars of the same height, then PhotoModeler is having trouble solving. A few bigger bars are generally OK as long as the bars start to get smaller. If the bars do not get smaller then the processing is failing. In this case PhotoModeler will eventually give up on the processing and tell you that the processing has failed. You can also click the "Quit..." button on the *3D Process Dialog* to stop the processing early if you wish.

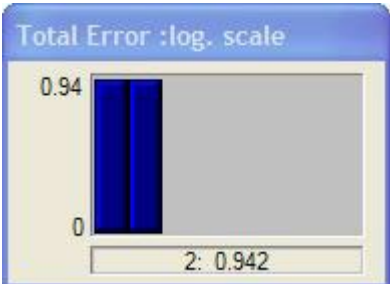
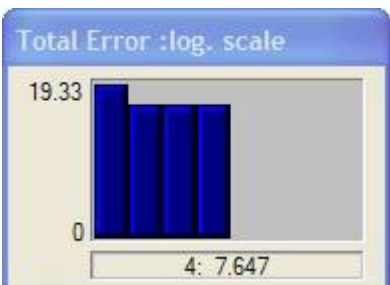
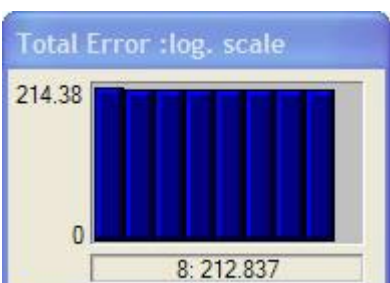
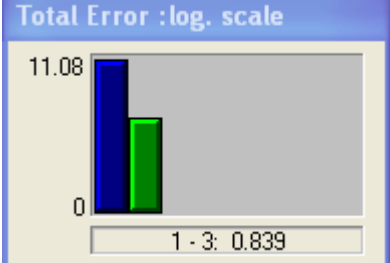
The Total Error Dialog will usually show two sets of bars separated by a gray area. The first set corresponds to the first Optimization phase and the second set of bars to the second Optimization and Self-Calibration phase. Sometimes the first vertical bar in the second set will be larger than the last bar in first set. This is normal and it does not mean that PhotoModeler is having trouble with the adjustment.

If the automatic high residual point removal feature is turned on (See *Preferences - Processing and Cameras*), the second set of bars at right may include a single green bar. This indicates that PhotoModeler has made changes to the project with the unreferencing of a high residual point. The *Project Status Report* will explain the change by indicating the point id and the photo on which the unreference occurred.

If the processing fails, no 3D model will result (or if previously solved there will be no change) and you will need to fix the problems. See the section called *When processing fails or 3D results look bad* for information on how to fix these problems.

You can think of the Total Error Dialog as the pulse of your project. While the most important thing is that the bars gets smaller as processing proceeds, one can get useful information by studying the shape of the error chart. The following examples show Total Error Dialog results for various types of projects along with hints of what is right or wrong:

 <p>The dialog shows a bar chart with 7 bars. The y-axis is labeled 'Total Error :log. scale' with a scale from 0 to 1.57. The x-axis shows '7: 0.872'.</p>	<p>Successful two stage processing. Most projects that are set up well will have error dialogs that look like this. After the initial orientation only small optimizations are needed.</p>
 <p>The dialog shows a bar chart with 2 bars. The y-axis is labeled 'Total Error :log. scale' with a scale from 0 to 0.56. The x-axis shows '2: 0.562'.</p>	<p>Successful two stage processing of a strong project that has probably been processed before (there is not much room for improvement).</p>
 <p>The dialog shows a bar chart with 4 bars. The y-axis is labeled 'Total Error :log. scale' with a scale from 0 to 0.98. The x-axis shows '4: 0.320'.</p>	<p>Successful two stage processing where the initial orientation was good but not perfect. The optimizer was able to produce a good solution in the first stage and the second stage was used as a check.</p>

 <p>Total Error :log. scale</p> <p>0.94</p> <p>0</p> <p>2: 0.942</p>	<p>Successful one stage processing where the initial orientation was ok but not perfect. The optimizer was able to produce a good solution in the first stage. A second stage was not run due to insufficient extra data or no self-calibration.</p>
 <p>Total Error :log. scale</p> <p>19.33</p> <p>0</p> <p>4: 7.647</p>	<p>Somewhat successful one stage processing where the initial orientation was weak. While the processing might have succeeded the final error is quite high (7.6, when good values are under 1.0). A model might have resulted from the processing but it is suspect. Look for referencing errors or camera parameters problems.</p>
 <p>Total Error :log. scale</p> <p>214.38</p> <p>0</p> <p>8: 212.837</p>	<p>Most processing failures will look something like this. You might see small decreases in the error bars or they may be all similar height. The error values will also be high. This implies some inconsistency in the project (perhaps a misreferenced point or camera parameters that are not quite correct).</p>
 <p>Total Error :log. scale</p> <p>11.08</p> <p>0</p> <p>1 - 3: 0.839</p>	<p>The green bar indicates that the automatic high residual point removal feature (See <i>Preferences - Processing and Cameras</i>) made a change to the project. The <i>Project Status Report</i> will explain the changes by indicating the point id and the photo on which the unreference occurred.</p>

Final Total Error

The final Total Error in processing is useful for gauging project quality. The final error is displayed as the last bar in the Total Error Dialog as well as in the *Project Status Report*.

Total Error is a statistical measure that is calculated in processing (bundle adjustment). In bundle adjustment we need to set a scaling value for all expected parameters precisions. This value is called sigma-naught (σ_0) (or more properly a priori sigma-naught (a priori means 'before')). In PhotoModeler we set this scale to 1.0. When all assumptions of the adjustment are met, the output sigma should be 1.0 also. This means that the total error value on the last iteration should be 1.0 if everything matches our expectations. What does it mean when the final total error is not 1.0?

When the final total error is less than 1.0, we can say that the data model (including camera parameters etc.) is good and the marking is more precise than the assumptions. These assumptions are shown in the Preference Dialog - Process / Default Point Standard Deviation Weights. For example, if the standard deviation for all the sub-pixel marked points in a project is 0.1 pixels and the final total error of processing that project is 0.5, then one could say that the actual marking precision is on average actually 0.05 pixels ($0.1 * 0.5$) and not 0.1. In other words you got better marking precision than first assumed. This is only a first assumption though because the camera calibration, for example, could perhaps be improved even further and then maybe the final total error would have been even smaller.

When the final total error is over 1.0 then some of the initial assumptions are incorrect. Those incorrect assumptions could be that the camera was properly calibrated, or that the marks are marked to the assumed precision (defaults are 1.0 pixels (one standard deviation) for manually marked points, and 0.1 pixels for sub-pixel points). When the total error is very large (let's say over 10) then there are probably gross errors too - such as mis-referenced points or a very badly calibrated camera.

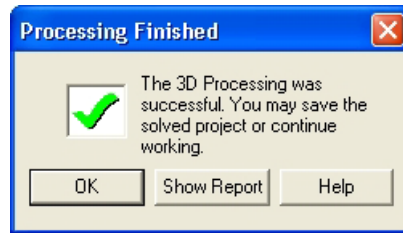
In conclusion, when the final total error is 1.0 or smaller then we probably have a reasonably good project and have met our expectations for marking quality and camera calibration. Note, it does not mean that it can't be improved further. When the final error is between 1.0 and approximately 10.0 then perhaps our marking precision assumption is wrong or the camera is not well calibrated. When the final error over 10.0 we may have a poor camera calibration but as well possibly some gross errors such as mis-referenced points or edges (or badly defined constraints). High total errors should be investigated (look for gross errors and consider how the camera was calibrated).

Note that we typically hold different project types to different standards. While a high-accuracy industrial survey may be unsuitable with a total error over 2.0, an accident reconstruction road project, or large architectural survey may be fine with a total error as high as 10.0. The higher error says that you could not meet your assumptions of marking points to 1.0 pixel precision (which is accepted when manually marking points on blurry road features, window corners, etc.). The higher error does not necessarily mean the project itself is bad or inaccurate. In Inverse Camera projects we accept even higher total error values (perhaps up to 15.0). Regardless, when the total error is very high (over 20) you should investigate the sources of errors (mis-marked or mis-referenced points, camera incorrectly calibrated, etc.). If you are carrying out very high accuracy work (target dots in a precise industrial survey for example) then search your project for problems at lower total error values (over 2.0).

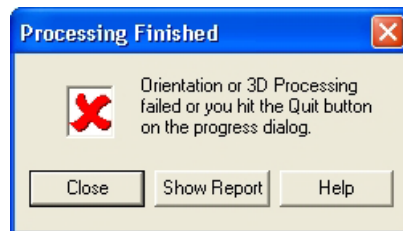
See also *Total Error Dialog*.

Processing Finished Dialogs

After processing is complete one of two dialogs will appear in the place of the Progress Dialog. The Total Error dialog will remain on the screen, for now, so you can review the results.

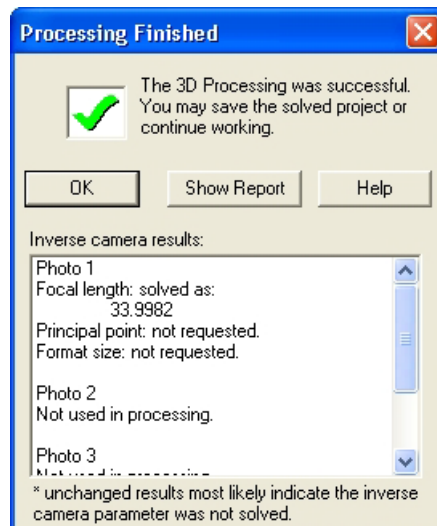


The dialog above appears when the processing was successful. When the OK button is pressed, this dialog and the Total Error dialog will close. If the Total Error Help button is pressed the *Total Error Dialog* help section is opened. When the Show Report button is pressed the *Project Status Report* will open.



The dialog above appears when the processing was unsuccessful. When the Close button is pressed, this dialog and the Total Error dialog will close. If the "Troubleshooting Help" button is pressed the help file will open at the *Processing Troubleshooting* section. When the Show Report button is pressed the *Project Status Report* will open.

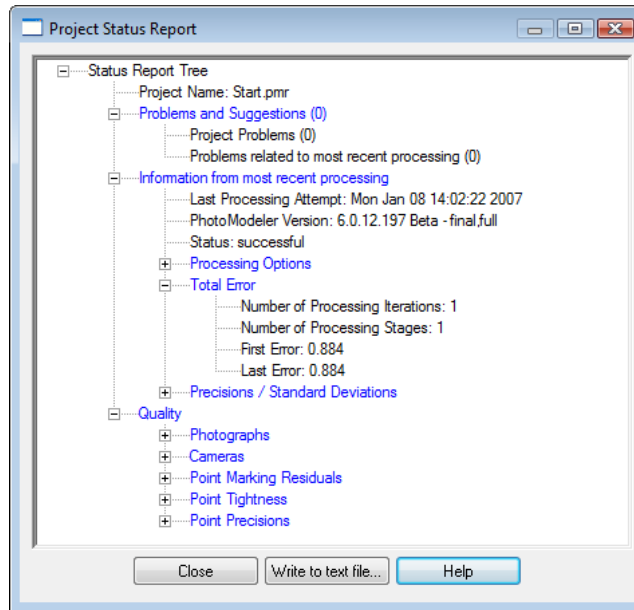
When Inverse Camera processing has been done on one or more photographs the dialog expands to show additional information:



The Inverse camera results pane describes what Inverse Camera processing has been done. If a photograph has its Inverse Camera flags set, then during processing PhotoModeler determines the parameters of the associated camera given the constraints or control points. If the parameters were not solved or changed from default values (but

you expected them to be) then you need to investigate if the correct settings have been made (see *Photo Properties*) and that there are sufficient constraints. See *Working with Unknown Cameras and Photographs* for more detail.

Project Status Report



Once you process your project, PhotoModeler generates a status report internally. The report stores various processing settings, the overall status of your project, as well as specific information about significant 3D points that may be weakening your project. The report can be used to monitor various aspects of your project's accuracy and ability to solve your 3D model. If you have not processed your project, no report is generated (you will get a warning message saying that no report is available). If you attempt to process your project and it fails, a report is generated to show possible reasons for failure, along with other processing status information.

The report is in a data tree format and the various branches or 'nodes' can be expanded to show additional information. If more information pertaining to the node is available, a small 'plus' sign will appear next to the node. Click the plus sign to expand the node and reveal the additional data. Once expanded the plus sign turns into a 'minus' sign which can be clicked to hide a node's additional data. Note that the Processing Report window is sizable so if you want to view more of the tree, you can expand the window by dragging its edge outward.

You access the report by clicking the Processing Report button on the toolbar, by selecting the Processing Report... menu item under the Project menu, or by clicking the Show Report... button on the Processing Finished Dialogs. Depending on how you access the report, certain nodes are expanded and others are contracted.

To export the Project Status Report to a text file click Write to Text File. A dialog will appear prompting you to save the report to a file and directory of your choice. The report

will be written to the text file with all nodes expanded. It is a useful way of documenting a snapshot of your project at a point in time.

The tree is broken into 3 main sections: Problems and Suggestions, Information from most recent processing, and Quality.

Problems and Suggestions

This node shows various problems identified with your project. These problems and suggestions are separated into two sub categories (three if your project failed processing): Project Problems - problems with your project that are fundamental to your overall project; Problems related to most recent processing - these are problems that were identified in your most recent processing attempt; Processing Failure Problems - this node will only appear if your project failed processing and it shows the most serious problems that could have caused the failure. See also *Processing Troubleshooting*, *Troubleshooting* and *Verifying the Processing Result*.

Some of the problems listed in the report may or may not cause processing to fail. Even if your project processes successfully, problems may be revealed that should be considered if you want to improve the overall quality of your project. For example, if you are using an uncalibrated camera, the report will alert you to this. If your project fails to process, more serious problems will be identified which attempt to explain why your project failed. For each problem identified in the report, one or more suggestions for improvement are provided.

One particular type of warning listed has to do with points that have been automatically unreferenced. See the *Reference Checker* section for more detail.

Similar to Reference Checker is the feature to automatically unreference high residual points from a project. See *Preferences - Processing and Cameras*. The feature is only on by default for automatic coded target projects. When a change is automatically made to a project by this feature, the status report will display the point ID(s) and the photo(s) from which the point was unreferenced.

Information from most recent processing

This section of the report shows the date and time of most recent processing, the settings you used when last processing your project, the total error of your project (see also *Final Total Error*), and the Precisions / Standard Deviations of your photographs' orientation parameters (and camera's parameters too if this is a calibration project).

These nodes provide an indication of the overall strength of the most recent processing. Note that these values may differ from values in the Photo Table as no conversion for Scale and/or Rotation has been applied.

Of particular note are the types of warnings that have to do with points that have been automatically unreferenced. See the *Reference Checker* section for more detail. Also there is an option to automatically remove/unreference high residual points during processing (see *Preferences - Processing and Cameras*), which is separate from the Reference Checker feature. When points are automatically removed during processing, the points will be listed here (you may notice one or more green bars on the *Total Error Dialog* which is another indication of point removal).

Another key notification shown in this section is a list of photos that have been automatically set to "Do not use in Processing" (see *Photo Properties*). The photos listed here have been removed so that orientation and processing can succeed. Photos may be set to "Do not use in Processing", because either their angles were low and/or their point count was low.

You want to see small deviation values for all the parameters. In the calibration case you especially want to check that the deviation of a parameter is not significantly larger than the parameter. E.g. K1 is $1.2e-5$ and K1's deviation is $3.0e-5$. This means that there is a 90% probability that K1's actual value is between $-4.8e-5$ and $7.2e-5$ (90% probability falls at twice the standard deviation (or sigma value)). This means that K1 is pretty likely also zero (0.0). K1 is then probably not significant and the calibration should be resolved with K1 missing. Note there may be other reasons why parameters in a calibration are not significant and those should be studied first (such as incorrect photographs or point coverage etc).

Quality

This section of the report shows the overall quality of various aspects of your project. See also *Audit Points*, *Fixing Audit Problems*, and *Point Audit Dialog*.

The Photographs node shows the number of photographs in your project and their quality, the number of oriented photographs and the number of photographs that have their inverse camera flags set. The photographs node helps you determine whether there were problems with photographs in your project before processing. See *Audit Overview* for more information on bad, weak and OK photographs.

The Cameras node lists the cameras in your project and displays their names, whether they are calibrated and the number of photographs assigned to the camera. See also *Camera Viewer Dialog*.

The Point Marking Residuals node (see also *Marking Residual Display* and *Visibility on Photos*) shows the overall RMS, the Maximum and Minimum point residuals and the Maximum and Minimum RMS. It provides a quick way of finding problem points in your project (the ID of the point and the photograph on which it appears is shown when the sub-node is expanded).

The Point *Tightness* node shows the maximum and minimum tightness values in your project. It also helps identified problem point marks in your project (the ID of the point is shown when the sub-node is expanded).

The Point Precisions Node shows various precision data for the overall project as well as the Maximum and Minimum point Precision. For further discussion of the meaning of precision refer to *Accuracy* and *Precision* in the Glossary.

Processing Troubleshooting

If the Processing Finished Dialog appeared during the Orientation or Global Optimization of your project indicating failure (dialog has big red "X"), then you either click "Quit" on the Progress dialog or PhotoModeler could not complete the processing.

In the case of using the "Quit" button on the Progress Dialog, no damage has been done and once you click the "Close" button on the Processing Finished dialog, you will be right back to where you were before you started the processing.

In the case of a PhotoModeler initiated failure some information PhotoModeler is working with is incorrect. What type of information might be incorrect?

- incorrectly marked points or edges,
- incorrectly referenced points or edges,
- incorrect control point values or incorrectly placed,
- incorrect or poor camera parameters,
- weak or insufficient point placement that leads to an incorrect orientation solution,
- incorrectly defined or conflicting constraints, or
- overly constrained data elements.

To help track down these problems there are a number of tools you can use and study.

- *Audit Dialog* to see if there are any suggestions or specific details listed that seem incorrect.
- *Point Audit Dialog* to review points one by one for proper referencing.
- *Point Table* and *Edge Table* to review points and edges to see how they are marked and referenced (by using the Photos column and the "W" key to move selections to photos).
- *Photo Table* to review which camera is assigned to which photo and to see if all the Camera parameters look reasonable.
- *Camera Viewer Dialog* to review the parameters on individual cameras.
- *3D Viewer* to check currently oriented Camera Stations to see if they "make sense".
- *Photo Properties* to temporarily remove one or more Photographs from processing.
- *Object Point Properties* to temporarily remove one or more Object Points from processing.
- *Constraints Dialog* and *Processing Dialog* to turn off some or all constraints during processing.
- *Processing Dialog* to try just orientation if both stages were being run, or to turn off Constraints if constraints exist in the project.

You may want to follow a more specific set of steps to resolve your processing problems. In that case, visit the section called *Troubleshooting Procedure* found later on in this document.

Verifying the Processing Result

After a 3D Processing has completed successfully there are a few quick checks you can make to verify the quality of the processing. These are:

1. Study the *Project Status Report* to see if there are any reported problems. Also review the largest *residual* information.
2. View all the photographs (perhaps use an Open All Photos) and turn on *Marking Residual Display*. If the residual error bars are large see the *Troubleshooting* section.
3. Open up the *3D Viewer* and study the shape of the resulting model. Does it look OK? Is the shape what you expect?
4. Also in the *3D Viewer* turn on Camera Station display. Verify that the Camera Stations have not moved unexpectedly. They will have moved but if they are now located where you do not expect them to be, there might be a problem.

5. The *Point Table* can be used to display all the solved points and sort by tightness which is another indication of point quality. A low tightness is desired for all points in the project.

Quality Review Points-Based

There are two features in PhotoModeler that make it easier to find marking and referencing problems. The first is called Marking Residual Display and the second is called Unreferenced Point Weld.

Marking Residual Display

The Marking Residual Display setting on the *Visibility on Photos* pane is used to control the *Marking Residual* display on Photographs.

When residual errors are displayed each Photograph will show a black bar starting at the Marked Point and going off in some direction. Where the black bar ends is where PhotoModeler thinks the Marked Point should be given other data such as referenced points, Camera Station orientations, Camera information, and any Control Point locations or Constraints.

In a well solved project, these Marking Residuals (also called *residual* errors) should all be very small. In fact they may be so small that you cannot see them when the Marking Residual Display comes up. Try using the zoom tool and zoom in on a Marked Point to see if the black bar is indeed there.

To get an overview of the errors when they are all small, there is a way to set exaggeration factor (see *Visibility on Photos*). When this factor is set to 1 (the default) then the end of the bar is where PhotoModeler thinks the point should be, when this factor is greater than 1, the bars are magnified by the factor. For example, if the magnification factor is 10 then the black bars are all drawn 10 times longer than reality but they still point in the same direction.

The Residual Marking Display can be very useful in tracking down certain types of marking and referencing errors.

a) Marking errors: if you have a point that has 5 references (appears on 5 photographs) but has been incorrectly placed on one of those photos then the Marking Residual error for the point will be large and will point in the direction on the photograph where it should be marked. This display will not work well though when there are not many references (i.e. 2 or 3 references) and one of the points is marked incorrectly. In this case, all the references on all the photographs will appear to have larger Residual Marking Errors.

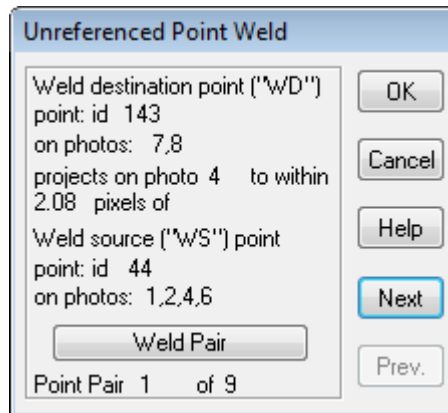
b) Referencing errors: if you have misreferenced a point (for example referenced the right headlight point on photo 1 to the left headlight on photo 2), the Marking Residuals for these points will be high and will point at the correct point to be referenced.

If you use a large magnification factor (over 15) do not be surprised by some large Marking Residuals. Some of these might be real problems that you should investigate but otherwise it is just showing the uncertainty in the system. Very high quality projects and some calibrations may require magnifications in the hundreds before the residuals and their patterns are visible.

Note: The Projection display is very similar to Marking Residuals. If you turn on 3D Points display in the *Visibility on Photos* pane and then turn on Marking Residual display with a magnification of

1.0 (which means "no exaggeration"), you will see that the residual vector is drawn between the marked point and the projected point. This is a good illustration of what a Marking Residual is.

Unreferenced Point Weld Dialog



The Unreferenced Point Weld Dialog is used for finding potentially unreferenced points in a project. This dialog can be used only with a processed project and should be used only after a project has been newly processed (i.e. there are not a lot of unprocessed points).

To best use this dialog:

1. process the project successfully,
2. open all or some of the photographs with potentially unreferenced points,
3. tile the photographs,
4. turn on Point ID visibility (optional),
5. start Unreferenced Point Weld,
6. step through all the points it provides paying particular attention to the first few,
7. if the points that are highlighted on the photographs should be referenced but are not, press the "Weld Pair" button.

When Unreferenced Point Weld mode starts, it will first do a search through all potential candidate referencing pairs. If there are no points that are suitable candidates, this dialog will not appear and message will say there are no possible unreferenced points.

If it finds some candidate pairs it will present each pair in turn; sorted by best candidate for referencing first and worst candidate last. The "Next" and "Prev." buttons step you through the pairs of points, one by one.

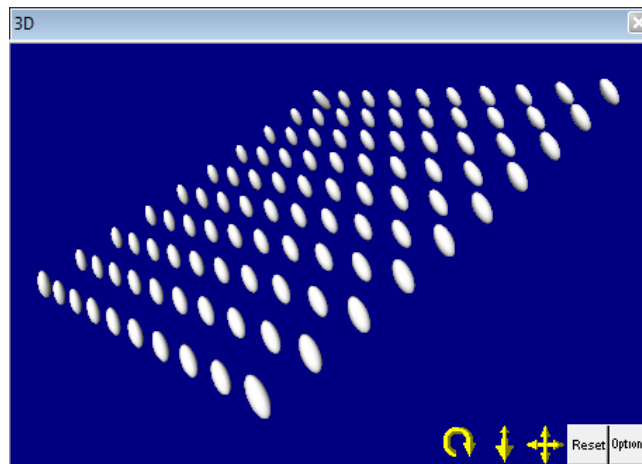
The first point is shown at the top of the dialog with its Point ID and the Photograph/Station numbers it appears on. The second point is shown at the bottom of the dialog with its Point ID and the Photograph/Station numbers it appears on. The top point will be highlighted in all open photographs with a tag "WD" and the second point with a "WS". This makes it easy to find the points.

The middle section indicates how good a weld pair this is. The lower the pixel distance is the greater chance these points should be referenced. Even so with low pixel distances

you should always check on the photographs to make sure before pressing the Weld Pair button.

During Unreferenced Point Weld mode, you can zoom and pan the photographs to take a closer look at a Weld candidate pair before deciding if they should be referenced.

Confidence Regions in the 3D Viewer



Confidence Regions (also known as Error Ellipsoids, see also *Confidence Region*) can be viewed in the 3D Viewer when enabled and the exaggeration is set high enough for them to be viewed. See *3D Viewer Options Dialog*.

Confidence Regions display a visual representation of a point's strength. These ellipsoids are useful when you look at a) their shape, or b) their relative size to other point ellipsoids. If a region is a sphere then the point's position is equally likely in all directions. If it is a strong oval shape then the point is less accurate in one direction (the longest dimension of the ellipsoid is the axis of most probable error of point). This is useful to see if for example that direction is very important for your measurement task. The relative size of the ellipsoids gives a very quick visual way to see if some points are more accurate (or inaccurate). The larger the region the greater probability that point is inaccurate.

The largest axis of the region is the direction that the point is least accurate. The surface of the region is the equi-probability surface - so anywhere on that surface (and surfaces parallel to that) the point is equally likely to be. Conversely the smallest axis of the region is where the point is most accurate. In other words, if a region is elongated as shown above, the region 'points' in the least accurate direction.

Shapes Modeling

A 3D model in PhotoModeler is composed of different types of 3D objects such as points, lines, curves, surfaces, cylinders, etc. Shapes are another type of geometric object that can be added to projects. Shapes can be thought of as solids (they completely enclose a volume). Shapes are a rapid way of modeling man-made objects (such as buildings or industrial equipment). As the nature of shapes, and how they are created and processed, is different than points and lines, we dedicate this section to describe all their capabilities.

What are Shapes?

Shapes are 3D geometric entities such as cubes, pyramids, and wedges that are easily created by marking their edges (or vertices) on photographs.

The following sub-sections provide an overview of the major capabilities of Shapes.

Shape Composition

Shapes are composed of faces, edges, and vertices. Faces enclose a solid volume. Faces have three or more edges that surround its perimeter. Edges have two vertices. For example a Box shape has six faces, and each face has four edges but those edges are shared by faces so the Box has 12 distinct edges in total. Each edge has two vertices but these are also shared so the Box has eight distinct vertices in total.

Since all pieces of a Shape are solved together as a single shape unit, once a shape is solved by marking enough edges (e.g. you mark 7 edges of the shape), the 3D model will have the fully solved shape (i.e. the shape will include the edges not marked and the faces not seen).

Shape Parameterization

Shapes are defined by their parameters. The simplest shape, the flat Rectangle, is defined by its width and its height. All shapes also have their transformation parameters - these are rotation and translation relative to the world coordinate frame. These can be thought of as three parameters for rotation (three angles about the coordinate axes) and three parameters for translation (x, y and z translation relative to the origin).

A Box shape has three parameters, width, height and depth, and combined with the transformation parameters, it is fully defined by nine parameters. A Truncated Wedge has ten parameters (because it has two 'widths' compared to the Box's one width parameter).

The Shape algorithm uses the edges that are marked on the photos to solve these parameters and rarely do you have to be concerned with them. The *Shapes Explorer* provides a means of viewing these parameters if you so wish.

CAD-like

Shapes are 'CAD-like' - that is they will always have 90 degree angles between edges and faces, edges are exactly the same length (when they should be - such as opposite sides of a rectangle).

You can also get CAD-like results over multiple shapes by using *Shape Relations*. You can get two or more shapes to line up perfectly, etc.

Surfaces and Faces

Shapes have surfaces that are like other Surfaces in PhotoModeler. These surfaces are called Shape faces and they can be textured and surface-drawn on (see *Surface Drawing* for information on drawing points, lines, and curves on the plane of a surface in one photo).

Other types of surfaces (Path, Loft, etc.) can be attached to Shape Edges just as they can be to lines.

Individual faces can be hidden so the interior of the shape can be seen. Also the faces can be turned inside out (so they face inward instead of outward - important for texturing

an interior such as a room model). See *Properties Pane* and *Shapes Properties* for information on setting various properties.

Solving Shapes

Shapes can be solved on one photo or as many photos as needed. Single photo projects with an unknown camera are very easy to solve with Shapes. To add more complex structure or to get photo texture all around the object, more photos can be added and the same shapes that are visible on those photos can be marked.

Under certain conditions a Shape can even be solved with no photo marking. If a shape has all its free parameters (size parameters and transform parameters) defined or fixed then it will become 3D automatically without any marking. *Shape Relations* are the tools that allow this to happen. An example of this is a 3D box which is defined by size (w,h,d), by position (Tx,Ty,Tz) and rotation (Rx,Ry,Rz) and if all of those have values before any marking is done the shape can be automatically created and solved in 3D. For example, this might be a box that sits on top of another shape (defines Tz), has a concentric relation (defines Tx and Ty), an aligned relation (defines Rx,Ry and Rz), and relations that define width, height and depth (such as parameter equal relations).

Shapes and other Objects

Other standard PhotoModeler items such as points, lines and curves can be added to Shapes-based projects. Surface draw can be added to a single photo shape project but to add 3D points, lines, and curves you need to use multiple photos.

Conversely Shapes can be added to a project that was started as a Points-based project. This is done by tying Shape vertices to existing 3D points during shape marking. See *Shapes in Points-based Projects* for more information.

Shapes-based Projects

How do Shapes-based projects and Points-based project differ? The main difference is which algorithm runs to create the 3D data. You decide whether a project is to be a shapes-based project or a points-based project at the beginning when the project is first created in the *Getting Started Panel*.

Here is a table of differences with further explanation below:

	Shapes-based project	Points-based project
Photos oriented by	Shape algorithm	Relative orientation algorithm
Coordinate frame (before scale/rotate)	Defined by base shape	Arbitrary (free-network) or defined by control points
Points are computed by	3D intersection math	Bundle adjustment algorithm
Shape's reference frame	The base shape	Tied to points

In a photogrammetry project we need to solve not only the 3D model but also the positions and angles of the photographs (called the camera station orientation) and we need to know or solve the camera's internal parameters. In a Shapes-based project the photos are

oriented when enough edges are marked on the base shape and when the shape-algorithm runs. The shape-algorithm is responsible for solving the shapes' parameters and positions as well as any camera parameters when needed. In a points-based project the photos are oriented by a relative orientation method based on six or more referenced points. Single-photo points-based projects are possible too using control points (in which case the photo is oriented by a point-resection algorithm – see *Imports* for more information on control).

Every project has a 3D coordinate reference frame. This can be thought of how the x, y and z axes line up with the project data. In a shapes-based project the coordinate frame is defined by the first shape added to the project (the x, y and z axes will line up with some of the edges of the first (or base) shape). In a points-based project with no control points the coordinate system is somewhat arbitrary (hence the importance of using the Scale/Rotate feature in points-based projects). If a points-based project has control points then these define the coordinate frame.

When points are marked and referenced across oriented photos they become 3D. In a points-based project these points are first computed by light-ray intersection math but later are computed more accurately with a bundle adjustment algorithm. In a shapes-based project referenced points are only ever computed by the light-ray intersection math. These points may be less accurate than they would be in a comparable points-based project.

When a shape is added to a shapes-based project it will always be related in some way to the first shape added to the project (or the base shape). This may be via relations to the base shape or via a shared ground plane. When a shape is added to a points-based project the shape must be either tied to some existing 3D points or be related to a shape that is in turn tied to some 3D points.

When to use Shapes-based projects

If you want the highest accuracy you will probably be using targets and a points-based project. If you have an unknown photo (no knowledge of the camera that took the photo) and the photo has distinct geometric shapes (such as box shaped buildings, not necessarily cube shaped) then a Shapes-based project may be the easiest way to start.

Shapes-based projects are easy to set up, easier to use with unknown photos but require some good regular geometric shapes with clear edges (such as a box or a rectangle) visible in the photos. Points can be marked and referenced in Shapes-based projects but solve by light-ray intersection only (which may not be as accurate as a points-based bundle adjustment solution). You can add curves, surfaces, etc. to the points in a Shapes-based project.

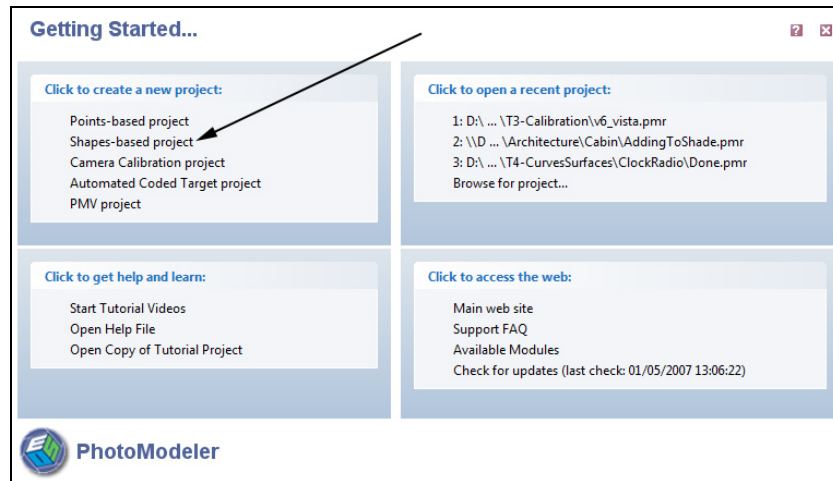
Points-based projects are described extensively in other sections of this document. When a Shape is added to a Points-based project it must have three or more of its vertices tied to existing 3D points (by marking shape vertices on top of Marked Points in a photo). Subsequent shapes in the project can be tied to points or be tied to existing Shapes though the use of Relations. See the *Shapes in Points-based Projects* section for additional details on how Shapes can be used in a Points-based project.

Note that in a Points-based project when processing is run (manually or automatically in the background) the bundle adjustment algorithm runs first and then the Shapes algorithm runs (to ensure shapes that are tied to points are recomputed). In a Shapes-based project the shapes algorithm runs after each new shape is added and after an adjustment to a vertex or edge is made on a photo (if *automatic processing* is on). Then any points in the

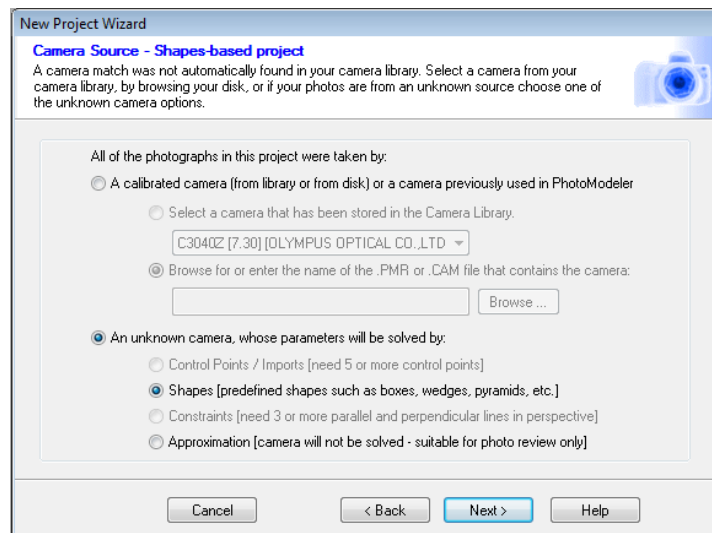
project that are referenced (or are on one photo in the case of surface draw) are recomputed.

Creating a Shapes-based project

To create a shapes-based project you click on the 'Shapes-based project' hyperlink on the **Getting Started Panel**. See also **New Project Wizard** for information on setting up new projects.



The Select Photos pane will then appear. Add one or more photos to the new project. At this point the **Camera Library** will be searched to see if any cameras you have stored will match based on EXIF image data (see **Camera Matching**). If no match was found then the Camera Source pane will appear:



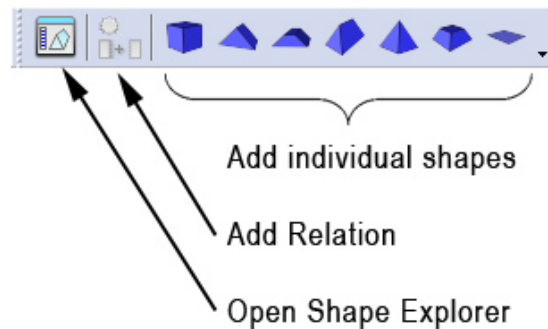
A common choice will be to say the camera is unknown and the camera will be solved by the shapes-algorithm. This common choice is shown in the figure above.

When the Next> button is pressed on this pane, the photo(s) will be loaded and the project work can begin. See [Adding Shapes](#).

Adding Shapes

Add Shapes Toolbar

Shapes are added to a project through the Add Shapes Toolbar. This toolbar will be opened automatically for a shapes-based project. Otherwise it can be opened by right-clicking on the program toolbar and picking the “Add Shape Tools” menu item (see also [Toolbar Customization](#)).



When a shape is added, the [Shapes Explorer](#) pane will open. The basic steps for adding a shape to a project and making it 3D are:

Choose the desired shape and click on that tool in the ‘Add Shape Tools’ toolbar.

Open one or more photos.

Orient the shape in the Shape Explorer 3D view using the rotation tool at bottom right of the viewer so it looks roughly the same as the shape in the photo (this is not a mandatory step but helps with the marking).

Ensure the program is in Shape Edge Marking mode (right after a shape is added via one of the tool buttons this will be the default mode). You can also enter Shapes Marking mode by clicking the Mark Shapes Mode button on the Marking menu, or the Marking Mode button on the Shape Explorer toolbar.

Mark the edges on the photo as indicated in the 3D view until the shape solves. See [Shape Marking](#).

Shape Marking

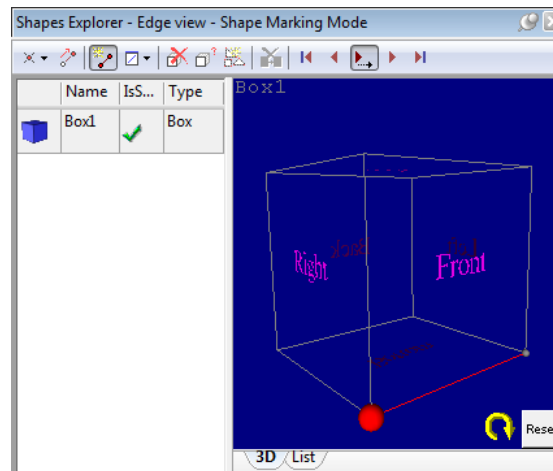
Once a shape has been added to a project it needs to be marked on one or more photos. There are some situations where marking is not needed if a shape has sufficient relations but that is addressed [Solving Shapes](#) section.

When you mark a shape on a photo you are making its edges. An edge has two end points but there is a short cut so that not all edges need both end points marked - this is called vertex marking. Vertex marking is the default marking mode as it is faster and generally easier to use. You switch to edge end-point marking when you can not see the vertex on

the photo (such as the corner of a building hidden behind a bush). See the *Shape Explorer Toolbar* section for information on switching between these modes.

Note: an edge has two end-points. An end-point differs from a vertex in that an end-point does not need to be marked at the corner (or vertex) of a shape.

You enter Shape Marking mode by depressing the Marking tool on the Shape Explorer Toolbar (it is depressed by default when a shape has just been newly added), or by choosing the Mark Shapes mode on the Marking menu. The Shape Explorer 3D Edge view will look like this:



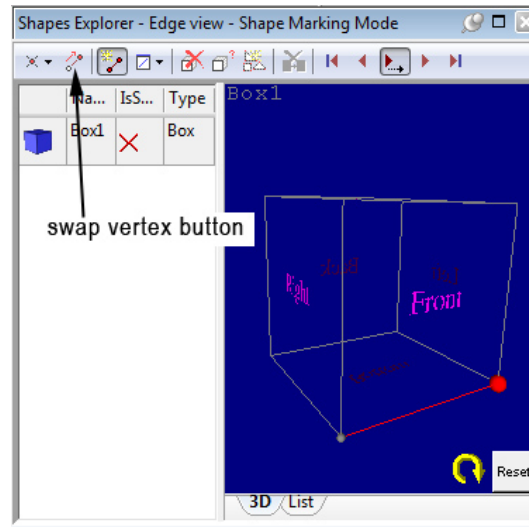
This shows vertex marking sub-mode. The red edge indicates the edge being marked and the red ball shows the vertex that should be marked next. When the cursor is moved over a photo it will show the shape vertex marking cursor. Click down on the corner of the object in the photo that matches the red ball. The red ball will advance to the other end of the edge to indicate what is to be marked next on the photo.

Note: it is helpful to rotate the 3D view of the shape so it approximates the orientation of the shape in the photo (even though it may not have the same size or proportions yet).

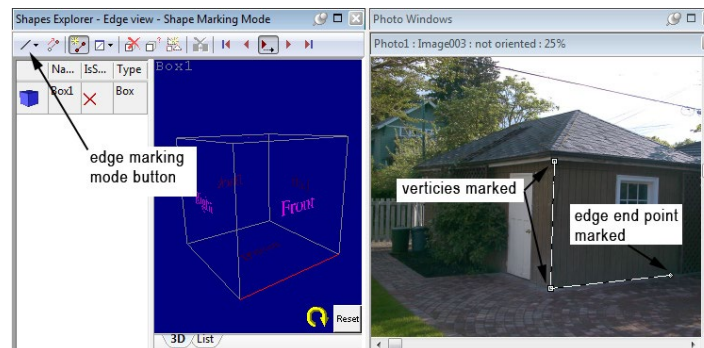
Also note: although the box shape above looks like a cube, boxes are not cubes when solved (that is, their width does not equal their height or depth). The box shape on the photo could be tall and skinny (like a bell tower) or flat and wide (like a two story parking garage).

If the edge or vertex that is highlighted in the 3D view is not one you can mark you can move to another edge in three ways. The first is to use the advance button on the Shape Explorer toolbar (looks like a red right arrow), the second is to use the ESC keyboard key, and the third is to use the cursor to click on an edge in the Shape Explorer 3D view.

If you wish to mark the other vertex of an edge you can use the switch vertex tool on the Shape Explorer toolbar. The red ball will move in the 3D view:



If the end of the edge that is being marked is not visible in the photo, the edge can still be marked. Switch to edge mode and then the end point can be marked anywhere along the edge in the photo (i.e. it does not have to be at the corner of the shape). The figure below portrays this showing an edge with two vertices marked at corners, and an edge marked with one end at a corner and the other end along the edge but not at the corner. Edges can have one or both of the end points marked as non-vertices.



On the photo when a vertex has been marked there will be a square symbol and possibly multiple edge marks attached. If an edge end point has been marked then a diamond symbol will appear along with just one attached edge.

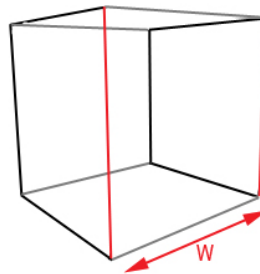
In fact a shape could be marked completely in non-vertex mode (i.e. every edge has both end points marked independently) but for most situations this is slower (more clicks needed because no end-points are shared between edges).

You can advance through edges using the forward and backward tools or the first edge and last edge tools on the Shape Explorer toolbar.

How Edge Marks Define Parameters

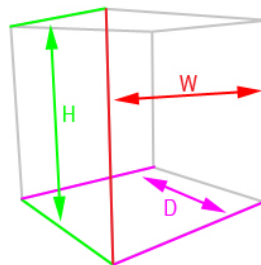
For a shape to solve it has to have all its parameters 'defined'. Parameters can get 'defined' by relations but here we discuss how they get 'defined' by edge marking only. Understanding how edge marking 'defines' a parameter will help you understand how many edges need to get marked to solve a shape or to understand why a shape may not be solving with the edge marks it already has.

A shape parameter (such as width) will be 'defined' and its value will be solved if two edges that are perpendicular to the direction of the parameter have been marked. See the figure below:



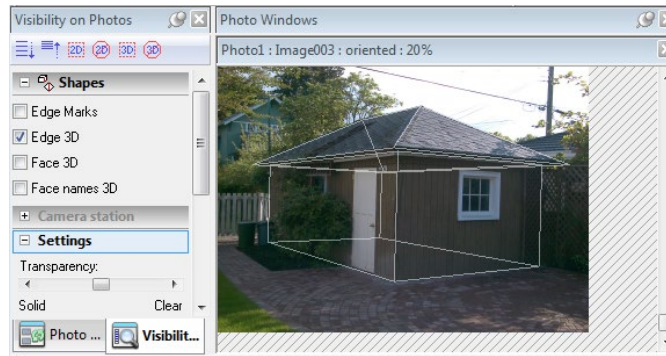
The width of the box is shown by the red W and the red arrowed dimension line. The edges on the box that are 'W' long are light gray. For the width to solve the two edges that are shown in red need to be marked on a photo and not one of the gray edges. Think of these red edges as cutting and defining the ends of the gray edge so it 'knows' its length. In other words, marking the light gray edges do not help solve for 'w' but marking the red edges does. Of course, the marking of the other edges helps 'define' and solve other parameters.

In the figure below we show a set of minimal edges marked in color that would help solve the three parameters (width, height, depth of the box).

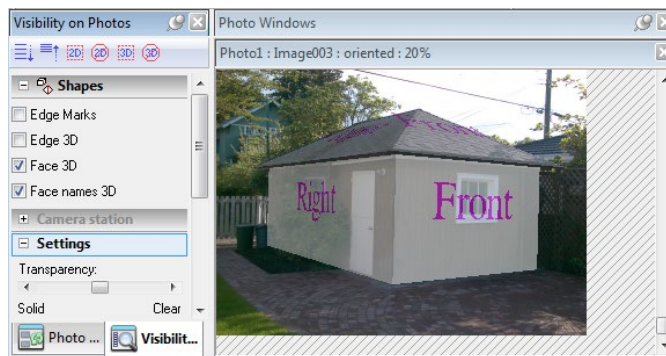


Photos Showing 3D Shape Data

The 3D data view on photos (projections) can be very useful to see how well the shapes are solved. Use the *Visibility on Photos* pane to turn on 3D shape edges and optionally turn off the marks and set the transparency to more solid to see the edges better.

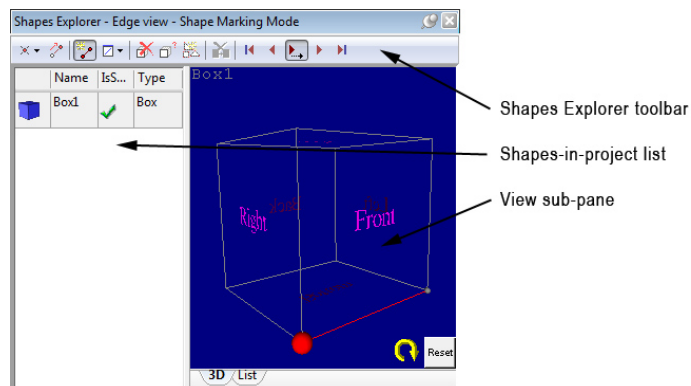


You can also turn on the shape faces and face names to check the face alignment.



Shapes Explorer

The Shapes Explorer is the main interface for adding, manipulating, reviewing and deleting shapes.



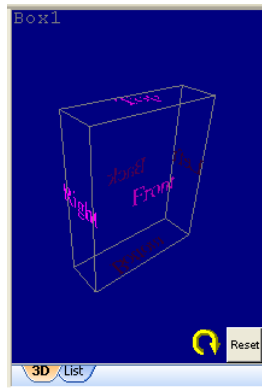
The Shape Explorer is made up of three sections: a toolbar, a shapes list and a multi-use view sub-pane. The toolbar is described below. The shapes-list shows all shapes that have been added to the current project whether they are 3D or not. The sub-pane can be one of: edge view, face view, relations view, parameter view and transform view. The type of view is chosen by one of the toolbar buttons as shown below. The edge and face views

are 3D views but also have text list views that show the individual edge names or face names.

The view sub-pane shows information for only one shape at a time. The shape that is currently selected in the shapes-in-project list on the left has its information shown in the view pane on the right.

The following sections describe the sub-pane view types.

Edge View

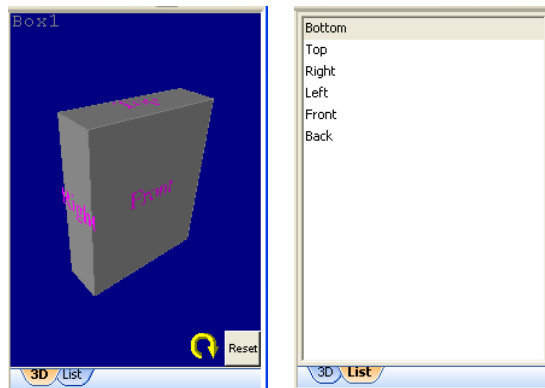


The Edge view of the Shapes Explorer is the first view to open as it is the one used most often (it is used during the marking of edges on photos).

The view shows all the edges of the selected shape along with the face names to assist with orientation. The view's rotation can be adjusted with the rotation tool at bottom right (yellow circular arrow). This 3D view rotation works similarly to PhotoModeler's main 3D viewer.

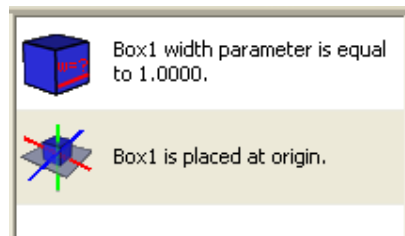
The List tab on the bottom show the shape edges in list form. One can select an edge by using the cursor to click in either the 3D or list views while in Select mode. See *Selecting Shapes and Shape Parts* for more information.

Face View



The Face view is similar to the Edge view in that it has a 3D view and a list view as shown above. A face can be selected by clicking in either of these views while in Select mode. Some operations (such as setting properties or adding relations) require faces to be selected and this view is a convenient location to do so. See *Selecting Shapes and Shape Parts* for more information.

Relations View



The Relations view shows all the relations for the selected shape. See the *Shape Relations* section for more information.

Parameter View

Parameter	Value	
width	1.0000	
depth	0.2990	
height	1.2522	

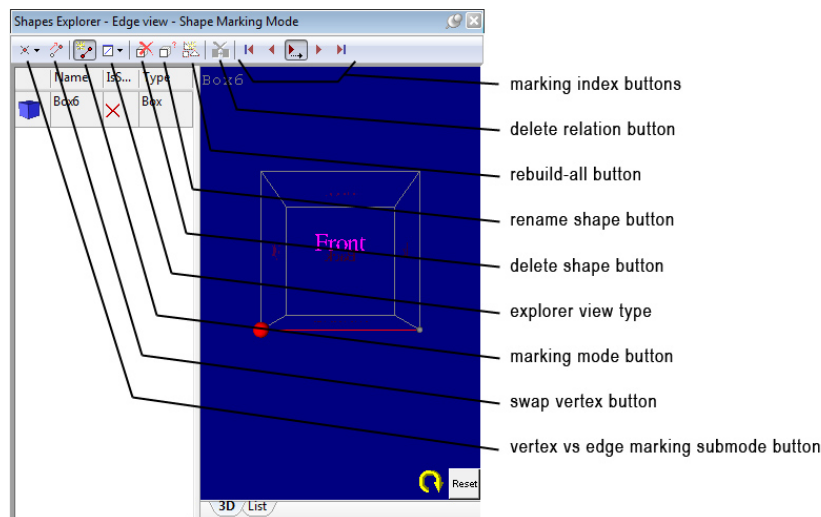
The Parameter view shows the values of the parameters that define the size of the currently selected shape. For example, a box is defined by its width, depth, and height. The values for the solved shape are 1.0, 0.299 and 1.2552 respectively. These are shown in project units (which may also be unitless if a scale has not been defined).

Transform View

Tx	0.0	
Ty	0.0	
Tz	0.6261	
Rx	0.0	degrees
Ry	0.0	degrees
Rz	0.0	degrees

The Transform view shows how a shape is positioned and oriented in the global coordinate system. The above shape has the same orientation as the global coordinate system (i.e. is not rotated) and is also sitting at the origin (Tx and Ty are the translation in X and Y and they are both zero). These translations are relative to the center of the shape. This object is sitting on the ground (z=0) plane and so its Tz is half the shape's height (bottom of shape sits at z=0 so center of box sits at z=0.626).

Shape Explorer Toolbar



Most of the operations in the Shapes Explorer are controlled by its own toolbar. The tools in that toolbar are listed in the figure above. The follow table describes each tool:

Tool	Description
explorer view type	A drop down button that allows you to choose between the edge, face, relation, parameter and transform sub-pane views.
marking mode button	A mode button that is 'down' when shapes are being marked on photos.
vertex vs edge marking sub-mode button	Controls whether edge marking or edge vertex marking is done. See Shape Marking.
swap vertex button	During edge vertex marking, this button allows you to switch which vertex is next to be marked for the current highlighted edge. See Shape Marking.
marking index buttons	These five buttons are: go to first edge to mark, go to previous edge to mark, auto-advance edge mode (automatically advances to next edge to mark after both ends of an edge are marked), go to next edge, and go to last edge.
delete shape button	Deletes the currently selected shape (after a confirmation dialog)
delete relation button	Deletes the currently selected relation (in relation view) after a confirmation dialog.
rebuild-all button	See Shapes Rebuild All.
rename shape button	Clicking this button allows you to rename the currently selected shape. Type the new name when the edit box becomes active in the name area.

Selecting Shapes and Shape Parts

There are a number of operations (such as adding relations, bringing up properties, etc.) that require parts of shapes to be selected. Here are the various parts, how they can be selected, and various things that can be done once selected.

Part	How to Select	Various things you can do
Shape	Click on the shape in the Shape Explorer Shape List. Select mode is not required.	-See shape parameters in sub-panes. -Bring up shape properties*. -Delete the shape. -Rename the shape.
Shape Edge	Click on: marked edge in a photo, edge in 3D Viewer, edge in photo projection, or edge in Shape Explorer Edge View.	-Add a Shape Relation for whole shape. - Add a Shape Relation that is edge based (collinear for example). -Bring up Shape properties*.
Shape Face	Click on: face in 3D Viewer, face in photo projection, or face in Shape Explorer Face View.	-Add a Shape Relation for whole shape. - Add a Shape Relation that is face based (coplanar for example). -Bring up Shape Face properties and Shape properties*.
Shape Marked Edge	Click on marked edge in a photo.	-Delete edge mark.
Shape Marked Vertex	Click on marked vertex in a photo.	-Delete all attached edge marks. -Drag vertex to new position.
Shape Relation	Click on relation in the Shape Explorer Relation View.	-Delete relation.

Note: when 'Properties' are mentioned in above table you may wish to refer to the *Properties Pane* section for further information.

Also note: when adding a relation between two existing shapes or two shape parts, both items need to be selected before the Add Relation tool is pressed on the toolbar. You can only select multiple shapes at once in the 3D Viewer or on a Photograph. The Shape Explorer window allows only one shape to be selected at a time.

Shape Relations

Every shape will have one or more relations. These relations define how the shape is 'related' to the other shapes, to the world coordinate system or to 3D points. Relations control the size, shape, position and orientation. This table lists all the relations types and what parts of the shape they use:

Shape Relation Type	Listed in Shape Explorer As	Based On Entities	Description
Base	is placed at origin	One shape	The shape sits at 0,0,0 and is aligned with the coordinate axes.
Ground	lies on ground	One shape face	The shape face sits on the ground plane.
Coplanar	shares same plane as	Two shape faces	One shape face is in the same plane as the other face.
Concentric	is concentric with	Two shape faces	The centers of the faces are the same. (requires a coplanar)
Aligned Face	is aligned with	Two shape faces	The two faces have the same rotation. (requires a coplanar)
Same Size Face	is the same size as	Two shape faces	The two faces have the same dimensions. (requires a coplanar)
Colinear Edge	is colinear with	Two shape edges	The two shape edges are colinear (both edges lie on the same infinite 3D line)
Same Shape Rotation	is the same rotation as	Two shapes	The two shapes have the same Rx,Ry,Rz rotation.
Same Size Shape	is the same size as	Two shapes	The two shapes have the same sizes. Shapes must have matching parameters.
Parameter Equals	is equal to	Two shape parameters, or a shape parameter and a constant	The two parameters are made equal or the parameter is made equal to a constant.
Points Base	is aligned by 3D points	Shape vertices and 3D points	The shape is solved so that the tied vertices line up with the 3D points as best as possible.

When to Use Relations

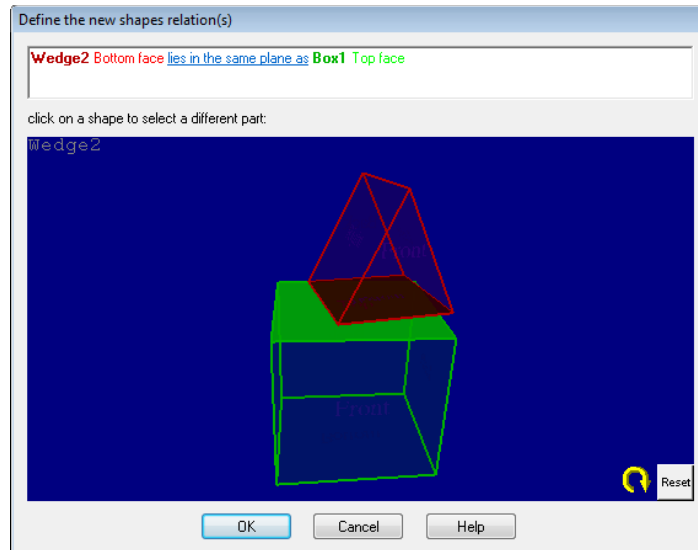
Some relations are mandatory and those relations are either added automatically by the program or they are a minimum choice in the Shapes Relation dialog. The mandatory relations that are added automatically are the Base relation for the first shape in a shapes-based project, and the Points Base relation for the first shape in a Points-based project. Then every subsequent shape must have at least one of: a Ground relation (the shape lies on the ground plane), a Coplanar relation (making one face of a shape lie in same plane as another shape's face), or a Points Base relation to tie the shape to 3D points. These

mandatory relations define the basic position of the shape in space. The remaining relations refine the shapes position, orientation or size.

In some circumstances relations can be used to define all the free parameters of a shape so that it will become 3D even without being marked (see also *Solving Shapes*).

Except for the starting mandatory relations, most relations are added using the *Shape Relation Dialog*.

Shape Relation Dialog



The Shape Relation dialog is used to define or refine shape relations. The dialog appears automatically when new shapes are added (after the base shape) or it can be brought up from the main application's "Add Shapes" toolbar using the "Add Relation..." tool.

Note, the "Add Relation" tool on the "Add Shapes" toolbar is enabled when an appropriate component of the shape is selected in the Shapes Explorer 3D or List view. See *Selecting Shapes and Shape Parts*.

The dialog has two sections. The top section is a rich-text control that describes the relation textually and may have hyperlinks to modify the relation. The bottom section is a 3D view that shows the one or two shapes being related. You click on the shapes in this bottom 3D view to make certain types of relation changes.

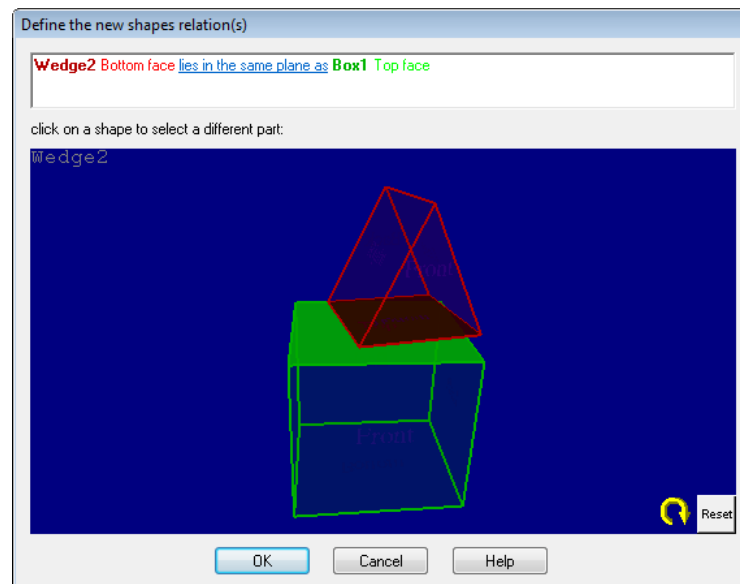
In the example above a box shape called Box1 was selected and then a wedge shape was added to the project. The dialog automatically appears and assumes that you want to place the bottom of the wedge on the top of the box. If this is correct you can press the OK button and proceed with the marking of the wedge.

You may not want this default choice though. If you wanted instead that the wedge sit on the ground plane you can click on the relation-type hyperlink *lies in the same plane as* and from the menu that appears pick the "lies flat on ground plane" option. You can make a similar change to tie this shape to 3D points.

The coplanar relation may be the relation you want but the face may be incorrect. In this case click on the box in the 3D view and a menu of face names will appear. As you mouse over these menu items the faces will highlight in the 3D viewer to give feedback as to your choice. You could choose “Right face” for example so the bottom of the wedge will sit on the box’s right face.

You can also change the face of the new shape at this time but a wedge can use the bottom face for coplanar relation only. If the new shape was a box or a truncated wedge then you could pick a different face for it also.

You can also refine the coplanar relation further at this stage. (Note you can come back later and refine the relationship between the two shapes). If you click on the relation-type hyperlink lies in the same plane as you can choose to add refinement relations (clicking on the relation in the menu toggles it on or off and you select a relation in the menu to activate or deactivate it – to activate multiple relations, click the hyperlink again to toggle a relation). Below we have set to use the Box1’s front face, and made the two faces coplanar, have the same center axis (concentric) and be aligned. This can all be done before marking is done on the wedge and this is used by the shape algorithm to improve the shape’s position and rotation.



Often it is advisable to pick the minimum relations for a new shape (e.g. choosing one coplanar or ‘lies on ground’) to start. After the shape is solved you may wish to refine it further. In this case you can select a single shape or two shapes to refine the relations. select edge marks in photos or edges and faces in the 3D viewer and then press the Add Relation tool in the Add Shapes toolbar. See *Selecting Shapes and Shape Parts* for more information.

Also see the section on the *Parameter Equal Relation* as this relation has some additional capabilities and user interface.

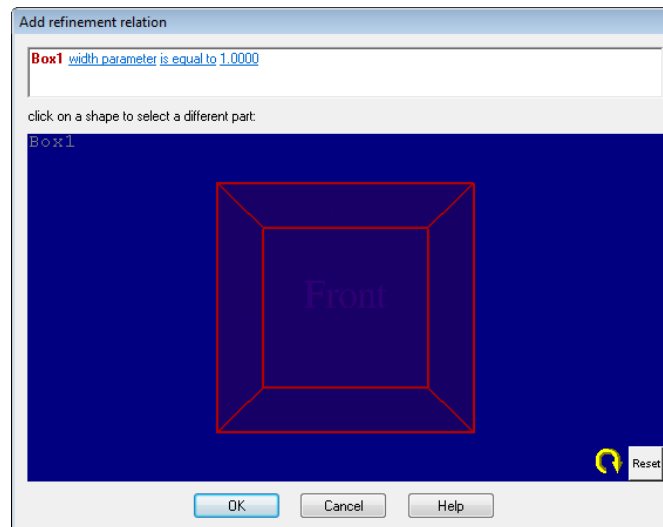
Shape Relations can also cause trouble with the model and the solution. You can add relations that conflict or you can add relations that are not true on the real world object (i.e. adding a concentric relation when the shapes in the real-world are actually offset).

Sometimes these conflicts will cause the solution to become slow and sometimes it will fail. See the [Troubleshooting Shapes](#) section for more information.

Parameter Equal Relation

The Parameter Equal Relation allows you to make two parameters on the same shape or on different shapes be the same value or you can make one shape's parameter equal to a constant. To set up this relation pick an edge of the shape in a photo or Shape Explorer and press the Add Relation tool on the Add Shapes toolbar.

The Add Relation dialog will appear showing the one shape in the 3D view:





It is the top part of the dialog that controls this relation. There are three hyperlinks: the first is the parameter of the selected shape that is to be related (here width parameter), the second is the relation (here is equal to), and the third is the other part of the relation (here a constant at 1.000). If you click on the first link you can choose which of this shape's parameters (width, height or depth for example) will be related. The second link allows one to switch to other single shape relations if the Parameter Equal relation was not the desired one. The third link brings up a menu of consisting of 'a constant' and the other parameters of this shape. This allows two parameters to be made equal on the same shape (e. box1 width = box1 height).

To get a parameter on one shape equal to a parameter of another shape you would select both shapes before pressing the Add Relation tool. Then one of the choices in the relation list will be 'is equal to'. That will form a rich-text description like above but with the choice of both shapes' parameters.

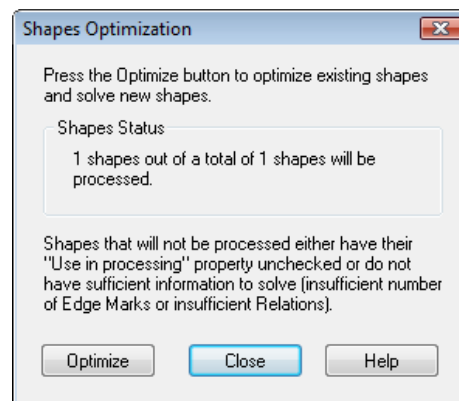
Processing Shapes

When a project is first started, it is set to automatically process the project on all changes (see [Automatic Processing](#)). This means that shapes, once they are sufficiently marked, will appear automatically in 3D with no further user interaction. Also when a shape is modified (photo mark moved, relation added, deleted, etc.) the shape algorithm will automatically run and all shapes will be updated.

When the project gets too large or certain relations are added, the processing might take longer than a few seconds. In this case you may wish to switch to manual processing. You can switch to manual processing when the delay message appears, by using the *Project Information Dialog* or by clicking on the 'processing man' symbol  in the *Status Bars* at the bottom of the application window. When the 'processing man' symbol is 'standing'  that means that manual processing is in effect. Changes to shapes will not be immediately reflected in the 3D data when manual processing is enabled. You can make a number of changes and then press the processing button on the main toolbar.

When the project is a Shapes-based project the main processing button will bring up the *Shape Optimization Dialog*.

Shape Optimization Dialog



The Shape Optimization Dialog appears when the Processing tool is pressed on the main toolbar and the project is a Shapes-based project.

This dialog is used when processing is not automatic (the 'processing man' symbol in the *Status Bars* is 'standing' instead of 'running'). This would be typical of when the shape processing is taking longer than a few seconds.


The dialog indicates how many shapes of the total number of shapes in the project will be processed. If this value is not what you expect some of the shapes may not have enough marks or the shape may have its 'do not process' property turned on.

To run the shape optimization algorithm press the Optimize button. The total error in the shape fitting will be displayed during each iteration of the optimization. This error value should be decreasing and then level out for a good solution.

Modifying Shapes

Shapes can be modified in a number of ways, even after they have been solved and are 3D. You can:

- finish marking the edges, which may improve alignment, using the Shape Explorer
- delete an edge mark by selecting the mark on a photo in select mode and pressing the Del key on the keyboard
- move edge and vertex points by selecting the points while in select mode and dragging

- add refinement relations using the Add Relation tool on the main Add Shapes toolbar (with appropriate items selected in photos or the 3D viewer - see *Selecting Shapes and Shape Parts* for more information)
- delete relations by using the Shape Explorer Relation view and the Delete Relation tool on the Shape Explorer toolbar
- rename a shape by using the Shape Explorer and the Rename Shape tool on the Shape Explorer toolbar
- If automatic/background processing is on ('processing man' in *Status Bars* is 'running' ) then any of these changes will cause all the shapes (and sometimes the photo orientation) to recalculate to take the new information into account.

Shapes in Points-based Projects

When a project has been started as a points-based project and typically solved with referenced points and points-based adjustment, shapes must be added with a points-base relation. In fact the first shape added to such a project will be added automatically with a points-base relation.

When a shape is computed by points, a few of the shape's vertices must be tied to existing 3D points in the project. This is done during vertex marking. Once the shape has been added and the Shape Explorer is in vertex marking mode, find the first vertex that matches an existing 3D point marked on a photo. Move the cursor over this point and the cursor will change to indicate that shape-vertex-3D-point tying will take place. Click on the marked point to tie this shape vertex to this point.

When a sufficient number of vertices have been tied to points the shape will solve if automatic processing is on or the status symbol in the shape list will turn to a yellow check mark. The project can then be processed. Note that when the Processing tool is used, the points-bundle algorithm will run first and then when it is done, the shape algorithm will run to solve the tied shape(s).

A box shape would typically need to be tied to six 3D points to solve. These requirements can be reduced by adding Parameter Equal relations to this shape. For example, you can set the depth of a box to be equal to its width and then only the front of the box (4 vertices) needs to be tied to points before it will solve.

Once there is one shape in a points-based project, subsequent shapes can be also tied to points or can be related to the first shape through the coplanar relation.

Troubleshooting Shapes

Occasionally you will not get the 3D shape result you expect. Either the shape will be the wrong size or it will have the wrong orientation (position or rotation). In this case follow these steps:

- Review all the edge markings using the Shape Explorer to ensure they match the shape correctly. Do this by opening the photos that shape is marked on and the Shape Explorer, then select an edge on the photo and hit the W key (or right-click and use the "Expand selection to all windows" menu item). You can verify the edge has been marked consistently. If it has not been, delete the edge mark from the offending photo (or adjust as appropriate).
- Next reduce the shape to its basic relations. In most cases this means reducing the shape to have only a base, ground, coplanar or points-base relation. If this fixes the problem,

add the relations back methodically to ensure none conflict or to find out which causes the problem.

- Lastly you can use the Shapes Rebuild All tool to rebuild a whole shape project shape by shape to find out where the problem lies.

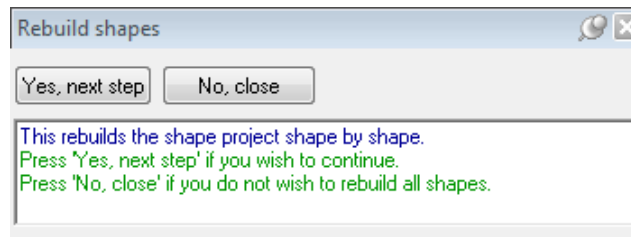
Shapes Rebuild All

There may be times when small fixes to the shapes (deleting relations, moving marks, etc.) will not fix the project. The Shape Rebuild Add tool can help you recover from this.

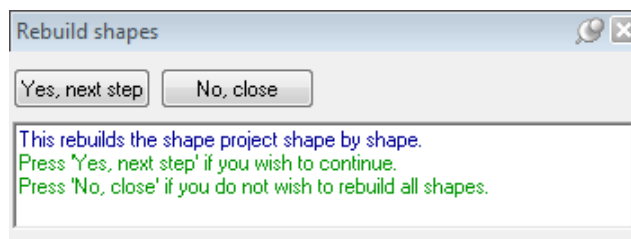
On the Shape Explorer toolbar there is a Shapes Rebuild tool. When this is pressed a pane will open up that will take you through the rebuild of the shapes in the project shape by shape. This pane looks like:



Nothing will happen until the Start button is pressed. And then it indicates what will happen and you get to choose at each stage whether to continue.



If you press “Yes, next step” it will proceed with the rebuild operation. In a shapes-based project the first operation is to unorient all photographs.



Then step by step it starts with base shapes (shapes with Base or Ground relations), solves them, and then proceeds to shapes that depend on those shapes. At any time you can review the results so far in the 3D viewer, shape explorer, etc. You would stop the rebuild at the point when the project is still correct. If you go too far you can start the rebuild process again.

You may need to fix up additional shapes and set their properties to “use in processing” once you have discovered the problem.

Adding Scale and Rotation

After a project has been processed properly, the 3D model's proportions will be correct. In other words, if the width of a door is half its height, PhotoModeler will calculate a value for the model door width that is half of its calculated height. On the other hand, the absolute value assigned to the width of the door may not be its actual value. To correct the scale so that the width of the door matches its actual measurement, you must enter a known distance between two points in your model.

Similarly the rotation of the model will seem rather arbitrary after processing. This is because PhotoModeler does not yet know which way the model is to be oriented (unless you have used control points or axes constraints). To correct this you need to tell PhotoModeler how to rotate the model for 3D Viewer display and for 3D Model Export.

The translation of the model has a similar requirement but it is not as noticeable unless you need your exported data to have particular coordinate values.

The modification of the coordinate system of the 3D model, which involves translation, scale and rotation, is called an affine transformation. That means it is a transformation that does not change the shape of the model.

The affine transform in PhotoModeler is not applied permanently to the model data, that way it can be changed at any time without affecting accuracy. The affine transform is applied before 3D Export, before displaying the 3D Viewer, and before displaying any data in Tables or Measure.

A PhotoModeler project can be in the following states with respect to the affine transformation (of translation, scale, and rotation):

- no applied affine transform (project will be in an arbitrary coordinate system after processing)
- no applied affine transform but the project was done with control points so the project is already in the user's desired coordinate system, and
- a combination of one, two or all components of translation, scale and rotation as defined by the settings described below

You will usually want to get your project into states 2 or 3 but this depends on your needs.

3D Scale and Rotation Dialog

The 3D Scale and Rotation Dialog is used to control the translation, scale and rotation of the project. See the section above for background.

The dialog is opened by using the Project menu, "Scale/Rotate ..." item. There are two forms of scale/rotation that can be set using this dialog: Position/Distance/Axes, and Three Point.

There are three components that define the affine transformation of your project:

Translation: the translation component is used to define a Point or Camera Station with a known 3D position, about which the model is oriented. Often the translation point is the origin (0,0,0) but it can be any coordinate value. The translation point is arbitrary in PhotoModeler unless you specify it.

Scale: the scale component is used to define a known distance between two Points, between one Point and one Edge, between two Edges, between a Point and a Camera

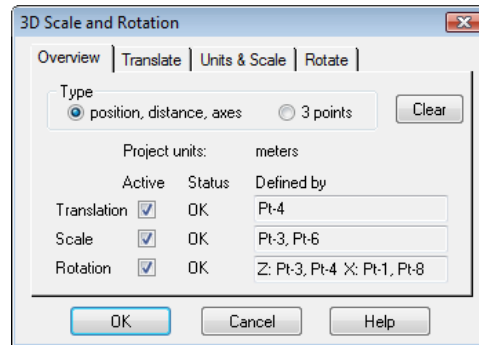
Station, or between two Camera Stations, so that you can determine absolute measurements in your model. The scale is arbitrary in PhotoModeler unless you specify it.

Rotation: the rotation component is used to define the directions of the Left/Right (X), the Front/Back (Y) and the Bottom/Top (Z) axes. You can use points or camera stations when defining the axes. These axes are arbitrary in PhotoModeler unless you specify them.

The Overview tab shows the status of the 3D Scale and Rotation (and its subcomponents) that is defined in your project. You can also clear the project's scale/rotate here.

To view and/or set the points that define the component click the appropriate tab.

Scale/Rotate Overview



The Overview tab provides an overall view of the state of the affine transformation. It allows you to set the type of scale/rotation and set the scale/rotation's components to active/inactive.

You can set the form of scale/rotate on the Overview tab by clicking one of the two radio buttons in the Type group.

Choosing the “position, distance, axes” button will bring up three tabs for:

- *Setting Translation,*
- *Setting Scale,* and
- *Setting Rotation.*

Choosing the “3 points” radio button will bring up one tab for:

- Setting the *Three Point Rotation.*

Whether you have either a “position, distance, axes” or “3 points” affine transform active, any or all of the three components can be set to active or inactive by clicking the “Active” check boxes next to the component. Setting a component to inactive will remove that component of the affine transformation from the model. Setting all components to inactive will remove all of the affine transformation from your model (and hence it will export, view and measure in its default post-processed state).

For example, if you have a translation, scale and rotation defined you can set the Translation part to inactive (no check mark in its Active box) and then only the scale and rotation parts will be applied (during export, 3D viewer, tables, measure, etc.).

Note: Your affine transformation settings are stored and remain in the project but they are not applied to your model when set to inactive. This allows you to easily test or compare your model with and without a scale/rotation applied, without having to redefine the components.

The text under the Status column will show whether the component is defined and if the definition of the component is valid. Once you define the component (each component has a tab on which you define points), the Status will switch from 'Not Set' to 'OK' (if the defining points are valid).

Once you define the points of the component, the text in the "Defined by" column identifies the points that define the component. If the component has been set to inactive, the "Defined by" text will be greyed out. If the component has not been defined, no points will be displayed.

Note: If text is truncated in any of the text boxes, you can scroll text into view using the mouse (click and drag) or by using the arrow keys.

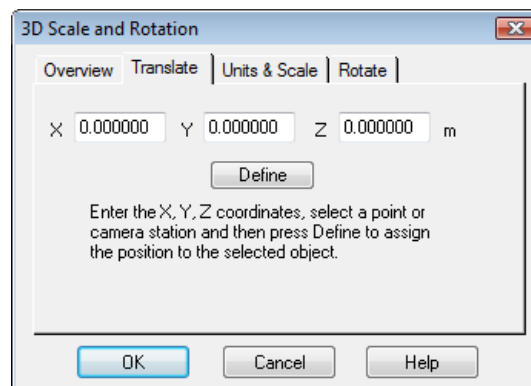
Whenever the Overview tab is active, the points that define the components of the translation, scale, and rotation are highlighted on the open photos and 3D Viewers. If a component is set to inactive, its points are not highlighted (note that if you switch to a component's tab, the defining points of the component are highlighted even if set to inactive).

When you first create a project, no affine transformation will be defined, so none of the three components will be defined and each component's Status will read "Not Set".

Note that in the case of scale, where points are mentioned above, edges also apply.

Pressing the Clear button will clear any existing scale/rotate assignments once OK is pressed. This is a permanent alternative to disabling or invalidating the affine transformation.

Setting Translation



The Translate tab appears when the scale/rotate type is set to "position, distance, axes" on the Overview tab.

Press the "Define" button when you have selected a 3D point in a photograph, 3D Viewer, or Point Table. A Camera Station can also be selected in the 3D Viewer. You will be shown

a warning message if the selected point/camera station is invalid (perhaps the point does not have a 3D position because it is not referenced).

Whenever this dialog tab is open the selected translation point or camera station will be highlighted on open photographs and 3D Viewers. The photograph will show it with a letter "T" and the 3D Viewer point will just be a different color. Note that even if the Translation component is set to inactive on the Overview tab, the point is still highlighted when the Translate tab is open.

The three text boxes are used to enter the known X, Y, Z coordinate values of the point (or camera station center) that you have selected. If these values are left at the 0,0,0 default then the point chosen will become the origin of your coordinate system.

If you return to the Overview tab, the status of the Translation component will be updated. After you have defined the translation item, pressing "OK" will save the changes into the project.

Translation steps

To add translation you need at least one Photograph, Point Table or 3D Viewer window open. You can open one of these while the 3D Scale Rotation dialog is open.

To add translation:

1. Select "Scale/Rotate..." from the Project menu.

PhotoModeler will bring up the 3D Scale and Rotation Dialog.

2. Select the "position, distance, scale" radio button from the Type group, and click the Translate tab
3. Enter the coordinates of the known point in the appropriate text boxes. You can leave it at 0,0,0 if your selected point or camera station is at the origin.

These coordinate values are by default in project units but you can specify any other type of units using the units drop down tool.

4. Using the Select tool, select the point or camera station for which you know the coordinates.

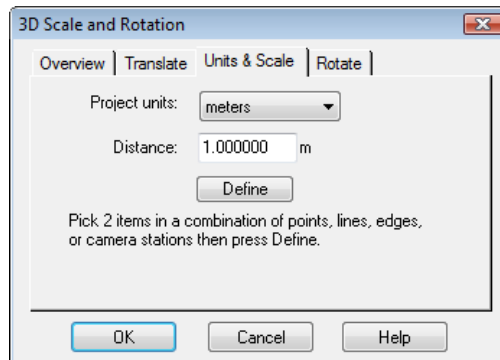
PhotoModeler will highlight the point with the selection color.

5. Press the "Define" button to set the point as the translation point.

PhotoModeler will highlight the translation point in green and draw it with a "T" tag in any open photos.

If you return to the Overview tab, the point that defines the translation will be identified. If you set the Translation component to active, once you press "OK", your model will have the defined translation applied.

Setting Scale



The Scale tab appears when the scale/rotation type is set to "position, distance, axes" on the Overview tab.

This tab is where you also set units for your project. Select the units of the scale using the units drop down selector tool.

Press the "Define" button when you have selected two points, one point and one edge, two edges, two camera stations, or one point and one camera station to use as your scale items. These points or edges can be selected in a photograph, 3D Viewer, or table. The camera station can be selected in the 3D Viewer. You will be shown a warning message if the selected items are invalid or do not have 3D position.

Whenever this dialog tab is open the defining objects will be highlighted on photographs and 3D Viewers and points will be tagged with an "S" on photograph windows. Note that even if the Scale component is set to inactive on the Overview tab, the points are still highlighted when the Scale tab is open.

The Distance text box is used to enter the known distance between the two points, edges or camera stations you have selected.

This is also where you set the project's units. These are the measurement units used by PhotoModeler to report all coordinates, distances, lengths, areas etc. such as in the Table View or Measure Toolbar. It also controls the default units used when the user enters a number such as a scaling distance or an X coordinate. These units can be one of kilometers, meters, centimeters, millimeters, miles, yards, feet or inches. Units can be changed whenever you want without affecting PhotoModeler's internal coordinate data.

If you return to the Overview tab, the status of the Scale component will be updated. After you have defined a scale, pressing "OK" will save your changes into the project.

Scale steps

To add scale you need at least one Photograph, Point Table or 3D Viewer window open.

To add scale:

1. Select "Scale/Rotate..." from the Project menu.

PhotoModeler will bring up the 3D Scale and Rotation Dialog.

2. Select the "position, distance, scale" radio button from the Type group, and click the Scale tab

3. Set the units using the drop down selector
4. Enter the known distance (perhaps a field measurement you recorded when taking the photographs) into the Distance text box.

This number by default is in project units but you can specify any other type of units using the units drop down tool.

5. Using the Select tool, select the two points, one point and one edge, two edges, two camera stations or a point and a camera station between which you know the distance.

To select two objects at once, use multiple-select. This can be done with shift-click or by selecting a line segment that contains both points. PhotoModeler will highlight these points with the selection color.

6. Press the "Define" button to set these points/edges as the scale objects.

PhotoModeler will highlight these scale objects in green and draw the points with a "S" tag in any open photos.

If you return to the Overview tab, the items that define the scale will be updated. If you set the Scale component to active and once you press "OK" your model will have the defined scale applied.

Note: when using edges in your scale it is closest distance that is used. If two edges are chosen then the closest distance between these edges is used to define the scale. This may be an unexpected distances if the edges are not parallel. Similarly for a point and edge, the scale is set so the closest distance between the point and edge is equal to the entered value.

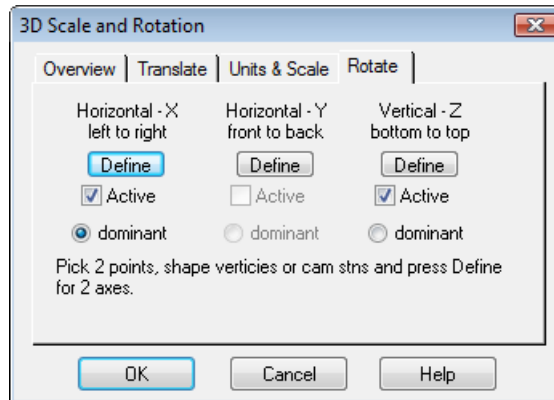
Setting Rotation

The 3D locations in the solved model are described in a Cartesian coordinate system by X,Y and Z values. The directions of the Left/Right (X), the Front/Back (Y) and the Bottom/Top (Z) axes are arbitrary in PhotoModeler unless you specify them.

There are four ways to fully specify the coordinate system:

- use Control Points,
- use Axes Constraints,
- use the Rotation component of the 3D Scale & Rotation Dialog, or
- use the "3 points" component of the 3D Scale & Rotation Dialog.

When the "position, distance, axes" type is selected on the Overview tab, setting up the rotation component involves selecting two points, a line, two camera stations or a point and a camera station, for each of two axes. You may specify any combination of two axes out of the three axes: e.g. Left/Right (X) and Front/Back (Y), Front/Back (Y) and Bottom/Top (Z), or Left/Right (X) and Bottom/Top (Z).



The Rotate tab appears when the scale/rotation type is set to "position, distance, axes" on the Overview tab. On the Rotate Tab there are buttons to define the Left/Right (X) axis, the Front/Back (Y) axis and Bottom/Top (Z) axis points. There also check boxes to set two axes active and radio buttons to set one of the axes to be the dominant axis. You only need to specify two axes. PhotoModeler uses a right handed coordinate system to define the third axis.

When setting up the rotation using axes, think about what you want to be top, bottom, left, right, etc. in your model or what you want the XYZ system to be - which ever you are more comfortable with. For a flat ground scene (for instance an accident scene on a road) you might set across the road to be "horizontal - left to right" and down the length of the road to be "horizontal - front to back". For a building on the other hand you might set across the front of the building to be "horizontal - left to right" and along the vertical side edge to be "vertical - bottom to top".

Each of the Left/Right (X) axis, the Front/Back (Y) axis and Bottom/Top (Z) axis is defined by picking points or camera stations (or a combination) and pressing the "Define" button for that axis. Any open photograph, or 3D Viewer window automatically display the chosen points or camera stations highlighted and tagged in photos. Note that even if the Rotation component is set to inactive on the Overview tab, the rotation defining points are still highlighted when the Rotate tab is active.

The two points defining the Left/Right (X) axis will be tagged with "X1" and "X2", the two points defining the Front/Back (Y) axis will be tagged with "Y1" and "Y2" and the two points defining Bottom/Top (Z) axes will be tagged with "Z1" and "Z2" in any open photograph.

The order of the points is critical. For example, if you have the "vertical - bottom to top" axis chosen and the bottom point is labeled "Z2" and the top point "Z1" then it is backward and the rotation will not come out as expected. The "1" and "2" axis points should be in the order shown on the dialog "1"-left, "2"-right ; "1"-front, "2"-back; or "1"-bottom, "2"-top. If you are thinking about these points in terms of the XYZ coordinate system then the "1" point is the one closest to the origin.

If you define more than two axes, you can choose which two are used by clicking the Active check box for an axis. When you set an axis to active, it and the next most recently activated axes will automatically be set as the rotation defining axes, and therefore the remaining axis gets set to inactive.

The first axis you define becomes the 'dominant' axis. The two active axes should be close to right angles but they do not need to be exactly 90 degrees apart. When the

coordinate system is computed, PhotoModeler calculates the exact secondary axis at 90 degrees to the dominant axis based on the plane defined by the two axes. The dominant axis becomes the exact one (that is the coordinate system exactly lines up with this chosen axis) and the other axis is fit as closely as possible.

You can also manually set one of the active axes to be the dominant axis in the rotation calculation. If the dominant axis becomes inactive (i.e. a new axis is defined or activated thereby inactivating the dominant axis if it wasn't one of the two most recently defined or activated axes), the most recently defined or activated axis automatically becomes the dominant axis. At any time, you can select one of the two active axes as the dominant one.

Note: the rotation is done about the origin (0,0,0) point of the coordinate system. If a Translation has not been defined this rotation is usually somewhere in the middle of the model (for non-control point projects).

Rotation steps

To add rotation you need at least one Photograph, Point Table or 3D Viewer window open.

To set the rotation of the coordinate system:

1. Select "Scale/Rotate..." from the Project menu.

PhotoModeler will bring up the 3D Scale & Rotation Dialog.

2. Select the "position, distance, scale" button from the Type group on the Overview tab.

PhotoModeler will show the Rotate tab.

3. Activate the Rotate tab.
4. Select two points, a line, two camera stations or a point and a camera station on an open window that define an axis. Use the shift-click in the photo or 3D Viewer or ctrl-click in the Point Table to select two items at once.
5. Press the "Define" button for this axis.

The axis' two items will be highlighted in green and tagged in any open photograph. You may change this axis point at any time by selecting a new point and pressing "Define" again.

6. Repeat steps 4 and 5 to define the one other axis.
7. If you decide you would rather use another combination of axes, simply redefine the new axes by repeating steps 4 and 5 and the two most recently defined axes become active. You can also choose any two axes to be active by clicking on the axis' active check box. Note that only two axes will be activate at any time, so the two most recently activated axes become the rotation defining axes.

Three Point Rotation

When you have survey data in conjunction with your PhotoModeler data you will often want to put the PhotoModeler model into a coordinate system defined by that survey data. This sort of coordinate conversion cannot be done with the axes definition above. Instead you would use the Three Point Rotation method. The Three Point Rotation method involves picking three non-collinear points in the PhotoModeler model and assigning real world 3D coordinates to them. This 3D data can come from a survey, a map or can be made up if you have a good idea of the effect you are after.

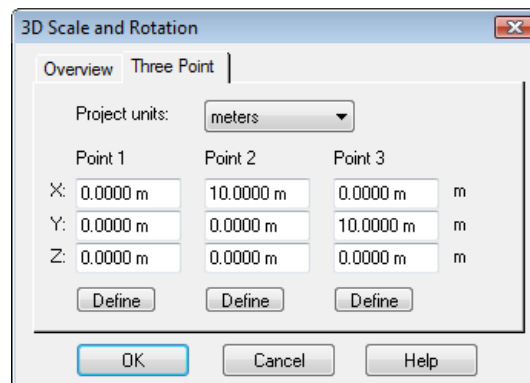
Note: If you have more than three known XYZ points with good spread over the model volume it would be a good idea to consider using Control Point Marking instead of Three Point Rotation. You will get better results if the control points are good quality. See the *Imported Objects* section.

The three point method defines the full affine transformation: translation, scale and rotation of the model. It is a complete replacement for the position, distance, and scale method as described above.

It is important to understand how the translation, scale and rotation are computed in the three point case so you can achieve best results. We will call the three points in the model M1, M2 and M3 and the three entered XYZ coordinates in the dialog as C1, C2 and C3. These correspond to the Point 1, Point 2 and Point 3 on the Three Point tab respectively. The transformations in order are:

1. Coordinates are translated such that M1 coincides with C1.
2. Coordinates are scaled such that the distance between M1 and M2 and the distance between C1 and C2 are the same.
3. Coordinates are rotated such that the vector between M1 and M2 coincides with the vector between C1 and C2.
4. Coordinates are then rotated such that the plane defined by M1, M2 and M3 coincides with the plane defined by C1, C2 and C3.

Note: the coordinates of the PhotoModeler points and your control points are in a *Right Handed Coordinate System*.



The Three Point tab has three boxes that hold the definition for points to be used in the three point scale and rotation. It also has a control to set units.

Select the units using the drop down selector tool.

Each point is defined by picking one model point and pressing the "Define" button in that box. To complete the definition of a point, enter in three values for the desired location of the point in your coordinate system.

This is also where you set the project's units. These are the measurement units used by PhotoModeler to report all coordinates, distances, lengths, areas etc. such as in the Table View or **Measure Toolbar**. It also controls the default units used when the user enters a number such as a scaling distance or an X coordinate. These units can be one of

kilometers, meters, centimeters, millimeters, miles, yards, feet or inches. Units can be changed whenever you want without affecting PhotoModeler's internal coordinate data.

To set the scale and direction using three points:

1. Select "Scale/Rotate..." from the Project menu.

PhotoModeler will bring up the 3D Scale & Rotation Dialog.

2. Select the "3 points" button in the Type group.

PhotoModeler will show the Three Point Tab.

3. Activate the Three Point tab.

4. Set the units for the project.

5. Select one model point on a photograph, 3D viewer or table.

The point will highlight in red.

6. Press the "Define" button of the point you wish to use.

The point will be highlighted in green and tagged with "P1", "P2" or "P3" on any open photograph. You may change this point at any time by selecting a new point and pressing "Define" again.

7. Enter in the coordinate values you wish this point to have in the X,Y,Z text boxes associated with this point in the dialog.

8. Repeat steps 4, 5 and 6 to define the other two points.

9. Press OK

The Three Point Scale and Rotation is now defined. It will be used during Measure, 3D Export and Table display and export.

Improving your 3D Model

Once a 3D model has been created for the first time, a number of things can be done to the model to make it more useful. These are:

- Add scale,
- Rotate model into a coordinate system,
- Add more detail by marking additional features (points, lines, edges, curves, cylinders, surfaces, or surface draw),
- Add constraints, or
- Improve the accuracy.

The following subsections deal with each of these improvements.

The *Accuracy and Overcoming Limitations* chapter in the Reference section describe various methods for improving accuracy and for dealing with difficult measuring situations.

Add Scale or Coordinate Axes

Once a 3D model has been created, you can add a scale to it. This scale sets up the model so that it is correctly dimensioned.

Besides adding a scale, you may wish to place the model in a particular orientation. For example, you might want the bottom of the object to lie on the XY plane so it fits with your other CAD work.

See the *Adding Scale and Rotation* section for details on adding scale and a coordinate system to your model.

Add Detail

After an initial 3D model has been created and verified through measurement or through a CAD program, you can go back to the photographs and from them add more feature detail. If the first 3D model is only a rough outline, you can zoom in and add point and line marks on detailed features.

If the initial model has no surface elements and you are using the model for 3D visualization or rendering work, then adding Surfaces to the model before export would be a good idea. See *Creating Surfaces*.

Once additional detail has been marked and referenced, you can reprocess the 3D model to create 3D information for the newly added features.

Note: You do not need to reprocess the project if all you have added to an already processed project, is Surfaces. Surfaces use the 3D points that are already there and do not create new ones.

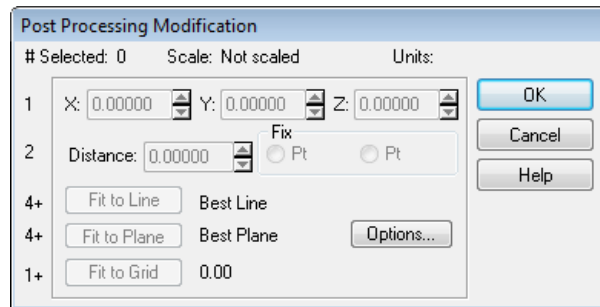
Improve Accuracy

If the 3D model you have created in PhotoModeler has low accuracy or poor shape, you can improve it by doing one or some combination of the following:

- Run through an Audit and improve the audit statistics (See *Audit*),
- Reduce the number of points marked on only two photographs,
- Review important points that have been marked and determine if they can be moved to better reflect the actual point location on the real world object (See *Moving Marked Points*),
- Add more points to the project with the aim of improving photograph overlap and photograph coverage (See *Audit*, *When processing fails or 3D results look bad*, *Marking Points* and refer to the section of the Quick Start Guide called Guide For Taking Photos),
- Add more photographs to the project with the aim of improving photograph overlap (See *Audit* and refer to the section of the Quick Start Guide called Guide For Taking Photos),
- Retake some photographs using man-made targets and re-mark those photographs (see the *Achieving the highest accuracy* sub-section).

After you have taken some action to improve the accuracy, reprocess the project and review the result using Measure (see *Measuring Features*) or your CAD program.

Post Processing Modification Dialog



This dialog provides some fitting and modification ability on Object Points. It is accessed from the Project Menu / "Post Processing Modification" item.

The long name for this dialog means that all modification made to Object Points by this dialog are after or post processing. If you process a project after carrying out operations here they will be lost. You may want to consider using Constraints instead.

PhotoModeler 3 users will remember these functions being available on the Table Viewer.

You have to select one or more points (from Photos, Point Tables, or 3D Viewers) before bringing up this dialog. At the top of the dialog it tells you how many points have been selected.

The operations that can be done on selected points are 3D modifications. Which modifications are available depends on how many points are currently selected:

Number of points selected	Operations Available
1	X, Y or Z value modification Fit to Grid
2	Distance modification Fit to Grid
3	Fit to Grid
4 or more	Fit to Line Fit to Plane Fit to Grid

Each of the modification operations is described in the following sections.

X, Y, Z Value Modification

When a single point has been selected the X, Y and Z spin controls are active. To change any of these values, type in new values or use the spin buttons.

Distance Modification

When two points have been selected the Distance controls are active. To change the distance between two points, enter in a new distance value or use the distance spin control. The distance change is done by moving the non-fixed point (the fixed point is set with the Fix radio buttons) along a straight line between the points. In other words, changing the distance between two points does not change the direction of the vector between the two.

Fit to Line

When four or more points have been selected you can force them all to fit on a line. There are a number of options of what type of line is fit. See the *Post Processing Options Dialog* for more details.

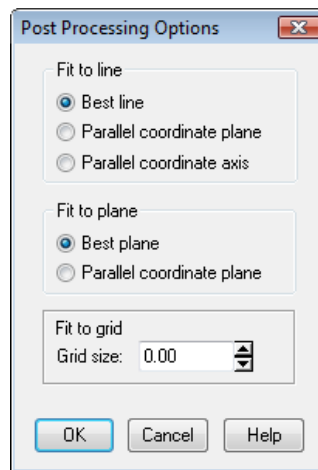
Fit to Plane

When four or more points have been selected you can force them all to fit on a plane. There are a number of options of what type of plane is fit. See the *Post Processing Options Dialog* for more details.

Fit to Grid

When one or more points have been selected you can force them all to fit into a grid. Imagine a 3D grid of stacked cubes. The size of the cubes is given by the Grid Size in the *Post Processing Options Dialog*. The grid lines up with current Cartesian coordinate system as defined by the current scale status (as shown at top of Point Table). When a point is fit to the grid it is moved to the closest corner of one of these stacked cubes.

Post Processing Options Dialog



The Post Processing Options Dialog is opened by pressing on the "Options..." button in the *Post Processing Modification Dialog*. This dialog controls parameters for Fit to Line, Fit to Plane and Fit to Grid point modification operations.

Fit to Line

The fitting to a line is done in one of three ways: best line, best line parallel to coordinate plane, and best line parallel to coordinate axis. All the currently selected points are processed by a least squares fitting algorithm that determines the best line in 3D space that passes through these points. When that line has been determined, all the points are dropped to that line at the closest point. The end result is a set of points that all perfectly lie on a 3D line. If you choose a set of points that are not very line like (i.e. the corners of cube) it will still try its best to fit a line to them and then modify all the points so they lie on that line.

When line fitting is complete a dialog will appear showing you the fitting error in the current project units. This error is the root mean squared error (sort of like an exaggerated average error) between the computed line and the 3D points. If this error is too large the fitting might not have worked as expected (perhaps some incorrect points are selected). In this case you can cancel and no changes will be made to the selected points.

The "best line parallel to a coordinate plane" is similar to the best fit except that an additional constraint is added that the fitted line should lie parallel to one of the XY, YZ or XZ planes. The "best line parallel to a coordinate axis" has the constraint that the fitted line should be parallel to one of the X, Y or Z axes.

Fit to Plane

The fitting to a plane is done in one of two ways: best plane and best plane parallel to a coordinate plane. All the currently selected points are processed by a least squares fitting algorithm that determines the best plane in 3D space that passes through these points. When that plane has been determined, all the points are dropped to that plane at the closest point. The end result is a set of points that all perfectly lie on a 3D plane. If you choose a set of points that are not very plane like (i.e. all the corners of a cube) it will still try its best to fit a plane to them and then modify all the points so they lie on that plane.

When plane fitting is complete a dialog will appear showing you the fitting error in the current project units. This error is the root mean squared error (sort of like an exaggerated average error) between the computed plane and the 3D points. If this error is too large the fitting might not have worked as expected (perhaps some incorrect points are selected). In this case you can cancel and no changes will be made to the selected points.

Fit to Grid

The fitting of points to a grid has only one parameter and that is the grid size. Enter in a non-zero value or use the spin controls to set the desired grid size in the specified measurement units.

Using the Model


Measuring Features

You can measure the dimensions of individual features from within PhotoModeler. This can be useful if you have measured something to determine its key dimensions and do not require a full 3D model. It can also be used to check your work.

To measure features, your project must be processed. See the sections on *Processing Points-Based*.

PhotoModeler allows measurement of point coordinates, line lengths, surface areas, edge end points, and cylinder attributes and other inter-object attributes.

To Measure

1. Click on the Measurement tool  from the toolbar or choose "Measurements" from the View menu.

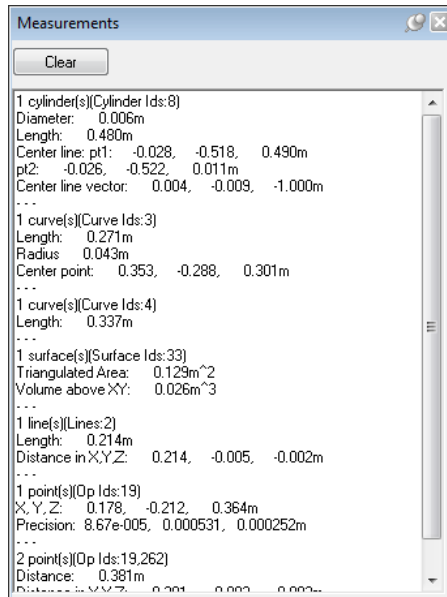
*PhotoModeler will open up the **Measurements Pane**.*


2. Click the select cursor on a point, line, curve, edge, surface, silhouette, cylinder, shape (vertex or edge) or combination thereof. To select more than one item, hold the shift key while selecting the second and subsequent features. These selections can be made in Photographs, 3D Viewers and Point Tables.

*PhotoModeler will display information about the selected items in the **Measurements Pane**.*

3. To measure another feature or set of features repeat step 2.

Measurements Pane



The Measurements pane can be opened at any time using the Measurements tool . It shows information on the current selection. The pane is not modal so it can stay open for as long as you want. It shows the results of items selected in photos, tables, 3D viewers, etc.. To close the pane use the X button in upper right.

As each item is selected the measurement is displayed at the bottom of the list and the list scrolls like a “rolling tape” of a calculator. Each entry starts with the type of objects selected as a heading and then below the heading are the actual measurements.

You can clear the list at any time by pressing the Clear button at the top. In addition you can select text in this list (use mouse to click drag to select a region) and then copy it (CTRL- C key) to the clipboard for pasting in other applications.

The Measurements pane will update as long as it is visible or tabbed and something is selected in a photo, table or 3D Viewer. It does not update if it is closed. To track measurement data on the Measurement pane’s list of various selected objects, make sure to have the pane opened (visible or tabbed with another pane).

Measurement Information

The information displayed in the Measurements Pane is based on what is currently selected. The following table shows what is displayed:

Items Selected	Information Displayed
1 point	x,y,z and x,y,z <i>precision</i>
2 points	distance between the points and XYZ difference
3 points	area of the triangle formed by the 3 points

1 line	length of the line and XYZ difference between the line's two end points
1 edge	length of the edge and XYZ difference between the edge's two end points
2 edges	same as 2 lines
2 lines	4 measurements: sum of line lengths, angle between lines, the closest distance between line segments as they appear in 3D (without extending lines infinitely), and closest distance between lines (as lines extended infinitely in both directions).
3+ lines	sum of line lengths
1 curve	curve length
1 curve (set to circle)	curve length, radius, and centre point XYZ
1 curve & 1 point	closest distance from point to curve
1 surface	surface area, volume above xy plane
2+ surfaces	sum of areas, sum of volumes above xy plane
1 silhouette	volume of solid, area of solid
2+ silhouettes	sum of volumes, sum of areas
1 cylinder	diameter of cylinder, length of cylinder, centerline end points, center line vector
2+ cylinders	the center lines are treated as lines above
1 point & 1 line	2 measurements: closest distance from point to line (with the line extended infinitely), and the closest distance between the point and line segment as it appears in 3D (ie without extending the line).
1 point & 1 surface	2 measurements: closest distance point to the infinite plane defined by the Surface (only displays with 3 point surfaces), and closest distance to nearest point of the surface (works for all 3D surfaces).
1 point & 1 cylinder	closest distance from point to cylinder center line
any combination of lines and cylinders	the cylinder center lines are treated as lines
1 camera station	the station's xyz perspective center
1 camera station & 1 point	the distance between the station's perspective center and the point and XYZ difference between the point and station's perspective center
2 camera stations	the distance between the stations' perspective centers, XYZ difference between the two stations' perspective centers, and the angle between the two stations.
1 camera station & 1 triangle surface	the closest distance between the station's perspective center and the plane defined by the surface (note, only works with 3 point surfaces)
1 Shape vertex	x,y,z position of the vertex

2 + Shape vertices	distance between the vertices and XYZ difference
1 Shape Edge	length of the edge and XYZ difference between the line's two end points
1 Triangulated PointMesh	volume above xy plane

Coordinate and distance measurements are shown in the current Project Units (meters, feet, cm, etc.). Areas are shown in units squared and volumes are shown in units cubed. Most of the above measurements should be self explanatory but some items need further clarification:

Closest Distance

When a point or line is selected along with a line or a Surface one of the displays is "closest distance". In the case of a point and a line, the closest distance is the length of the perpendicular from the line to the point (note the closest distance between the point and the line segment to the point without extending the line). In the case of a point and a Surface, the closest distance is the length of the perpendicular from the plane of the Surface to the point (for 3Point surfaces), while the closest distance between the point and the defined surface without extending the plane is also shown.

In the case of two lines or edges, the closest distance is the distance between the perpendicular between both lines (this will be where the lines are closest). If the two lines are on the same plane this closest distance will always be zero unless the lines are perfectly parallel.

Volume above XY Plane

The volume measurements are given under a selected Surface (or set of Surfaces) and above the XY plane. For example, two Surfaces covering the area between (0, 0, 10), (1,0,10), (1,1,10), and (0,1,10) have a volume above the XY plane of 10 cubed units.

You need to be aware of the coordinate system of the project to get useful volume measurements. For example, if you wanted the volume of a pile of sand you would:

1. Mark and reference points on the sand pile surface.
2. Process the project.
3. Cover the points with Surfaces so the whole sand pile is covered.
4. Set up the project coordinate system using scale and rotation (see *Adding Scale and Rotation*) so that the ground plane is the XY plane (you would need a suitable set of points marked and referenced at ground level).
5. Bring up the measure toolbar and select all the Surfaces (made easier by using the *Visibility Settings* to turn off all features but Surfaces).

The end result would be a volume measurement of the sand pile in project units cubed.

Measurement Precision

When a single point is selected the precision may be shown. The precision values are in the same units as the x,y,z positions. Approximated points do not have precision values displayed because precision calculations depend on 3D processing.

These precision values are one standard deviation based on the post-processing covariance matrix of the 3D object points. These precision values give a 68% confidence interval for that point (i.e. a 68% probability that the true point falls within the area defined by the precision numbers).

For further discussion of the meaning of precision refer to *Accuracy* and *Precision* in the Glossary.

Viewing the 3D model

The 3D data created by processing and other algorithms can be viewed graphically in the 3D Viewer and projected onto Photographs and can be viewed in tabular form in the Tables.

- *Photo Projections* show the 3D data projected back onto the photograph so you can check alignment and completeness of the markings on that photo.
- The *3D Viewer* provides an interactive and dynamic view of the 3D data in the model.
- The *Point Table* provides a list of *Object Point properties* including their XYZ locations.
- The *Other Object Tables* (Edge, Curve, and Cylinder) provide lists of each of these types of objects and their properties.
- All tables can be configured to show just the information you need. The *Table Layouts Dialog* takes care of that.

Photo Projections

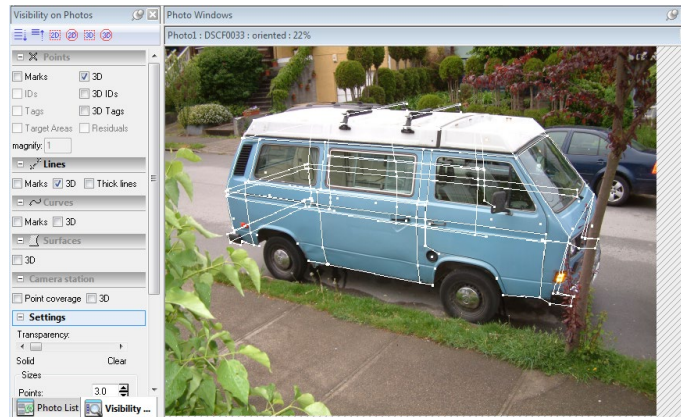
A projection is 2D view of the current 3D model data such that the viewpoint and view parameters exactly match the camera station and camera of the photograph they are being displayed on.

Projections are very useful in a number of different ways:

- they can help determine how complete the markings are on a photograph,
- they can be used to determine accuracy of marking and the solution,
- they can be used to determine if any areas are covered by surfaces in other photographs but not this one,
- they can be used to see how well an external DXF or control file matches with an oriented photo, and
- they can be used to help mark control points where no visible feature exists.

Photo projections (i.e. the display of 3D data on photos) are controlled by settings on the *Visibility on Photos* pane.

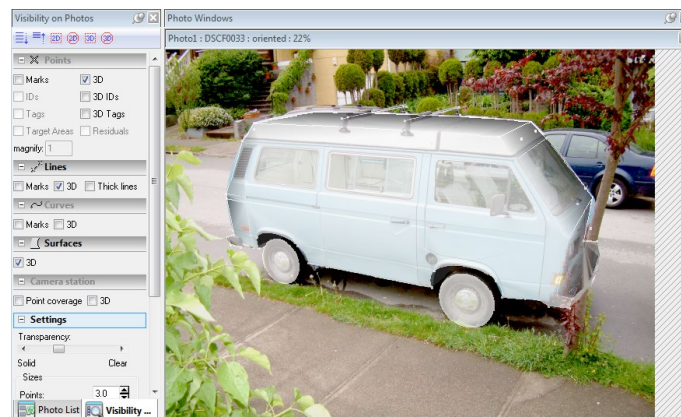
The following shows the visibility set so all normal marks are off and the Points and Lines Projection visibility is on. You can see the whole wire frame model of the CRT monitor including those lines behind. This view quickly tells us that the 3D and camera station solution for this photograph are reasonable good.



Projections Display Example

Note that projections display on photographs that are oriented only.

The example below shows the same model but with surface projections on with the Settings Tab slider set to full opaque (solid).



Projections with surfaces shown fully opaque

Fast Projection Style

There are two styles of projections available for points and lines (and control points and control lines). The default style is to use renderings, as shown above. The rendering is well suited to surfaces and cylinders but it can be a bit slow (because each change to the view requires a full re-rendering of the 3D scene and a blending with the photograph).

If one is interested only in points, lines, control points or control lines (as some projects may not have surfaces at all), then there is a fast projection option. This option is set in the Image tab of *Preferences - User Interface*. When this option is chosen, and the projection visibility is set to match the chosen options or a smaller set, then only the fast projection method will be used. Selection will be faster, image scroll will be faster, etc. As soon as

other projection visibility is turned on (e.g. surface, cylinder, curves projections) though the more complete (but slower) rendered projection system will come into play. Both the fast non-rendered system and rendered system can be used at the same time.

Here is a list of differences in the two systems:

	Rendered	Fast Non-Rendered
Can project points, lines, control points and control lines.	Yes	Yes
Can project edges, surface draw, curves, cylinders and surfaces.	Yes	No
Speed of zooming and panning photographs.	Slower	Fast, if only it is on.
All projection settings on Visibility on Photos pane's Settings section.	Work	Do not work.
Colors of projections can be based on the object's Material.	Yes	No, fixed 16 color set.
Accuracy of points and line end points.	Good, depending on settings	Best
Accuracy of line middles with high lens distortion cameras.	Good	Does not account for lens distortion in line middle.
Lines that have an end point behind the camera of the current photo still display in the projections.	Yes	No

3D Viewer

The 3D Viewer shows all the 3D objects in the project that have valid 3D locations. Objects that do not have 3D locations (because they appear on only one photograph or cannot be computed by some other algorithm) will not appear in the 3D Viewer.

To open a 3D Viewer use one of the following:

- Select the "Open 3D View" menu item from the View menu.
- Select the "Open 3D View" tool on toolbar.
- Use the "Open 3D View" keyboard shortcut (key is shown beside menu item)
- The menu and toolbar also have an alternate called 'show options'. This tool is chosen on the toolbar using the drop down arrow on the right of the 3D View tool. You may wish to change the 3D View settings before the 3D View opens (to speed up the opening in large projects for example) - when you use the 'Open 3D View (show options)' command the options dialog appears before the view opens allowing you to change the settings.

Multiple 3D Viewer windows can be opened at once. Each of the open 3D Viewers can show different contents and different view points. All 3D Viewers are grouped in one top-

level pane called “*3D View Windows*” and can be closed all at once by closing the top-level pane.

Manipulating the 3D View

In the bottom right corner of the 3D Viewer window there are five special buttons:



From left to right, these are: Rotate, Zoom, Pan, Reset and Options.

To use the three yellow graphic controls you click and hold down the left mouse button. Then while holding the mouse button down, you drag the mouse around. The rotate and pan controls work off the x and y drag and the zoom works off the y (up and down) drag. It is easier to try these to see how they work than to explain!

The model rotates about the “Center-About” point which is described in the Rotate Around - Model Centering section below.

You can also navigate the model scene by holding down the Alt key with left, center or right mouse button and dragging while positioned anywhere in the 3D Viewer window. By default the left mouse button rotates or orbits the model; the middle button pans the model left/right/up/down; and the right button zooms the model in/up, out/down. You can reconfigure your mouse button actions so that they match other software you may use, using the settings on the *Preferences - 3D Viewer*, Selection and Navigation page.

You can also use the Zoom In and Zoom out tools from the Window menu or toolbar to manipulate the magnification of the 3D Viewer window.

One can also zoom using the wheel in your mouse (if it has a wheel) and this can be done at any time the 3D Viewer window is active. It can also be done while the rotate or pan controls are being used which allows for easy manipulation of the view.

The fourth control is the Reset button which resets the view to the default when clicked. See the ‘Reset Direction’ section below.

The fifth control brings up the 3D Viewer Options Dialog when clicked.

Selection in the 3D Viewer

You can select items in the 3D Viewer by clicking on them. If the mouse clicks on or close to more than one item, a menu will appear from which the desired selected item can be chosen. The *Region Select (Temporary)* mode tool is also available for the 3D Viewer.

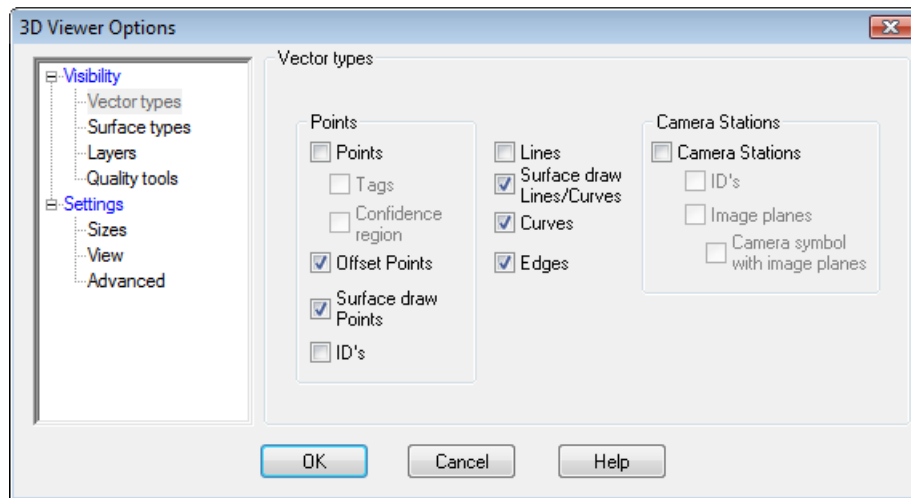
3D Viewer Options Dialog

The 3D Viewer Options Dialog controls the display of one 3D Viewer window. This dialog appears when the “Options” button in the bottom right corner of the 3D Viewer is pressed (or optionally when the ‘Open 3D View (show options)’ tool is clicked).

This dialog is divided into sections controlled by the tree on the left. The controls in each section are described in the sections below.

When the OK button is pressed, all the changed options from all sections will take effect on the associated 3D Viewer window. If Cancel button is pressed instead no changes will be made.

Visibility - Vector Types

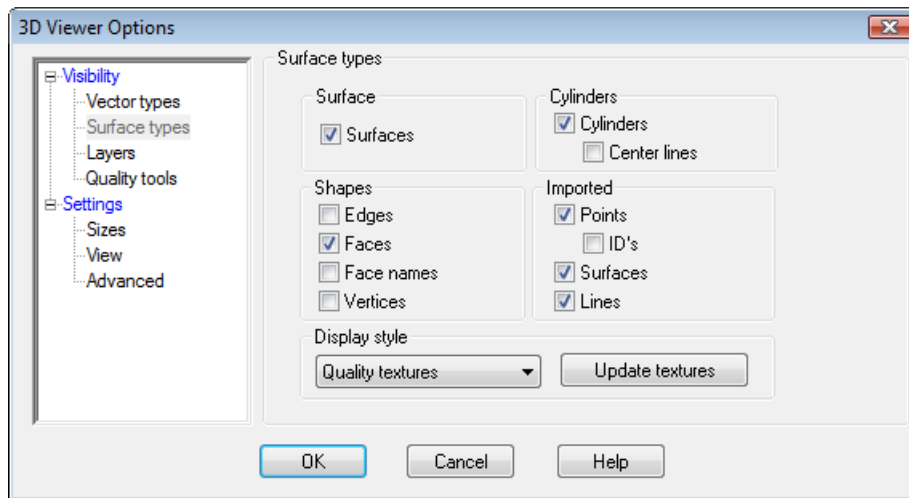


This section controls what type of objects are visible in the associated 3D Viewer. This section encompasses non-surface types.

Points	When this box is checked, all 3D Points in the project that have solved xyz positions will be drawn as small squares using the diffuse color of their assigned material.
Point Tags	When these boxes are checked, all 3D Points in the project that have been tagged are displayed with a 'T' for tag.
Point Confidence Region	When this box is checked the error ellipsoid is displayed for each point. This object shows the <i>confidence region</i> (also known as Error Ellipsoids) for the point. Normally these are so small you will need to use the Point confidence region scale factor in the Sizes section of the 3D View Option to see them.
Offset Points	When this box is checked, all valid <i>Offset Points</i> (ie those associated with 3D Object Points) will be shown.
Surface Draw Points	When this box is checked, the points associated with the drawn Surface Draw features are shown.
ID's	When this box is checked, all 3D Points in the project are displayed with their ID number (perhaps user name too). Coded Targets have a unique set of ids and the id is shown in square brackets: [1002] is point id 1002 and code 2. Available only when at least one type of point is checked.
Lines	When this box is checked, all Lines that connect solved 3D positions will be drawn as vector lines using the diffuse color of their assigned material.
Surface Draw Lines/Curves	When this box is checked, all Surface Draw (lines and curves) that have solved 3D positions will be drawn.

Curves	When this box is checked, all Curves that are 3D will be drawn as curved lines using the diffuse color of their assigned material.
Edges	When this box is checked, all Edges that have a solved 3D position will be drawn a vector lines using the diffuse color of their assigned material.
Camera Stations	When this box is check, Camera Stations that have been solved (the location of the camera when it took each photo) will draw as either a symbol (a box with lens cylinder) or as an image plane (when the Image Planes box is checked). The size of the symbol and the size of the image plane are affected by the Camera Station symbol size in the Sizes section of the 3D Viewer Options. The Image Planes are a great illustration and quality check tool - esp. along with Light Ray display (see Quality Tools section of 3D Viewer options). You can also show camera station symbols while image planes are visible (option enabled when Image planes are checked).

Visibility - Surface Types

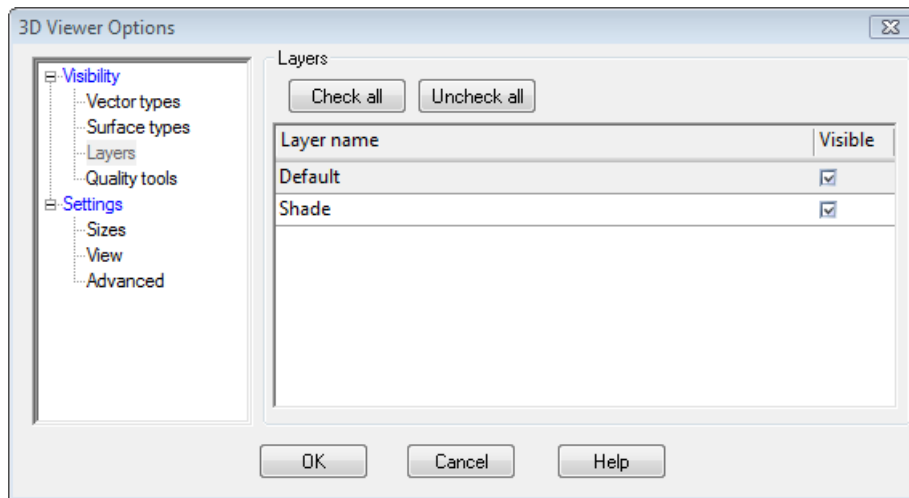


This section controls what type of objects are visible in the associated 3D Viewer. This section encompasses surface types and surface related items as well as Imports.

Surfaces	When this box is checked, all Surfaces that have solved 3D positions will be drawn using the display style selected in the Display Style drop down.
Cylinders & as Centerlines	When this box is checked all Cylinders that are solved will appear. If "as centerlines" box is checked then they will be drawn as lines down their centerline otherwise as full cylinders.

Shapes	The boxes under Shapes control the visibility of different Shape sub-types. When Faces are on, their display is controlled by the Display Style drop down. Face Names, when on, draw the name of the face in text in front of each face.
Imported	The boxes under Imported control the visibility of the different Import sub-types.
Display Style	<p>Surfaces, Cylinders, Shapes and Imported Surfaces can display in different styles. That is controlled by the Display Style drop down. The options are:</p> <p>Shaded - Displays the Surface using solid faces in the diffuse color of their assigned Material.</p> <p>Wire Frame - Displays the edges of the triangles defining the Surface in the diffuse color of the Surfaces material.</p> <p>Dots - Displays the corner points of the triangles defining the Surface in the diffuse color of the Surfaces material.</p> <p>Fast Textures - Displays the surfaces as solid faces in the diffuse color of the Surfaces Material. If the Material is photo-textured the corresponding area of a photograph(s) assigned to the Material will be mapped to the surface.</p> <p>Quality Textures - As with fast textures, displays the Surfaces as solid textured faces. With this setting the texture quality will be improved by accounting for perspective correction and object occlusion. These textures will take longer to calculate and will only update when the 'Update' button is pressed.</p> <p>Note: By default the backsides of surfaces will display in a darker/unlit material. To increase the speed of 3D rotation when lots of surfaces are displayed this can be turned off on the preferences dialog.</p>
Update Textures	Pressing Update will cause the textures to be recomputed. See also <i>3D View Options - Notes</i> .

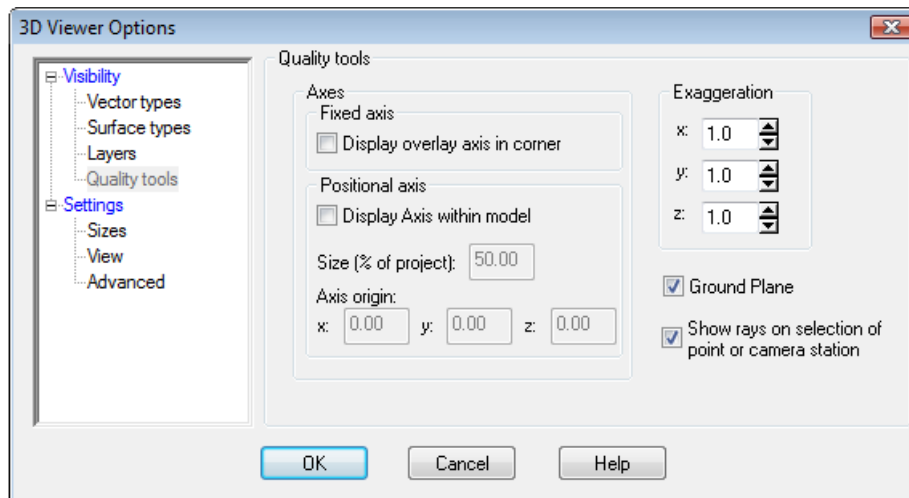
Visibility - Layers



This section controls the visibility of layers. If you have multiple layers in your project you can make all the objects on a particular layer invisible by unchecking the corresponding Visible box.

The 'Check all' and 'Uncheck all' buttons at the top provide a way to show/hide all layers in the 3D Viewer to be opened.

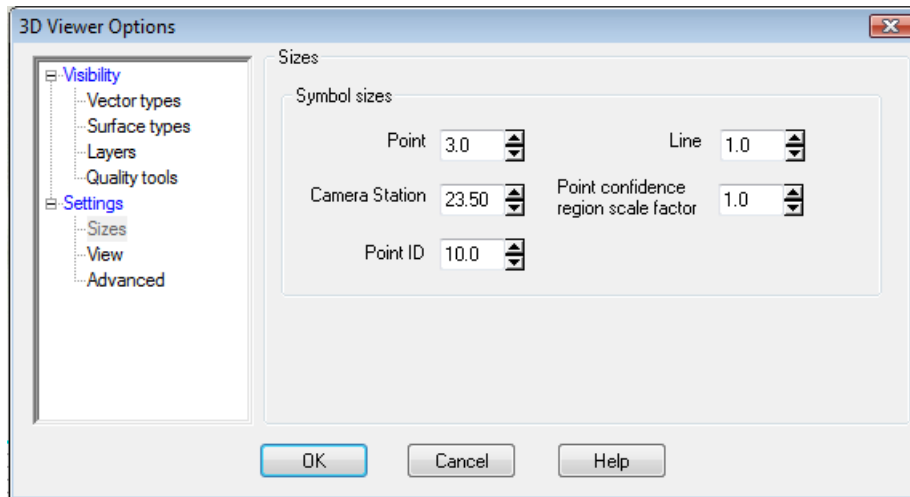
Visibility - Quality Tools



This section controls the visibility of a number of tools used for quality assurance.

Axes	The Axis section controls whether the X, Y, Z axes are displayed in the 3D Viewer window. Check one of the two Display Axes options. The first places an axes display in the corner, and out of the way and the second is configurable and can display the axis anywhere. The length of the axis lines (each one has its own color and the letter drawn at the end) is controlled by axis scale. The origin of these lines is usually 0,0,0 but that can be changed also.
Exaggeration	The Exaggeration factors control how much the model data is scaled along one axis. This is useful for exaggerating small effects (e.g. small z perturbations off an XY surface). These exaggeration factors are applied after and Scale/Rotate in the project.
Ground Plane	When checked this displays a semi-transparent planar rectangular surface on the XY plane.
Show rays on selection of point or camera station	When checked, this displays one or more vectors from a point to a camera station when an item is selected. If a point is selected, then all the light rays for where that point is marked are shown back to the corresponding camera stations. If a camera station is selected then all the marks on its photo are shown with light rays. Multiple points and multiple camera stations can be selected at once. This is an excellent demonstration, debugging and quality checking tool.

Settings - Sizes

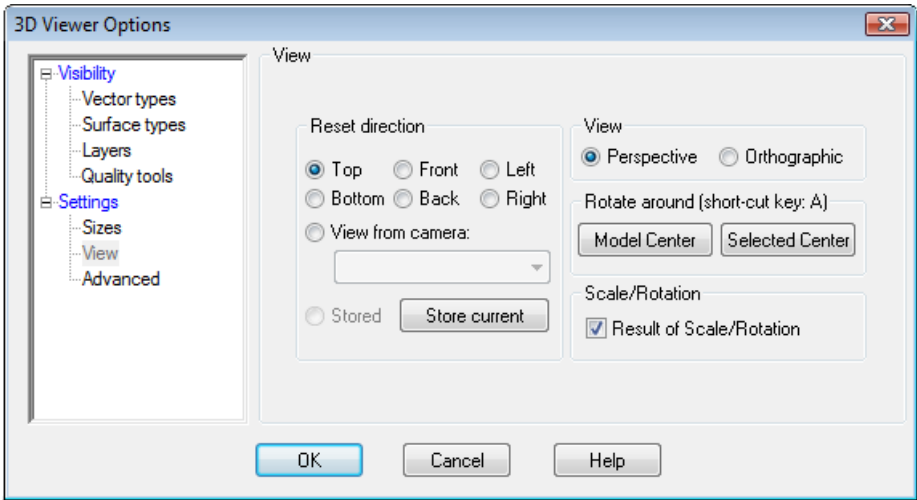


PhotoModeler uses some heuristics to display the real- sometimes do not give the desired emphasis to the object you are studying (maybe you want the point symbols to be large one time and small the next). The Point, Line and Camera Station spins control the relative sizes of these symbols. The numbers shown are the OpenGL size/width of the objects and as such the range of sizes is limited by your OpenGL driver. Note that Line controls all vectors types such as lines, edges, curves, shape edges, etc.

The Camera Station size scales the camera station symbol but also the view volume when Camera Station Image Planes are turned on. Note that when an Image Plane view is scaled it is still an accurate presentation of the camera (as can be verified when Rays are turned on). The image plane is scaled but so is the focal length (the line that appears between middle of image plane and the center of perspective). If the symbol size is 1.0, the image plane will be same size as the camera's format size and the length of the focal line will match the camera's focal length. At 1.0 scale, usually these will be far too small to see. You can increase the size so the image plane is behind your object too, which can be interesting.

Point/Camera Station ID setting controls the size of the font used when ID's are displayed.

Settings - View



This section controls the current view (what the rendering camera does when rendering the 3d model).

Reset Direction: The orientation of the view is controlled by a number of things. The main controls are the rotate, pan and translate drag-controls found at the bottom right of the 3D Viewer window. There are a number of controls in the Options Dialog that also affect what you see.

If you change the reset direction when you exit the Options Dialog or any time you subsequently press the Reset button, the 3D Viewer will redraw such that the model sits in the defined scale and rotation with a view from the front (down the y axis).

Note: the orientation of the model and hence the reset direction depends on the setting of "Result of Scale/Rotation" in the Show section of the settings tab.

You can think of reset direction as where the view camera will be (i.e. Top means the view camera is above the model looking down). The directions are defined here in terms of PhotoModeler's right handed coordinate system:

Reset Direction	Camera Looking in this direction
Front	from -Y axis towards +Y axis

Back	from +Y axis towards -Y axis
Top	from +Z axis towards -Z axis
Bottom	from -Z axis towards +Z axis
Left	from +X axis towards -X axis
Right	from -X axis towards +X axis
View from camera	Based on the solved camera position
Stored	Store and restore any user-chosen view. To store a view click the Store button. You will then be able to restore this view when the Stored radio button is selected, but only during the session (i.e. this setting is not stored with the project when saved).

Note: you can only “view from camera” for *oriented* camera stations. When the view is set to “view from camera” you will not be able to rotate, pan or zoom the 3D viewer, only view the model from the solved camera position.

View: The View setting determines the projection type: Perspective projection is a view like a camera with perspective (objects farther away appear smaller) and Orthographic projection is a view like in CAD package (objects project onto viewing plane with parallel light rays and objects of the same size render as the same size no matter how far they are from the viewer). The Perspective projection is the most natural and the one you will use most often but the Orthographic projection is quite useful for checking to see how well objects, points, lines etc. line up with each other.

Rotate Around - Model Centering: Normally, when the rotate control is used in the 3D Viewer, the view rotates about the center of mass of the model. This is suitable for small and un-complex models but not as useful when you are zoomed-in on a complex model. In this case you might want to use the arbitrary center method.

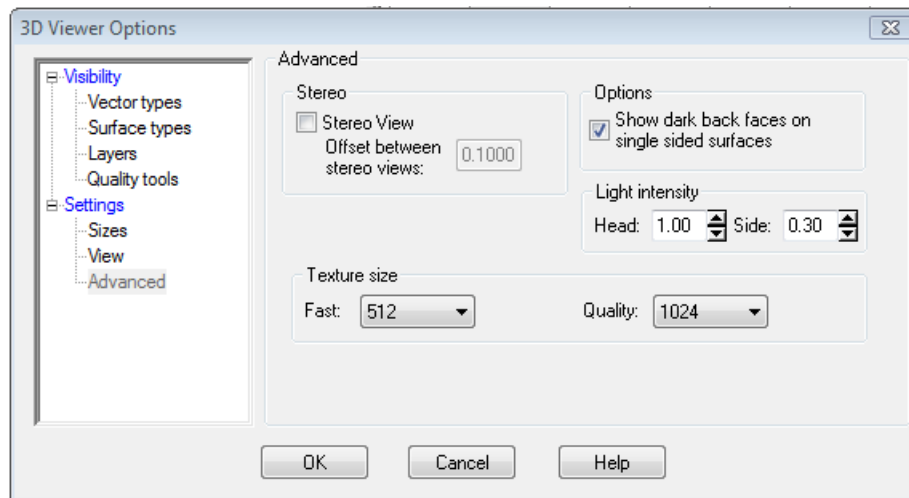
If you select an object in the 3D Viewer window and then press the A key, the view will then rotate about that object when you next use the rotate control. You can also perform the same operation by bringing up the Options Dialog and pressing the “Selected Center” button. When you are in this mode the caption of the 3D Viewer says [Re-centered]. If you want to rotate about the model center again, click the mouse off the model to clear all selections and press the A key again (or in the Options Dialog use the “Model Center” button).

If you select an object that is not a point (a line, edge, curve, surface, or cylinder) or a group of objects, the rotation center becomes the center of the bounding 3D solid of all the selected objects. For example, if you had a Curve circle selected and pressed A, the rotation center would become the center of the circle.

Scale / Rotation: When the “Result of Scale/Rotation” is checked, the 3D data shown in the 3D Viewer is first scaled and rotated according to the project Scale and Rotation (see *3D Scale and Rotation Dialog* for more information). When you are freely navigating around a model using the three drag controls in the 3D Viewer this check box has little

effect. It is most useful when you use the Reset button in the 3D Viewer along with the Reset Direction radio buttons in the Options Dialog. Before you export a model to CAD or an external graphics package you might want to see if it is sitting in the desired coordinate system (remember PhotoModeler's default coordinate system is arbitrary and probably not what you want for most exports).

Settings - Advanced



The “Show dark back faces on single sided surfaces” controls whether the 3D Viewer renderings show the back sides of surfaces. If they are not displayed (box not checked) the 3D rendering is faster (half the amount of surface calculations to do) but the back faces do not appear at all and that can make non-solid models look strange and incomplete.

The Light intensity controls how bright the two lights are in the scene used to render the model data. 1.0 is full brightness and 0.0 is the light is off.

The two Stereo View settings control the red/cyan anaglyph stereo mode for this viewer. If you are wearing the appropriate red and cyan glasses you can see the 3D model in stereo with realistic depth perception. The offset between stereo views controls how pronounced the depth effect is. If this value is too large you will not be able to see stereo (or it will strain your eyes). If the value is too small you will see little stereo or depth effect. Note that some 15% of the population are not able to see stereo.

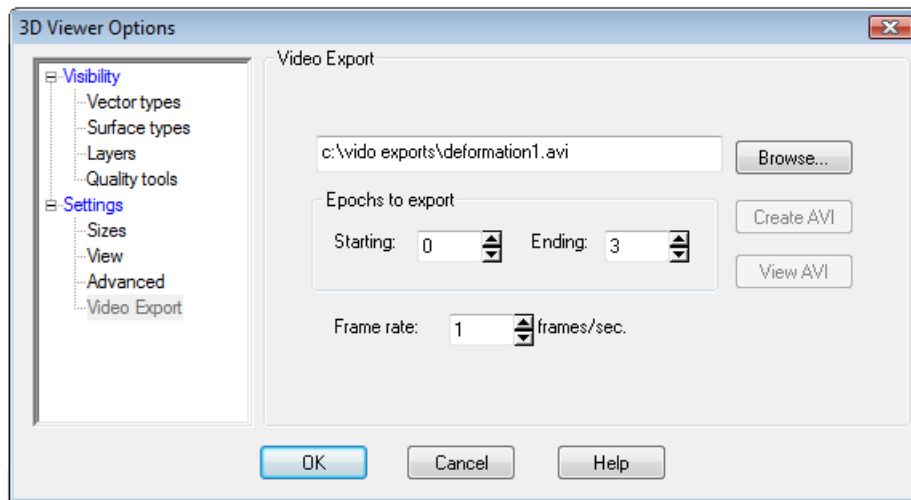
The Texture size items determine the size of the texture maps used by the 3D Viewer OpenGL rendering engine. The maps will be square of this size (e.g. 512 by 512). A power of two value will make rendering faster (i.e. 256, 512, 1024). The larger the value the better the quality but the slower the navigation/rendering. The top control is the map size for Fast Textures (see Visibility Tab) and the bottom control is for Quality Textures.

Note 1: Some video cards have limits on the maximum texture size. This is often 1024 square. If you choose a size bigger than this, the image gets down-sampled by the video driver. This will degrade the quality and increase the setup time. A warning will appear if you attempt to use a setting that is larger than the maximum. Check the video card documentation or contact your video card manufacturer to determine the maximum size.

The 3D viewer can support textures larger than what is supported by your video card, by splitting large textures into smaller portions. With the majority of drivers these textures will be seamless but, depending on the installed driver, the divisions between the textures may be visible. If this is the case check for an updated driver for your video card.

Note 2: Quality Textures often require much larger map sizes to produce similar quality to Fast Textures (since all triangles are mapped into one image in the Quality mode). This means that for some projects the Fast Textures will look higher resolution than the Quality Textures if the video card has a maximum map size (see Note 1).

Settings - Video Export



When the PMV Module is installed and a PMV project is loaded the 3D Viewer Options Dialog shows another entry called 'Video Export'. See *PMV 3D Viewer Animation Export* for more information.

3D View Options - Notes

Note: When turning on visibility for items in an already opened 3D viewer if these items appear outside of the current view you may need to hit 'reset' before these items show on the screen. This is typically the case with camera stations as they tend to lie on the furthest extents of the model. Due to the way orthographic views work hitting reset may not be needed if viewing in orthographic mode.

Note 2: The Materials can be changed while the 3D Viewer window is open and it will update automatically to reflect the color changes. The only Material attribute that does not appear all the time is photo-texture, which only displays when the surface display type is set to "Fast" or "Quality" textures. There is a control in the dialog to turn this on and off because photo-textured objects are slower to open and slower to navigate.

Quality Textures

When the Surface mode is "Quality Textures" a number of advanced remappings and texture optimizations take place. The first is called perspective correction, and the second feathering.

Perspective distortion in textures is most noticeable with surfaces that are textured from photos taken at shallow angles to the surface. Only photos that are perfectly parallel to the surface have no perspective distortion. On some projects the distortion will not be very noticeable and on others the model will look poor without it.

Feathering is a process of blending the edges between different photographic source data. For example, if there are two surfaces that are side by side in the model but use different photographs as the source for photo-texturing (due to being forced to use those photos or because of angle settings etc.) the transition may be quite obvious. This is especially true if there are any color or intensity differences between the two photos. The feathering process smoothes that transition so it is not as obvious.

Next to the Surfaces check-box in the 3D Viewer Options dialog is an "Update textures" button. Pressing Update will cause the textures to be recomputed (applies to fast and quality textures).

The algorithms used to form Quality textures are very advanced and exact and so it can be slow with big photographs. For this reason, PhotoModeler will display a user optional warning before recomputing the textures (eg after processing). When the textured model becomes in whole or in part untextured (white surfaces) you can enter the Options dialog and press the Update button to have the textures recomputed again.

There are settings in the Preferences dialog that control the processes that are carried out during quality texture creation. See *Preferences - Exports and Output*. For example, feathering for quality textures in the 3D Viewer may be turned off by default.

Tables

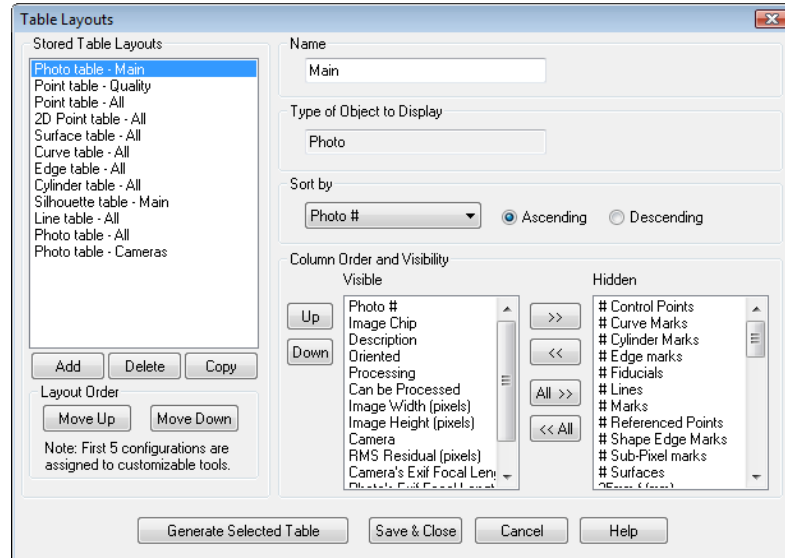
Tables are similar to spread sheets with rows and columns of data. The available tables in PhotoModeler are:

- the *Photo Table*, used to view and manipulate photograph, camera and camera station data and is described below,
- the *Point Table*, used to view the properties of Object Points and is described below,
- the *2D Point Table*, used to view the properties of 2D marked points on photos and is described below,
- the *Offset Point Table*, used to view the properties of *Offset Points* and is described below,
- the *Line Table*, used to view the properties of all Lines in the project and is described below,
- the Edge Table, described in the *Other Object Tables* section below.
- the Curve Table, described in the *Other Object Tables* section below.
- the *Surface Table*, used to view the properties of Surfaces and is described below.
- the *Silhouette Table*, used to view the properties of Surfaces and is described below. and
- the Cylinder Table, described in the *Other Object Tables* section below.

Note: Tables that are open can be printed or exported (to file or clipboard) using the *Output to Printer, Clipboard or File* feature.

Table Layouts Dialog

The Table Layouts Dialog is used to generate and configure table layouts.



On the left is the list of stored table layouts. Once you create a layout, it will be stored on disk and will show in this list. See [Application Data and File Locations](#) for information on the location of stored files. As you select a layout in this list, the properties of the layout are shown in the area to the right. Note that the user specified name is displayed in the list after the table type, as in Photo Table – Main, where Photo Table is the table type and Main is the Name.

Properties of a Table Layout

The Name section displays the name you provide. As you edit the Name the layouts list at left is immediately updated, unless it is not a unique name. The name of the layout must be unique, so as you type, the name will not be updated in the list if the name is already associated with another table layout of the same type.

The Type of Object to Display section displays the type of table. You first select a table type when you created a new layout.

The Sort by section allows to set up how the table is sorted by default when opened (you can always change the sort once a table is opened, see [Interaction with Tables](#)). The drop down list shows all columns in the selected table. Select the heading by which your table will be sorted. Then select whether the sort should be ascending or descending using the controls adjacent to the column heading list.

The Column Order and Visibility section is where you set up which columns to show in the table and their order as they appear from left to right. Move column headings between the visible and hidden lists to show/hide them (you can always change the sort once a table is opened, see [Interaction with Tables](#)) using the >>/<</All>>/<<All buttons when a heading is selected, and use the Up/Down buttons to change the order of a selected heading. The first heading in the list of visible columns appears leftmost in the table.

Table Layout Actions

A series of controls are shown below the list of stored layouts.

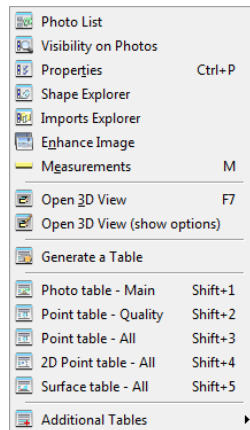
The Add button adds a layout to your list. You will be prompted to select a type on the *Select Table Type Dialog*. A table layout with default properties will be created. Then modify the properties to configure your table.

The Delete button deletes the selected table layout. The layout will be immediately removed from the list, but the delete will clear the layout from disk once you hit Save & Close or Generate Selected Table.

The Copy button copies the selected layout and all of its properties into a new layout. This is useful when you just want to make minor changes to a table without replacing it.

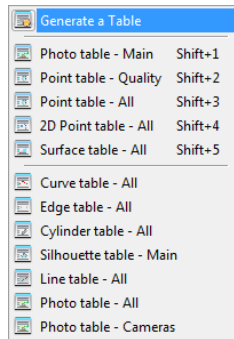
The Layout Order section has controls to set up the order in which Table tools appear on the PhotoModeler menu. Move a selected layout using the Move Up/Move Down buttons. The top 5 layouts show first in the View menu and Tables dropdown list on the Open View Tools toolbar, and also have assignable shortcut keys (see Toolbar Customization).

This shows the menu items from the View menu on the main PhotoModeler menu:



The menu items below Generate a Table are the first 5 in the list of table layouts as shown in the Table Layouts dialog. The rest of the table layouts are in the Additional Tables fly-out menu.

This shows the menu items from the Tables drop down menu from the Open Views toolbar:



Again the top 5 table layouts as shown in the Table Layouts dialog are shown first, with their keyboard shortcut keys.

Placing often used table layouts in the top 5 of the list provides a way to assign a keyboard shortcut, which in turn provides quick access to your main table layouts. Viewing tables like the Photo table – Main and Point Table – Quality (pre-installed) are very useful when monitoring or troubleshooting your project.

Dialog Actions

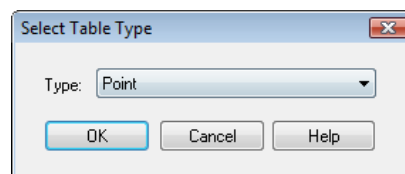
The Generate Selected Table stores all changes to any edited layouts, closes the dialog and opens the selected layout in a Table window.

The Save and Close button stores all changes to any edited layouts and closes the dialog.

The Cancel button cancels any changes made to layouts and closes the dialog.

The Help button brings up the Help file in this section.

Select Table Type Dialog



When the Add button on the *Table Layouts Dialog* is pressed the Select Table Type Dialog appears which allows you to select from a drop down list of available table types. See *Tables* for information on the various available types. When you press OK, a new layout of the selected type will be created with default properties. Once the default is created, you can modify its properties on the Table Layouts Dialog.

Press Cancel to cancel the new table creation.

Interaction with Tables

There are a number of actions that can be done to tables by either clicking on various features of a table (like column headers), or using a context or right click menu.

Table Features

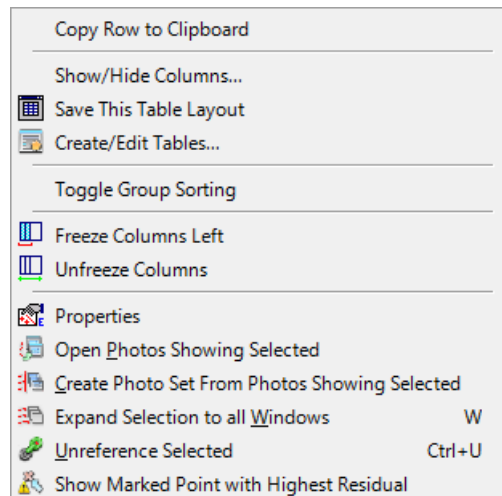
Tables can be sorted by clicking on a header title (click once to sort in ascending order and click again to sort in descending order). A small arrow head appears next to the header title when the table has been sorted indicating whether it has been sorted in ascending or descending order. You can also change the sort order of columns in the *Table Layouts Dialog*.

The order of columns can be changed in two ways: by clicking and dragging a column into position (click in a header tile, hold down the mouse button and drag into position; as you move the mouse over other columns, two small arrows will appear on the table header indicating the where the column will be placed when you release the mouse). You can also change the order of columns in the *Table Layouts Dialog*.

The width of columns can be changed by moving the mouse cursor over the boundary between column headers and when the cursor changes to a width sizing cursor click and drag the boundary so the column is the desired width.

Table Context or Right Click Menu

When right clicking in the data area of a table, the table context menu will appear. This is the point table's context menu (other tables may have slightly different tools):

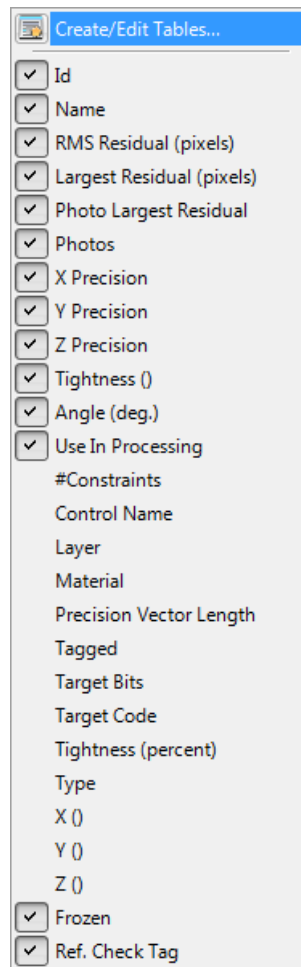


Various tools are available on this menu that allow you to manipulate the table in useful ways:

- **Copy row to clipboard:** copies the selected row to clipboard. You can then paste this row of data into a document in another application.
- **Show/Hide Columns...:** Use this tool to show/hide columns in the table. A menu appears showing all column headings and you toggle the visibility of the column by clicking on the column header title. A header title with a check mark will be visible. This list can also be accessed by right-clicking anywhere on the column header row.
- **Save This Table Layout:** When you make changes like change the sort column or reordering columns etc, you use this tool to save the layout. You do not need to reopen the Table Layouts to make and save all layout changes.

- **Create/Edit Tables...:** Use this tool to bring up the Table Layouts dialog to make changes to the active table's layout (it will be selected in the dialog when accessed from this menu) or any other saved table layout. Note that changes made to a an active table's layout on the Table Layouts dialog won't take effect until it is reopened.
- **Toggle Group Sorting:** This tool toggles sorting of the table between convention top-down sorting and group sort, based on the current sort column (the column header with the sort arrow visible). Group sorting groups all rows of data that have a common value in the sort column. For example, if you have Group Sorting on and you sort by Photos in a Point Table, all points that are marked on the same photo or set of photos will be grouped together. These groups can be contracted or expanded using the small – or + symbol next to the group heading. This is especially useful for the 2D Point Mark Table when sorting by Object Point ID as it groups all 2D point marks by Object Point.
- **Freeze Column Left:** This tool 'freezes' all columns to the left of where the mouse was clicked so that they never scroll out of view. This is useful when you have a very wide table and you want certain columns to always remain visible, even when scrolling horizontally, for example when you want a Point table to always show the Point ID, even when scrolling the table to the right.
- **Unfreeze Columns:** This removes the frozen property from any frozen columns; all columns will scroll when using the horizontal scroller.
- **Show Marked Point with Highest Residual:** this tool provides an easy way to open the photo(s) and display and select the marked point with the highest residual. This tool (only available from this right click menu) is useful when troubleshooting a project and looking for problem points.
- **Properties, Open Photos, and the rest of the tools on this menu** are described elsewhere in this document and are common to other right click menus, and are not described here.

When right clicking in the column header area of a table, a menu showing a list of columns will appear:



This menu appears showing all column headings (a point table's column list in the example above) where you toggle the visibility of the column by clicking on the column header title. A header title with a check mark will be visible. This list can also be accessed from the "Column Visibility" tool on the right click menu that is brought up by right-clicking in the data area in a table. You can also access the *Table Layouts Dialog* using the Create/Edit Tables... tool on this popup menu.

Photo Table

Phot #	Image Chip	Descri...	Orient...	Proces...	Can be Proces...	Image Width (pixels)	Image Height (pixels)	Camera	RMS Residual (pixels)	Camera's Exif Focal Length	Photo's Exif Focal Length	Largest Residual (pixels)
1		p1	yes	Use an...	yes	1280	960	C3040...	0.0897...	7.3000000...	7.3000000...	0.3124...
2		p1r	yes	Use an...	yes	1280	960	C3040...	0.0784...	7.3000000...	7.3000000...	0.4259...
3		p2	yes	Use an...	yes	1280	960	C3040...	0.0789...	7.3000000...	7.3000000...	0.2999...
4		p2r	yes	Use an...	yes	1280	960	C3040...	0.0790...	7.3000000...	7.3000000...	0.3373...
5		p3	yes	Use an...	yes	1280	960	C3040...	0.0628...	7.3000000...	7.3000000...	0.1303...
6		p3r	yes	Use an...	yes	1280	960	C3040...	0.0699...	7.3000000...	7.3000000...	0.2294...

The Photo Table is a key capability of PhotoModeler for reviewing photograph, camera and camera station data. A Photo Table can be opened by clicking on a Photo Table tool from the View Menu. A Photo table can be configured and then displayed using the **Table Layouts Dialog**.

See the sections below called **Table Windows** for more background on tables, configurability and user interaction.

The properties of Photographs and Camera Stations can be modified by selecting one or more of them in the table, right clicking and pressing the Properties of selected photo button. This brings up **Photo Properties**.

There are numerous columns and properties that can be displayed in the Photo Table:

Property	Type	Description
Image Chip	image	Small version of the photograph. See Photo Chip .
Photo #	number	Unique identifier number
Description	text	User define photo name

Camera Station Property	Type	Description
Center X, Y, Z	# units	The Camera Station position in the current coordinate system.
Omega, Phi, Kappa	# degrees	The Camera Station angles.
Target X, Y, Z	# units	A point at arbitrary distance that the camera is looking at.

Roll Angle	# degrees	The roll angle about the above described direction vector.
Oriented	boolean	Indicates whether the position and angles have been solved.

Image Property	Type	Description
Image Height	# pixels	The size of the image in
Image Width	# pixels	numbers of pixels.
Rotation	# degrees	The rotation of the photograph when displayed on the screen.
File Name	string	The file name of the image
Mask Name	String	The file name of the mask image (See <i>Mask image file name</i>)

Processing & Quality Property	Type	Description
Can be Processed	boolean	"yes" if this photo has sufficient information to process.
Processing	enum	The user setting for how photo should be handled during processing
Quality	number	The user setting for photo-texture extraction order.
Largest Residual	# pixels	The largest <i>Marking Residual</i> on this photo.
RMS Residual	# pixels	The RMS (root mean squared) Marking Residual on this photo.
Inverse Focal Length	boolean	"yes" if InverseCamera solution for focal length is requested.
Inverse Format Aspect	boolean	"yes" if InverseCamera solution for format size is requested.
Inverse Principal Point	boolean	"yes" if InverseCamera solution for principal point is requested.

Camera Property	Type	Description
Camera	string	Name of the camera used by this photo.
Focal Length	# mm	The focal length of that camera.
Format Height	# mm	The size of the imaging format of that camera - height.
Format Width	# mm	- and width
Prin. Point X, Y	# mm	The principal point of that camera.

K1, K2, K3, P1, P2	number	Lens distortion parameters for that camera.
35mm f	# mm	The 35mm camera equivalent focal length for digital cameras.
FOV Horiz, Vert	# degrees	The field of view of that camera.

Counts Property	Type	Description
# Referenced Points	number	Number of points that are referenced on this photo.
# Marks	number	Total number of all marks on this photo.
# etc.	number	Various counts of lines, surfaces, curves etc. on this photo.

Using Camera Station Information

Sometimes it can be useful to know where the Camera Stations were located and what direction they pointed when the photographs were taken. When PhotoModeler processes a 3D model it also repositions all the Camera Stations. It calculates exactly where the photographs were taken from.

Many rendering programs allow camera positions to be defined in terms of position, target position, twist or roll angle and a focal length. This information can be obtained from PhotoModeler by using various export features, either by exporting the table data directly to a text file (see *Print and output Options dialog*), or by exporting the model directly to an external program such as Maya (see *Export the Resulting 3D Data to a CAD or Graphics Program*). This information can be used to do *Perspective Matching*, that is, matching the perspective of a camera in an animation program (called a CG camera) to a photograph.

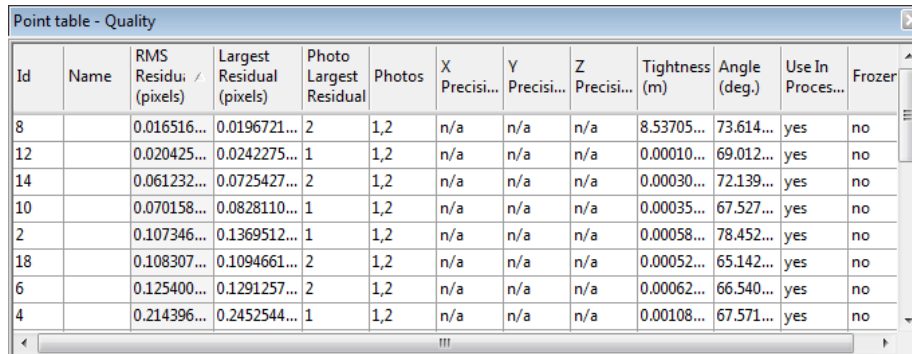
Using Station Export in a CAD / Rendering / Animation Program

The interfaces of CAD and animation programs for defining camera position, angle etc. are all quite different. Usually the data given above can be manipulated into a form needed by your program. Here are a few pointers:

1. Make sure the PhotoModeler project is in the coordinate system you want (by using Scale / Rotate or Control Points) before exporting the Camera Station data.
2. The target location given in the file is really just a direction vector and you should not be concerned by its actual distance from the camera. The position of the target point is not important, what is important is the direction of the target from the camera position. Many CAD and animation programs will have a target camera type definition you can use.
3. The roll angle should be very precise and give you good matches. Do note that the sign might be opposite; so try negating the roll angle to see if you get a better match.
4. The focal length you should use depends on the interface of the program. For simple programs that assume a 35mm type camera (i.e.. 36x24mm format size) then you can use the 35mm equivalent focal length in the file. If you have more control over this you might consider using the field of view (FOV) numbers instead.

See also *Perspective Matching*, *Idealize Project* and *Imported Objects*.

Point Table



Id	Name	RMS Residual (pixels)	Largest Residual (pixels)	Photo Largest Residual	Photos	X Precisi...	Y Precisi...	Z Precisi...	Tightness (m)	Angle (deg.)	Use In Proces...	Frozer
8		0.016516...	0.0196721...	2	1,2	n/a	n/a	n/a	8.53705...	73.614...	yes	no
12		0.020425...	0.0242275...	1	1,2	n/a	n/a	n/a	0.00010...	69.012...	yes	no
14		0.061232...	0.0725427...	2	1,2	n/a	n/a	n/a	0.00030...	72.139...	yes	no
10		0.070158...	0.0828110...	1	1,2	n/a	n/a	n/a	0.00035...	67.527...	yes	no
2		0.107346...	0.1369512...	1	1,2	n/a	n/a	n/a	0.00058...	78.452...	yes	no
18		0.108307...	0.1094661...	2	1,2	n/a	n/a	n/a	0.00052...	65.142...	yes	no
6		0.125400...	0.1291257...	2	1,2	n/a	n/a	n/a	0.00062...	66.540...	yes	no
4		0.214396...	0.2452544...	1	1,2	n/a	n/a	n/a	0.00108...	67.571...	yes	no

The Point Table displays information about Object Points in the currently open Project. See the *Tables* and *Interaction With Tables* sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the *Output to Printer, Clipboard or File* feature.

The 3D data in the Point Table is displayed in the project's current scale and coordinate system. See *3D Scale and Rotation Dialog* for more information.

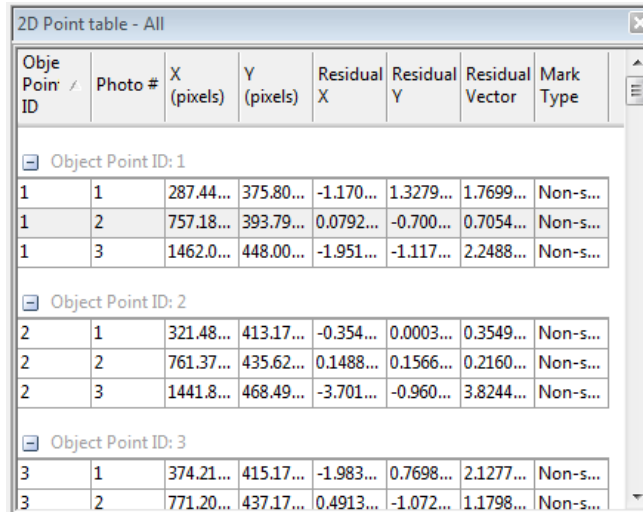
Multiple Point Table windows can be opened simultaneously. The contents of the Point Table keeps in sync dynamically with the remainder of the project. For example, if you drag a Marked Point around on a photograph its 3D position in the Point Table is automatically updated on the fly. Similarly, if you modify a position in the Point Table, any open 3D Viewer windows will automatically update to show the change.

You can select one or more Object Points and study their properties (using the Right Click menu or the Properties button on the Edit menu) or view the corresponding marks using the "Expand Selections to all Windows" ("W" key) command.

The Point Table is a key capability in PhotoModeler for review, troubleshooting and for output (to printer/clipboard/file).

The right click popup menu for the Point Table has a tool called "Show Marked Point with Highest Residual" which provides an easy way to open the photo(s) and display and select the marked point with the highest residual. The tool (only available from the Point Table's right click menu) is useful when troubleshooting a project and looking for problem points.

2D Point Table



The screenshot shows a window titled "2D Point table - All". It contains a table with the following columns: "Objec Point ID", "Photo #", "X (pixels)", "Y (pixels)", "Residual X", "Residual Y", "Residual Vector", and "Mark Type". The table is grouped by "Object Point ID" with expandable sections for IDs 1, 2, and 3. Each section contains a list of points with their respective photo numbers, pixel coordinates, residuals, and mark types.

Objec Point ID	Photo #	X (pixels)	Y (pixels)	Residual X	Residual Y	Residual Vector	Mark Type
Object Point ID: 1							
1	1	287.44...	375.80...	-1.170...	1.3279...	1.7699...	Non-s...
1	2	757.18...	393.79...	0.0792...	-0.700...	0.7054...	Non-s...
1	3	1462.0...	448.00...	-1.951...	-1.117...	2.2488...	Non-s...
Object Point ID: 2							
2	1	321.48...	413.17...	-0.354...	0.0003...	0.3549...	Non-s...
2	2	761.37...	435.62...	0.1488...	0.1566...	0.2160...	Non-s...
2	3	1441.8...	468.49...	-3.701...	-0.960...	3.8244...	Non-s...
Object Point ID: 3							
3	1	374.21...	415.17...	-1.983...	0.7698...	2.1277...	Non-s...
3	2	771.20...	437.17...	0.4913...	-1.072...	1.1798...	Non-s...

The 2D Point Table displays information about 2D Points (the point marks on photos) in the currently open Project. See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts. In the example shown in the screen capture above, Group Sorting has been activated, which in this case groups all 2D points by their associated object point.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

The 2D Point table lists each 2D Point's associated object point ID, it's XY pixel location on its photo, it's residual (XY and vector) and it's mark type (i.e. sub-pixel, or non-sub-pixel etc).

Multiple 2D Point Table windows can be opened simultaneously. The contents of the 2D Point Table keeps in sync dynamically with the remainder of the project. For example, if you drag a Marked Point around on a photograph its XY position in the 2D Point Table is automatically updated on the fly.

You can select one or more 2D Points and study their properties (using the Right Click menu or the Properties button on the Edit menu) or view the corresponding marks using the "Expand Selections to all Windows" ("W" key) command.

Offset Point Table

Id	X (in)	Y (in)	Z (in)	Type	Value	Material	Layer	OP #2
2	4.7767...	9.5062...	4.6968...	Target on cone (Z axis off...	9.8425...	White	Defaul...	n/a
3	4.7645...	15.673...	-3.161...	Z axis offset	2	White	Default	n/a
6	5.1486...	9.5062...	35.951...	Two point offset (2)	45	White	Default	2
7	4.6986...	15.610...	0.7821...	Target on cone (Z axis off...	9.8425...	White	Defaul...	n/a

The Offset Point table displays information about *Offset Points* in the currently open Project. See the *Tables* and *Interaction With Tables* sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the *Output to Printer, Clipboard or File* feature.

The Offset Point table lists the associated object point's ID, the offset point's XYZ position, the Type (X axis, Y axis, Z axis, 2 Point, and Custom), the value (i.e. offset distance from associated object point) material, layer, and the 2nd Object Point ID if the type is a Two Point offset. When an offset's Type is a "Two Point offset" the offset's second point ID is also shown in brackets (eg. "Two point offset (2)") and the ID of the second point is shown in the OP#2 column; when an offset's Type is a Custom offset, the user specified name is listed under type and the axis is shown in brackets (eg. "Target on cone (Z axis offset)").

The value is displayed in the project's current scale and coordinate system. See *3D Scale and Rotation Dialog* for more information on setting units and scale etc.

Multiple Offset Point Tables can be opened simultaneously. The contents of the Offset Point Table keeps in sync dynamically with the remainder of the project. For example, if you change the material of an offset point, or if the offset point's associated object point's position changes, the table is automatically updated on the fly.

You can select one or more offset points and study their associated object point properties (using the Right Click menu or Edit menu). An offset point selected in the table will cause the 3D offset point in open photos to be selected.

Surface Table

Id /	Surface Type	Photos	Material	Layer	3D Position	Compute 3D shape	Double...	Smoot...	Outer Trim	# Holes	# Defining Objects	# Triangles
2	Cone		Surfac...	Default	yes	yes	no	yes	no	0	2	46
3	Cone		Surfac...	Default	yes	yes	no	yes	no	0	2	46
4	Cone	1,2	Surfac...	Default	yes	yes	no	yes	no	0	2	87
5	Defined by path	1,2	Surfac...	Default	yes	yes	no	yes	no	0	4	2
6	Loft	2	Surfac...	Default	yes	yes	no	yes	no	0	3	34
7	Sweep	2	Surfac...	Default	no	yes	no	yes	no	0	2	n/a
8	Defined by path	1,2	Surfac...	Default	yes	yes	no	yes	no	0	3	1
9	Boundary Patch	2,3	Surfac...	Default	yes	yes	no	yes	no	0	4	2

The Surface Table displays information about Surfaces in the currently open Project. See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

The Surface table lists each surface's ID, whether it has a 3D position, the Surface Type, the number of Defining Objects, the number of triangles that make up the surface, the photos on which the surface appears, the surface's material, the surface's layer, whether it is double-sided or not, whether it is Smoothed or not, whether it is set to be computed, and the surface's trims and holes count.

Multiple Surface Tables can be opened simultaneously. The contents of the Surface Table keep in sync dynamically with the remainder of the project. For example, if you change the material of a surface, the Material column is automatically updated on the fly. You can select one or more Surfaces and study their properties (using the Right Click menu or the View menu) or view the corresponding projections using the "Expand Selections to all Windows" ("W" key) command.

Silhouette Table

Id /	Name	Photos	Material	Layer	3D Position	Compute 3D shape	Form	Tolera...	Smoot...
10		1,4	White	Default	no	yes	Poly	1.0000...	no
13		1,2	White	Default	yes	yes	Poly	1.0000...	no

The Silhouette Table displays information about silhouettes in the currently open Project. See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

The Silhouette table lists each silhouette's ID, User Name, the list of photos on which it is marked, the material, the layer, whether it has a 3D position, whether it is set to be computed, its form (Poly or NURBS), its tolerance, whether it is smoothed, its center of mass calculation (X,Y,Z) and its volume calculation.

Multiple Silhouette Tables can be opened simultaneously. The contents of the Silhouette Table keeps in sync dynamically with the remainder of the project. For example, if you change the material of a silhouette, the Material column is automatically updated on the fly. You can select one or more Silhouettes and study their properties (using the Right Click menu or View menu) or view the corresponding projections using the "Expand Selections to all Windows" command.

Note: If the 'Volume' column is visible in the current configuration, the calculation time for complex silhouettes (i.e. those with a 3D position marked and referenced on many photos) and hence the time it takes to display table data can be lengthy. Calculation/display time increases as silhouette complexity increases. If you have many complex silhouettes in your project you can avoid delays in table display by using a default table configuration that does not show volume data.

Line Table

Line table - All													
Id	End Point 1 ID	End Point 2 ID	End Point 1 X	End Point 1 Y	End Point 1 Z	End Point 2 X	End Point 2 Y	End Point 2 Z	Line Type	Length	Material	Layer	
1	1	9	-0.196...	-0.197...	1.5458...	1.2559...	1.2537...	2.3479...	Line M...	2.2043...	White	Default	
2	9	8	1.2559...	1.2537...	2.3479...	2.7955...	-0.243...	1.5254...	Line M...	2.2998...	White	Default	
3	8	7	2.7955...	-0.243...	1.5254...	2.7503...	-0.076...	1.4531...	Line M...	0.1873...	White	Default	
4	7	6	2.7503...	-0.076...	1.4531...	2.6128...	9.0779...	1.4518...	Line M...	0.1621...	White	Default	
5	6	5	2.6128...	9.0779...	1.4518...	2.6028...	1.3877...	1.3010...	Line M...	1.4518...	White	Default	
6	5	4	2.6028...	1.3877...	1.3010...	0	0	0	Line M...	2.6028...	White	Default	
7	4	3	0	0	0	-1.683...	6.9388...	1.4551...	Line M...	1.4552...	White	Default	
8	3	2	-1.683...	6.9388...	1.4551...	-0.128...	-0.120...	1.4512...	Line M...	0.1639...	White	Default	
9	2	1	-0.128...	-0.120...	1.4512...	-0.196...	-0.197...	1.5458...	Line M...	0.1399...	White	Default	
10	12	13	0.9443...	-1.173...	1.3359...	1.6878...	-1.162...	1.3335...	Line M...	0.7435...	White	Default	
11	10	11	0.9443...	-1.173...	1.3359...	1.6878...	-1.162...	1.3335...	Line M...	0.7435...	White	Default	

The Line Table displays information about Lines in the currently open Project. See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

The Line table lists each line's ID, two end point ID's and XYZ positions, Line Type (line mark or surface draw), material, layer and length. The length is displayed in the project's current scale and coordinate system. See [3D Scale and Rotation Dialog](#) for more information.

Multiple Line Tables can be opened simultaneously. The contents of the Line Table keeps in sync dynamically with the remainder of the project. For example, if you change the material of a line, the Material column is automatically updated on the fly. You can select one or more lines and study their properties (using the Right Click menu or Edit menu) or view the corresponding projections using the "Expand Selections to all Windows" command.

PointMesh Tables

PointMesh table - All														
Id	Name	# Points	# Triang...	Non-tex Material	Layer	Surface ID	Texture Photo	# Conto...	Samplin Rate	Samplin Rate Units	Depth Range Above (cm)	Depth Range Below (cm)	Texture Type	Extents
5	Photo...	21480	0	White	RawDS...	n/a	1	0	10.000...	mm	63.800...	63.800...	2	DSM T...
6	Photo...	8129	0	White	RawDS...	n/a	3	0	10.000...	mm	63.800...	63.800...	2	DSM T...
7	Photo...	11771	0	White	RawDS...	n/a	5	0	10.000...	mm	63.800...	63.800...	2	DSM T...
10	Modifi...	30620	60614	White	Hidden	n/a	5	0	n/a	n/a	n/a	n/a	n/a	n/a
12	Modifi...	1828	3030	White	Default	3	5	0	n/a	n/a	n/a	n/a	n/a	n/a

The PointMesh Table displays information about PointMeshes in the currently open Project. See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

The PointMesh table lists each pointmesh's ID, name, number of points in the pointmesh, number of triangles in the pointmesh (if it has been triangulated using the meshing steps), Material, Layer, associated surface ID (if it has been converted to a regular PhotoModeler surface. The Texture photo (as set on properties) shows the id of the photo from which the pointmesh obtains its photo texture and RGB values. The Number of contours is shown if the contours for the pointmesh were generated. The remaining settings show the various settings used when the pointmesh was created (eg Sampling Rate, Depth Range Above, Depth Range Below, Texture Type, Extents); these are useful when comparing the result of various changes to settings when generating a pointmesh.

Other Object Tables

There are three Tables that have similar form. These are the Edge, Curve and Cylinder Tables. These tables display information about Edges, Curves, and Cylinders in the currently open Project.

Edge table - All												
Id /	Photos	Material	Layer	Comput 3D shape	3D Position	End Point 1 X	End Point 1 Y	End Point 1 Z	End Point 2 X	End Point 2 Y	End Point 2 Z	
3	1,2	White	Default	yes	no	n/a	n/a	n/a	n/a	n/a	n/a	

Curve table - All												
Id /	Photos	Material	Layer	Comput 3D shape	3D Position	End Point 1 X	End Point 1 Y	End Point 1 Z	End Point 2 X	End Point 2 Y	End Point 2 Z	
2	n/a	White	Default	yes	yes	0.0000...	0.0000...	0.0000...	-0.059...	4.3399...	0.0108...	
3	2,1	White	Default	yes	yes	n/a	n/a	n/a	n/a	n/a	n/a	
5	n/a	White	Default	yes	yes	1.2559...	1.2537...	2.3479...	0.0000...	0.0000...	0.0000...	

Cylinder table - All												
Id /	Photos	3D Position	Comput 3D shape	Material	Layer	End Point 1 X	End Point 1 Y	End Point 1 Z	End Point 2 X	End Point 2 Y	End Point 2 Z	
3	1,2	yes	yes	White	Default	0.2679...	-0.047...	1.3560...	0.2835...	-0.069...	0.0693...	

See the [Tables](#) and [Interaction With Tables](#) sections above for background information on tables, various types and layouts.

Note: Tables that are open can be printed or exported (to file or clipboard) using the [Output to Printer, Clipboard or File](#) feature.

There are data columns for the object ID number, a list of photographs its Marks appear on, and its Material and Layer, Compute 3D flag to set whether the curve will be computed in 3D if possible (default is on - uncheck this to stop a curve from having a 3D representation without getting rid of its marks), 3D Position (whether the object has a 3D position), and the 3D coordinates of the object's two end points.

Multiple Table windows can be opened simultaneously..

You can select one or more Objects and study their properties (using the Right Click menu or the Properties button on the View menu) or view the corresponding marks using the "Expand Selections to all Windows" ("W" key) command.

Using your 3D Model with another program

Many computer programs work with, manipulate and render 3D models. Most of these programs will accept one of the file formats exported by PhotoModeler. Some of these programs that support rendering also provide the ability to define where a camera is stationed and allow you to view a rendered model as if from that camera. PhotoModeler exports camera station information for this purpose.

2D versus 3D

PhotoModeler exports data in the following 3D file formats: .dxf (3D DXF), .3ds (3D Studio), .obj (Wavefront), .raw (raw coordinates), .wrl (VRML 1 and 2 - Virtual Reality Modeling Language for the Web), .igs (IGES), .3dm (Rhino), .stl (STL), .ma (Maya Script), and .kml/.kmz (Google Earth).

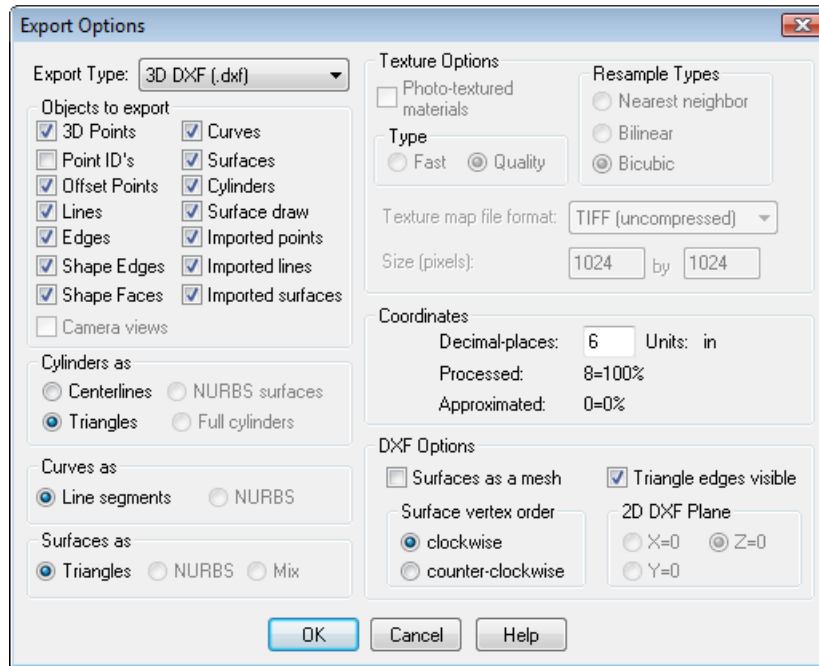
PhotoModeler can also export the 3D data in a model projected onto a plane in 2D. It can export this 2D data in the 2D DXF format. 2D data should be used only for relatively planar surfaces such as road drawings, or building elevation drawings.

The CAD or graphics package you use with PhotoModeler must handle one of the above formats. If you are using one of the 3D formats then your CAD package should have 3D capabilities.

Data can also be extracted from PhotoModeler using the DDE interface but this is a more advanced method that usually involves programming. See the section titled *Programming PhotoModeler - DDE Interface*.

3D Model Export

3D Model Export Dialog



The 3D Model Export Dialog (Export Options) controls all the options for export of all the 3D model data from PhotoModeler for use in external CAD, graphics, animation and rendering packages.

Different parts of the project 3D data can be exported, in different forms and to different file formats. Each section of this dialog deals with some aspect of these controls. The following sub-sections describe these in greater detail.

Export Type

The Export Type drop down list specifies which type file format to export. Currently supported types are: Autodesk DXF (2D and 3D), 3D Studio, Wavefront OBJ, VRML (1&2), IGES, OpenNURBS/Rhino, StereoLithography, RAW, Maya Script format, and Google Earth's KML and KMZ, Max Script, and FilmBoX.

See the table below for a list of how objects are handled by each format.

The DXF file format is supported by virtually every 3D package so it is a good format for sharing geometry but it is limited in the type of data it can transfer. You cannot export texture maps, nor fully-defined materials in the DXF format.

3D Studio, OBJ, VRML and Rhino file formats all handle fully-defined object materials and photo-derived textures.

The 2D DXF format is a sub-set of normal 3D DXF in that it has no Z coordinates. PhotoModeler produces these files by projecting the 3D model data onto a specified plane

thereby making it 2D. This can be useful if you are moving data from PhotoModeler into a 2D CAD package or if you are not concerned with the 3rd dimension (such as creating the map of road for skid marks). See the DXF Options section below for how the plane is defined for the 2D projection.

The IGES format is used by high end CAD and graphics packages. IGES, Wavefront and Rhino are the only formats that currently support NURBS curves and surfaces in their native format.

The RAW format is a simple table of 3D coordinates of points, lines or faces. There is no extra topological, structure or material information included. This format is useful for import into various math analysis packages and spread-sheets.

Export of point and camera data in a Maya .ma script format is also available. Maya does not create 'locators' when importing other 3D formats from PhotoModeler so this export option can be used to bring point data into Maya. Maya export support camera data that is useful in matching perspective to background plates. Lines and Curves are also exported. Other data types (surfaces, etc.) can be exported to Maya using one of the other formats.

The two Google Earth export formats (.kml and .kmz) are for putting 3d models into Google Earth. KML is the basic format that supports points, lines, curves and surfaces and works in most Google Earth versions. KMZ is a compressed format based on the DAE Collada format and works in Google Earth 4 and later. KMZ adds supports for textures. See the *Google Earth Coordinate Dialog* section below for further information.

Note 1: If exporting smoothed models to 3DS format with photo-texture maps you should note that 3DS has a limitation. It is not possible to describe a fully smoothed photo-textured object in 3ds when there are different photo-texture files. If you are using 3D Studio Max* you can get around this by importing the 3DS model generated by PhotoModeler into Max and then do Mesh Modifier and weld all the vertices. Once the vertices are welded you can render properly smoothed across boundaries that have different texture files.

Note 2: Some format types specify the units of all 3D coordinate data. VRML files are always in meters and 3DS files are always in inches. If your project is using another set of units, the 3D coordinate data will be converted to the specified units during export.

Note 3: There are ways to combine exports too. For example, if you wanted a model showing photo textured surfaces along with camera positions in Maya, you could export textures using the .obj format and then add cameras using the .ma format as a separate export, and then import both files (.obj and .ma) into Maya.

The standard file extensions for these files by type are: 3D DXF (.dxf), 2D DXF (.dxf), 3D Studio (.3ds), VRML 1.0 (.wrl), VRML 2.0 (.wrl), Wavefront (.obj), raw coordinates (.raw), IGES (.igs), OpenNURBS / Rhino (.3dm), Stereo Lithography (.stl), Maya (.ma), Google Earth (.kml or .kmz), Max Script (.ms), and Filmbox (.fbx) .

The following tables list all the types of objects exported by PhotoModeler and how they are handled in various formats. If a cell in the table says "yes", this means the object is exported natively (i.e., Points export as POINT objects in DXF). If a cell is blank then that object type is not exported in that format (usually due to a limit of that format). If a cell has some other string this means the object is exported as a non-standard entity.

	D X F	3 D S	V R M L	O B J	I G E S	S T L
3D Points	yes			yes	yes	
Point IDs	as text					
Offset Points	yes			yes	yes	
Lines	yes		yes	yes	yes	
Edges	as lines		as lines	as lines	as lines	
Curves	yes ⁴		yes ⁴	yes ⁵	yes ⁸	
Surfaces	yes ¹	yes ¹	yes ¹	yes ²	yes ⁷	yes ¹
Cylinders	yes ⁶	yes ⁶	yes ⁶	yes ⁶	yes ⁷	yes ¹
Surface Draw	yes		yes	yes	yes	
Photo-Textures		yes	yes	yes ³		
Cameras			yes ¹¹			
	3 D M	R A W	M a y a	G o o g l e	M a x	F B X
Points	yes	yes	yes	yes	yes	yes
Point IDs	yes ⁹					
Offset Points	yes	yes	yes	yes	yes	yes
Lines	yes	xyz's	yes	yes	yes	
Edges	as lines	xyz's		yes		
Curves	yes ⁵		yes	yes	yes	
Surfaces	yes ²	xyz's		yes		yes
Cylinders	yes ⁶			yes		yes
Surface Draw	yes	xyz's		yes	yes	points only
Photo-Textures	yes ³			yes ¹⁰		yes
Cameras			yes		yes	yes

1 Surfaces are exported as tessellated triangular faces.

2 Surfaces can be exported as either tessellated triangular faces or as NURBS Surfaces, controlled using the Export Surfaces as setting. The surface ID is exported as the name of the surface in Rhino, which helps match surfaces in the two applications.

3 Photo-Textures are only output for surfaces output as tessellated triangular faces. NURBS Surfaces are not textured.

4 Curves are exported as tessellated line or poly-line segments.

5 Curves can be exported as either tessellated line segments or as NURBS Curves, controlled using the Export Curves as setting.

6 Cylinders are exported as tessellated triangular faces that look like a cylinder, as a centerlines, as a cylinder (VRML), or as NURBS surfaces controlled using the Export Cylinders as setting. Not all types available in all formats.

7 Surfaces are exported as NURBS surfaces in IGES type 128.

8 Curves are exported as NURBS curves in IGES as type 126 form 0.

9 Point IDs are output in the object name field. If the point has a user name it is output as "123:User name", where 123 is the point's ID.

10 Textures exported with the Google Earth .kmz format only.

11 VRML 2 format only.

Note 1: the tolerance of surface and curve tessellations can be controlled on the *Preferences* dialog.

Note 2: in the past the Wavefront OBJ file format was exported in a rotated coordinate system for use with older Alias/Wavefront software. This is generally not needed now and since version 4.0c PhotoModeler exports OBJ in the same coordinate system defined by the user. There is a Preference setting called "WavefrontRotated" that provides the capability to use the former rotation export method.

Export Data Types

PhotoModeler can export the following types of data from the project: 3D Points, Point IDs, Lines, Edges, Surfaces, Surface Draw, Curves and Cylinders. Not all file formats can support all these types (for example, 3D Studio file format does not understand points, lines or curves). The various export data types will enable or disable based on the Export Type selected and what that format can support.

Note: It is important to remember that the Materials and Layers affect how these objects are exported. See the *Materials Dialog* and *Layer Dialog* for more details.

Coordinates

In some formats you can control the number of decimal places that are used to describe a X, Y, or Z coordinate - these formats are: DXF, OBJ and VRML. If you enter 2 for the number of coordinate places all coordinates will be rounded to the closest 100th and output like this: 34.12 or 4623.00.

This can be used to reduce the precision of the project to a more meaningful quantity or to reduce the size of the files (fewer characters output).

The "Units" string shows what measurement units will be used to export the coordinates in. Most of the time this will be the project units. Some formats such as VRML specify that the coordinates be in meters so that is how they are always exported and 3D Studio is exported always in inches.

The Processed and Approximated items of the 3D Export dialog provides a little information on the "quality" of the 3D data being exported. 3D Points in PhotoModeler can either be "fully processed" or "approximated". To be processed a point has been through Global Optimization - this means the point is as accurate as can be given the input data. To be approximated a point has a 3D location based on the intersection of light rays from two or more photographs but has not yet been through Global Optimization. In strong projects sometimes there is not much difference between approximated and processed but if you are interested in highest accuracy you might want to process the project before export. In other projects there can be a large difference between processed and approximated 3D Points so again it is a good idea to reprocess the project before export.

Export Curves as

When curves have been chosen as an export type, the export "Curves as" section becomes active. If the format type allows, Curves can be exported as either line segments or NURBS. "As Line segments" will break the curve down into small tessellated line segments that are exported as line or polyline entries. The tolerance of this tessellation can be controlled on the *Preferences* dialog. "As NURBS" will export the curve as an exact mathematical representation of the curve. Not all formats can handle the NURBS form.

Export Surfaces as

When surfaces have been chosen as an export type, the "Export Surfaces as" section becomes active. If the format type allows, Surfaces can be exported as either triangulated faces, NURBS or a mix. "As triangles" will break the surface down into small triangular faces that are exported as individual face entries. The tolerance of this tessellation can be controlled on the *Preferences* dialog. "As NURBS" will export the Surface as an exact mathematical representation of the surface. These formats can support Surfaces in NURBS form: OBJ, IGES, 3DM.

If a format supports both triangles and NURBS the "mix" option will be available, when selected this option will output surfaces as NURBS when possible, and triangles when there is no NURBS representation for the surface (e.g. A triangulated path).

Surfaces exported as NURBS are not textured. Surfaces and Cylinders need to be in triangle form to support photo-textures.

When surfaces are exported as NURBS any defined *Trim* (outer or hole) will be exported in the formats that support them. In IGES, Trims are exported as type 142/144.

When Surfaces are exported as triangles, each surface is exported as one "mesh" of triangles in the formats that support that form (3DM/Rhino).

Export Cylinders As

When cylinders have been chosen as an export data type, the export "Cylinders as" section becomes active. Cylinders can be exported in one or more of the following ways: as centerlines, as full cylinders (solids), as tessellated faces, and as NURBS surfaces. Centerlines are just 3D lines that extend from one end of cylinder to other and no diameter information is output. Only formats that can handle lines (such as DXF, OBJ and VRML)

can handle cylinder centerlines. Full cylinders are a solids description of a cylinder and currently only the VRML format handles it. Tessellated triangular faces are a set of triangles that describe the surface and the end planes of the cylinder appropriate for a package that works mostly with meshes and faces (such as 3D Studio). NURBS surfaces are three closely tied surfaces per cylinder (body and two end caps). Formats that can accept NURBS surfaces (OBJ, IGES, 3DM) can handle cylinders as NURBS surfaces.

Texture Options

When Surfaces or Cylinders are chosen for export, the Texture Options become available.

Note: Textures are only exported for a surface or cylinder if that object is set to have a Material with "Diffuse Color from" single or multi photo-texture. See the *Materials Dialog*.

The first control, "Photo-texture materials", controls whether surfaces (cylinders) with photo-textures will be exported. When this is turned off no textures will be created. All surfaces (cylinders) will be exported as non-textured.

The second control, "Type", determines what adjustments PhotoModeler will do to the images when converting them to texture files. "Fast" will resample the photos to match the texture options size settings and map the surfaces to the photos based on the settings in their materials. "Quality" will detect which regions of each image are used for texturing, remap each portion to account for perspective, perform other blending and matching, and combine these regions into one file matching the texture options size settings. "Fast" results in one texture map per photograph used for texturing, where as "Quality" results in one texture map file for the whole model. "Fast" textures are much faster to create but "Quality" textures usually have been appearance with rendered models. See also *Quality Textures* in the 3D Viewer section.

The third control, "Resample Types", determines what technique should be used when re-sampling the photos to match the new texture options size. Bicubic will provide the best quality but the texture creation process will take longer, Bilinear trades of quality for speed, Nearest neighbor is the fastest remap type but will produce a lesser quality resampling.

The fourth control, "Texture map file format", sets which image file format is used for the texture maps. Be sure to check the software you are using to import your models that the texture file format you use is supported. 3D Studio R4, 3D Studio Max, Truespace and Nugraf support all our image formats. When exporting to VRML, only the JPEG file formats will be available (at three different quality levels).

The fifth control, "Size (pixels)" controls the size of the texture file(s) created. In the case of Fast textures each image will be remapped and then padded to this size, in the case of Quality textures the final combined image created will be this size. You can set the width and height independently to optimize the size of your textures, however some graphics engines and rendering systems prefer the sizes to be powers of two (256, 512, 1024, etc). Since in the Quality mode all textures are placed in one file, you will typically need to enter larger values for map size to get similar effective resolution in the map as compared to Fast mode.

The sixth control, "1:1 Size" is a button that when pressed will provide the best texture size given the current settings. The returned size provides for close to one texture map pixel to one source photograph pixel. That is, the map will have sufficient resolution to capture most of the photographic detail available but no more. Note that if you want a power of two texture as described above you can then change the returned values to be the next smallest or next largest power of two.

DXF Options

The DXF Options section of the 3D Export Dialog has a few controls for the DXF file format.

"Surfaces as a mesh" is used to specify that all Surfaces in the project should be exported as one DXF polygon mesh.

"Triangle edges visible" is used to specify if the "visible" flag is to be set when exporting the edges of the 3D triangular faces. Without this setting some packages will import the PhotoModeler created DXF file with faces but none of the faces will appear (they will be there, just not visible).

"Surface vertex order" is used to specify whether vertices in the triangular faces in the DXF file should be in clockwise or counter-clockwise order. You should check the package that is importing the files to see which it expects for normally oriented faces.

The "2D DXF plane" control is used only with the 2D DXF file format. By choosing one of the coordinate planes (x=0, y=0, or z=0) you are specifying which plane all the 3D data should dropped onto and the 3rd coordinate removed. You will probably want to set up an appropriate coordinate system in your project first (see [Adding Scale and Rotation](#)) before using this option.

If you choose x=0, all the 3D Points are projected onto the YZ plane and then all Y values become X and Z values become Y in the 2D DXF (which are always defined by X and Y coordinates only). If you choose y=0, all the 3D Points are projected onto the XZ plane and then all X values become X and Z values become Y in the 2D DXF. If you choose z=0, all the 3D Points are projected onto the XY plane and output as X and Y.

Google Earth Coordinate Dialog

	Point or Camera ID	Latitude	Longitude	Altitude		
Location 1:	1	0.000000	0.000000	0.000000	Paste from GE	Geo exif
Location 2:	2	0.000000	0.000000	0.000000	Paste from GE	Geo exif
Location 3:	3	0.000000	0.000000	0.000000	Paste from GE	Geo exif

The Google Earth Coordinates dialog is used when a KML or KMZ file is exported. It is used to place the 3D model in PhotoModeler into the correct geographic coordinates for use in Google Earth.

To place the model in the correct geographic coordinate system that Google Earth uses you need to pick three points or camera stations that can be seen in the Google Earth imagery at the location. These same three points have to be 3D Points, Shape Vertices, or Camera Stations in the PhotoModeler model. The idea is to match them up so

PhotoModeler knows how to translate, rotate and scale the internal model into the earth-centered system.

The above dialog appears as the last step of exporting a KML or KMZ model (after the file dialog).

The easiest way to get the Google Earth coordinate data into PhotoModeler is to use Google Earth place marks. Zoom in on the imagery and place three Place marks on the imagery. Then right click on the place mark and Copy. In the above dialog use the Past from GE button to place the coordinate data into the correct field. Choose the height units that Google Earth is currently using if you have non-zero heights (usually feet or meters).

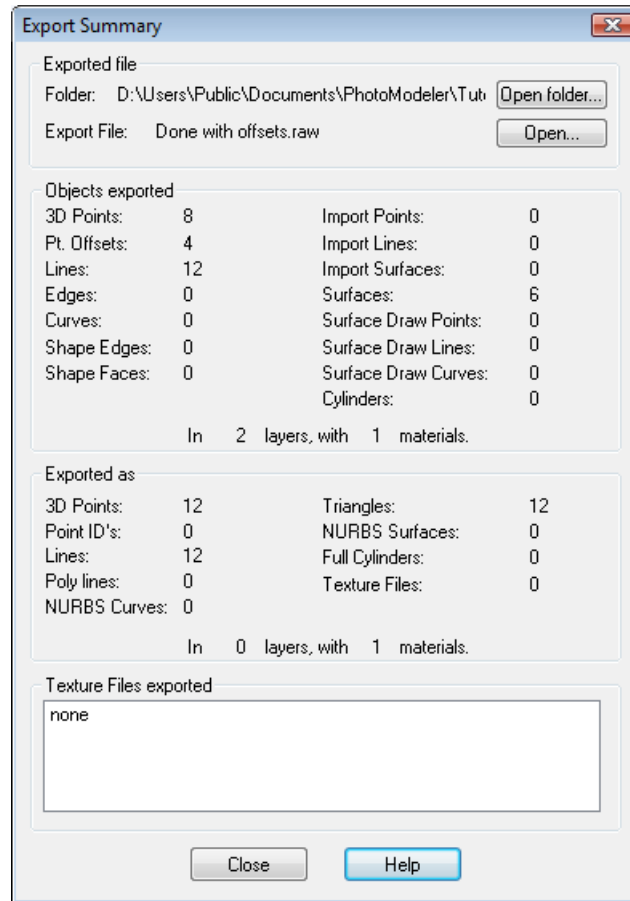
If your images are 'geo-coded' (i.e. your digital camera has a GPS and embeds location data into the image's EXIF header), the "Geo exif" buttons enable after you enter the camera station identifier (e.g. cs1) . You then press the Geo exif button to extract the GPS information from the camera station's associated image which gets placed into the latitude and longitude boxes automatically. This is another way to place your model in the correct geographic coordinate system.

The three PhotoModeler points that correspond can be 3D Point IDs entered directly here or chosen by selection before the export is started.

For Shape Vertices you need to first select them (in the 3D Viewer for example) before Export Model is chosen. The identifiers will be automatically entered.

When entering Camera Station identifiers, you need to use "cs" before the id (e.g. "cs1"), but you can also first select the camera stations in 3D viewer before proceeding with the export.

Export Summary Dialog



The Export Summary appears after a successful 3D file export. It has four sections:

Exported File

This section displays the name of the file exported and the folder/directory where the file is located. The “Open folder” button brings up a File Explorer pointed to that folder/directory so you can conveniently access the files just created. The “Open” button will attempt to open the exported model in the application that is associated with the file type.

PhotoModeler Objects exported

This section lists the PhotoModeler objects that were exported and their counts. The contents of this section depend on which options were chosen in the 3D Model Export Dialog and the contents of the PhotoModeler project.

Exported as

This section lists the types of data and their counts that are in the exported file. Each 3D format handles object types differently and so this section reflects how the conversion was made during the export. For example, if you exported 16 Surfaces (as shown in the “PhotoModeler Objects exported” section), but had the Triangles open turned on, then you might see that 28 triangles were exported to the file. This would be the total number of triangles used to describe those 16 Surfaces in triangular mesh form.

Texture Files exported

This section lists the names of the texture files that were exported, if any. These files will be in the folder/directory shown at the top of the dialog.

Making the Textured Models Look Better

Once you successfully generate a 3D model with textures there are a number of things you can do to improve how they look. The following sub-sections deal with these.

Add a Scale/Rotation to the model

The 3D models in PhotoModeler have an arbitrary coordinate system until set by you. You may find that the VRML model exported by PhotoModeler is rotated incorrectly relative to the starting view you want or the world you are building. Use an axes based rotation to clean this up. See *Adding Scale and Rotation*.

Increase the resolution of texture capture

Try using a higher Texture Quality to see if the results look better in your graphics package. At some point you will notice the diminishing returns and decide that the texture files are large enough and very little improvement is being seen.

Add Photographs with less perspective foreshortening

If one of more of the photographs in the PhotoModeler project has large perspective distortion then you will get a variation in perceived resolution in the output image textures. The only way to correct this is to add some photographs to the project that are more parallel to the side of the object with the distortion.

The following building model example illustrates this point. The photograph on the left has large perspective distortion on the walls and the roof whereas the photograph on the right has little distortion on the front wall. Both photographs could be used for texture extraction but the results using the photograph on the left would not be as good due to variable photographic resolution.

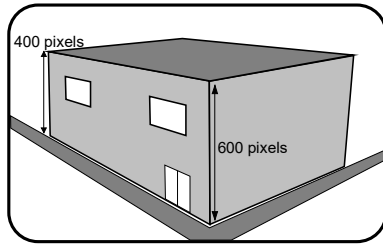


Photo Texture of wall will have variable resolution

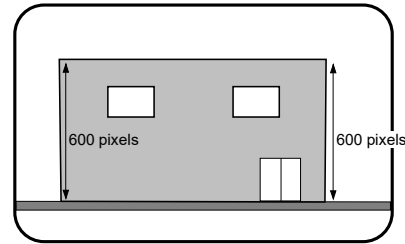


Photo Texture of wall will have constant resolution

Add Surfaces to better match the surface

One of the strangest effects you will see with this type of texture mapping is a distortion of the image on the surface that "appears" to move on the surface as you move around the object. This is an optical illusion caused by our expectation of what the surface should look like and the mismatch with the mapped textures. This can also be seen as straight lines that appear crooked in the texture-mapped model.

These problems occur because the Surfaces defined in the model do not match the real surface of the object. For example, model a car door with only two Surfaces describing a flat plane. The car door is actually curved and so when the image is captured from the photograph and mapped back onto a flat surface you will get distortion.

To correct this, you need to add more Surfaces. Break up large Surfaces (by deleting them) and replace them with smaller Surface that follows the surface of the object more closely. Remember that you are approximating the curved surface by a set of connected planar triangles.

The trade-off is that as more Surfaces are added, the output file will get larger and the texture export will take longer. Depending on the result desired you can do as little or as much of this as is needed to get good looking results.

Switch to color photographs

Often we use monochrome images in PhotoModeler to speed up image load time and to reduce disk storage requirements. If you use monochrome photographs you will get monochrome texture output. If the original photographs were color you can switch these with the monochrome ones in the project and have PhotoModeler extract the textures in color.

To switch to color photographs:

1. Take note of the file names of the photographs used in your project.
2. Move all the monochrome images into a separate sub-directory.
3. Find the corresponding color image for each of the photos found in step 1. and rename them so they have the same file names as their monochrome counterparts.
4. Copy these color images into the directory where the monochrome images used to be.
5. Load the PhotoModeler project that used the monochrome images.

You will see that your chip images are still monochrome but when you open a full image you will see it is color. If you want color chips, delete all the .CCH files in the project directory and reload the project.

6. Open all the images to make sure they match the markings and no mistakes have been made in step 3.
7. Do the 3D model export again.

Clean up intensity variations between images

You may see triangular regions on the object in your graphics package that have noticeably different intensities than their neighboring triangles. You may see one quite dark face surrounded by lighter faces or the reverse. This is due to PhotoModeler extracting adjacent face textures from different photographs. These photographs might have different brightness and contrast.

Imagine walking around a building taking pictures; some of the pictures may have a lot of sunlight and others might have a lot of shadow. These images vary quite a bit in brightness and contrast. The textures extracted from these photos will have similar variations in brightness and contrast.

If you just have one or two Faces that seem out of place, you may be able to fix it with judicious choice of the Photograph quality.

For more widespread intensity variations you will need to use an external image processing program (e.g. PhotoShop) to play with the intensity and contrast of the images to try to even them out.

Clean up/remove targets

When modeling/measuring objects with curved surfaces you may use targets. See *Using Targets*. Since these targets appear in the photographs they will also be extracted during the texture extraction. You may not want this to happen. For example, you placed 100 sticky dots on a modern day car with complex curved surfaces so you could get a realistic shape, now when you produce the model of the car, you get a texture mapped car with lots of dots on it!

There are a few ways around this but the methods all use the same basic technique. What you need are two versions of each photograph (one with targets showing for marking use and one with no targets for texture extraction). Here are a few ways to accomplish this:

- Use a projection system to generate the targets, use a tripod to take pictures and then take two photographs at each position, one with projector on and one with projector off.
- Use targets that are very high in contrast in one of the red, green or blue bands but are almost invisible in the other bands. Then use an imaging program to create two monochrome versions of each image. One will have the high contrast targets visible and in the other, the targets will be invisible (or close).
- After the project is complete, read copies of the photographs into an image processing program (e.g. PhotoShop) and use the various painting and cloning tools to erase the targets. Make sure you do this to copies of the photographs as you will not want to lose the originals if you need to work on the project in PhotoModeler again.

Animation Output Dialog

The Animation Output dialog provides tools to create simple 3D animations from 'keyframes' (i.e. snapshots) from the PhotoModeler 3D Viewer. The basic process is to add keyframes to the animation and PhotoModeler will complete the animation by smoothly filling in the frames between the keyframes. The process can be summarized as follows:

1. Position the model in the viewer as your starting point
2. Click "Add keyframe"
3. Reposition your model for the next keyframe using pan, rotate and zoom or any combination of these for each keyframe (remember that PhotoModeler fills between keyframes, so your movement can be significant – some experimentation may be required)
4. Click "Add keyframe"
5. Continue this process until you are happy with your sequence.
6. Once you're done, click the "Play" button to review your animation. You'll notice that the keyframes will highlight with a red outline as the animation reaches each one. This shows you the interval at which the animation is playing.

Note: The amount of change between keyframes may require some experimentation. You may need to remove or insert keyframes to get the animation that you're looking for. See the section below for more information on settings and output control.

Animation Output Settings

Keyframes section: This section shows keyframes that you've added to the animation:

- "Add keyframe" adds a keyframe to the end of the sequence.
- "Remove keyframe" removes the selected keyframe from the sequence (click a keyframe 'chip' to select it).

- “Insert keyframe” copies the selected keyframe and inserts it immediately after the selected keyframe.
- “Frames between this keyframe and the next” setting controls how many frames are to be inserted between the selected keyframe and the next one in the sequence. PhotoModeler will automatically ‘smooth’ the animation between the keyframe positions. This number can vary between each pair of epochs.

3D View section: This section shows the model in 3D in an interactive 3D View, and has the familiar 3D controls at bottom right:

- “Play” will play the animation in the 3D View based on the keyframes that have been added.
- “Size” settings control the size of the output when exporting to GIF or AVI

GIF section: This section shows the settings to control the animated GIF file output, specifically for the GIF option:

- “Override frames between keyframes” controls the number of frames to place between keyframes in the GIF output. This overrides the variable “Frames between this keyframe and the next” setting in the Keyframes section, which is useful when you want to keep the GIF file as small as possible.
- “Loop” controls whether to loop and how many loops are to be included in the GIF output.
- “Delay between frames” controls the speed of the animation in the GIF output. The larger the number the slower the animation
- “Create Animation” button writes the animated GIF file. You will be asked for a file name and location to save the file. Once the video export is complete a dialog will now ask if the video should be played in the file’s associated application.
- Note the “Size” settings in the 3D View section control the dimensions of the output

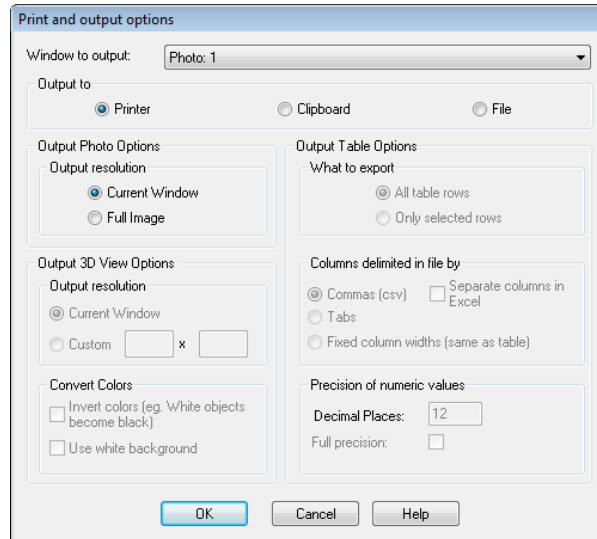
AVI section: This section shows the settings to control the AVI file output, specifically for the AVI option:

- “Frames per second” controls the speed of the animation in the AVI output. The larger the number the slower the animation
- “Create Animation” button writes the AVI animation file. You will be asked for a file name and location to save the file. Once the video export is complete a dialog will now ask if the video should be played in the file’s associated application.
- Note the “Size” settings in the 3D View section control the dimensions of the output

Output to Printer, Clipboard or File

You can output view (i.e. Photo, Table or 3D Viewer) to a Printer, Clipboard or File, using the Print and Output Options dialog. For other output options (e.g. export) see *Using Your 3D Model with Another Program*.

Print and Output Options Dialog



This dialog provides options to output the contents of an open view:

Window to Output: Select the view to output using the Window to output dropdown control. This control will list the currently open views from which you can select a view to output (photos, tables and 3D views will be listed). Depending on the type of view that you select, various options in the dialog become enabled or disabled.

Output to: The radio buttons in the “Output to” section allow you to select the destination of the output, either Printer, Clipboard, or File.

Output Photo Options: When a photo is selected for output, the controls in this section enable and allow you to select whether to output the photo as is currently shown in PhotoModeler, i.e. Current Window (current zoom) or the Full Image (disregards current zoom).

Output 3D View Options: When a 3D Viewer is selected for output, the controls in this section enable with these options:

- **Output Resolution:** Select Current Window to output as is currently shown in the open 3D Viewer, or choose Custom resolution, and enter the dimensions for output.
- **Convert Colors:** Select whether to invert colors and/or use a white background (i.e. you may prefer to have a light background instead of dark to save on printer ink).

Output Table Options: When a Table is selected for output, the controls in this section enable with these options:

- **What to Export:** Select whether to export all rows in the table, or just the rows that are currently selected.
- **Columns delimited in file by:** When outputting to clipboard or file, select how to output the table data, i.e. separate the columns in the output by Commas (then choose whether to separate columns for output to Excel), Tabs or Fixed Column Widths (i.e. widths as shown in the open table).

- Precision of Numeric Values: Select the number of decimal places to show in the output (i.e. numeric data only), or choose Full precision for maximum decimal places.
- When printing a table, a preview is first displayed which allows you to check layout and formatting etc. before sending the document off to the printer.

Note that when exporting a table, you can optionally add a newline and a carriage return for better formatting in other software, such as Notepad. Set PhotoModelerPro6.ini's "AddCarriageReturnToExportEndOfLine" setting in the [General] section to TRUE.

Ortho-Photo Export

Ortho-photos (orthographic photographs) are images that have been remapped to remove the effect of surface variations and camera position from a normal perspective photograph.

Ortho-photos can be used for two purposes: 1) to extract a remapped photo for use in mapping or presentation, 2) to extract a planar texture for use with a rendering program.

Remapped ortho-photos are useful aids for mapping and presentation because all the perspective distortion has been removed. This makes the photograph have the 2D geometry of a drawing. It can be useful also to change the view point (e.g. from a photo taken on the ground to one taken from a high-flying aircraft).

The strength of an orthographic drawing or photograph is that it is 'to scale' and can be used for measurement. That is if two objects are the same size in the ortho photo that means they are the same size on the real object (for objects parallel to the projection plane - see below). Ortho-photos can be created with a specific scale so you can measure an object in the ortho-photo and know how big it is in the real world. You cannot do with perspective images (i.e. those taken by a real camera).

An ortho-photo is a projection of the 3D model onto a plane using parallel projection. That is, all the rays of projection are parallel to each other and also perpendicular to the plane. The 3D model is assigned photographic data for every part of its surface and it is this photographic data that is projected. The result of this process is an image file that can be printed or saved on disk.

Many advanced 3D computer graphic rendering and animation programs accept texture images for mapping onto surfaces. The goal in using textures is to improve the realism of the rendering or animation. For example, a rendered building looks much better if the red brick pattern is a realistic one derived from photographs of real brick, or a rendered store front has a store sign from a photograph mapped onto its walls.

The extraction of an image or a texture from a photograph used in PhotoModeler involves determining the relationship between the surface of the object and the photograph in 3D space. Once this 3D relationship is known, an inverse mapping can be done to extract an image that is orthographic (i.e. flat to the surface with no perspective distortions).

Textures and images are extracted from photographs in PhotoModeler by choosing processed Surfaces or Points. They need to be processed/solved because the 3D position of the Surfaces and the Camera Station are needed to perform the inverse 3D mapping. The following section describes how to extract images and textures from photographs in PhotoModeler.

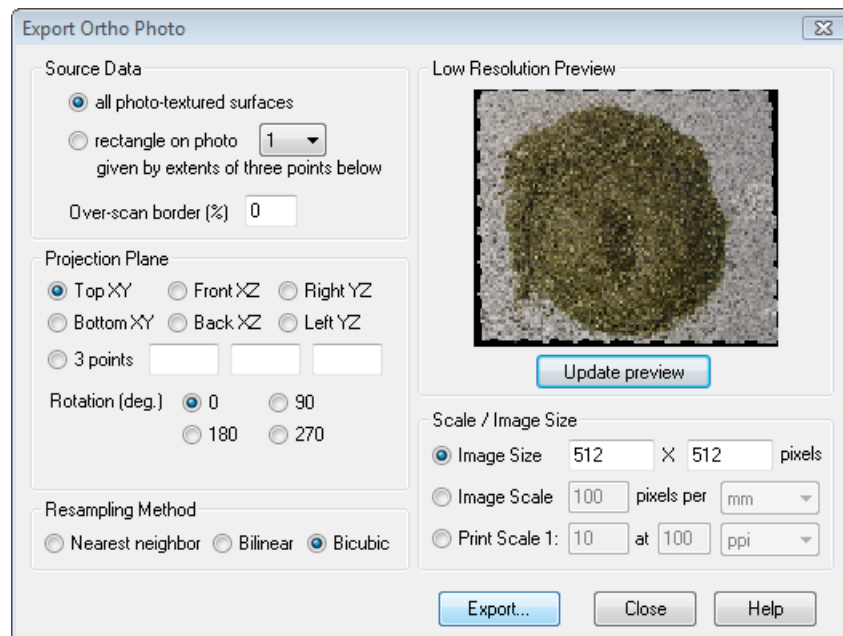
See the *3D Model Export* section for a method for extracting textures tied directly to the 3D model.

Ortho-photo vs Rectified Photo

Ortho-photo production can also be used to create rectified photographs. A rectified photograph is a remapping of a single plane viewed in perspective to an orthographic view. Rectified photographs are used to turn a slanted photograph of a building facade into a straight-on view suitable for doing drawings and measurements. Rectified photographs are accomplished in PhotoModeler by defining three or more control points to define the plane of the building facade. Once solved the three point extents and projection plane method of ortho-photo creation as described below can be used.

Note the definitions of rectified photo and ortho-photo are not always clear. Generally a rectified photo of a surface that has some depth variation (e.g. the facade of a building) will still contain distortions caused by perspective - only the gross perspective distortion will be removed. On the other hand, an ideal ortho-photo will have all effects of perspective distortion removed but this requires that every facet of the surface be modeled accurately.

Ortho-photo Dialog



The Export Ortho Photo dialog is used to create a new photographic image that is similar to an orthographic drawing. An orthographic drawing is one where length and distance is constant (that is all objects of the same dimension will be the same size in the orthographic drawing). This is opposed to a perspective drawing where as objects get farther from the viewer they get smaller. See the sections above for more detail.

There are five steps to creating an ortho photo image file.

1. Choose the source of photographic data.
2. Define the projection plane.
3. View the preview and adjust parameters as needed.
4. Choose the type of scale for the image.

5. Generate and export the full resolution ortho photo to disk.

These steps are described in the sections below.

Note: one of the most important aspects to consider when generating accurate ortho photos is that the modeling surface must match the true object. If using the Surfaces source option, that means the surfaces used to model the object should follow the object shape as closely as possible. If using the three point source option, that means the object being mapped should be planar and in the plane defined by the three points.

If the object does not follow the surfaces or plane then the ortho photo will be distorted in those areas of mismatch. For example, if the modeling surface is the front of a building and the inset windows are not modeled then the windows will not be true orthographic representations in the ortho-photo (since they lie behind the modeling surface).

Ortho Photo Source Data

The first step to create an ortho-photo is to decide where the photographic data is going to be extracted from. There are two choices for photographic source data: photo-textured surfaces and a single photograph.

When using the first choice, “all photo-textured surfaces”, the project must have one or more surfaces with a photo-textured material applied. See *Materials Dialog* for instructions on how to set up and use photo-textured materials.

If you can see a 3D model in the *3D Viewer* with photographic quality textures then you can use this first option to create ortho-photos. In fact an ortho-photo created using the “all photo-textured surfaces” option is very much like having a photo textured model displayed in the 3D Viewer with the “orthographic view” setting turned on. The ortho-photo will be more accurate though (as it compensates fully for all camera characteristics) and more importantly can have an accurate scale.

The second choice: “rectangle on photo N given by extents of three points below” does not require any surfaces to exist in the project. It is suitable for an object with only one plane (such as the front of a flat building). Multiple ortho-photos can be created with different planes though and combined in an external program such as PhotoShop.

To use this option, the ID's of three object points (or edge end points) must be entered in the three boxes in the Projection Plane section. See below for more information. A rectangle is formed which is the bounding box of the three points on the projection plane and the photographic data from the photograph with the ID shown in the drop down list is extracted for that rectangle.

	All photo-textured surfaces	Rectangle from points and photo
Pros	<ul style="list-style-type: none">- Can extract photographic data from multiple photographs.- Easier to create an ortho-photo of a complex model.	<ul style="list-style-type: none">- Can create a simple ortho-photo from planar object quickly.- Can be used to extract multiple ortho-photos that line up on an edge from multiple planes

		(in separate passes).
Cons	- Requires the project have surfaces and that they have photo-textured materials with appropriate parameters.	- Area to be sampled is limited to that defined by a bounding box of three points.

The 'Over-scan border %' setting controls how much extra photographic data is captured during the ortho-photo creation. This setting is more useful with the "Rectangle from one photo and 3 points" option. Extra pixels are added to the output ortho-photo given by initial image width * overscan / 100. The scaling and final image sizes are modified to properly account for the overscan. The extra pixels will be black when the "All photo-textured surfaces" option is chosen and will be pixels from the source photo outside the rectangle when the other option is chosen.

Ortho Photo Projection Plane

The second step to create an ortho-photo is to choose the projection plane. The projection plane will normally be parallel to the plane(s) of the object being viewed but that is not a requirement. Scale measurements taken from the resulting ortho-photo will be valid only for those surfaces that are parallel to the projection plane.

There are two ways to define the projection plane. The first is from the coordinate system. One can choose a projection plane parallel to the XY, XZ or YZ planes. These are given the more understandable names of Top, Front and Right. In PhotoModeler the convention is that Z is height so that is why the top view of an object looks down on the XY plane. This option makes most sense when the project has a Scale/Rotate defined or has been done with known control points. See [Adding Scale and Rotation](#).

The other option for defining the projection plane is to choose three Object Points or Edge Points. Three points will define a plane and the projection plane for the ortho-photo can be thought of as being parallel to this plane. The three points are defined by entering in the point ID numbers (turn on Point ID display in one of the [Visibility Settings](#) controls to see them). A short cut is provided - if three points are selected before this dialog is opened, they are automatically placed in the three edit boxes.

When an edge is chosen the point displayed will have an 'a' or a 'b' appended. So 14a means the first point of edge with ID 14. Object Points and Edge Points can be mixed. So the three edit boxes might contain: 12, 14a, 14b which means that the projection plane is defined by Object Point 12 and both end points of Edge 14.

Defining the projection plane alone is not enough to produce the desired ortho-photo in most cases. You also need to define the view direction, and what will be the horizontal and vertical axes of the image.

If one of the coordinate planes is chosen, the view direction is defined by which of the two types is chosen. For example, the XY plane has both a Top and Bottom option. Top means the ortho-photo is created as a view looking down at the XY plane and Bottom means the ortho-photo is created as a view looking up at the underneath side of the XY plane. Having this choice is important esp. when modeling a solid object and using the "all photo-textured surfaces" option. In addition there is a rotation control which defines which way the ortho-

photo is oriented. The angles are in degrees clockwise. Use the preview as discussed below to ensure the result will be oriented as you wish.

Three Point Projection Plane

If the three point projection plane is chosen, the view direction and rotation is defined by the Horizontal and Vertical Axes controls as shown below:

Projection Plane

☐ Top XY ☐ Front XZ ☐ Right YZ

☐ Bottom XY ☐ Back XZ ☐ Left YZ

☒ 3 points 51 50 49

Horizontal Axis:
left to right 51->50 ☒ dominant

Vertical Axis:
bottom to top 49->51 ☐ dominant

When using the Horizontal and Vertical Axes controls it can be very handy to have a photograph or 3D Viewer open with point ID's showing before opening this dialog. First you will decide which is to be the dominant axis (the axis that will line up perfectly with the edge of the image). The three points chosen do not need to be at a perfect 90 degrees to each other so this option can be useful.

Once the dominant axis is chosen, you will decide which points and which order will define that axis. The horizontal axis is defined by two points in order from left to right. Look at your points and decide which points will line up with the horizontal axis of the image and which order will give left to right ordering - then pick that from the choices given in the drop down. The vertical axis is defined by two points in order from bottom to top. Once the dominant axis is chosen, pick the other axis. Use the Preview as described below to ensure the correct axes (and order of points defining axes) have been chosen.

Ortho Photo Preview and Adjustment

The third step to create an ortho-photo is the review if the Preview Image and the adjustment of parameters as necessary.

After the first two steps of ortho-photo setup, as described above, are complete you simply press the 'Update preview' button. A low resolution version of the ortho-photo is created and displayed. This may take a few moments depending on the complexity of the model and the options chosen.

If the orientation does not seem correct, choose different options on the left of the dialog and generate a new preview. You can generate as many previews as you need until you have the desired result.

If you press the 'Update preview' button and nothing happens and no preview image appears in the dialog then the incorrect options have been chosen. Possible reasons for not getting a preview or ortho-photo are:

- the project has not been processed (can you see anything in the 3D Viewer?)

- the 'all photo-textured surfaces' option is chosen but the project has no surfaces or no surfaces with photo-textured materials applied (can you see photo-textured surfaces in the 3D Viewer?)
- the 'rectangle from photo and 3 points' option is chosen but the three edit boxes do not have three valid 3D points listed
- the '3 points' projection plane option is chosen but the three edit boxes do not have three valid 3D points listed
- the '3 points' projection plane option is chosen but the three edit boxes contain the ID's of three points that are colinear (all lie in a straight line).

Ortho Photo Generate and Export

The fourth step to create an ortho-photo is to determine the image size or scale and export the result to an image file of the desired type.

Ortho-photos are often used as a form of scale drawing. In that situation, you need to be able to export an image that has a defined scale relationship with the real object being modeled in PhotoModeler. Note you should add a Scale to your project first unless it was done with Control Points.

There are three ways of defining the output image size and the scale. The first is the simplest and you enter in the number of horizontal and vertical pixels in the output. This provides an image of known size but of unknown scale.

The second, is to define the image scale in terms of pixels per unit. For example, you might want the exported ortho-photo to have 20 pixels for every foot on the real object (defined in the mapping plane by orthographic projection). That way you could measure pixels in the image and get true dimensions (10 pixels in the image would 0.5 feet on the object).

The third, is to define the image scale in terms of the print scale. This is used when you are printing the image and want the printed result to be a scaled drawing. First you define the scale you want (e.g. 1 to 10), then you define the pixels-per-inch (ppi) or pixels-per-mm (ppm) that the image will be printed at (note that you might need to use an external program like PhotoShop to change the image dots-per-inch and then have it print it). There are many rules for picking an appropriate number of pixels per unit but as a rule if you are printing to a 600 dots-per-inch black and white laser printer, and you want reasonable grayscale rendition you should not use much higher than 100 pixels-per-inch.

Once scale is chosen, you press the Export... button. A file dialog appears where you pick the file type and the file name for the exported image file. When the Save button is pressed on the file dialog the generation of the full ortho-photo will start. If a high resolution scale has been chosen, and/or the model is complex this may take some time. When the file has been created and saved a message will appear on the screen.

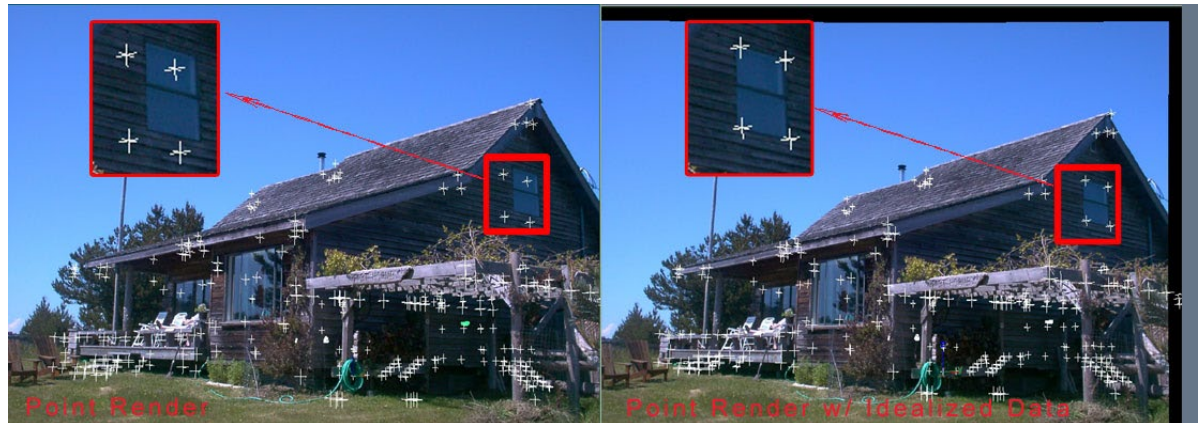
Note: see the *Ortho Photo Preview and Adjustment* section above for some trouble shooting tips if the generate and export does not work.

Idealize Project

The Idealize Module is an add-on to PhotoModeler. This module provides the capability to convert the camera(s) in the project from real form to ideal form. An ideal camera has no lens distortion, square pixels, and a centered principal point. The images in the project are

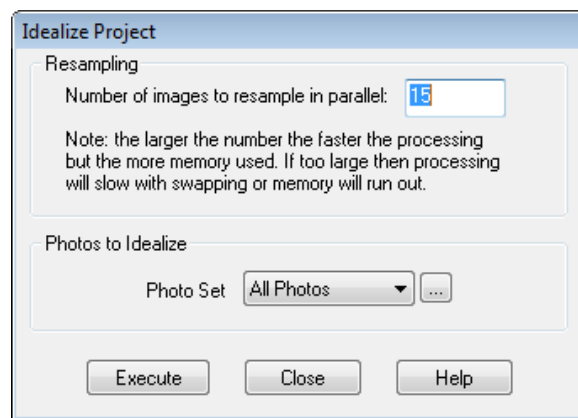
resampled and the photographic marks are shifted to match the new idealized images. See *Perspective Matching* for other information.

The typical use for this modified project is to export the camera data and images for use in a rendering / animation program - as these programs work with ideal cameras only, as shown in the example below (a screen capture from Maya):



The Idealize Project command is run from the File menu. It brings up the Idealize Project Dialog.

Idealize Project Dialog



This dialog performs the *Idealize Project* command. To execute the command and convert the project to ideal form, press the Execute button. Generally the default values of the two controls, chosen by the program, will be sufficient.

The first control, Number of images to resample in parallel, is a control on speed. You want this number to be as large as possible without running out of memory. For example, if you have 5MB images, then running Idealize with 10 images in parallel means that 50MB of memory will be needed. The Idealizer will load 10 images, idealize them, close them and then load the next 10 images.

The second control, Photo Set, let's you pick which photographs to idealize in the project. If you only idealize some photos in a project, there will be two copies of the camera, the original camera for the unidealized images, and a new idealized camera (centered principal point, no lens distortion, etc.) for the idealized images.

After execution completes, this project will have been modified but can be used and saved like any other project.

The photographs, after being idealized, are saved with the word '_idealized' tagged to the file name. The original photograph files are not modified.

It is often a good idea to reprocess the project to fine tune it after idealize to account for any round off errors. This will give maximum accuracy. The 3D data can be exported (model and camera stations) to programs such as Maya along with idealized photographs to be used as background plates. This data will provide pixel or sub-pixel level matches for modeling in your external package. Note that the match in your external package will be similar to the residual error of that point in PhotoModeler. For example, if the highest residual of a point in the idealized project is 5 pixels, then you can expect to have some points not match the background plate in your rendering package to about 5 pixels.

Perspective Matching

Perspective Matching is the process of determining the position of a camera when it took a photograph so that 3D graphics can be combined with that photograph and 'match'. To combine 3D graphics with a photograph in a 3D rendering program you have to indicate where to place the camera, how to orient the camera, and what are the specifications for the camera's internals. When this information is accurate, the rendering will match the background image/plate for a high degree of realism..

When PhotoModeler is solving a project to create a 3D model, it computes the exact position and orientation of the camera for each photograph. It also knows the accurate specifications for the camera's internal parameters (focal length, field of view, etc). This information can be exported from PhotoModeler for use in rendering and animation programs (such as Maya, XSI, 3D Studio Max, Truespace, Cinema 4D, Real3D, etc.) .

The example below starts with an image of a cardboard box of known dimension. On the other hand we know nothing about the camera that took the photo - we don't know what type of camera, what its focal length is, or where it was in space when the photo was taken. In this case we use another feature of PhotoModeler called *Inverse Camera*.

PhotoModeler's Inverse Camera feature and control points (control points are known x,y,z locations) are used to solve the camera parameters and orientation. That information is then given to the Real3D animation/rendering program along with the 3D box model to perform a perspective match and rendering.

Note that control points and inverse camera are used in this example because we have a single frame from an unknown camera but perspective matching can be used with normal projects with calibrated cameras too.

The steps of this example are as follows:

- 1) Start with an unknown photo of a box and import into PhotoModeler.



If you are using a calibrated camera you can achieve a better match by removing lens distortion from the images. The mathematical model of the camera used by rendering programs is 'ideal' and typically does not account for lens distortion, non-centered principal point, or non-square pixels. PhotoModeler's Idealize module (see *Idealize Project*) provides a function for removing all these distortions from the images and the solutions for the model and camera stations. You would run Idealize Project before the export and then you will find your matches in your rendering program can be very accurate.

See also *Using your 3D Model with another program* and *Imported Objects* for other pertinent information.

Working with Imports and Constraints

When working with Imports and Constraints, the user has some known geometry (or is willing to assume) about the model object or scene that is provided to PhotoModeler to help solve certain problems.

There are two main categories of known geometry in PhotoModeler: Imports and Constraints.

Imports are made of data that the user has about the X,Y,Z coordinate values of a point in the scene or on the object. This information is either imported from an external file containing the data, or is created within PhotoModeler. There are three types of imports: Control Points, Pinned, and Static.

Constraints are pieces of information that the user knows or is willing to assume about the scene like distances, length, parallelism, intersections, and angles. Several constraints are built into PhotoModeler and one or more can be selected and assigned to parts of the model object or scene. There are two types of constraints: Multiphoto constraints and Axes constraints.

Imported Objects

Imported objects are known 3D data obtained from an external source and brought into PhotoModeler. Interaction with imported objects happens via the *Imports Explorer*.

There are three types of Imported objects: control, pinned and static. The type is set when the imported object is added to the project.

Control imports define the projects orientation. The project adjusts to match the positions of the marked control points, for example when taking points from a survey and using them to orient a project in the same coordinate system. Control points are also used when solving for unknown cameras using Inverse Camera features (see *Inverse Camera solves for*).

Pinned imports adjust to match the projects orientation. The imported object is attached to existing points in the project by pinning them. When sufficient points have been pinned the imported object aligns it's self with the project, for example when bringing a CAD diagram of an existing part of an object an aligning it with a photo or adding it to a existing PhotoModeler project so that data does not have to be re-modeled.

Static imports retain the coordinate system they are imported with and have no affect on the project coordinate system. For this reason static imports should match the project coordinate system before being brought into the project, for example when bringing a

model back into PhotoModeler for texturing after first exporting it and adding more detail in another package.

All imported objects consist of points, lines and triangular surfaces. Imported objects can come from: DXF, 3DS, OBJ, TXT files (see *control file format*) or entered manually into the *Imported Point Editor*.

Control Imports

Controls Points are known and pre-measured locations in a 3D coordinate frame. For example, a survey of a building may indicate the accurate positions of the foundation corners to be (450.2,210.3,32.4), (480.5,210.0,32.0), (480.2,270.2,32.0), and (450.1,270.0,32.1) feet in a city wide mapping coordinate system. These points are known before you start measuring any other part of the building and these point can then be used to "control" the size, position and orientation of the remaining measurements.

Control points are also used when solving for unknown cameras using Inverse Camera features (see *Inverse Camera solves for*).

here are several cases when Control Imports are used in PhotoModeler:

1. for Inverse Camera (recreating parameters for unknown Cameras): Control Points can be very useful when trying to recreate a description of a Camera from photographs of unknown source, which is often required for *Perspective Matching*.
2. for single photograph projects: When you are extracting information such as Surface Drawings, photo-textures and ortho photos (see *Ortho Photo Export*) from a single photograph, Control Points can be used to set up the planar geometry and to solve for the Camera Station location.
3. for tying together and improving the accuracy of projects with large numbers of photographs spread out over a large or long area: If you are modeling a large area with many overlapping photographs, errors will slowly be introduced into the model as you go from overlapping photo to overlapping photo. For example, modeling a very long wall without any overall photographs using just photographs that overlap as you move along the wall will generally give a result where one end of the model is rotated or skewed relative to the other end. A sparse network of control points along the wall will help alleviate this problem.
4. when Camera Station geometry is quite weak (i.e. low angles): Control Points can be useful when the Camera Stations are in poor positions. Two cases of this are: a) the Camera Stations have similar angles, and b) the project contains only two Camera Stations. In both these cases it is important to get accurate positions and orientations for the Camera Stations or the resulting 3D data may be inaccurate. Having accurate Control Points marked on these photographs can help PhotoModeler considerably in determining the true positions of the Camera Stations and hence improve overall accuracy.
5. when the source of Control Points is of much higher accuracy than PhotoModeler and accuracy is a prime concern in the project: Control Points can also be useful in creating accurate 3D surveys. For this to be true in the normal circumstance with PhotoModeler, the Control Points have to be more accurate than PhotoModeler or they have the potential for degrading PhotoModeler's accuracy. For example, if you are using digital camera with a resolution of about 1500 pixels across and the Camera Stations all have good angles then you could expect accuracy from PhotoModeler of about 1 in 1000. To improve this project with Control Points, they should be accurate to about 1 in 5000 and

the points should be well distributed in space and be well distributed on the photographs.

Control Import Precision

The precision value tells PhotoModeler during processing how accurate you think the control points are. Mathematically this number is defined as the standard deviation of the normal distribution of the error in the control points x, y and z coordinates. The smaller this number the less PhotoModeler will try to adjust the position of the control point to compensate for errors. If these control points were collected in an imprecise manner you can have PhotoModeler adjust them along with all the other data by giving them a larger precision value.

The precision values in a TXT/CTL file (if present) will override the precision in the dialog.

If the "fixed" option is selected or a precision value is negative the corresponding control point will not adjusted at all. In other words it is considered to be infinitely precise. If you lock down a control point that has a poor value by using a negative precision value you will probably cause processing to fail. Control points that are fixed will appear with "fixed" in the precision field of the *Imports Explorer* and the *Measurements Pane*. Points used for *inverse camera* should be imported as "fixed".

Pinned Imports

Pinned imports are 3D model data that is attached or 'pinned' to 3D points already defined in a project. Once 3 or more pinned imported points are attached or already solved 3D points, the pinned points are used to scale and rotate the imported 3D model to match the already solved project.

Some example cases where pinned imports are useful:

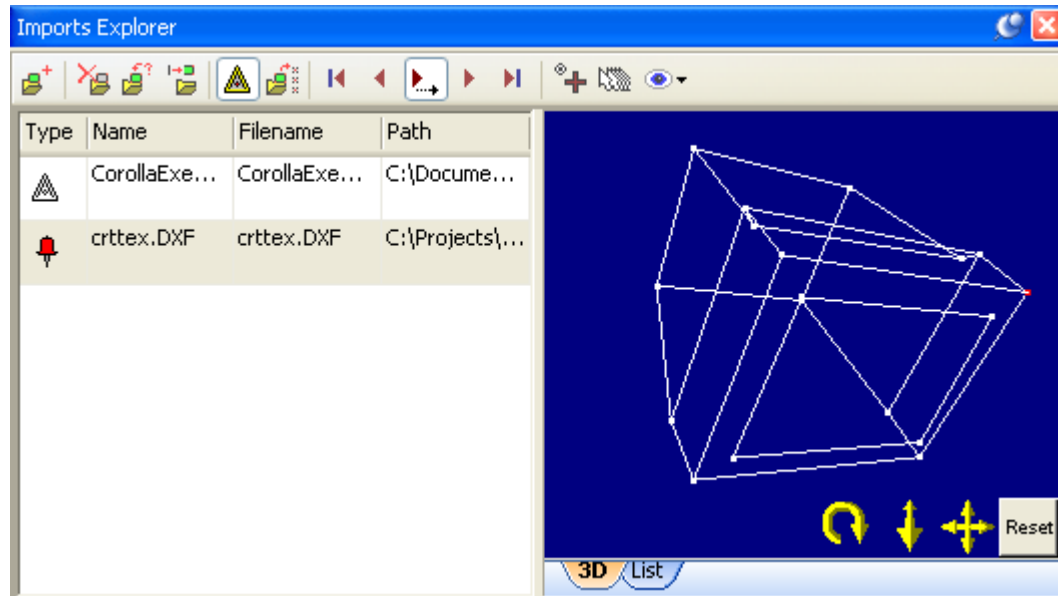
1. when an existing model (perhaps created with a separate PhotoModeler project) is duplicated in a scene: Instead of modeling multiple copies of the same object the model can be imported multiple times and pinned to a few points to define it's position. For example if there are several chairs in the scene one can be modeled and then imported and pinned to a few key points on each chair in the scene removing the need to model the entire chair at each position.
2. for texturing an existing model: A non textured model can be imported, pinned and then extract it's texture from the photograph.
3. projecting an existing model to compare against photograph: A model of an object can be imported, pinned and then projected on to a photograph to see how the model compares to the photo. Or the pinned import can be used for measurement comparisons with parts modeled with PhotoModeler.
4. adding an already modeled object that does not appear in a photograph: An object that does not appear in the photo can be brought in and pinned. For example a piece of paper could be placed on a desk and an existing model of a lamp could be pinned to the papers corners to place a lamp in the modeled scene.

Static Imports

Static Imports are used when you have an existing model that shares the same coordinate system as the project and you want to view the existing model along side the current project without marking or pinning any points.

Imports Explorer

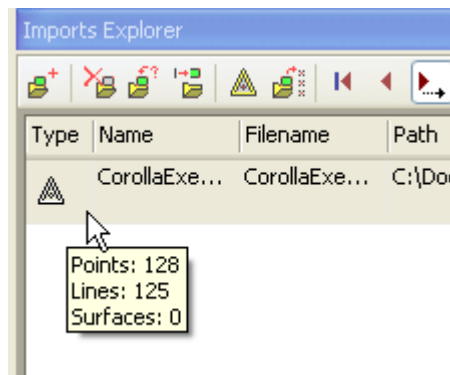
The Imports Explorer allows you to add, delete, view, mark and edit imported objects.



The toolbar at the top of the explorer allows *Adding Imports*, *Deleting Imports*, *Renaming Imports*, *Modifying Imports*, *Marking/Pinning Imports*, *selecting associated import points*, *navigating the imported objects points*, *sub-pixel control point marking*, *import auto-drive*, and *adjusting the import 3D view visibility*.

The list on the left shows a grid with the following columns: the imported objects type

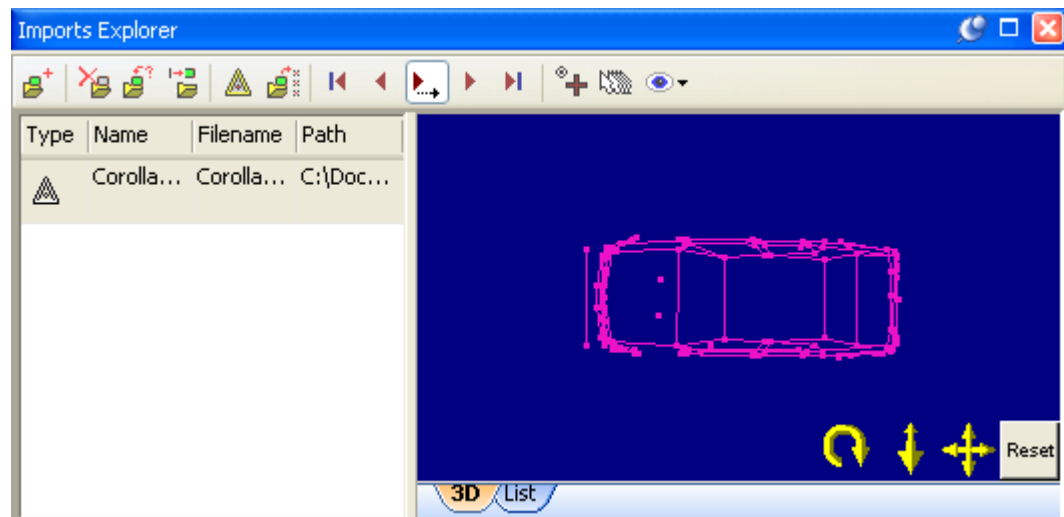
(*control imports* , *pinned imports* , *static imports*), the imported objects name, the name of the file imported and the full path of the file that was imported.



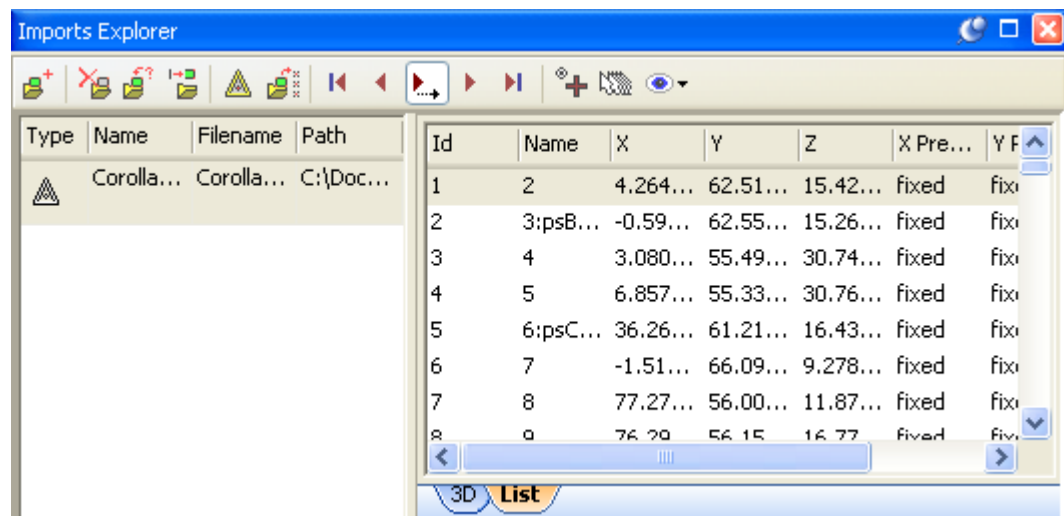
Hovering the mouse over the type column will give information on the number of points, lines and surfaces in the imported object.

The right side of the Imports Explorer displays the selected imported object in either a list or 3D view. The tab at the bottom allows you to toggle between the two.


3D:




The same points in list view:



Adding Imports

Imported objects are added to a project by clicking the add import object button . You can also use the "Imports..." button on the File menu. These will bring up a dialog allowing you to browse for the file to import (.DXF, .OBJ, .3DS or .TXT/.CTL).

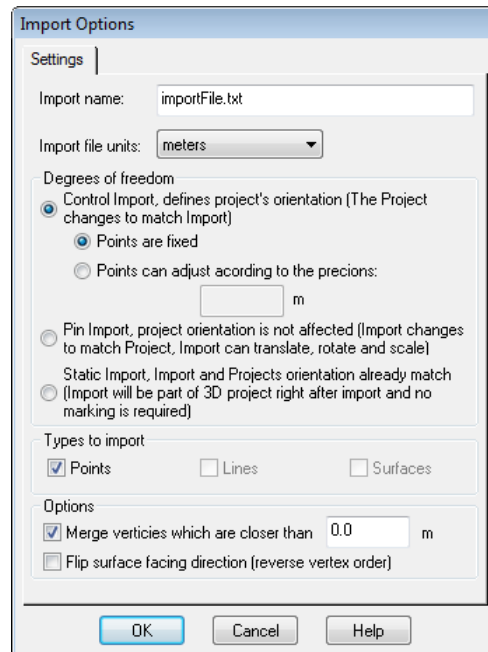
Alternately, if no imports have been added to your project and you do not have a file to import you can create a blank imported object and enter control point X,Y,Z coordinates

manually by selecting Modify Import  which will create a blank control import and open the *Imported Point Editor*.

After selecting a file to import the *import options dialog* will allow you to control properties of the imported object.

Import options dialog

The import options dialog controls how an import file is read into PhotoModeler.



The import name will default to the file name but can be changed to help identify it from other imported objects.

The file units should be set to match the units the file was created in. If your project already has units set the file will be converted from the selected units to the projects units.

The degrees of freedom allow you to set the type of import, either: *Control Imports*, *Pinned Imports* or *Static Imports*. Control imports can have a *control import precision* set or if you are only marking a small number of points or using them for inverse camera you can leave the points as fixed.

The types to import control what objects are read from the file: Points, Lines or triangular surfaces and meshes. If a point entity does not exist at a lines end or a triangles vertex one will be created.

Note: NURBS surfaces are not imported, you should triangulate NURBS surfaces before importing them.

The options allow you to control when vertices are merged and which direction faces should point (i.e. is their ordering clockwise or counter-clockwise).

Some file formats have specific options available on a second tab. For example DXF allows you to import TEXT entities as point names.

Control File Format

Files can be imported as standard DXF, OBJ or 3DS files. Additionally the text control file, a simple ASCII text file, can be used to define x,y,z points. You import it much like the other file formats. The only differences are that the file format is different and the precision can be set on a point by point basis.

The CTL file is a simple text file that can be created with any text editor (such as Notepad that comes with Windows). The format of this file is: one control point per line with each line having the control point ID, x, y, z and precision values. The file can have blank lines and lines that begin with # which are both ignored. These files can have file extensions of either .CTL or .TXT. An example CTL file:

```
# PhotoModeler Control File for Boiler A
# units are feet
# ID      x      y      z      prec.
c1      23.2     341.2   22.7     0.01
c2      31.0     349.3   44.1     0.01
ela     10.0      256.0   41.0     0.5
elb     11.0      350.0   25.0     0.5
```

The precision values can be set for the whole point (affecting x, y and z) or they can be set for x, y, z individually. In this example all the z values are fixed so they will not adjust:


```
# PhotoModeler Control File for Road Scene
# units are feet
# ID      x      y      z      prec. x,y,z
p1      23.2     341.2   0.0      0.1  0.1  0.0
pa42     31.0     349.3   0.0      0.1  0.1  0.0
pa43     10.0      256.0   0.0      0.2  0.2  0.0
fh      11.0      350.0   1.4      0.1  0.1  0.0
```

You can also leave the precision values out of the file completely and then the precision setting of the Control Import dialog takes precedence.

Note: CTL files are easy to create. You can start the Notepad program, type in the text as shown above and then save the file with whatever name you choose. The CTL file can have either a .ctl or .txt file extension. So "Car.ctl" and "Car.txt" are both valid file names for CTL import.


Deleting Imports

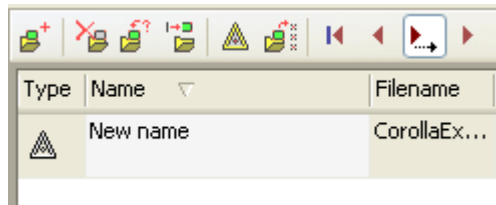
To remove an imported object select it in the *Imports Explorer* and press the delete

imported object button . The object will be removed and any connections to these


points will be removed. That is any control marks will become regular marks and pinned associations will be removed.

Renaming Imports

To rename an imported object select it and press the rename import button  and the selected item in the grid will become editable. Enter the new name in the grid.

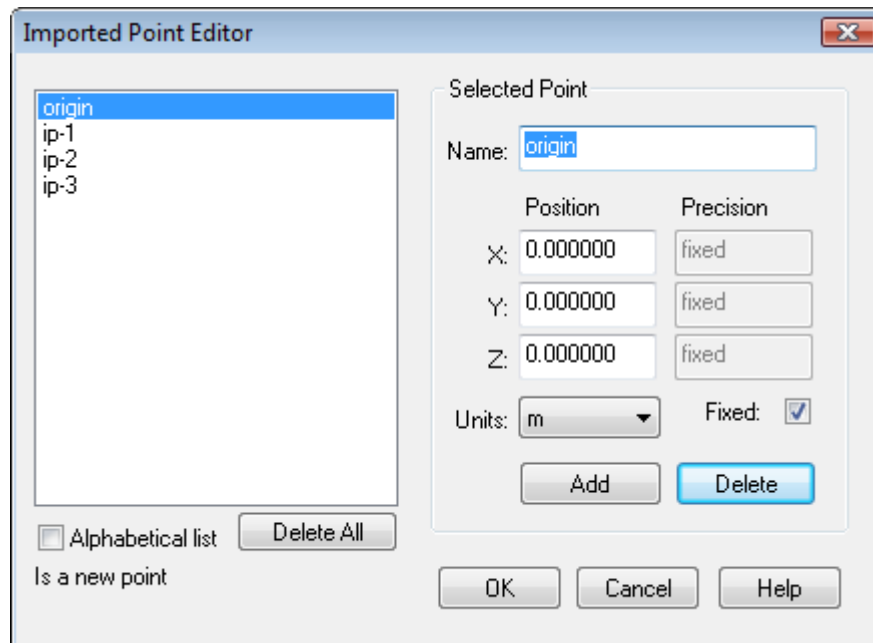


Modifying Imports

To modify an existing imported objects points: select the imported object and press the modify import button . This will open the *Imported Point Editor*. Pressing this button when no imported objects have been added to the project will create a new blank one allowing you to use the *Imported Point Editor* to enter the X, Y, Z values manually.

Imported Point Editor

The import point edit dialog provides for the addition, deletion and edit of Imported Points.



The list box contains a list of points from the selected imported object. You have the option of sorting the list alphabetically in this dialog by checking 'Alphabetical list'.

When you select a point from the list box, its name, x,y,z position, and x,y,z precision will be shown in the fields at right.

The status line at bottom left of the dialog shows you the number of photos on which this point was marked. This is significant because you will not be able to delete a point if it has been marked on any photos without first un-controlling or deleting the marks.

Choosing units from the 'Units' list will convert visible values from project units to the units selected in this dialog. Once you exit this dialog, all values will be converted back to the project's overall units.

Marking/Pinning Imports

Selecting the Mark/Pin imports button  will activate import marking/pinning mode.

When in mark/pin mode any points in the selected imported object that have already been marked/pinned will highlight in green on photos and in the 3D view.


You should select an imported point, in the 3D or list view, to mark or pin.

If you have a control imported object selected click on a photo to identify the correct location for the selected imported point. Selecting an existing non-control point will convert it to a control point, clicking where no mark exists yet will create a new one.

If you have a pinned imported object selected click on an existing mark to pin the selected imported point to the already marked point. Once a pinned imported object has 3 or more points pinned to existing 3D points it's position will be calculated and the entire pinned imported object will be visible in 3D.

Static Imports are not marked or pinned. You can not perform any actions on a photo when selecting a static import while in mark/pin mode.

Selecting associated import points

Pressing the select associated import button  will select the imported control or pinned point associated with the selected points or marks. You can select a point in 3D or on a photo and press this button to find out which imported point is associated with it, this can be useful in locating incorrectly marked or pinned points.

Navigating the imported objects points

You can select specific imported points from the list or in 3D, or if you would like to go through them sequentially you can use the navigation buttons on the import explorer




when the middle button (auto-advance) is down marking or pinning an imported point will automatically advance to the next point.


Sub-pixel control point marking

When the control sub-pixel marking mode button is down  and you are marking control points (see *Marking/Pinning Imports*) new marks will be created as sub-pixel marks, just as with regular *Sub-pixel Target Marking*.

Import auto-drive

When the auto-drive (on/off) button is down  and you are *Marking/Pinning Imports* when you activate an oriented photo the mouse cursor will jump to the projected location of the point. If a project is solving correctly this location should be close to where the point lies making it easy to mark/pin.

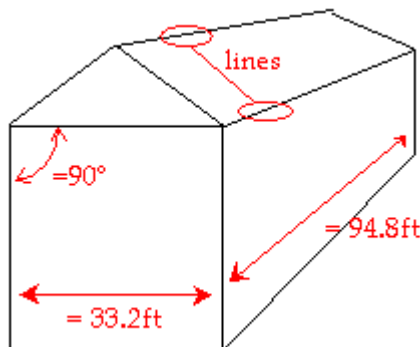
Adjusting the import 3D view visibility

The visibility of imported points, point IDs, lines and surfaces can be turned on and off in the *Imports Explorer* 3D view by using the visibility drop down  and checking or unchecking the corresponding items.

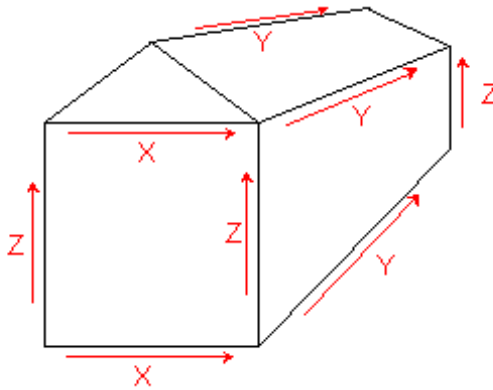
Working with Constraints

There are two types of constraints: multi-photo constraints are used when there are more than one photo in a project; axes constraints are used when there is only one photo in the project and the photo contains appropriate horizontal and vertical features in adequate perspective.

Multi-photo Constraints are pieces of knowledge on various things like distances, length, parallelism, intersections, and angles, as shown in the diagram below. These constraints do not affect single photo projects.



Axes Constraints are pieces of knowledge regarding how lines, edges and surfaces line up with Cartesian coordinate system axes. For example, it is common practice when modeling a building to have the building's vertical edges parallel to the z-axis, the building front edges parallel to the x-axis and the building side edges parallel to the y-axis.



A project like this can be set up so the lines and edges are constrained to a particular axis. This is very useful for single photo projects and can be used in multi-photo projects also to ensure your building is square (with parallel lines and right-angle corners etc.).

The *Constraint Types* section has a breakdown and description of each constraint.

Note: Constraints are not intended to correct gross errors in a project. For instance, if your model does not look quite right because of misreferencing, incorrect camera parameters etc., then Constraints should not be used to correct for these deficiencies. First, ensure your model has basically the correct shape, then use Constraints if needed to refine the model.

The sections below discuss how to use the various dialogs, toolbars, windows and cursors to add, remove and modify constraints in PhotoModeler.

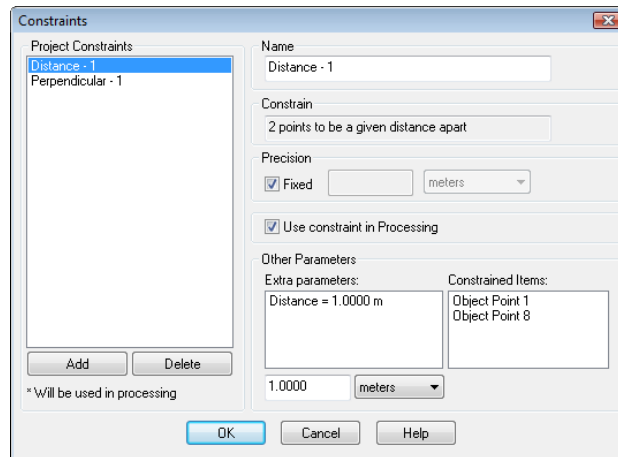
Manipulating Constraints

All Constraints (multiphoto and/or axes constraints), have a unified method for being added, removed, and modified.

Constraints can be added two ways. The first is through the *Constraints Dialog*, and the second is through the *Constraint Tool Bar*. Both are described below.

Constraints hold two types of data. The first is a list of the objects to be constrained and these are modified by using the *Constraint Tool Bar*. The other type of data is the constraint parameterization, which is manipulated by the *Constraints Dialog*. See the sections below for details.

Constraints Dialog



This dialog can be accessed through either the Open Constraints Dialog menu item on the



Project Menu or the button on the *Constraint Tool Bar*. The Constraint Toolbar appears when you are in Constraint Definition Mode, which happens when clicking the Constraint Definition Mode on the Project menu.

This dialog lists all the Constraints that are set up in the open project. The list shows the user name for the constraints and a "*" beside those Constraints that can be processed or what we call "active". An active constraint has the correct number of constrained objects and has not been disabled by the user.

When you click Add, the *Select Constraint Type Dialog* appears which allows you to choose the constraint type to be added to the project. Constraints added this way will have no constrained objects (points, lines, etc.) but they can be added later.

The Delete button is available when a Constraint is selected. This immediately deletes the selected Constraint.

The right part of the dialog provides facilities for modifying and setting:

- a user name for the Constraint,
- the precision,
- whether it will be used in processing, and
- any extra parameters.

It also displays a list of objects currently part of the Constraint.

The user name can be any non-blank string of letters, numbers and spaces but must be unique among all constraints.

The precision can be "fixed", which means PhotoModeler tries its best to meet the constraint exactly (this may not always be possible). The precision can also be a non-fixed value. Example, a parallel constraint might be fixed (which means PhotoModeler tries its best to make the two edges or lines perfectly parallel), or with a precision of 1.5 degrees (which means PhotoModeler tries its best to keep the edges or lines parallel with a 60%

probability (one standard deviation) to within 1.5 degrees. For further discussion of the meaning of precision refer to *Accuracy* and *Precision* in the Glossary.

The Constraint can be removed from processing without being removed from the Project by unchecking the "use constraint in Processing" check box. If this box is unchecked, when Processing is run, this constraint will be ignored, as if it were not in the project at all. This is useful for finding constraints that may be causing problems with processing, without the need to remove the constraint from the project completely.

Some Constraints have extra parameters, and some display error amounts after processing. The next section discusses these. To edit the value, you select the parameter in the Extra Parameters list, and under this list type in the known value, and pick the desired units.

When a distance constraint has been added, you can also set the units for the project here. .

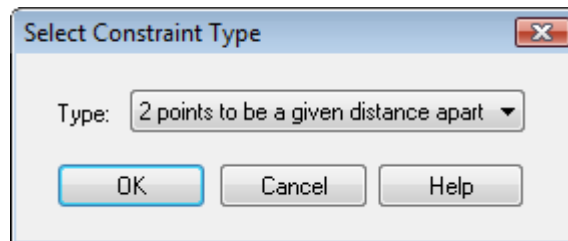
When Constraints have been processed, constraints that have non-fixed precision will also show the error amount - that is, the difference between the ideal and what PhotoModeler achieved during processing.

Note that you can also disable a Constraint temporarily - see the next section.

The OK button closes the dialog and applies all changes to the project. The Cancel button closes the dialog but does not apply any of the changes to the project.

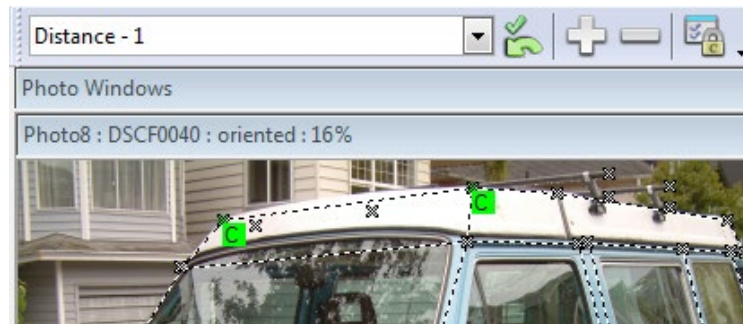
See the section, *Constraint Types*, for additional information on the various types of constraints available.

Select Constraint Type Dialog



This dialog appears when adding a new constraint on the *Constraints Dialog*. The drop down control lists available constraints. Select the type and click OK. The constraint will be added to the list of project constraints on the Constraints Dialog.

Constraint Tool Bar



The Constraint Tool Bar appears when you enter Constraint Mode. This tool bar is used to add and remove objects from Constraints.

This tool bar has six controls, from left to right:

- the current constraint drop down list,
- the active constraint status icon,
- the add (+) and remove (-) objects buttons,
- the Constraint Dialog button.

Current Constraint Drop down list: All Constraints, whether active or in-active, that are part of the current project will be available in this drop down list. To view or modify the objects in a Constraint you first select the user-named Constraint in this list. The Constraint, called "Distance - 1" has been selected above. This drop down list also contains an entry called "All Constraints" which highlights all constrained objects on open views.

Active Constraint Status Icon: Once a Constraint has been selected in the drop-down, the icon will appear in one of three states. If the green check mark is visible, the selected Constraint is valid and "active". If it has a red 'x', Constraint does not have sufficient objects to be valid and is "inactive". If the icon is gray without an 'x' or a check mark, the Constraint has sufficient objects but the user has turned the Constraint off.

Add/Remove objects buttons: As soon as a Constraint is selected in the drop list, all objects that are part of the Constraint will be highlighted in open Photograph and 3D View Windows. Points will have a green "C" tag and Lines, Edges and Surfaces will have their background drawn green. Note that the default Constraint color can be modified in the *Preferences* Dialog.

To add an object to a Constraint, you first select the Constraint in the drop list, select the object(s) in the views (photo, tables or 3D), and press the "+" button. The newly added objects will immediately redraw with a Constraint highlight.

To remove an object from a Constraint, you first select the Constraint in the drop list, select the object(s) in the views (photo or 3D), and press the "-" button. The objects that were removed will immediately redraw with the Constraint highlight removed.

Open Constraints Dialog button: is a short cut to the *Constraints Dialog* where you can add, delete or modify constraints in a project.

Processing Constraints

Constraints are processed by different parts of PhotoModeler depending on their type.

Multi-photo Constraints are processed only during Global Optimization.

Axes Constraints are processed by a special algorithm that processes just these single photo constraints and is run as part of Orientation. Axes Constraints may also be "reaffirmed" and processed after Global Optimization runs. This second stage provides the ability to use single photo techniques to complement a multi-photo project.

Control Points are used in both Orientation and Global Optimization.

Inverse Camera processing, described in the section *Working with Unknown Cameras and Photographs*, is done in the Orientation stage and can use both Axes Constraints and Control Points.

The *Processing Dialog* has a checkbox that allows the user to turn off all Constraint processing. This is useful for comparing results to non-constrained processing and for trouble shooting which is described in the next section.

Troubleshooting Constraint Processing Problems

If you have Constraints defined in the project and processing is failing (or producing strange results) you should first try the processing with Constraints turned off. This can be done in the second tab of the Processing dialog.

If the project still does not process with Constraints turned off then there is another problem (such as incorrect references or bad camera parameters). See the *Processing Troubleshooting* section.

If the project processes with Constraints turned off, you need to study the Constraints to see if there may be a conflict. Reduce the Constraints defined to just one or two by opening each Constraint in its *Constraints Dialog* and turning it off. Then try to process again with just these fewer Constraints active. By choosing which Constraints are active and reprocessing you can determine which Constraint or set of Constraints is causing the problem.

If you find one or more Constraints that will not process you should first look for incorrect definition (for example including a line in the Parallel Line Constraint when it is clearly not parallel to the other lines) or for conflict (for example including a line in two Perpendicular Line Constraints when those Constraints conflict).

A more difficult situation is when all the Constraints are defined correctly but there are too many of them on an object or some sub-set of objects. In this case we call the object "over-constrained". This can cause the global optimizer to fail. In the case one must reduce the Constraints on the object until processing works.

Note: Constraints are not intended to correct gross errors in a project. For instance, if your model does not look very good because of misreferencing, incorrect camera parameters etc., then Constraints should not be used to correct for these deficiencies. First, ensure your model has basically the correct shape, then use Constraints if needed to refine the model.

Constraint Types

This section lists all the Constraints provided by PhotoModeler. For each Constraint a brief description is given along with the requirements for its use.

Multi-photo Constraints

All Multi-photo Constraints are solved during the Global Optimization stage of Processing. These Constraints are not available if there is only a single photograph in the project.

Note: Constraints are not intended to correct gross errors in a project. For instance, if your model does not look very good because of misreferencing, incorrect camera parameters etc., then Constraints should not be used to correct for these deficiencies. First, ensure your model has basically the correct shape, then use Constraints if needed to refine the model.

2 points to be a given distance apart

Description:	Constrain two points to a known distance.
Objects:	Exactly two 3D Object Points
Extra Parameter:	Distance
Number allowed:	One constraint for every known distance
Use:	To improve shape and get accurate scale when extra distance measurements are known. Used only in multi-photo projects and solved in Global Optimization.

3 or more points to be collinear

Description:	Constrain three or more points to lie in a straight line.
Objects:	Three or more 3D Object Points
Extra Parameter:	None
Number allowed:	One constraint for every known set of collinear points
Use:	To make points lie up and line segments create a straight line. Used only in multi-photo projects and solved in Global Optimization.

4 or more points to be coplanar

Description:	Constrain four or more points to line on a plane.
Objects:	Four or more 3D Object Points
Extra Parameter:	None
Number allowed:	One constraint for every known set of coplanar points
Use:	To make points lie all in one plane. Note the plane can be at any angle. Used only in multi-photo

	projects and solved in Global Optimization.
--	---

2 lines to be perpendicular

Description:	Constrain two lines (their four end points) to be 90 degrees angle apart.
Objects:	Exactly two Lines (with 3D Object Points as end points)
Extra Parameter:	None
Number allowed:	One constraint for every pair of known perpendicular Lines
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 or more lines to be parallel

Description:	Constrain two or more lines (all their end points) to be parallel.
Objects:	Two or more Lines (with 3D Object Points as end points)
Extra Parameter:	None
Number allowed:	One constraint for every set of known parallel Lines
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 lines to be a given angle

Description:	Constrain two lines (their four end points) to be a known angle apart.
Objects:	Exactly two Lines (with 3D Object Points as end points)
Extra Parameter:	Angle in degrees
Number allowed:	One constraint for every pair of known angle
Use:	To set a non-zero or non-90 degree angle between lines. Used only in multi-photo projects and solved in Global Optimization.

2 or more lines to be equal length

Description:	Constrain two or more lines (their end points) to be the same length.
Objects:	Two or more Lines (with 3D Object Points as end points)
Extra Parameter:	None
Number allowed:	One constraint for every set of Lines that are the same length
Use:	To improve the shape and squareness of objects and sometimes to improve dimensional accuracy. Used only in multi-photo projects and solved in Global Optimization.

2 edges to intersect

Description:	Constrain two edges to intersect.
Objects:	Exactly two Edges
Extra Parameter:	None
Number allowed:	One constraint for every pair of Edges to intersect.
Use:	To use Edges and produce a more complete wire frame. Processed only in multi-photo projects and solved in Global Optimization but also used to extend the 3D Edges to the common point even if not processed.

1 edge to intersect one point

Description:	Constrain an edge to go through (and stop at) a 3D Object Point.
Objects:	Exactly one Edge and one 3D Object Point
Extra Parameter:	None
Number allowed:	One constraint for every pair of Edge/Point intersections.
Use:	To use Edges and produce a more complete wire frame. Processed only in multi-photo projects and solved in Global Optimization but also used to extend the 3D Edges to the point even if not processed.

2 edges to be a given angle

Description:	Constrain two Edges to be a known angle apart.
Objects:	Exactly two Edges
Extra Parameter:	Angle in degrees
Number allowed:	One constraint for every pair of known angle
Use:	To set a non-zero or non-90 degree angle between Edges. Used only in multi-photo projects and solved in Global Optimization.

2 edges to be perpendicular

Description:	Constrain two Edges to be 90 degrees angle apart.
Objects:	Exactly two Edges
Extra Parameter:	None
Number allowed:	One constraint for every pair of known perpendicular Edges
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 or more edges to be parallel

Description:	Constrain two or more Edges to be parallel.
Objects:	Two or more Edges
Extra Parameter:	None
Number allowed:	One constraint for every set of known parallel Edges
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

Axes Constraints

All Axes Constraints are solved during the Orientation stage of Processing. These Constraints are typically used in single photo projects but can be used in multi-photo projects also (they act on a single photo at a time).

Note that during the processing of a multi-photo project, normal global optimize runs without the axes constraints being used at all. When the global optimize is complete, the axes constraints are reviewed to see if any objects need to be forced to lie along certain axes or planes etc. This means you can have some objects (points, lines, edges) appear

on only one photo of a multi-photo project and they can have computed 3D positions if they are constrained by one of these constraints.

Note also that the axes constraints allow some limited Inverse Camera solutions (solving for focal length and principal point) on a single photo if the perspective is strong enough. To solve focal length you typically need a strong two point perspective (that means vanishing lines in two directions (x and y axes for example)). To solve focal length and principal point you need strong three point perspective. See the *Working with Unknown Cameras and Photographs* section for more detail.

Lines/Edges to be horizontal left to right (x axis)

Description:	Constrain a set of Lines and Edges to be parallel to the x-axis
Objects:	Any number of Lines and Edges
Number allowed:	One constraint per project
Use:	Collecting all Lines and Edges in the project that are parallel to the x-axis (by convention is horizontal left to right). Used mainly in single photo projects.

Lines/Edges to be horizontal front to back (y axis)

Description:	Constrain a set of Lines and Edges to be parallel to the y-axis
Objects:	Any number of Lines and Edges
Number allowed:	One constraint per project
Use:	Collecting all Lines and Edges in the project that are parallel to the y-axis (by convention is horizontal front to back). Used mainly in single photo projects.

Lines/Edges to be vertical (z axis)

Description:	Constrain a set of Lines and Edges to be parallel to the z-axis
Objects:	Any number of Lines and Edges
Number allowed:	One constraint per project
Use:	Collecting all Lines and Edges in the project that are parallel to the z-axis (by convention is vertical). Used mainly in single photo projects.

Surfaces to be horizontal (xy plane)

Description:	Constrain a set of Surfaces to each be parallel to the xy plane
Objects:	Any number of Surfaces
Number allowed:	One constraint per project
Use:	Collecting all Surfaces in the project that are parallel to the xy plane (by convention is horizontal). Used mainly in single photo projects.

Surfaces to be vertical - front (xz plane)

Description:	Constrain a set of Surfaces to each be parallel to the xz plane
Objects:	Any number of Surfaces
Number allowed:	One constraint per project
Use:	Collecting all Surfaces in the project that are parallel to the xz plane (by convention is vertical front). Used mainly in single photo projects.

Surfaces to be vertical - side (yz plane)

Description:	Constrain a set of Surfaces to each be parallel to the yz plane
Objects:	Any number of Surfaces
Number allowed:	One constraint per project
Use:	Collecting all Surfaces in the project that are parallel to the yz plane (by convention is vertical side). Used mainly in single photo projects.

Surfaces to be planar (any plane)

Description:	Constrain one multi-point surface to be a flat plane at any orientation
Objects:	One multi-point Surface (must have 4 or more 3D Object Points in Surface)
Number allowed:	One constraint per planar Surface
Use:	Since any Surface with 4 or more points is not necessarily planar, this constraint lets you specify this. This allows you to propagate 3D information along a surface plane when three of the points of the surface are already computable in 3D. Used mainly in single photo projects. For multi-photo projects and solution during Global Optimization stage see the 4 or more points to be coplanar Constraint.

Working with Unknown Cameras and Photographs

In some fields, such as forensics or archaeology, it is quite common to need measurements from unknown photographs. These unknown photographs can come from archives, historical files, police, bystanders etc. In these cases, there is little or nothing known about the camera that took the photographs.

PhotoModeler normally requires information on the camera (focal length, principal point and format size) before photographs taken with it can be used. The Inverse Camera feature of PhotoModeler overcomes this problem.

To use Inverse Camera some information about the scene or object is required, such as known 3D points or constraints (see the *Working with Imports and Constraints* section for more detail).

You may be asking, "If I know the 3D positions of the points already why would I need PhotoModeler?". What PhotoModeler solves is the case of knowing some points or shapes in the photographs but not the information required. For example, you might need to get the relative position of two cars that appear in a few photographs from an unknown camera. You know the dimensions of one of the cars but not the dimensions of the other car nor their relative position. This is a case Inverse Camera can give you the answers you want.

Inverse Camera is carried out by using Constraints. The most common form is done with Control Points. Single photo Axes Constrained projects can also perform Inverse Camera to a certain extent. To get a photograph to process its Inverse Camera information you set the Inverse Camera Flags in the *Photo Properties*.

Inverse Camera

What are the minimum criteria for a successful processing of an unknown photograph project?

This section discusses a number of criteria which make good and bad photographs for Inverse Camera work. We are assuming here that little to nothing is known about the Camera that took the photographs or the photographs have been printed and there are no fiducial marks and the 35mm frame does not appear on the prints. If you know the camera and you have a frame of reference (fiducials or film frame) then you can use standard PhotoModeler techniques.

Also see the summary steps in the section below called *Inverse Camera Review Steps*.

Check for coverage of object

First check to see if the object or scene you want measured is fully covered by the photographs.

Good example: you want to measure the fender on a car and the photographs you have include the fender and a good part of the car around it.

Bad example: you want to measure a road intersection but none of the photos you have include the north east or north west corners.

Check for angles

Second check to see if the photographs are taken from different angles. Close to 90 degrees is best.

Good example: You are measuring the front of a historic building and you have three photographs- one taken straight on, one from the left corner and one from the right corner.

Bad example: You have a bunch of photographs of an accident scene and all the shots have been taken by the person walking down the center line of the road so the angle between the shots is almost zero degrees.

Check for reference count

Third, review all the points and edges that are important to you on the object or in the scene and then look at all the photographs and determine how many times each point appears in a photograph. The photographs for each point should also have good angle separation.

Good example: You are modeling a van and all the points you want in your model appear in at least two photographs and a number of them appear in three or four photographs.

Bad example: You are measuring five key points on a water stain but three of the points appear on only one photograph and the other two points appear on two photos but the angle between those photos is 5 degrees.

The one case where reference counts are not important is when a single photograph project is being done to extract ortho-photo or Surface Drawings. In this case the Control Points or Constrained Lines and Edges appear on only one photograph.

What source of control is there?

Fourth, check to see what you know or can find out about the objects that appear in the photographs. Do you know or can you measure some 3D locations in the scene as it exists now? If you cannot get 3D locations of points by surveying or by knowing something about one of the objects in the scene then you will not be able to use control based Inverse Camera.

The known information can be in the form of XYZ Control Points or in the form of Axes Constraints. See the Single Photo tutorial for an example of using Axes Constraints to solve for focal length.

If you are using Control Points to do Inverse Camera processing you must meet some minimum requirements. If you are solving just focal length in Inverse Camera (most common) then each photograph, that has Inverse Camera focal length turned on, must

have four or more Control Points with a good spread. If you have asked for principal point solution also you will need an additional two Control Points and for format size an additional one Control Point. So if you have all three Inverse Camera parameters turned on for solution you will need at least seven Control Points on that photo.

Good example: You have two photographs of a car in which the front has been crushed in. The photographs show large parts of the undamaged vehicle and you have easy access to an undamaged exemplar vehicle of the same make and year. You can measure the exemplar vehicle with PhotoModeler and use the output DXF as the input source of control for Inverse Camera on the unknown photographs. You can obtain 15 or more control points to mark on most of the unknown photos.

Fair example: You can see an ambulance in a couple of photographs and you can get the dimensions of the rear box but the photographs are taken in two point perspective (the vertical edges of the box appear to be straight up and down in the photos). You have a source of control but the control is not very strong. If you need to recover focal length, principal point and format size you may have trouble.

Bad example: You have some photographs of an accident scene of a very rare automobile. The automobile has been crushed. The road scene it was photographed in has changed (the road has been repaved, the surrounding buildings have been torn down). You have no source of known points in the photographs! This project probably cannot be done.

Proper perspective for Axes Constraints

If you are using *Axes Constraints*, you have to have a photo with the correct perspective. With Axes Constraints you can solve for focal length if you have a strong two or three point perspective and you can solve for focal length and principal point if you have a strong three point perspective.

A single point perspective photo has just one vanishing point and the horizon is near the center of the photo. If a photographer was standing in the middle of some train tracks and took a photo looking down these tracks and the tracks vanish in the distance to a point near the center of the photo then that is a single perspective photo and Inverse Camera will not work.

A two point perspective photo has two vanishing points. A photo taken at 45 degrees to the corner of a building but the camera still parallel to the ground plane (which makes the vertical edges appear vertical in the photo) is a two point perspective photo. If the perspective is strong enough PhotoModeler can solve for the camera position and focal length for this photo. You would mark two sets of lines or edges and set up two Axes Constraints.

A three point perspective photo has three vanishing points. A photo taken at 45 degrees to the corner of a building with the camera pointed towards the top of the building (which makes the vertical edges appear to vanish to a point near the top of the photo) is a three point perspective photo. If the perspective is strong enough PhotoModeler can solve for the camera position, focal length and principal point for this photo. You would mark three sets of lines or edges and set up three Axes Constraints.

Good example: You are modeling a building or a room and the camera was at a sharp angle to all surfaces (perhaps a video surveillance camera pointing down and way from the corner). This photo is perhaps in three point perspective and you may be able to solve for focal length and principal point.

Bad example: You have a single photograph of a road taken right down the middle. The camera was parallel to the ground and the horizon is close to the center of the photograph. This photograph is probably in single point perspective and no Inverse Camera solution can be done.

Note: axes constraints cannot be used to solve for Inverse Camera in a multi-photo project. Instead work with each photographs individually and then combine the results (camera parameter solutions and photos) into a multi-photo project.

If you managed to get through this review and answer positively to all of the questions you will have a good chance of getting the 3D measurements you want. If some of the aspects are weak or poor you might still be able to do something. If the reference count check is bad and there is no source of good control then you are probably out of luck and these photographs cannot be used to get 3D measurements.

Unknown Camera Procedure

The procedure for handling photographs from unknown cameras is:

1. Review the photographs to ensure they are suited to PhotoModeler use. See the *Inverse Camera* section above for photograph guidelines. Also review the overview steps below in *Inverse Camera Review Steps*.
2. Scan the photographs making sure they are as square to the scanner as possible. Scan them at sufficient resolution to see your details (usually a monochrome image file size about 1MB is a good starting point). Digital photographs can be used also in which case the scanning step is omitted.
3. Start a new PhotoModeler project.
4. Create a new Camera using the "An Unknown - InverseCamera" setting.
5. Proceed through the wizard answering the other questions as appropriate.
6. Import the scanned photographs or digital images into the Project. Note that imported photographs assigned to a camera with the "Inverse Camera" flag will automatically have their "solve for focal length" property set (see *Photo Properties*).
7. Mark your Control Points or constrained Edges, Lines and Surfaces.
8. Process the project (Inverse Camera processing occurs only during the Orientation stage of processing).
9. Review the status of the Inverse Camera processing in the *Processing Finished Dialogs*.
10. Review the results to ensure they are accurate and consistent. Use the Point Table to check the largest *residuals* (should be as small as possible and usually under 5 pixels). Use the control projections on the photo to see how well the result matches. Use the *Post-Processing Report* to check for high parameter correlations.
11. Proceed with the remainder of the project as normal, do the required marking, referencing and then processing to get the final result.

The Inverse Camera process is carried out automatically by Processing if required. All the user needs to do is make sure sufficient control points are marked and that the appropriate Inverse Camera flags are set for the photograph in *Photo Properties*.

If the processing fails very quickly when doing Inverse Camera the control points are immediately suspect. Check you control points:

1. to make sure the inputted x,y,z locations are correct (even if the surveyor that gave you the points said they are fine make sure yourself!)
2. to make sure the correct control points are marked on the correct points on the photographs.
3. to make sure the starting parameters for the Camera or Cameras are close to reality. Sometimes when they are very far off (i.e. giving a first approximation of 35mm focal length when the photograph was really taken by a 150mm lens) the Inverse Camera part of processing can fail.

Note: If you want to reprocess just one Photograph for Inverse Camera purposes (perhaps you have moved or changed the control points on the photo and you want to see how it affects the camera solution), you need to reorient just the one photograph. See the Force Unoriented button in *Photo Properties* or a way to do this.

Post-Processing Report

If you are solving for more than just focal length in an Inverse Camera project it is important to check the *Project Status Report* after a successful processing. You are looking for high correlations between the camera parameters and high standard deviations. Correlation values over 95% are suspect and if a camera parameter being solved by inverse camera has a correlation over 98% you should probably not be solving for it (you should instead leave the parameters at a reasonable default, such as square pixels and centered principal point).

In this example, from a real-world single photo inverse camera project, part of the status report has these values:

Photo 1 Standard Deviations [and correlations over 80.0%]

Omega: 0.016 rads [Phi:97.1% Fw:97.9%]

Phi: 0.023 rads [Omega:97.1% Focal:83.6% Fw:99.1%]

Kappa: 0.013 rads [Z:91.9%]

X: 0.216 m

Y: 0.290 m

Z: 0.423 m [Kappa:91.9%]

Focal: 0.250 mm [Phi:83.6% Fw:81.4%]

Fw: 0.195 mm [Omega:97.9% Phi:99.1% Focal:81.4%]

You can see a correlation between Fw (this is 'format width' and what is computed if you select "format aspect" in the Inverse Camera section of the photo's property dialog) and the station angle phi of 99.1%. This means the solver could not distinguish errors in Fw versus errors in Phi. This means that neither have solved well. Also note the one-sigma standard deviation of 0.195mm for Fw as this somewhat high because Fw error can introduce quite a bit of error into a project.

This is the same project solved with just a focal length inverse camera setting:

Photo 1 Standard Deviations [and correlations over 80.0%]

Omega: 0.003 rads

Phi: 0.003 rads

Kappa: 0.004 rads

X: 0.207 m [Z:92.3% Focal:97.4%]

Y: 0.270 m

Z: 0.139 m [X:92.3% Focal:91.6%]

Focal: 0.146 mm [X:97.4% Z:91.6%]

Note that we still have quite a high correlation between focal length and the camera station position but often this cannot be avoided as it is difficult to make reasonable assumptions about the true focal length. Also note that the one-sigma standard deviations are generally smaller on all parameters so this is a better solution than the one above. In this particular forensic project, other data was checked after the processing (*residuals*, check distances, etc.) and the results were shown to be reasonably accurate.

Inverse Camera Review Steps

This section provides a brief outline of the procedure to follow for PhotoModeler Inverse Camera projects. The previous sections go into more detail and background. This section is a quick set of steps to go through when starting any forensic, accident reconstruction, or historic photo project.

Steps

1. Review the photographs available
 - i. How many photos?
 - ii. What angles between photos?
 - iii. How much overlap (shared points)?
 - iv. What is photo quality and sharpness?
 - v. The critical dimensions, do they appear on multiple photos or on a known plane in a single photo?
2. Review what is known
 - i. 2D or 3D control points available?
 - ii. Survey data available or a survey can be done?
 - iii. Can 3D control be made from other knowns?
 - iv. Is there enough control to do project and have accuracy comparison? If using Control Points, do you have at least four Control Points on each unknown photo?
 - v. Does the control cover the photos well (i.e., not all in small portion of photo)?
 - vi. If no control points, do you have strong perspective and can use Axes Constraints on parallel edges and lines?
 - vii. If a crash project, is car make/model/year known?
 - viii. Is there access to an exemplar vehicle?
 - ix. What is known about the camera that took the photos?
3. Make a decision based on 1) and 2) if you can proceed based on number of photos, what is needed for the case and the amount and type of knowns
4. Decide on the approach
 - i. Single photo resection with measurement/mapping on plane?

- ii. Multiple photo - inverse cameras and normal projects
 - iii. Is an exemplar needed? Front crush, side crush, using offsets.
 - iv. Combined crush/exemplar project or separate projects?
 - v. How will accuracy of the result be determined? Are there enough left over unknowns? Can you do some logical consistency checks?
5. If using an exemplar, do exemplar PhotoModeler project
 - i. Do standard multiple photo, known camera, PhotoModeler project to map out points that will be key in doing InverseCamera on unknown photos, and to map out points that will help measure the crush.
6. InverseCamera project: Start with single best photo
 - i. Photo with most control visible (with control visible over depth)
 - ii. Photo that is sharpest
 - iii. Photo that covers most of the area of interest
7. If using Control Points, Import the Control
 - i. Lock control points down with negative precision or check box
 - ii. If exemplar project done with PhotoModeler, export a DXF or text file from PhotoModeler and re-import in the Control Import Dialog (same or different project). Also see the Crush tutorial for an example.
8. Decide on which camera parameters to solve for
 - i. With film and scanned prints you can usually determine format size before hand (at least to a good enough approximation).
 - ii. Start off solving for focal length only (then add principal point if greater precision is needed).
9. Test the single photo solution if possible.
 - i. Test using any known dimensions on planes.
 - ii. Review camera parameters to see if they make sense.
 - iii. Study the 3D viewer to see if it makes sense.
 - iv. Study marking *residuals* carefully. Esp. look for residuals changing in size as distance of point to camera changes (indicating a poor focal length solution).
10. Add new photos and base new cameras on solved one
 - i. Using the camera parameters from the first good solution make up new cameras for each photo if you think a zoom lens was involved.
 - ii. Do inverse camera on each new photo/camera combination allowing only focal length to be solved in InverseCamera. Do each photo one at a time.
11. Complete project in single photo or multi-photo mode
 - i. If using multiple photos, just complete the project as any normal PhotoModeler project.
 - ii. If single photo, map out planar sections and then use surface drawing or ortho-photo. Note: the accuracy of surface draw or ortho-photo depends very heavily on the solution of the overall project (i.e.. where the camera station ended up relative to the plane). If the orientation and project solution is not very accurate the surface draw or the ortho-photo will be inaccurate also.

Note: there are some limits to using the single-photo axes constraints for solving camera parameters. First, format size aspect is not solved (whether it is checked or not in the *Photo Properties*). Second, you have to have strong three point perspective to solve for principal point.

Third, you have to have at least a strong two point perspective to solve for focal length. If the perspective is weak or non-existent, the Audit Summary dialog will warn you before processing.

Using the Automated Tools

PhotoModeler has three tools that significantly decrease the time it takes to complete certain types of projects. These tools are:

- Automatic Target Marking - for automatically marking sub-pixel target points in projects with many high contrast targets
- Automatic Referencing - for automatically referencing point marks between photographs in projects (or subsets of projects) that are generally one sided and 2.5D
- Automatic Surfacing - for automatically creating triangular surfaces between points on flat or 2.5D objects, or on 3D convex objects.

While these tools work well independently and can be used on many different types of projects their main use is in the creation of DSM (Digital Surface Models). DSM are two and half dimension surfaces (think of a rubber sheet with parts pulled up or down).

The following sections describe each of these tools, how they work, and when they can or cannot be used.

Also see the *Automated Coded Targets Project* section that describes even further automation possible when *Coded Targets* are used in a project.

Automatic Target Marking

Automatic Target Marking will search out and mark, with sub-pixel precision, many circular targets in a user defined region (or whole photo).

The targets will usually be one of three types:

- stick-on natural-light targets,
- stick-on retro-reflective targets, or
- projected targets.

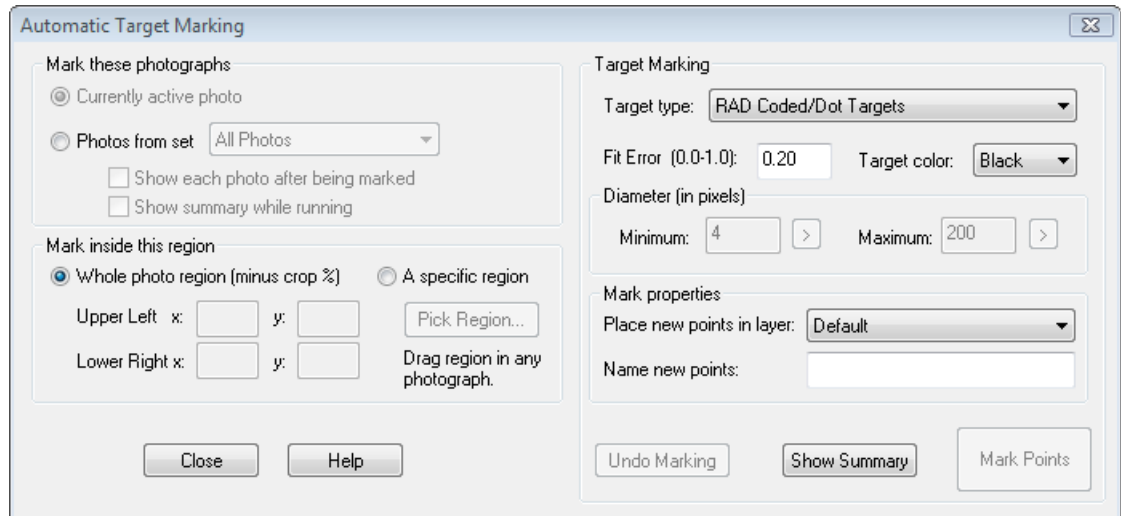
There will normally be a large number of targets in a region (otherwise one or two isolated targets would normally be marked manually using the Point Tool and the Sub-Pixel Target Mode) and there will little background noise in the region that can be confused as a target.

Note: PhotoModeler can read images in many bit depths (1 bit black and white, 4 bit color, 8 bit monochrome, 8 bit color with palette, and 24 bit full RGB color) but some processes (such as sub-pixel target marking) only work on 8 bit monochrome (no palette) or 24 bit full RGB images.

See *Targets - Do's and Don't's* for tips on using targets in your project.

In addition to plain circular dots for targets, PhotoModeler, with the add-on *Coded Targets* module, can automatically mark, recognize and reference targets with special code rings.

Automatic Target Marking Dialog



The Automatic Target Marking dialog is accessed from the Marking Menu / Automatic Target Marking item.

How you interact with this dialog depends on the type of automarking you want carried out. There are five steps to running an Automatic Marking but some of these steps can be skipped depending on the situation. The five steps are:

- Choosing which photographs should be marked,
- Choosing which region of the photograph(s) should be marked,
- Choosing a target type and target identification parameters,
- Choosing the name and layer in which to place new points,
- Executing the Automatic Marking.

Each step and its variations are described here:

Choosing which photographs

The auto-marking can be run on one photograph at a time or on a number of photographs at once. To run it on one photograph you would open the photograph (before or after the dialog is open), and choose the 'Currently active photo (#N)' option. 'N' is the number of the currently active photograph so you can be sure what will be marked. To run it on a number of photographs or all photographs in the project you choose the 'Photos from set' option and then pick a Photo Set. The default is the 'All Photos' set which would mark all photographs in the project.

If you use the 'Photos from set' option you can check the 'Show each photo after being marked' option and then during the marking, after each photograph has been marked, it will be opened so you can view it (while the remaining automarking continues).

You also select whether to display the summary showing the status of the automatic marking (ie number of points marked, reasons for regions not marked etc see *Automatic Marking Summary Dialog*).

Choosing which region

Sometimes you may wish to have only a portion of the photograph automatically searched for targets - for example, to speed up the operation or to separate out any regions of clutter and noise. You can enter the region of the photograph to be marked or select it using the 'Pick Region...' button. The region is rectangular and is defined by the upper left and lower right corners (in pixels).

1. To pick a region, choose the 'A specific region' option and then press the 'Pick Region...' button.

The dialog will disappear and the selection region cursor will appear when the cursor is over a photograph.

2. Click and hold the left mouse button over the one corner of the region in any photograph (it can be any corner).
3. Drag the mouse (while continuing to hold the left button down) to outline the region that contains the targets in the photo.
4. A marquee box will appear showing you the region being chosen.
5. Release the mouse when the region is defined.
6. The dialog will reappear with the coordinate of the chosen region shown in the Region Edit boxes. These values can be edited by hand if desired. Hitting the ESC key during this region capture mode will cancel it.

Choosing a target type and target identification parameters

There are different types of targets that can be automarked - the default being **RAD Targets** (if you have the Coded Targets module installed), or circular dots. If at least one target has been marked in the project already, the default will be that type of target. Other possible target types include RAD Targets, ringed dots, and coded targets of various bit sets, and template targets (see **Coded Targets**). If any Template Targets have been loaded in the project then the 'Target' drop down box will allow you to choose those to be automatically marked also. See the **Template Target Marking** section for more information on marking template targets.

Pick whether the targets are white circles on a dark background (typical of projected targets and retro-reflective targets) or black circles on a light background (typical of laser printed naturally lit targets).

To ensure that the target marker does not pick up very large circles or very small noise-like points there are some settings that control the nature of target to detect. Enter the diameter (in pixels) of the smallest and largest target in the region or areas to be marked. This number does not need to be exact. If you do not know the sizes you can measure typical targets using the > button which operates much like the Pick Region mode. In this case you zoom in on the largest or smallest target and you draw a box around it that just encompasses it. The largest should be larger than your largest target and the smallest should be smaller than your smallest target. Targets outside of the range will not be marked. If you are using RAD targets, you can just use the default size settings so there is not need to measure or make changes to these values.

An ideal dot target (the dot alone or the center of a coded target) will look like a perfect filled ellipse (or circle) with a uniform color and uniform blurred edge in the photos. If a target is misshapen (due to imaging problems, blur, noise, non-flat surfaces, or improper manufacture) the ideal ellipse shape will not 'fit' as well. These less-than-ideal ellipse shapes will be rejected. To get more of them accepted you can increase the 'Fit Error'. Its maximum value is 1.0. If you lower the Fit Error threshold, more target dots will be 'rejected' and will not be marked.

Increasing the threshold will allow more dots to be 'accepted' and marked.

Note: You can set which RGB channel to use during automatic target marking using this ini setting (default is 1 green channel):

[General]

SubPixelMarkingColourChannel=-1

(where 0=RED, 1 = GREEN, 2 = BLUE, -1 = convert to grey scale)

Using just one channel (usually green) may increase precision because this minimizes any chromatic aberration effect of the lens.

Choosing name and layer

You can select an existing layer into which all newly marked points will be added. You can also add a user name to the marked points. Leaving the name field blank will leave newly marked points unnamed.

Typical Scenarios

A typical usage for a single photograph using RAD Targets would be to: a) open the photograph, b) open the Automatic Target Marking Dialog, c) leave most of the default values alone, d) choose the 'Currently active photo' option, and f) press the 'Mark Points' button.

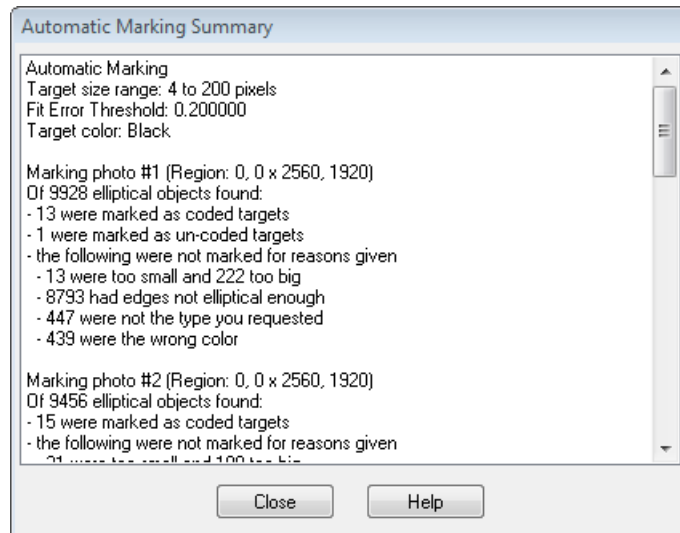
A typical usage for marking all photos using RAD Targets would be to: a) open the Automatic Target Marking Dialog, b) leave most of the default values alone, c) choose the 'Photos from set' option (set All Photos), e) enter/pick a maximum and minimum target diameter, and f) press the 'Mark Points' button.

A typical usage for marking photos *without* RAD targets would be to: a) open the Automatic Target Marking Dialog, b) leave most of the default values alone, c) choose the 'Photos from set' option (set All Photos or currently active), e) enter/pick a maximum and minimum target diameter, and f) press the 'Mark Points' button.

The Undo Marking button will become available after an automated target marking is complete. Pressing it will remove all marks placed in the most recent automatic marking session.

See also *Targets - Do's and Don't's*.

Automatic Marking Summary Dialog

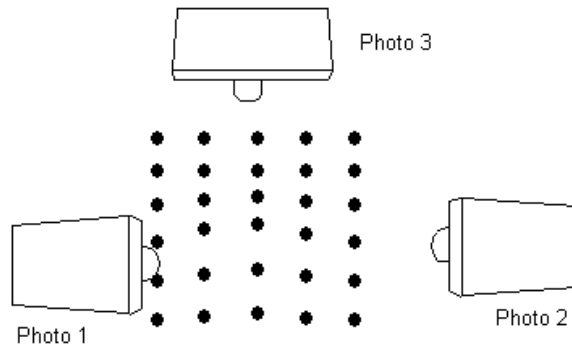


The Automatic Marking Summary provides a list of results from the most recent automarking session. It lists a summary of automarking parameters, then for each photo it counts the number of elliptical objects found, the number of targets marked (coded and non-coded targets), and counts the number of targets rejected due to size, RMS (i.e. a bad target 'fit'), target type and color.

Automatic Referencing

Automatic Referencing will search through a set of specified unreferenced Marked Points or Silhouette Marks (depending on the type of objects that you are referencing) and attempt to optimally reference them together.

Note that this set of points or silhouette marks cannot describe a multi-sided object (for instance points marked on windows and door on both sides of a house) and each point or silhouette should appear on three or more photographs (four is preferred). Also note that these photographs have to have a geometric relationship similar to that described in the Quick Start Guide section - Photography for Curves, Edges and Cylinders. One possible configuration is like this:



Automatic Referencing Dialog

There are two forms of the automatic referencing dialog. The first is the standard dialog and it appears whenever there are three or more oriented photographs in the project. The second appears when there are only two oriented photographs in the project. For more information on the two photo case see [Automatic Referencing with Two Photographs](#).

The screenshot shows the 'Automatic Referencing for Three or More Photographs' dialog box. It is divided into five sections:

- 1. Which Objects ?**
 - ☒ All points in project
 - ☐ All points in layer: Default
 - ☐ All silhouettes in project
 - ☐ All silhouettes in layer: Default
- 2. Parameters**
 - Project Scale Status: Scaled and
 - Search Distance: 1.808 in
 - ☒ Perform search distance doubling iterations
 - Minimum number of photos: 3
- 3. With automatically referenced points**
 - Name them: at
 - ☐ Set them to "do not process"
- 4. Referencing**
 - Number of oriented photographs: 8
 - On one (1) photograph: 3
 - On two (2) photographs: 90
 - On three (3) photographs: 26
 - On four or more (4+) photographs: 30
 - Execute Referencing
- 5. Undo Automatic Referencing**
 - Number of saved referenced marks: 0
 - Unreference previous references

At the bottom of the dialog are Close and Help buttons.

The Automatic Reference dialog is brought up from the Automatic Referencing item in the Referencing Menu.

There are four main stages to Automatic Referencing.

1. Decide whether to reference Marked Points or Silhouette marks in the project, and whether to do all or just those in the selected layer.
2. Set up the initial algorithm parameters (often leaving the default values is correct).
3. Decide what should be done with the automatically referenced points (they can be given special names and set to "do not process"). This does not apply to Silhouette referencing.

4. Perform the referencing.

Some projects are naturally one sided and so all items in the project can be successfully referenced together. If you have a more complex object or you wish to reference only a subset of the items, you would place a subset of points in a Layer (see *Layer Dialog*) and then use the "All points in layer:" option (the same goes for silhouettes if the silhouette option is selected). Note, because some points or silhouettes are not yet referenced, you will have to place all marks on all photographs, which are part of this subset, into the same layer. You can segment an object this way into multiple parts by using multiple layers and then run automatic referencing on them separately. Layers are saved with the PMR file so you can repeat the segmenting and processing as needed.

The parameters that control how items are matched are in the second section of the dialog. The Search Distance defines how far apart the intersection of the light ray from one marked point and the light ray from another marked point can be before the points are determined to be mismatching. This threshold value is automatically filled in as the largest tightness value any current point in the project has. This is directly related to the search distance so this is often a good match. In some poorly oriented projects with sparse points you may need to increase this distance to get any items to match and in poorly oriented projects with dense point or silhouette sets you may need to decrease this value to reduce mismatches.

We suggest that you do not ask for two photo references except in projects with strong geometry and sparse points or silhouettes. Two photo references are very ambiguous and it is very easy for the algorithm to misreference items that appear only on two photos. Note that this is different than the two-photograph-referencing described below when there are only two oriented photographs in the project.

Points that are successfully referenced by this function can have their User Name (as seen in the *Object Point Properties* or in Point ID display) set to a specified name. Note that this does not apply to silhouette automatic referencing. If the name is blank no changes will be made. You might want to name points to distinguish them from those manually referenced. You can also set all successfully referenced points to be set to "do not process". If the automatic referencing is making too many errors with point referencing you may want to set this so these points will not affect any subsequent processing.

The Referencing section of the dialog provides some information on the current referencing state of the chosen points or silhouettes. These numbers are updated as the algorithm runs.

After automatic referencing you can undo the referencing by hitting the "Unreference previous references" button. The useful thing here is that this "unreference" ability is available even after this dialog is closed. In fact you can do an automatic reference, close this dialog, process the project and then still come back and unreference all the automatically referenced items. If you close the project or PhotoModeler the ability to undo the automatic references is lost.

Note: "Unreference previous references" is not a true "undo". It restores the previous reference state (which marks were associated with which 3D objects), but leaves the items' properties in their changed state. That is, if the automatic referencing named some points to 'ar' or changed a point's material or layer, then these changes are not reversed.

To perform Automatic Referencing:

1. Orient and process all the photographs that have marks that will be referenced. Check the quality of the orientation carefully (by checking *Marking Residuals* and Point

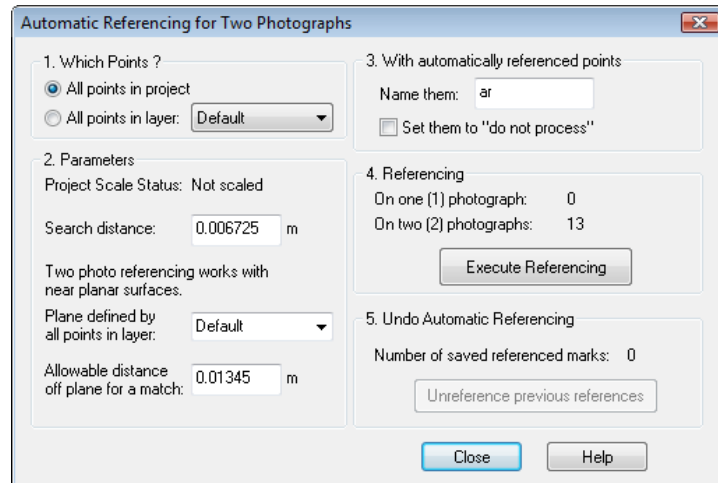
- Tightness etc.). The quality of the automatic referencing depends very much on the quality of the photo orientation.
2. If only a subset of the project's Marked Points or Silhouette marks are to be referenced (such as in a non-one-sided object) put those points in their own layer.
 3. Open the Automatic Referencing dialog.
 4. The dialog will show the counts of the selected items in terms of how many references they currently have.
 5. Choose which items are to be referenced in section 1.
 6. For point referencing, decide which settings you want in section 3 (naming and processing status of referenced points).
 7. Press the Execute Referencing button.
 8. A progress dialog will appear as the algorithm runs and depends on the number of internal stages, the information in section 4 may update. When the process is complete you will be returned to the dialog and the change in the references will be displayed.
 9. Depending on the results displayed you may wish to rerun the referencing right away (in which case you press the "Unreference previous references" button, change parameters in section 2 and then press "Execute Referencing" again) or you may wish to study the results outside the dialog.
 10. Press Close on the dialog.
 11. Review the results of the referencing by studying the 3D Viewer and the Tables. If the result is not satisfactory you can reopen this dialog and press the "Unreference previous references" button to remove all the references just made. At this stage you may either change the parameters or study the project to see why the referencing might not have worked (inappropriate choice of search distance, poor photo orientation, poor mark placement, etc.).

Points that do not auto-reference

There are a number of reasons why some points may not automatically reference no matter your choice of search distance. The two main reasons are: 1) there is too much ambiguity between the matches, and 2) the projections of the points do not match across photographs well. For 1) you should consider taking a different set of photographs with different angles or changing the spacing of the points (if you have control over this). For 2) make sure the camera is well calibrated and the orientation of the stations is good. Also note that the preference called "Use accurate lens distortion correction for projections" in the General tab should be turned on if you have a camera with non-zero lens distortion parameters.

Automatic Referencing with Two Photographs

When there are only two oriented photographs in a project a different dialog appears:



If your surface is planar or near planar, automatic referencing can be carried out with only two photographs. The constraint provided by the surface shape allows PhotoModeler to work with the normally ambiguous case of two photographs. Note that you cannot automatically reference silhouettes that are marked on just 2 photos.

The dialog shown above contains many of the same controls as the standard 3+ photo automatic referencing dialog and so they are not described here - see the section above. There are two new controls:

"Plane defined by all points in layer:" is a drop down list showing all Layers in the project. See the [Layer Dialog](#) for more information. Pick the layer that contains only 3D points on the planar surface. You need to mark and reference at least three points on the planar surface before using this method.

If there are points in the project that are not on the planar surface you need to use one of the layer boxes to segment the data correctly. Before you start the automatic referencing you should assign your points to layers. If all the points in the project lie on the planar surface then no action need be taken - just leave all points in the Default layer. If some points lie off the surface then place the points (those that are referenced and are 3D and those points to be referenced) into their own layer (ex. "planePoints"). Then use one or both of the layer drop down lists to pick the new layer to define what is to be referenced and where the 3D points are that define the plane.

Note that if there are more than three points chosen to define the plane, a least-squares fit is done with the points to produce the "optimal" plane before proceeding.

The other new control on this dialog is "Allowable distance off plane for a match:". Here you enter a threshold for distance off the plane. If the surface was a perfect plane you could enter zero or a very small number here. This controls how far off the plane a point is allowed to be before being considered an inappropriate match/reference.

The trick to using this facility is to pick the two thresholds ("Search distance" and "Allowable distance off plane for a match") so that you get all or most of your points referenced. The Search distance is closely related to tightness of the points and often the default chosen by PhotoModeler is sufficient. The distance off the plane threshold will depend on the separation of your targets and how flat the surface is. One good way to pick an initial value for this is to open your two photographs and misreference two points

that are close to each other and then see how far off the plane the misreferenced point is. Pick a threshold just smaller than this. So for example if we had rows of points and on photo 1 there was a row with point ID's: 12, 13, 14, 15 and on photo 2 the matching points are supposed to be: 112, 113, 114, 115 - manually reference points 12 and 113 (which is an incorrect match but the closest mismatched pair). Place a surface on the object using the Surface tool and then use Measure to get the distance from this misreferenced point to the surface. The allowable distance threshold should be just smaller than this. If the surface has more shape variation than this amount then it will be difficult to reference the whole surface at once.

When the distance off plane threshold gets too big there will be more ambiguous matches and the points will tend not to get referenced. If the surface is not very planar then misreferences could result also.

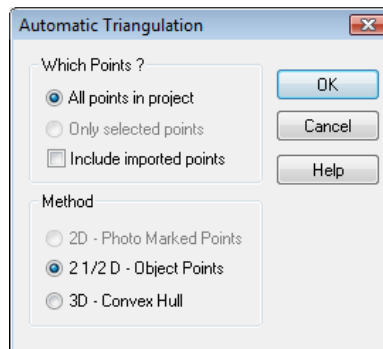
Another approach is to pick a very small off-plane distance threshold and then execute the referencing. Only points that are very close to the defining plane will be referenced. Then pick a bigger threshold and repeat until you get to the biggest threshold as described above. In this way, at each stage, you remove a set of unreferenced points thereby making the referencing easier for the next stage.

Automatic Surfacing

Automatic Surfacing creates triangular surface elements between Object Points.

This function works only on Object Points and may not be able to automatically triangulate your whole project. See the next section for details.

Automatic Triangulation Dialog



The Automatic Triangulation dialog appears when the Automatic Surfacing/Triangulation... item is chosen from the Surface Tools sub menu on the Marking menu (or the Surfacing toolbar).

This function can work with either selected points (you select them before bringing up this dialog) or with all points in a project. If no points are selected when this dialog appears, then the "Only selected points" and 2D options will not be available.

There are three different triangulation types for:

- 2D - the selected points are 2D Marked Points on a photograph on a flat plane that is close to being parallel to the image plane.
- 2.5D - the points are 3D and describe a two and a half dimensional shape (think of a rubber sheet on the floor with various objects underneath it stretching it up off the floor in places).
- 3D - the points are 3D and describe a solid convex shape (with no concave sections).

Not often will the whole project fall into any one of these three categories. You can proceed by either selecting the points anyway, triangulating them and then deleting the incorrect triangle surfaces or you can select sub-sets of the points that do meet these descriptions.

You can undo the creation of the surfaces by using Edit/Undo menu item.

To surface a flat object with many points (such as the front of a building with many window and door corners marked):

1. Open the photograph showing the points.
2. Using the select area tool (or any other selection mechanism) select all the points to have surfaces drawn between.
3. Open the Automatic Triangulation Dialog.
4. Press the OK button (because all the defaults should be correct for this operation).
5. The surfaces will be created and will appear on the photograph between all the selected points.
6. If the shape of the points was not purely convex in 2D you may need to delete some extraneous surface triangles around the edges.

To surface a 2.5 D "rubber sheet" object (such as a sheet metal part):

1. Assuming the whole project is the one object, open the Automatic Triangulation Dialog.
2. Press the OK button.

Since no points are selected the defaults will be "All points" and "2.5D".

Surfaces will be created between all 3D Object Points in the project based on the best fit plane 2D triangulation.

To surface a 3D convex object (such as the upper or lower block of the Toy Blocks tutorials):

1. Open a Point Table, 3D Viewer or Photograph.
2. Select the points on the part of the object that is purely convex.
3. Open the Automatic Triangulation Dialog.
4. Select the "3D - convex hull" option.
5. Press the OK button.

The surfaces will be created and will appear on the photographs and 3D Viewers between all the selected points.

6. If the shape of the points was not purely convex in 3D you may need to delete some extraneous surface triangles around the edges.

Dense Surface Modeling / PhotoModeler Scanner

Introduction

Dense Surface Modeling is a set of tools for extracting and manipulating a dense pattern of points from photographs. The surfaces in the photographs should have a visible random and/or natural texture and the photographs should ideally be taken in a paired stereo configuration.

Dense Surface Modeling can be thought of as a camera-based 3D 'laser-scanner'. DSM can obtain detailed surface measurements and models that would not be practical otherwise with point-based photogrammetry.

Dense Surface Modeling (DSM) is available in the PhotoModeler Scanner product. PhotoModeler Scanner has all the capabilities of PhotoModeler plus the ability to do Dense Surface Modeling.

What is DSM Used For?

Dense Surface Modeling is used in any application where a large number of 3D points (a point cloud) is needed. The surfaces being modeled do need a natural or random texture (or that texture can be applied or projected). Most applications where a laser scanner works, DSM will work also.

Some example applications are:

- Architecture and Preservation: obtain a dense surface cloud of an old stone wall or structure; capture the detail in a building facade.
- Archeological digs: get a dense cloud of points of stratified dig surfaces; non-contact scans of artifacts.
- Museum / curatorial: non-contact surface scans of bas-reliefs, masks, and some statues.
- Forensics: 3D scans of bite marks; 3d surface scans of tire marks and foot imprints in soil and wet sand.
- Mining, Excavation and Geotechnical: surface models of open pit mine faces, cliffs, exposed rock characteristics; models of slag heaps and stockpiles; volcano monitoring.
- Civil Engineering: models of cuts and fills in road work; models, surfaces and measurements of stock piles; sand dune surveys for erosion monitoring.
- Mechanical Engineering and Industrial Measurement: surface shape of manufactured parts (using a projected random pattern); modeling deformation of fabrics and gossamer materials.
- Medicine: 3D scans of skin surface for body morphological measurements; point clouds and surfaces of a child's back with scoliosis.
- Film and animation: produce highly accurate bump maps of real surfaces; scan sets and objects for modeling

See the PhotoModeler website for example images and data in these application areas.

Laser Scanner Comparison

It is natural to draw comparisons between PhotoModeler Scanner and a 3D laser scanner (or structured-light scanner) because they both produce 3D point clouds. They both have their respective strengths and you might choose one technology over the other based on your application and budget.

The first two lists show the respective strengths of the technologies. The table afterwards shows how different surface types are handled.

PhotoModeler Scanner Strengths:

- low purchase and operating costs
- field equipment is easy to transport, move around the site, and is small (a camera)
- less time in the field, comparable time back in the office
- can work from an unstable instrument platform
- can scan moving and unstable objects or scenes (if using synchronized cameras)
- can scan very small objects accurately (if they can be photographed and have texture)
- can scan objects at great distance (as long as there is a visible texture in the photos)
- produces a superior photo-textured 3D model

3D Laser Scanner Strengths*:

- can scan textureless (or repeating texture) surfaces (as long as the surface is Lambertian or near-Lambertian and reflects light back to scanner). See surface table comparison below.
- may handle scenes with large and sudden depth changes better
- does not need a priori knowledge about the approximate depth range
- does not need targets or other sharp features to be identified in paired photos
- can scan surfaces that might appear textureless at the distance that photography is needed for PhotoModeler Scanner
- can scan at night and in dark locations (PhotoModeler Scanner would need additional lighting)

* Note: there are many different laser scanner products (and structured-light scanners) available and this list lumps them together and describes them in general terms. Some products may be better than others with respect to these criteria.

No scanning method works perfectly for all surface types. The nature of the surface will determine how well PhotoModeler Scanner works. This table is a comparison of PhotoModeler Scanner and a typical laser scanner in relation to the type of surface being scanned. The middle column shows PhotoModeler Scanner with additional hardware - that is, a projector (lcd, 35mm slide, or gobo) that can project a random dot pattern on the surface. The cells in the table indicate whether the product will normally produce a good 3D point cloud.

Surface Characteristics	PhotoModeler Scanner	PhotoModeler Scanner with projected pattern	Laser Scanner
Natural or randomly textured	Yes	Yes	Yes

surface			
Man-made repeating- pattern surface	May have some trouble. Careful setting of parameters may resolve.	Yes	Yes
Flat, non-textured surface	No	Yes	Yes
Dark surface esp. in laser's bandwidth	Yes if can be lit in visible spectrum	Yes if can be lit in visible spectrum	No, or difficult
Non-Lambertian highly reflective surface with no texture	No	May have trouble	Usually has trouble

See the section on requirements for further discussion on surface type.

DSM Quick Start Guide

This section provides a quick guide to creating a new DSM project. Details on these guide steps are found in the *Creating and Modifying Dense Surface Models* section.

1. Take photographs of your object and textured surfaces. See *DSM Photo Requirements* for how to take photos for DSM use. Note it is often a good idea to combine standard PhotoModeler photos (strong angles) with stereo pair photos as outlined in that section.
2. Mark and reference points and then process as with a standard PhotoModeler project.
3. Ensure the project is high quality and the largest residual is less than 2.0 pixels (**max. residual preferably under 1.0 pixel**).
4. Idealize the project which removes image distortions. See *Idealize Module*. You may need to reprocess.
5. Define the extents of the region to extract a dense surface. This is usually done by marking DSM Trims but you can also use the entire photo boundary, or in some cases, create an approximate surface:
 - i. Define one or more 2D polygon regions on one or more photos using the DSM Trim tool to outline the region of interest (see *DSM Trims*); or,
 - ii. You may also choose to use the entire image boundary; or,
 - iii. Create an approximate surface using any of the PhotoModeler surface tools. This surface is 'close' to the surface of the object being modeled with a point cloud. It approximates the surface and does not need to be accurate representation of the surface. For example a stone wall could be approximated using a flat plane while the final DSM model will show details of

each stone in the wall. Cylinders can be used too for this approximate surface.

6. Save the project to disk - as a basis for future work.
7. Open the DSM Dialog.
8. Choose the appropriate DSM parameters and Execute.
9. Iterate on the parameters and the clean up steps (editing and mesh tools) to obtain the desired result.
10. Either export the PointMesh directly or convert it into a PhotoModeler Surface for texturing or combining with other project 3D model data.

How does DSM Work?

Dense Surface Modeling is a search algorithm that uses an existing pre-oriented project and pairs of photos from that project to search for image patches that 'look' alike. This search is done in a regular grid-like manner so a grid of 3D points is computed. When a good match is found between two photos, the orientation and camera data allows the program to compute the correct 3D location of the surface point corresponding to the image patch.

The basic steps of the DSM process are:

1. Start with an oriented, idealized, high-quality PhotoModeler project with low residuals and at least two or more camera stations with suitable base-to-height ratios. See *Select Best Photo Pairs Dialog*.
2. Define the extents of the search using *DSM Trims* (a trim can include the defined area or optionally exclude it), using the entire photo boundary (PhotoModeler will define the combined area of the selected images), or using one or more approximate surfaces (these surfaces can be path surfaces, NURBS surfaces, surface draw connected surfaces, or even cylinders, see *DSM Approximate Surfaces*).
3. Run the DSM process with appropriate settings. Steps 4 through 11 are carried out by the program automatically.
4. The DSM algorithm first collects the pairs of photographs to be processed.
5. For each pair of photographs, overlap is checked, and if they overlap the images are resampled to a) align the image rows along the epi-polar lines, and b) to reduce the image to the region of interest (defined by DSM Trims, entire images, or approximate surfaces).
6. The algorithm searches along a row of the destination image using an NxN patch of imagery from the source image. Where it finds a good match it records it. The search range is controlled by the depth range parameters in the DSM dialog, which is based on the selected surface or, if no surface is selected, an implicit surface defined by PhotoModeler using the 3D points in the project (see *DSM Approximate Surfaces*). The step size in the source image is defined by the sampling rate parameter in the DSM Dialog.
7. All the matches are then optimized for the best overall fit, throwing out bad and weak matches, plus handling occlusions and large depth changes, etc.
8. A subpixel refinement is carried out for the matches.
9. The matched positions are used to create 3D points using camera station information.
10. If more than one pair of photographs is being run, the results of each point cloud are then registered and merged into one cohesive point cloud.

11. The data clean up and meshing steps then convert the point cloud into a triangulated mesh surface.
12. In some projects noise is inevitable (noise is 3D points solved off the correct surface). High quality projects minimize this but there may be background imagery that gets in the way to create noise. In these cases, the point meshes can be created by DSM without a meshing step. Then using the manual point edit mode you delete the unwanted points. Then you run the registration, meshing and smoothing as a separate step.

DSM Project Requirements

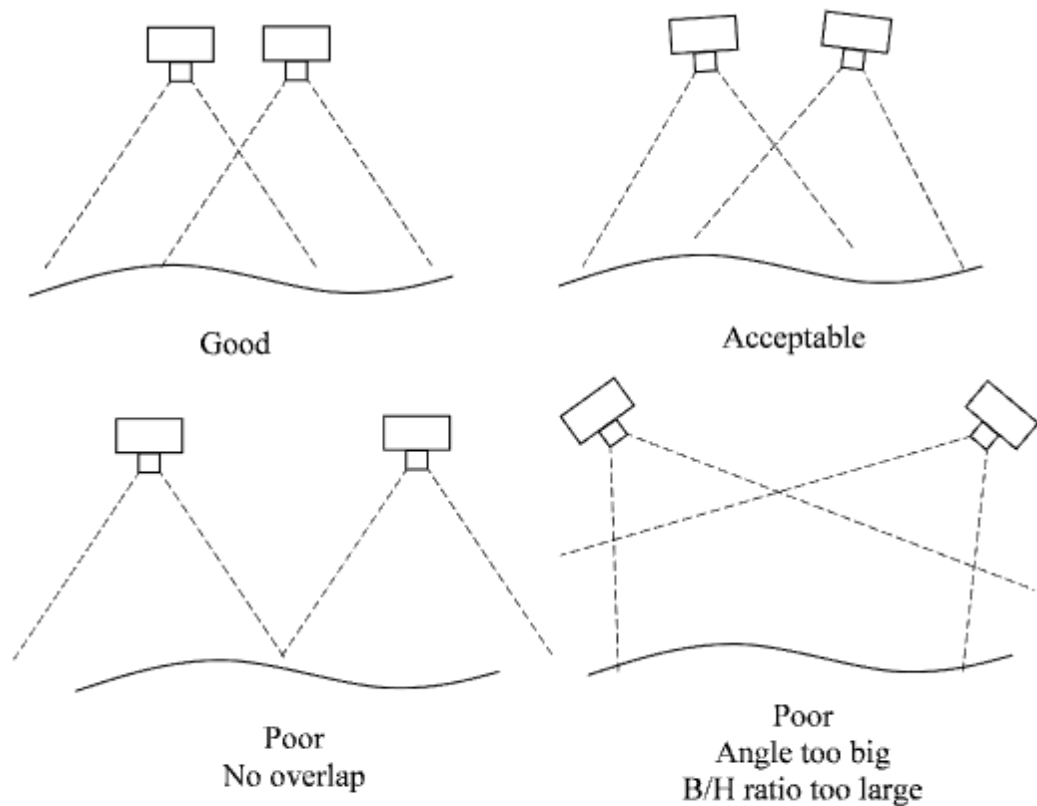
For a Dense Surface Model project to work well there are some requirements that should be met. These requirements are associated with how the photographs are taken, the nature of the surface being modeled, and the quality of the project.

DSM Photo Requirements

When taking photographs for a DSM project you should have a goal of acquiring overlapping pairs. That is, take photographs in pairs with overlap on the surface of interest. Ideally, keep the camera in similar orientation for the pair with a shift sideways between photographs. There can be small changes in height and angle without compromising quality but if the angles get too large then the DSM project may not produce good results.

The key with DSM photography and project set up is to recognize that PhotoModeler works best with photographs that have good angle separation (30 to 100 degrees) so that relative orientation can work, but DSM works best with photographs that have smaller angle separations. The two ways to resolve and work with these seemingly conflicting goals are, a) combine both types of photos in one project (parallel 'stereo' pairs for DSM in addition to wide angle photographs for orientation, or b) use control points (which allow much narrower angles between camera stations).

The figures below show good, acceptable and poor setups for a pair of camera stations used in the process of obtaining a dense surface point cloud from that surface (the wavy line):



The lighting of the object and scene should also be considered. Usually it is not desirable to use a flash mounted on the camera because the shadows would move on the object between photos. Other similar light sources (including a bright sun) should not move between photographs. In the case of sunshine and outdoor scenes do not take photos hours or days apart, so that these types of lighting issues are minimized.

Avoid using lighting in the scene that causes glare, reflections or shadows on the surface. The glare/shadows on the surface can cause problems for the matching algorithm since the effects will appear in a different location in each photo and can be mistaken as part of the surface texture. This is especially true of shiny surfaces. Matte surfaces that do not show highlights from directed light sources are less prone to this problem and some side lighting and shadows are acceptable. Generally try to use flat light source such as the light outside on a cloudy day.

DSM Surface Requirements

The surfaces to be modeled by dense point clouds need to have a visible random texture/pattern. Examples of random textures are rock, dirt, skin, wood grain, bricks, trees, etc. Examples of surfaces that are not textured are plaster-board walls, metal surfaces or glass windows. Some items may appear to be textured but the texture is consistently

repeated and not random (certain cloth patterns, man-made objects like a window screen, or a faux-leather pattern).

A surface with no texture (a body panel of a car for example) can still be DSM modeled if a random texture pattern is applied or projected onto it. A random dot pattern (Eos Support can provide a file) put on a 35mm slide or a gobo slide and projected on the surface can give enough texture to extract the surface in 3D. It is important to ensure that the surface and projector are not moving during the photography.

DSM Project Requirements

For successful DSM results the PhotoModeler project needs to be high quality. This means using a properly calibrated camera, and ensuring the project has a low maximum residual (under 1.0 pixels preferably) before proceeding with DSM processing.

The project must be Idealized (which removes all lens distortion from the images and the project) before proceeding. The DSM Dialog will warn if a project has not been Idealized.

The project also needs an 'extents' definition. That is, a definition of the region in the photos to be scanned. There are three options:

1. Most common and the simplest approach is to use *DSM Trims* to define one or more trim regions, where you draw one or more polygonal regions in one or more of the photos. PhotoModeler will restrict the DSM based on the trim region defined (note the trim's properties will dictate whether the inside ("Trim outside boundary"), or outside (i.e. "Cut hole") of the trim boundary will be used in the search process).
2. In some situations you may opt to use the entire image boundary to define the DSM extents. The DSM will cover the area that is common to both photos.
3. In other situations (e.g. weaker projects, or if an initial DSM is too noisy) you may get a better result by defining an approximate Surface in the project to guide the DSM algorithm. This Surface needs to appear on the pairs of photos but can extend off the photos. The DSM will be confined to the approximate boundaries of this surface which allows you to control how much of a surface is modeled. If you want to create a DSM that is larger than the approximate surface, you will need to extend the surface. One way of doing this is to use Surface Draw to define new boundaries outside of the original surface, then use the new Surface Draw boundaries to define a new larger surface. See *DSM Approximate Surfaces*.

DSM needs to know how far to search in the images. This is given to it by the approximating surface and depth range values in the DSM Dialog. The approximating surface can be created automatically during the DSM run (using already solved 3D points in the project) or you can create a Surface and select it before going into the DSM Dialog. If the latter explicit Surface is used it will be the same Surface as the one described in step 3 above for the extents definition. If you are using the automatic/implicit surface then no further project work is required and you can proceed to run the DSM algorithm (by opening the *DSM Options Dialog*).

Creating and Modifying Dense Surface Models

This section outlines the details of the process and user interface of Dense Surface Model creation.

How to Create Dense Surface Models

To create a Dense Surface you will need to set up an appropriate PhotoModeler project, select a defining region of interest, run the DSM algorithm, and then optionally convert the point cloud(s) to a triangulated mesh and a Surface. See *How does DSM Work?* for an overview of the basic steps.

The Appropriate Project for DSM

See *DSM Project Requirements* for the basic requirements for project setup.

A DSM project will begin like a standard PhotoModeler project. This involves importing photos, marking points (perhaps with targets or coded targets for efficiency and accuracy), and processing the project. It is important to ensure the project is high quality and has low residuals. Aim for a maximum point residual of 1.5 pixels - the lower the better. A properly calibrated camera will be important. Fine tune your points and re-process until the project is precise.

Then run Idealize on the project (see *Idealize Project*). DSM will warn you if the project is not Idealized.

Next, define the DSM area of interest using the DSM Trim tool (see *DSM Trims*). The region should encompass the area to be modeled with the dense point cloud. The trims can be on one or both of the photos in a pair. You can also choose to use the entire photograph to define the boundary or you can use an approximate Surface. If you use a Surface it should approximate the real surface but does not need to be very accurate. For example you could use a flat rectangular surface to approximate an ancient stone wall (which is anything but flat). You can use surface draw and attach Path Surfaces to it, or use a NURBS surface, or even a cylinder) (see *DSM Approximate Surfaces*).

Save this project to disk as your starting point (you may wish to return to it as you experiment).

You can now run the DSM process.

Click the Create Dense Surface tool (Dense Surface menu, Create Dense Surface...) to start the process (note if you decided to use a predefined approximate Surface for the DSM extents or depth range, select the Surface first before clicking the Create Dense Surface tool - the Surface can be selected in a Surface Table, a 3D Viewer or on a photo 3D projection).

In the DSM Options Dialog select the pairs of photos to process (we suggest a single pair to start with but you can select one or more pairs or use the *Select Best Photo Pairs Dialog* tool define a set of photo pairs to process, see also *Multiple Photo Projects*), choose an Extents type (from *DSM Trims*, whole photo boundary, or from selected surface(s)), and change any other parameters you need (we suggest leaving the default values to start with), and press Execute.

Open a 3D Viewer and in the 3D Viewer Options Dialog turn on PointMesh display (in Surfaces branch). Turning the surface type to textured will display the point clouds using an individual RGB color extracted from the photo making the cloud appear textured. Study your result and then fine tune with changes in parameters or changes in photo pairs. See the *DSM Troubleshooting* section if you don't get the result you expect.

Multiple Photo Projects

When using a project with more than two photographs some care is needed to pick suitable pairs for processing. In some projects you can let PhotoModeler Scanner process all pairs automatically. This type of project would be one where all photos were parallel to a somewhat flat object and the photos were taken with a regular spacing. An example might be a line of photos taken at a regular interval perpendicular to a wall. PhotoModeler Scanner will discard photo pairs it determines to have no overlap (given the region defined by *DSM Trims* or other extents definition). The processing will create a PointMesh per pair and the meshing steps will register and merge these, then triangulate.

For most projects you will need to manually pick appropriate photo pairs when running the DSM process. Choose the pairs that meet the requirements as described in *DSM Photo Requirements*. These can be run all at once or one at a time. The *Select Best Photo Pairs Dialog* can be used to select one or more photo pairs based on certain criteria.

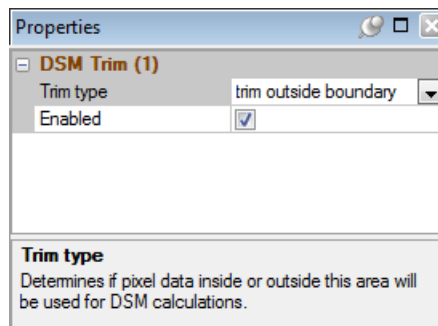
DSM Trims

A DSM Trim is a 2D polygonal region defined on a photo in a DSM project. These trim boundaries restrict the DSM algorithm to search only within (or outside, depending on the trim type property, see below) the outlined areas of the photo(s). This allows you to focus your DSM in a specific area of your photo(s) and can help reduce processing time by reducing the search area, as well as reducing noise and unwanted regions (such as windows in a building).

To define a DSM Trim, first open one or more photos, then click the DSM Trim Mode button on the Dense Surface menu, or on the Dense Surface toolbar. The cursor will change to indicate the mode, and you click on the photo to define each segment of the polygon region. To finish a trim click on the first point in the trim region, or right click to display a popup menu and click 'Finish Trim' to complete the closed boundary (or 'Cancel Trim' to cancel the trim drawing). Once a trim is defined, you can use it to set the extents in the search algorithms. You can define any number of DSM Trims on any number of photos and the DSM search will only take place inside or outside (depending on the trim type property) the trim boundaries.

To use trims in processing the 'Extents from' setting in the *DSM Options Dialog* needs to be 'DSM Trims'.

Once you define a DSM Trim, it can be enabled or disabled individually using the DSM Trim Properties, which can be displayed on the Properties pane or clicking 'Properties' tool on the right-click popup menu while selecting a DSM Trim in Select mode:



Only enabled DSM Trims are used to define the extents when running the DSM algorithm.

The other DSM Trim property is the 'Trim type' setting. The "trim outside boundary" setting will exclude image data outside of the trim boundary, i.e. only pixels inside the trim region will be used, while the "cut hole" setting will exclude image data inside the trim region.

A photo can have more than one trim and they can overlap. The 'union' (in the sense of mathematical sets) of the trims on the photo is used. The insides of the 'trim outside' trim boundaries are unioned and the insides of the 'cut hole' trim boundaries are intersected and removed.

When a pair of photos is processed (searched for matches) either one or both of the photos can have trims. The result is the intersecting set.

To delete a DSM Trim, select the trim on a photo and hit Delete.

As an alternate to DSM Trims, you can define a DSM region of interest using the entire photo boundary or you can create and select an approximate surface (see *DSM Approximate Surfaces*).

Note: When the Extents from DSM Trim option is chosen on the dialog and a pair of photos being processed has no enabled 'trim outside boundary'-type trims then no 3D data will be generated.

DSM Approximate Surfaces

For the DSM calculation to work, an approximate version of the shape needs to be defined to establish a depth range to contain the point cloud. The closer this approximate shape is to the real world shape, the smaller the depth range search can be (and a smaller depth range search lowers the possibility of an incorrect match producing noise data). You can define this approximate surface shape in two ways:

1. Create and select one or more surfaces that roughly match the object (e.g. for a pile of dirt this approximate shape might be a rough pyramid). These surfaces can be path surfaces, NURBS surfaces, surface draw connected surfaces, or even cylinders.

or, a method requiring less manual work:

2. Run DSM without selecting any surfaces. In this case an 'implicit' approximate surface will be created using the existing points in the project. A different implicit surface is created for each photo pair being processed. Only those 3D points that are marked and referenced on both photos of the pair are used and if there are DSM Trims on the photos, only the 3D points that 2D project to be inside the enabled trims will be used. A best fit plane is created from these points and then they are triangulated and extended and trimmed as needed to match the desired extents.

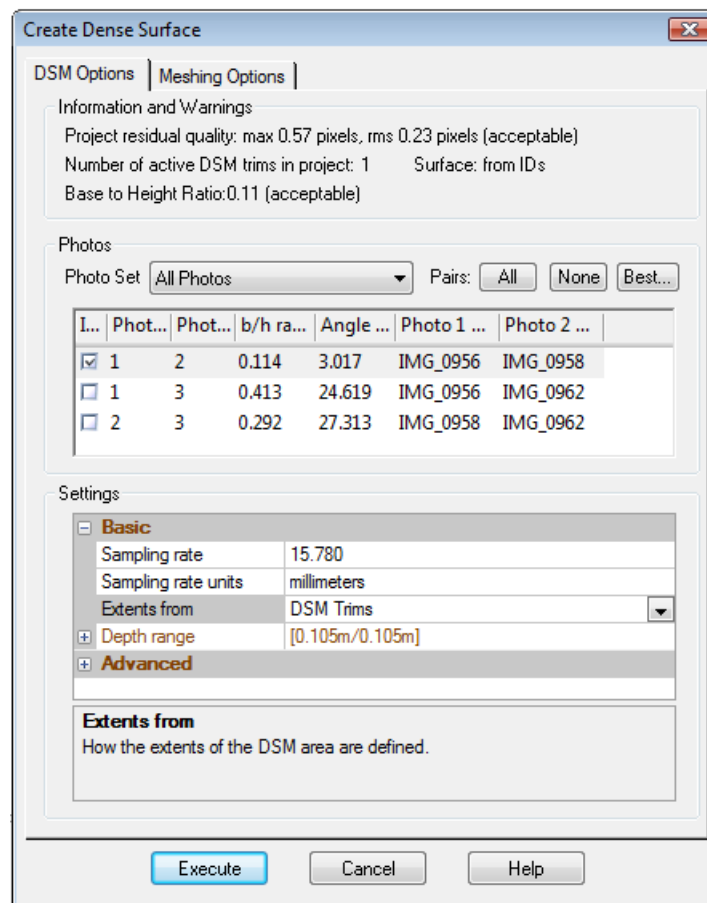
With certain point sets, method 2 may produce a best fit plane that is not suitable and is not perpendicular to the camera plane. In these cases you may need to use method 1, manually creating a suitable approximate shape.

An approximate surface (i.e. a Surface defined in PhotoModeler using any of the surfacing tools) can be used to define the extents of a DSM or it can be used as a 'base' surface to set the depth range.

Note 1: When an approximate surface(s) is selected before opening the *DSM Options Dialog*, the 'selected surface(s) extents' option becomes available in the 'Extents from' setting. If no surface is selected, 'DSM Trims' (if any are defined) or 'whole photo boundary' will only be available.

Note 2: When an approximate surface(s) is selected before opening the *DSM Options Dialog*, the depth range values will be based on the selected surface. If no surface is selected, the depth range will be based on a best plane fit implicitly defined by PhotoModeler based on the 3D points in the project.

DSM Options Dialog



Dense Surface Models are created via the Create Dense Surface Dialog. The first tab that opens in this dialog is the DSM Options. The DSM Dialog is opened with the "Dense Surface / Create Dense Surface..." menu item or toolbar item.

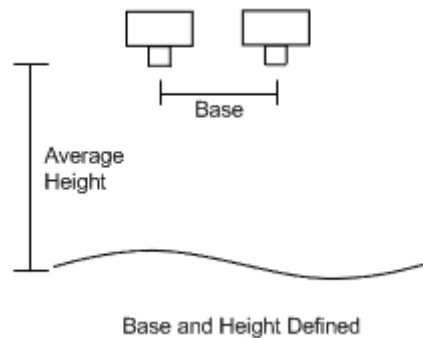
The dialog is composed of two tabs: the DSM Options tab (shown above and described below) and the Meshing Options tab described in the *Meshing Options Dialog* section.

The DSM Options tab displays a prediction of the results quality as well as allowing you to set parameters to control the DSM process. The tab is divided into three sections: the Information and Warnings section, the Photos section and the Settings section.

Information and Warnings Section

This section of the DSM Options Tab provides four pieces of information. The first is the quality of the project in terms of point mark residuals. Both the maximum and RMS residuals are given for the whole project. Beside this is an indication of whether this is acceptable or not for a good DSM result. The process of matching of image regions across images means that the photos have to be oriented to within 1 to 2 pixels. If the maximum residual is too large it will be indicated here. You may proceed with the DSM regardless but you might find the result is too noisy. The result can be so noisy as to be unusable. To get good results ensure the maximum residual is less than 2 pixels and less than 1 pixel is better.

The second piece of information is the range of base-to-height ratios of the selected photo pairs (from Photos section below). It will show the smallest to largest base-to-height ratio and an indication of what this might produce. If only one pair of photos has been chosen below then only one value is displayed. The base-to-height ratio tells us how far apart the cameras were compared to their distance from the surface. The base is the distance between the camera stations and the height is the average distance from camera station to the surface. If this ratio is too small or too large you may not get a good DSM result. A ratio of 0.2 to 1.0 is good.



The number of active DSM Trims (i.e. Trims with their enabled property set) is listed, and the ID numbers of the Surfaces that were selected when the dialog was opened are listed.

Photos Section

This section of the DSM Options tab allows you to select which pairs of photographs are processed for a PointMesh. Each pair produces one PointMesh and then the Meshing steps will combine them into one cohesive whole (if you wish).

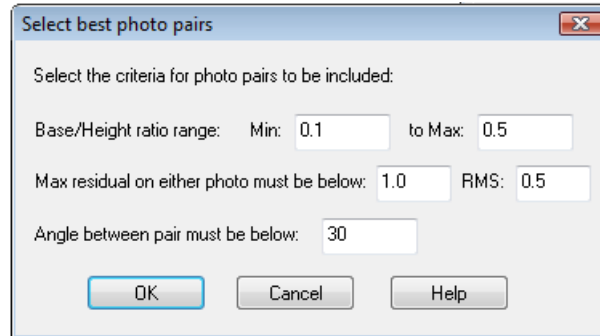
At the top of this section is a selection for *Photo Set*. All photos in the chosen photo set are paired automatically in the grid below. Beside this control are three buttons for selecting all pairs of photos (the default), no pairs of photos or the best pairs of photos as defined in the *Select Best Photo Pairs Dialog*.

The grid shows on each row a pair of photos, the photo numbers, their base-to-height ratio (listed as b/h ratio), the angle between the camera stations, and the two photos' names (to

further help with identification). The grid can be sorted by any column by clicking on the column header.

When starting a new DSM project we suggest picking the strongest single pair of photos first and then processing this pair to see if acceptable results are achieved. Then additional pairs can be added.

Select Best Photo Pairs Dialog



This dialog allows you to select a set of photo pairs based on certain criteria. You can define the minimum and maximum Base/Height ratio range, the maximum residual and RMS, and the maximum angle between photos in the pair.

See the *Information and Warnings Section* for information on appropriate values for these parameters.

When you click OK, all photo pairs meeting these requirements will be selected on the *DSM Options Dialog*.

Settings Section

This section of the DSM Options tab provides for user control over how the DSM process works and the density of the data produced. The most important setting is 'Sampling rate' - which defines how many points are produced and how dense the resulting point cloud is. Often the default value is suitable for a first try but you will usually increase this value to get your desired results. If this value is small, a dense point cloud will be created and the processing will take more time.

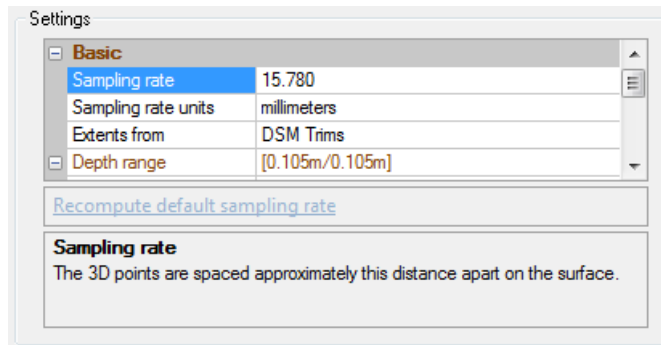
To change a value you click on it and it will highlight. You can then edit it (type new value, move slider or pick a value from drop-down list). The DSM settings are divided into Basic and Advanced Settings. For most projects you will not need to change the Advanced settings but they are available for certain situations - see *Setting Descriptions* below.

When you select a setting, the box at the bottom will display some help text for that parameter. You can drag the window divider above the help text box to change its vertical size. Some of the settings also have a 'verb' which is a hyperlink that when clicked will perform some calculation. The verbs appear above the help and only when a selected setting has an associated verb.

Setting Descriptions

The following lists all the groups and their parameters with a brief description. Note also that the settings used for each PointMesh are stored and shown on the *PointMesh Tables*.

Basic - Settings that usually change with each new project.

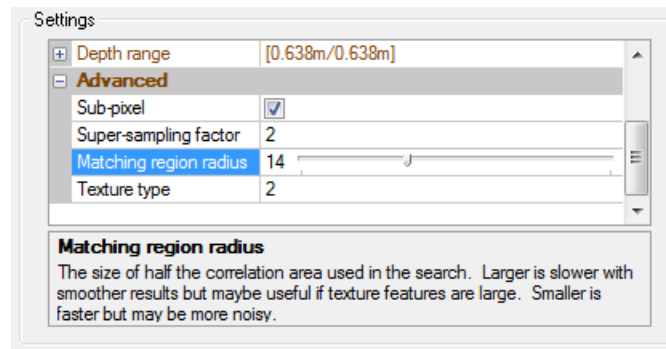


- **Sampling rate** - The 3D points are spaced approximately this distance apart on the surface. Make this number smaller to get more points (points closer together) and make it larger to get fewer points. The smaller the value the longer DSM processing takes. If the project has a scale this value may make more sense. A default value is computed to give a reasonable number of points in reasonable time but you can override and make smaller to get greater density. The 'Recompute default sampling rate' verb displays when the Sampling rate setting is selected to allow you to revert to the default rate after it has been manually edited. The calculation of the default value depends on the "Maximum number of samples in default point cloud" setting in *Preferences - Dense Surface*.
- **Sampling rate units** - The units of the sampling rate number above. This will match the units set on the project, but you can change it if you want to use different units for this setting.
- **Extents from** - The region that is searched for correlation matches. Select one of these options to define the extents of the DSM region of interest. If you have DSM Trim(s) defined and they are enabled, the 'DSM Trims' option is available; if you have surface(s) selected the 'selected surface(s) extents' option is available; while the 'whole photo boundary' is always available. Note that if the extents type is set to 'DSM Trims' and you are executing a multi-photo (3 or more photo) dsm extraction, no 3D data will be generated for a pair of photos that have no enabled 'trim outside boundary' type trims marked on either photo (see *DSM Trims* for a description of trim properties, and *DSM Approximate Surfaces* for a description of how to use surfaces to define extents).
- **Depth range** - The correlation search range. These settings can be important if you see unexpected noise (in an otherwise high quality, low-residual project). In a high quality project, if the range is too small there may be incorrect matches and erroneous 3D points can result. In a weaker project (orientations not as good and residuals not as good) you may find fine tuning the range of searching for matches above and below the starting surfaces can reduce the errors. You will need to define the projects scale for the depth range to match a real-world measurement. If no scale is defined this range is in the same arbitrary scale as the non-scaled project so can be harder to understand. The 'Recompute default depth range' verb displays when the Depth Range setting is selected to allow you to revert to the default setting, which can be useful when experimenting with various values.

- Above surface - The distance above the base surface that a 3D point can be created. Increase this to remove unexpected noise above the surface. See note below. When this selected, the “Recompute default above depth range” verb displays allowing you to recompute just this parameter.
- Below surface - The distance below the base surface that a 3D point can be created. Increase this to remove unexpected noise below the surface. See note below. When this selected, the “Recompute default below depth range” verb displays allowing you to recompute just this parameter.
- Units - The units of the two depth numbers above.

Note: DSM will search for 3D matching points in a range based on a surface and distances above and below that surface. The distance above and below the surface that the algorithm searches can be entered manually or you can have a default value computed. The default value is based on the existing 3D points that are imaged on both photos. Beware if you have a project where all the 3D points are on a plane (e.g. survey targets all on the ground plane under a rock pile). The computed range may be very small or zero. In this case the default values will not be useful and you will need to override the above and below values manually (or place some 3D points on the top of the pile).

Advanced - Advanced settings that may need to change for some projects.



- Sub-pixel - Use to get more accurate surfaces. Slower but usually required.
- Super-sampling factor - A factor used in the subpixel method. The higher the factor, the less wavy artifacts in the resulting surface but the slower the subpixel stage will be. A value of '2' will usually work.
- Matching region radius - The size of the correlation area used in the search. Larger is slower with smoother results but maybe useful if texture features are large. Smaller is faster but may be noisier. The default radius is based on the resolution of the image. In some projects if the texture 'elements' are large, you may need to pick a larger radius. Higher resolution cameras may require larger window sizes also.
- Texture type - 1 means the source images have random non-repeating texture. 10 means source images have a repeating texture. Use higher number to reduce noise in repeating texture images. A lower number produces a denser (but sometimes noisier) result. If you have a project with low noise but a large number of 'missed' points, lower this value to fill in the gaps.

Meshing Tools

The DSM process creates an object called a PointMesh. A PointMesh is a set of 3D points with optional triangles connecting them. A PointMesh can be just a cloud of 3D points or it can be a full mesh/triangulated surface. The PointMesh created by the DSM process is a point cloud and to convert it to a useful surface, some meshing tools need to be run. The meshing tools can be run as a second step after the DSM runs or they can be accessed independently. By default, the meshing tools are not run automatically after the point cloud is created. You can set whether the meshing tools run on *Preferences - Dense Surface*.

Besides converting point clouds to meshes, the meshing tools will also fill holes, smooth the data etc.. In addition there are tools for editing/deleting individual points, for flipping the normals, and for loading and saving meshes from/to disk.

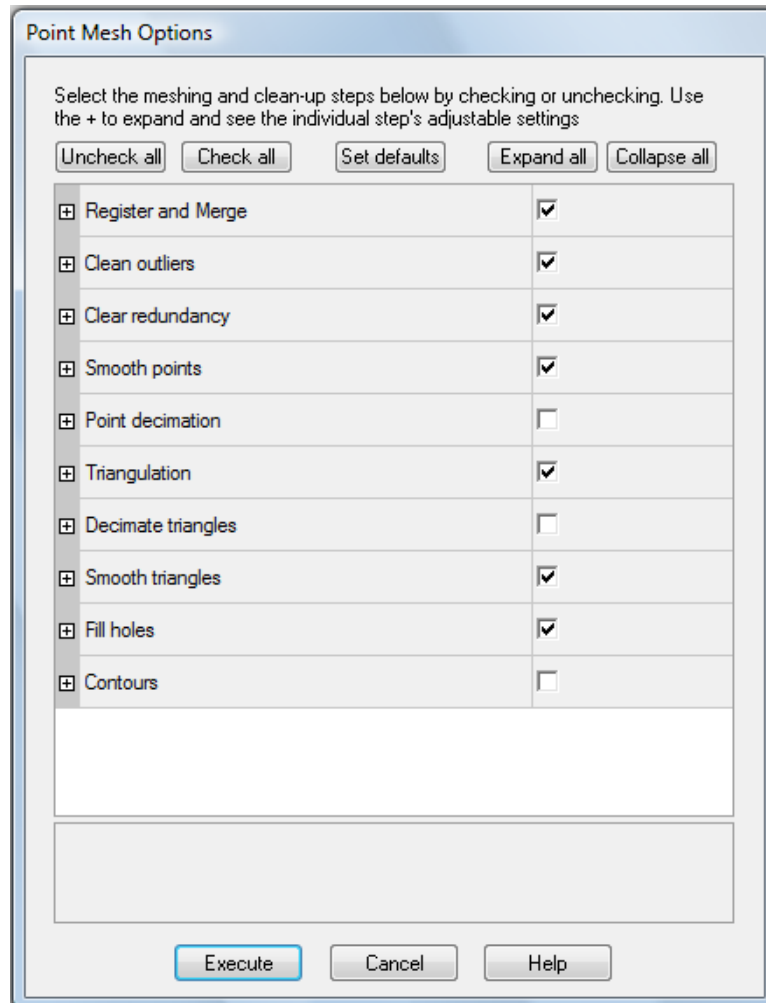
Modify PointMesh

An important step, after DSM creates one or more 3D point clouds, is to convert that cloud of points into a high quality triangulated mesh. This is taken care of by the Meshing Tools. These tools are available for automatic execution after DSM runs or as a separate process. The Meshing Options Dialog controls the actions that will be carried out.

To run the Meshing tools as an independent set of steps use the menu item: "Dense Surface / Modify PointMesh...". This will bring up the *Meshing Options Dialog*.

You may find that for certain projects you will run the DSM process a few times without any meshing steps. You can then later take one or more of the resulting PointMeshes (which will be just point clouds), select them and run the Meshing tools to register, denoise, mesh and smooth.

Meshing Options Dialog



The Meshing Options appear as the second tab of the *DSM Options Dialog* as well as the only tab in the Meshing Tools Dialog when opened by the menu item: "Dense Surface / Modify PointMesh...".

The Meshing tools are a set of steps that are run in a particular order. Shown above, the steps are run from top to bottom. The individual steps can be turned off by unchecking the check box to the right of each step.

When the Meshing tools are run as a second stage to DSM, all the point clouds produced by that DSM operation are acted upon by the Meshing tools. For the independent Meshing tools (when brought from menu/toolbar), one would select one or more PointMeshes first (from Table or 3D Viewer) and then select the tool/menu item.

If you select more than one mesh and open this dialog, you would run the "Register & Merge" step that registers and merges the meshes into one mesh for the latter operations.

If you select more than one PointMesh and do not do the registration/merge step then only the first PointMesh is operated on.

An example of using the Meshing tools independently might be to reduce the number of triangles in a PointMesh and remesh it to further improve the result. You would select a triangulated PointMesh, select the “Modify PointMesh” tool or menu item, press the “Uncheck all” button to clear all steps, check the boxes beside the “Decimate Triangles” and “Remesh” steps and perhaps change parameter settings, then press the Execute button. A new PointMesh will result and the original PointMesh remains in the project unaltered.

Note: when executing the Meshing Tools a new PointMesh object is created. You can delete the input PointMeshes or hide them in their own layer.

Meshing Steps and Settings

The steps available with the Meshing tools are shown below with their individual parameters described.

This figure shows the parameters for Smooth points and Point decimation. To access the settings you press the “+” button to the left of the step name. You can then change the setting by selecting the value on the right and either enter a new numeric value, use the slider, or use the drop down list as appropriate.

<input type="checkbox"/> Smooth points	<input checked="" type="checkbox"/>
Smoothing amount	20
Iterations	10
<input type="checkbox"/> Point decimation	<input checked="" type="checkbox"/>
Percent	16

In addition when a step or setting is selected some help text will appear in the box at the bottom. The vertical size of the box can be changed by dragging the separator line between it and the setting/step box, for example:

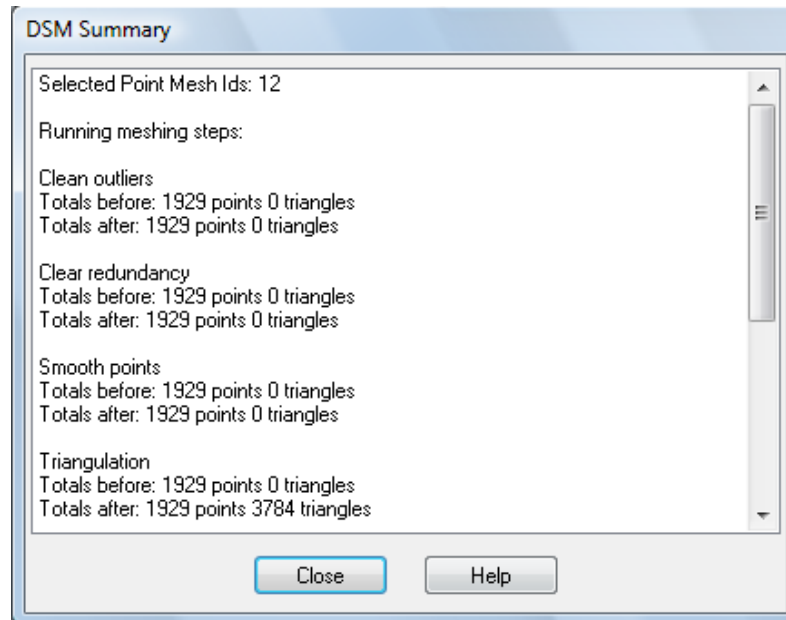
<input type="checkbox"/> Smooth triangles	<input checked="" type="checkbox"/>
Preserve boundary	<input checked="" type="checkbox"/>
Smoothing amount	20
Number of iterations	10
Smoothing amount The amount of adjustment that will be done during smoothing. The larger the value, the smoother the result.	

The following summarizes the meshing steps and their parameters. Generally the default values for the parameters should produce good results, but some experimentation with parameters may be required for certain projects. You can use the ‘Set Defaults’ button at the top of the dialog to reset any adjustments made.

1. Register and Merge - Register and merge two or more PointMeshes in point cloud form. Improve line-up, reduce data in the overlap areas and then produce one combined PointMesh.

- i. Merge Only – In certain cases (e.g. point clouds with noise), the registration step can result in mismatches and a distorted point cloud. If this is checked the registration step can be skipped and point cloud data is only merged.
2. Clean Outliers – Removes points and small point clusters from the mesh that are separated from the main mesh and a probably noise.
 - i. Minimum cluster distance – Minimum distance that defines an isolated cluster. The average distance between points in the mesh multiplied by this value.
 - ii. Maximum cluster size – The maximum number of points in a cluster that will be removed. The total number of points in the mesh multiplied by this value.
3. Clear redundancy – Remove duplicate points that are close to each other within the mesh.
 - i. Minimum distance – Points within this distance of each other are considered redundant and will be removed. The average distance between points in the mesh multiplied by this value.
4. Smooth points – Adjust the points in the mesh to remove small bumps and imperfections.
 - i. Smoothing amount – The amount of adjustment that will be done during smoothing. The larger the value the smoother the result
 - ii. Iterations – The number of times smoothing will be performed. The larger the value, the smoother the result.
5. Point decimation – Reduce the number of points while retaining the shape of the point cloud.
 - i. Percent – The percentage of points to be removed.
6. Triangulation – Triangulate a point cloud to form a surface.
 - i. High noise mesh – If the mesh being triangulated has a high level of noise use this flag to produce a smoother more consistent triangle set.
7. Smooth triangles – Adjust the triangles in the mesh to remove small bumps and imperfections.
 - i. Preserve boundary – If checked do not adjust the shape of the mesh's outer edge.
 - ii. Smoothing amount – The amount of adjustment that will be done during the smoothing. The larger the value the smoother the result.
 - iii. Number of iterations – The number of times smoothing will be performed. The larger the value the smoother the result
8. Fill holes – Fill enclosed areas that were not triangulated due to missing point data.
 - i. Maximum hole size – Maximum size of hole to fill. The average distance between vertices in the mesh is multiplied by this value.
9. Contours - Creates contour lines at regular intervals on the surface.
 - i. Spacing - the distance between contours in the direction of the axis. This value is in project units.
 - ii. Axis - which of the three coordinate axes to step along. Note that a Project Rotation (see *Adding Scale and Rotation*) should be set up before running this step to get best results. For example if you wanted height contours (as we are used to seeing on topographic maps) you would set up a project rotation such that the X,Y plane was the ground plane and Z was 'up'. Pick the 'Z axis' option here and the height spacing required in the Spacing parameter above.

DSM Summary Dialog



The DSM Summary dialog displays a progress report while the DSM is being created. The report shows the various stages that ran and the results, such as the number of points created in the point cloud, the number of triangles created in the point mesh etc. The dialog provides a good way to review the results of the DSM modeling process.

Edit/Delete/Measure Points in a PointMesh

You will sometimes need to delete points from a PointMesh before meshing or export. These can be unwanted edge points on a background surface, or error points due to problems with camera orientation or weak texture.

To delete one or more points from a PointMesh, first open a 3D Viewer window with PointMeshes displayed and then enter 'PointMesh Edit Mode'. Use menu item "Dense Surface / PointMesh Edit Mode".

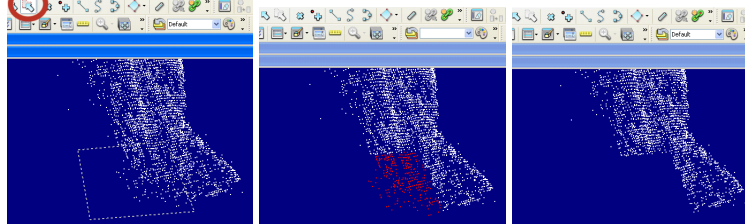
While in PointMesh Edit Mode you can click on points in a PointMesh and they will highlight. You can hold the shift key to select multiple points. Once the points are selected you can press the Delete key on the keyboard to delete the points.

Note: You can open the Measurements pane (see *Measuring Features*) and measurements (such as point to point distance and xyz coordinates) will be shown for selected PointMesh points while in PointMesh Edit Mode.

If more than one PointMesh is displayed, all points in all meshes under the mouse click location will be selected. If you want to edit one mesh only, hide the other meshes using layers and layer visibility.

You can use Region Select sub-mode as well (see *Region Selection*). While in PointMesh Edit Mode, press the Region Select tool, outline a region in the 3D Viewer that contains the

points you want to delete, right click to end the Region Select sub-mode, and then press the Delete key to delete the selected points. The following three screen shots depict these steps: a) PointMesh Edit Mode with Region Select Sub-Mode (circled tool) and 3 vertices of polygon clicked, b) after the region is selected (right click at 4th vertex location) the points of the mesh are highlighted in red and 'selected', and c) lastly the mesh after the Delete key was pressed.



Split PointMesh

Some or all of a PointMesh's point cloud or its triangles can be 'split off' and placed in a new PointMesh. While in PointMesh Edit mode, select points or triangles (shift select or use the temporary region select), then click the Split PointMesh tool on the toolbar.



The selected points and triangles will be cut and placed into a new pointMesh(es).

If you select points from multiple PointMeshes the selected points will be placed together into a single new pointmesh.

If you select triangles while also selecting points from separate PointMeshes, the selected triangles will be cut and put into a new PointMesh and the points will be put into a separate PointMesh.

Flip a PointMesh

Sometimes after DSM processing and meshing, the PointMesh surface will be facing the wrong way. That is, the object or surface will appear dark in the 3D Viewer when looking at the correct side and bright when looking at the incorrect side.

To flip all the normals so the surface faces the correct direction, first select the PointMesh in the 3D Viewer or Table, and then pick the Flip PointMesh tool or use the menu item "Dense Surface / Flip PointMesh".

Convert a PointMesh to a Surface

A PointMesh is not a sub-type of PhotoModeler Surface. Some operations (such as advanced texturing, export as a surface) require a PhotoModeler Surface. A manual step is needed to convert PointMeshes to PhotoModeler Surfaces. We recommend that you reduce the number of triangles as much as possible (while still maintaining your desired shape and accuracy) using the triangle decimation option of the *Meshing Options Dialog* before doing the conversion because Surfaces in PhotoModeler are more 'heavy weight' and take more resources than PointMeshes. To convert, select the PointMesh (in the PointMesh Table or 3D Viewer) and use the menu item "Dense Surface / Convert".

PointMesh to Surface". The original PointMesh will remain. The new Surface is tied to the PointMesh as can be seen in the Surface ID column of the *PointMesh Table*.

Load / Save PointMesh

PointMeshes can also be loaded off disk in a number of formats. Use the "Dense Surface / Load PointMesh ..." menu item. The loadable mesh formats are:

- ASC/TXT (a space-separated, one per line, x y z point-only ASCII raw format)
- DAT (the format PhotoModeler uses to store PointMeshes)
- OBJ (Wavefront OBJ - only triangles in the file are loaded)
- PLY (PoLYgon - Stanford Triangle Format)
- BYU ("Brigham Young University" 3D geometric surface shape format. A standard format specified in the 70s but still used in a number of CAD systems.)

Once a PointMesh has been loaded, any of the Meshing Tool commands can be run on it. See an example below.

PointMeshes can be saved directly to disk (compare this with converting to a Surface and exporting with the rest of the PhotoModeler project data). Use the "Dense Surface / Save PointMesh ..." menu item to save the currently selected point mesh (e.g. select from PointMesh Table, 3D Viewer) to disk.

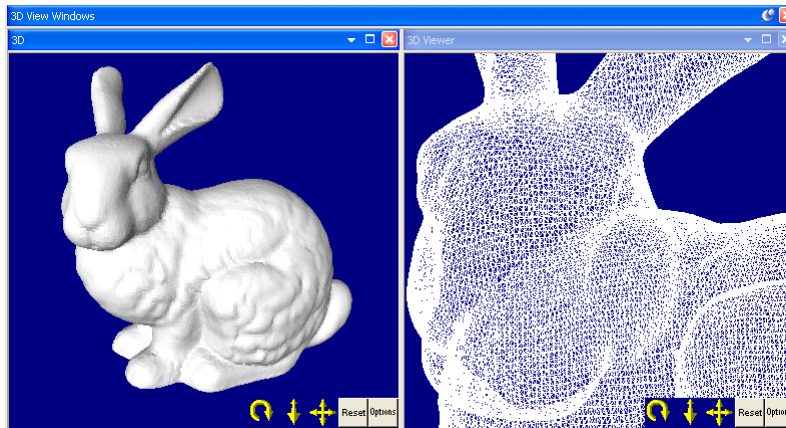
When you save a PointMesh, the "Save as type:" drop down selector on the File Export name dialog will show the formats that are supported, along with information about the type of data that will be saved (eg poly, points).

The formats that can be saved are:

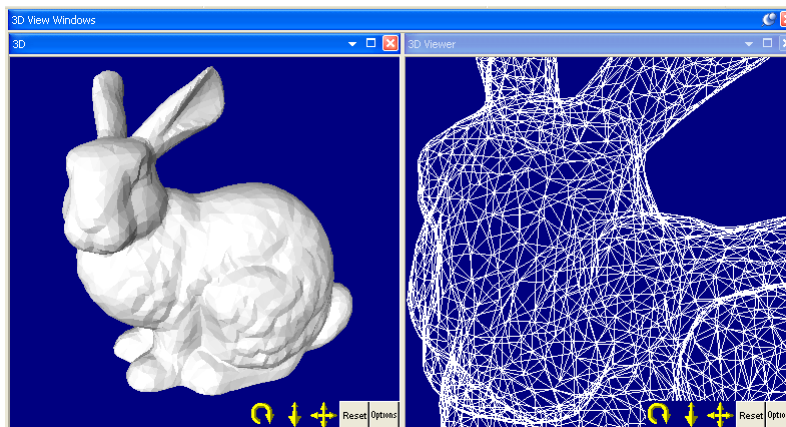
- STL (STereo Lithography format - a common industrial format for triangle meshes - esp. in rapid prototyping machines, poly data saved)
- PLY (PoLYgon - Stanford Triangle Format, poly data saved)
- ASC/TXT (x y z coordinates with RGB values (see *Preferences - Dense Surface* for option whether to include RGB values in the report) ASCII raw format, points / RGB data saved)
- BYU ("Brigham Young University" 3D geometric surface shape format. A standard format specified in the 70s but still used in a number of CAD systems, poly data saved)
- IV (Inventor format – points and triangles are saved)
- FACET - a simple ASCII 'raw' format (the ASC/TXT 'raw' format handles poly data only)

Load / Modify Example

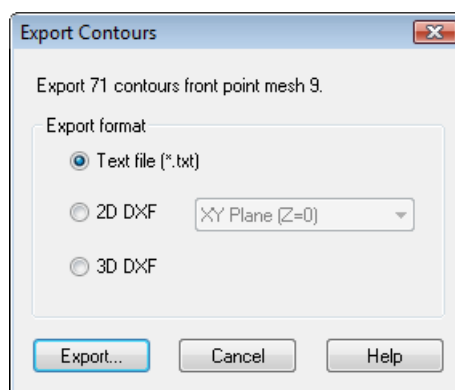
Here is an example of using the Load PointMesh and Modify PointMesh tools of PhotoModeler Scanner. Below we have loaded the famous Stanford Bunny model in .ply format. This model was not created by PhotoModeler Scanner. The model has 69,000 triangles:



We then performed a Triangle Decimation step from the Meshing Tools with 90% decimation. The result is this bunny PointMesh with only 6,900 triangles:



Export Contours

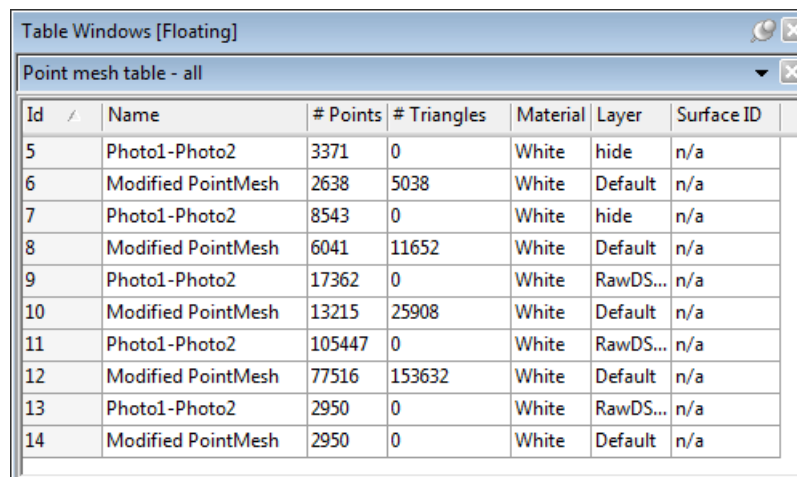


The Export Contours dialog allows you to export the contours of the selected point mesh in one of three formats:

- Text file: Format of the text file is as follows, where the Header shows the PointMesh number and the number of contours, followed by contour number, its height along the shown axis, and the XYZ coordinates of the points that form the poly line:
 - Point Mesh 15
 - 5 contours
 - Contour #1
 - Height: 0.000mm Axis: Z
 - 50.684, 39.176, 0.000
 - 49.611, 39.747, 0.000
 - 48.932, 39.990, 0.000
 - 47.904, 40.858, 0.000
 - ...
 - Contour #2
 - Height: 5.000mm Axis: Z
 - 44.703, 28.596, 5.000
 - 44.129, 28.842, 5.000
 - 43.081, 29.476, 5.000
 - 42.601, 29.438, 5.000
 - ...
 - Etc.
- 2D DXF: Select which plane to export in the 2D DXF format.
- 3D DXF: Export the contours in the 3D DXF format.

Note: In order to export contours, the selected point mesh must be triangulated/meshed with contours generated, as set in the *Meshing Options Dialog*.

PointMesh Table



Id	Name	# Points	# Triangles	Material	Layer	Surface ID
5	Photo1-Photo2	3371	0	White	hide	n/a
6	Modified PointMesh	2638	5038	White	Default	n/a
7	Photo1-Photo2	8543	0	White	hide	n/a
8	Modified PointMesh	6041	11652	White	Default	n/a
9	Photo1-Photo2	17362	0	White	RawDS...	n/a
10	Modified PointMesh	13215	25908	White	Default	n/a
11	Photo1-Photo2	105447	0	White	RawDS...	n/a
12	Modified PointMesh	77516	153632	White	Default	n/a
13	Photo1-Photo2	2950	0	White	RawDS...	n/a
14	Modified PointMesh	2950	0	White	Default	n/a

The PointMesh Table can be displayed using the Generate Table tool. The table lists all the PointMeshes in the project. For each row it lists the name of the PointMesh, the number of points, the number of triangles, the PointMesh's material and layer, and the ID of the associated Surface if it has been converted to a Surface (see [Convert a PointMesh to a Surface](#)). Note that PointMeshes created directly by DSM are named PhotoA-PhotoB to denote the two photos from the project used to create the point cloud. PointMeshes created by the Meshing Tools are named "Modified PointMesh".

You can view PointMesh properties on the Properties pane (or Properties dialog) when a point mesh is selected. See [PointMesh Properties](#).

PointMesh Display

A PointMesh (i.e. a raw point cloud or the triangulated mesh) can be seen in 3D in a 3D Viewer. A PointMesh's properties can be seen in a [PointMesh Table](#). Once a PointMesh is converted to a PhotoModeler Surface, it can also be projected onto photos, as with any other surface.

When a 3D Viewer is set to display textures the points of point meshes created during pairwise DSM will display using an RGB value extracted from the photo giving the point cloud a textured appearance. This gives you an impression of how well the surface solved and can help when cleaning up stray point mesh points.

A similar property is in place for a triangulated point meshes which will texture the triangulated mesh using the photo assigned to the meshes "texture photo" property. This allows you to view the point mesh result photo textured without the need to convert to a PhotoModeler Surface, however the texture comes directly from the single photo so does not include any perspective correction, occlusion checking, multiple source photos and other features available when texturing a Surface using a material.

How PointMeshes and Surfaces are Stored

Most PhotoModeler data (except for the images themselves) is stored on disk in the .pmr file. PointMeshes can have a very large number of points and triangles and if stored in the pmr file would 'bog' it down and would slow down the loading of projects. For this reason, PointMesh data is instead stored independently in .dat files. You will see the .dat files in the same folder as the .pmr project and with the same starting file name. Each PointMesh is stored in its own file. If you wish to save a Dense Surface Model project or sent it to someone you will need to send not only the pmr file but all dat files with the same file name prefix. If the .dat files are missing the project can still be loaded but the PointMeshes will not appear in the 3D Viewer and cannot be operated on by any of the Meshing Tools. They still appear in the PointMesh Table though.

DSM Troubleshooting

There are five typical problematic results after running DSM:

1. there are too few (or no) 3D points in the resulting cloud.
2. there is a lot of noisy data - 3D points in the wrong place forming a cloud.
3. there are noisy 3D points along the edge of the meshes.
4. there are bumps on the surface where not expected.
5. low-angle photo projects are difficult to process.

Too few 3D points produced

This problem result is a PointMesh with just a few points or no points at all. The result is not the dense grid of points expected. This can result when:

There were not enough sample points in the region.

solution: Decrease the sample size in the DSM Basic settings.

There was no overlap in the photo pairs chosen.

solution: Review the orientation and overlap of the photos to see if they image the same part of the surface. Also review the *DSM Trims* or the selected surface(s) to see if visible in the chosen pairs of photos. You can use the 3D Surface Photo Visibility as one way of doing this for surfaces. Defined trims are always visible on photos. Ensure that the chosen pairs of photos have the trim(s) or selected surface(s) appearing on both photographs.

Also note that if the extents type is set to 'DSM Trims' and you are executing a multi-photo (3 or more photo) dsm extraction, no 3D data will be generated for a pair of photos that have no enabled 'trim outside boundary' type trims marked on either photo (see *DSM Trims* for a description of trim properties, and *DSM Approximate Surfaces* for a description of how to use surfaces to define extents).

The depth range setting is too small and does not match the reality of the distance of the real surface from the approximating surface.

solution: Under the Basic DSM settings there is Depth Range - PhotoModeler sets a default range but it is a guess based on either the 3D points in the project or the selected surface. If the range is too small no good matches will be found within the search distance or bad matches will be found. The stronger the project (lower residuals, non-moving object/cameras, and strong random texture) the larger this range can be and you will still get good results. In a strong project the range can be far larger than it needs to be and good results can still be obtained. Shrinking the range is needed for projects that are not as strong.

The texture of the surface is man-made and consistency repeating (so it is hard to tell which is the correct match).

solution: A repeating texture may give too much choice for matching. Shrinking the depth range may assist. Alternatively decreasing the texture type value to 1 (in DSM Advanced Settings) may increase noise in this case but may give more useful data as well.

The surface is flat or has no random texture.

solution: Perhaps the surface can be photographed with different lighting or with a higher resolution camera to improve texture capture. If it is truly a textureless surface, perhaps a random pattern can be projected or painted on before photography.

The approximating surface is too far away from the true surface.

solution: For the search range to be reasonable the approximating base surface (i.e. defined implicitly by the 3D points in the project, or by a selected surface) needs to be close to the real surface. Some projects will work with the base surface not being exact but it depends on the randomness and how visible the texture is. Make sure the approximating surface is closer to the real surface.

The object moved between photographs.

solution: The object needs to be very steady between photos of the pairs being processed. It should be completely stationary or move less than 2 pixels. If you are modeling an object you know will move then multiple synchronized cameras must be used.

The correlation window is too small compared to natural feature size.

solution: The default search window is 11 by 11 pixels. Look in your images and outline an 11 by 11 region. Does it seem small compared to the elements of the texture? A quick test also is to rerun one of the photo pairs increasing the window size (under DSM Advanced Settings) to see if more data is created.

The texture type is set to too high a value.

solution: The higher the texture type value (under DSM Advanced Settings) the less data will be produced. You use a higher value to trade off noise vs density in surfaces that have textures that are not that globally random (i.e. image patches are good matches for multiple patches in the other image).

A large noise cloud is the only result

This problem result is a PointMesh looks like a cloud of noise and not a surface.

This can result when:

Orientation for that pair is not good enough (residuals too big). Note the lower the base-to-height ratio the better the orientation needs to be.

solution: Strive for a maximum residual under 2 pixels. If the photos being used have a very small base-to-height ratio (less than 0.1) then strive for less than 1.0 pixel maximum residual. Study your points carefully and adjust or retake photos using targets for the orientation points.

The depth range setting is too small and does not match the reality of the distance of the real surface from the approximating starting Surface.

solution: Under the Basic DSM settings there is Depth Range. The program sets a default range but it is a guess based on either the 3D points in the project or the selected surface. If the range is too small no good matches will be found within the search distance or bad matches will be found. The stronger the project (lower residuals, non-moving object/cameras, and strong random texture) the larger this range can be and you will still get good results. In a strong project the range can be far larger than it needs to be and good results can still be obtained. Shrinking the range is needed for projects that are not as strong.

Base-to-height ratio is too large for one or more photo pairs.

solution: As the camera positions get too far apart (and usually angled more to get the same part of the object imaged in the pair) the surface starts to look too different in the images. The matching cannot be done successfully with too large a difference. Choose pairs of photos with base-to-height ratios under 1.0 (under 0.5 better). A base-to-height ratio down to 0.05 can be processed but only for very strong high-quality projects.

The sampling density is too low.

solution: In some circumstances when the sampling density is too low the optimization algorithm picks the wrong matches for the image samples. The number of potential matches per row needs to be increased so there is a greater probability that the correct match (and hence the correct final 3D point) is chosen. In the DSM Options dialog try

making the Sampling Density value smaller (try a factor of 2 to 10 smaller at first). The DSM processing will take longer and the number of points returned will be higher but the amount of noise may decrease. If the resulting density of points is too high for your application you can use the Modify Mesh tools to decimate the cloud.

The approximating base surface is too far away from the true surface.

solution: For the search range to be reasonable the approximating base surface (i.e. defined implicitly by the 3D points in the project, or by a selected surface) needs to be close to the real surface. Some projects will work with the base surface not being exact but it depends on the randomness and how visible the texture is. If you are not seeing any data or very little this is an important item to check. Make sure the base surface is closer to the real surface.

The object moved between photographs.

solution: The object needs to be very steady between photo pairs being processed. It should be completely stationary or move less than 2 pixels. If you are modeling an object you know will move then multiple synchronized cameras must be used.

A flash was used or some lighting source moved between photographs causing shadows and textures to change.

solution: If you can see shadows (large or small) move between photographs then this will cause mismatches and noise. Do not use a flash mounted to the camera if the camera is moving. Light sources that do not move between photographs are best. Some Lambertian smooth surfaces can be modeled with a small amount of light source movement.

Some noise points surround the edges of the cloud

This problem result is a PointMesh that for the most part looks correct but there are points in the wrong place around one or more outside edges.

This results when background pixels that are not on the desired object are depth extracted. To fix you can improve the shape of the DSM Trim boundary, or the approximating starting Surface to better match the object's shape or you can delete the edge points before further processing (like registration or meshing). See [Edit/Delete/Measure Points in a PointMesh](#).

Some bumps and noise on the resulting surface

This problem result is a PointMesh that has the basic correct shape but has bumps that are not part of the true surface. These bumps are often regularly spaced. This is due to small mismatches and it happens more as the surface becomes less textured and/or as the orientation degrades (esp. for low base-to-height ratio pairs). The bumpiness also tends to get worse as the sampling rate gets smaller. Pick a larger sampling rate to see if you can balance the density required with the bumpiness of the result. Alternatively pick photo pairs with larger base-to-height ratios and/or decrease the project's maximum residual and reprocess.

Low-angle photo projects are difficult to process

This problem is not directly related to DSM-creation as it can apply to any PhotoModeler project. The problem of processing a project with many low-angle photos applies to non-DSM projects as well but happens more often with DSM work.

In DSM projects you often have one or more pairs of photos that have low angles. These pairs are suited to the stereo-processing done by DSM but can cause trouble with camera station orientation when the project is first being set up.

There are a few ways of handling this. The first is to combine enough high-angle (25 degrees and larger separation) photos in the project so the low angle pairs can orient against them. You would not use the high-angle photos for DSM work but they do help with orientation of the project. Also you may wish to do a field calibration (to improve camera parameters) and the high-angle photos (along with rolled photos) help with that.

The second method involves changing some of PhotoModeler defaults. You will decrease some of the angle thresholds to allow lower angle photography to be used. In Preferences (Options / Preferences... menu item) in the Audit branch change these two values to zero: 'Angle maximum (deg.) - Bad', and 'Angle maximum (deg.) - Weak'. You may also wish to uncheck 'Perform Angle Checks' under the Preferences Orientation branch.

The third method is to use control points. You import control points from an external source (a survey or a high accuracy PhotoModeler project done with other photos), mark them on the low angle photo pairs and then process (see *Working with Imports and Constraints*). Note some of the Preferences setting changes for angle thresholds, as described in method 2, may still be required when using control points. The control points will give you stronger orientations and may improve project quality in some circumstances.

PMV PhotoModeler Video

PhotoModeler Video (PMV) adds the time dimension to PhotoModeler. PMV accepts video data or sequences of frames from a camera and has the ability to track targets over time.

PMV is an add-on module. For information on installing the PMV module see the *Modules and Licenses* section.

There are two types of PMV projects: A Type 1 project is for static (non-moving) cameras, and a Type 2 project is for one or more moving cameras with some static (non-moving) points.

PMV's primary purpose is the modeling and measuring of shape and position change of targeted objects over time. PMV deals with 'epochs'. An epoch is one instant in time when two or more synchronized image frames have been captured (type 1) or when the moving points in the project are temporarily stationary (type 2).

The basic concept behind PMV is to first set up a standard PhotoModeler project in the first epoch (using marking, automatic target marking, referencing and automatic referencing, and processing) and then to use tracking to follow the targets across epochs thereby giving the 3D position of the targets in each epoch.

The results can be exported in an epoch table for analysis by external programs and can be animated in the 3D Viewer.

Each epoch is essentially a separate PhotoModeler project but when PhotoModeler is in PMV mode it knows the relationship of these projects. There are some other differences too as described below.

Operations carried out in most epochs can be automatically transferred to other epochs (for instance deleting a point so you do not have to change to each epoch and delete it there too).

In a type 2 project, the object is recorded using two or more images (can be from one camera) in its starting state. Four or more static points which do not move throughout the entire project must be present and have sufficient data to compute their 3D position. Once appropriate images have been captured in the starting state the object or scene can be altered (except for the static points) and recaptured using two or more images from the same or different locations as the previous epoch. These stages are repeated as needed.

See *The PMV Procedure - Type 1* section for guidelines on how to use PMV with static cameras.

See *The PMV Procedure - Type 2* section for guidelines on how to use PMV with a moving camera and static points.

See *The PMV Images* section for the image requirements.

See *The PMV User Interface* for details on how to access and use various PMV functions.

The PMV Procedure - Type 1

The basic steps in a PMV Type 1 project are:

1. Targeting your moving object (with stick on target dots or projected target dots) (targets can be coded),
2. Setting up your two or more stationary synchronized video cameras,
3. Capturing the video frames needed for your analysis and modeling (see The PMV Images),
4. Starting a PMV Project in PhotoModeler using the wizard (see Project Wizard: Welcome (PMV)),
5. Perform point marking (automatic if possible), referencing (a combination of manual and automatic), and processing in the first epoch.

Note: for greatest efficiency try to do as much set up work and modeling in the first epoch as possible before switching to the next epoch or performing tracking. Once the project is in a mode where propagation is needed, things proceed more slowly. This means get all your photographs marked, referenced, oriented and processed before doing any multi-epoch work.

6. Once the first epoch is set up and you can see all your targets in the 3D viewer, tracking (see PMV Tracking Dialog), or moving to the next epoch can begin (see Switching between epochs).
7. After tracking has been completed to your satisfaction, you can play back the result using the PMV Auto Advance Dialog, or write out multi-epoch 2D and 3D data using the PMV Epoch Report Dialog.

The PMV Procedure - Type 2

The basic steps in a PMV Type 2 project are:

1. Targeting your moving object and four or more static points (with stick on target dots or projected target dots). The points can be coded or non-coded targets or manually marked points. PMV Type 2 projects are considerably easier to do and more efficient if coded targets are used for the static points.
2. Taking two or more photos of the object and static points as you would with a regular PhotoModeler project.
3. Have the object move or change shape to its next un-changing position and shape. Note: any non-coded targets of the object should not move excessively between epochs or they may not track successfully. Coded targets on the object can move considerably as they are tracked by their code rings and not by how they move. The static points should not move at all.
4. Repeating steps 2 and 3 as needed.
5. Starting a PMV Type 2 project in PhotoModeler using the wizard (see *Project Wizard: Welcome (Type 2 PMV Project)*)
6. Performing point marking (automatic if possible), referencing (a combination of manual and automatic), and processing in the first epoch.

The next steps depend on whether coded targets were used for the static points or not. If coded targets were used, the steps are:

1. Identifying four or more static points in the first epoch that are also coded target points. See the *Static Points Dialog*.
2. Tracking with coded target search turned on. The *PMV Tracking Dialog* is used with the “Run coded target auto-marking before tracking each epoch” box checked. If each epoch is to be automatically processed after tracking and coded target marking, use the “Process each epoch after coded target marking” checkbox in the *Track Coded Target Settings* dialog.
3. When the tracking is complete and processing of every epoch was successful, the project should be complete and ready for analysis. If processing was not carried out during the tracking, then run processing on each epoch to ensure all static points have computed 3D positions. Once the static points all have computed 3D positions, all epochs will be in a consistent coordinate system.
4. After tracking has been completed to your satisfaction, you can play back the results using the *PMV Auto Advance Dialog*, export the 3D data as an AVI, or write out multi-epoch 2D and 3D data using the *PMV Epoch Report Dialog*.

If coded targets have not been used for the static points a more manual method is used to ensure the static points match across epochs. These steps are:

1. Identifying four or more static points in the first epoch. See the *Static Points Dialog*.
2. Assigning unique user names to the static points in the first epoch. See *Object Point Properties* Dialog.
3. Marking and referencing sufficient points to orient the camera stations in all the remaining epochs (e.g. epoch 2, 3, 4, etc.).
4. Marking and referencing the static points (if they aren't already) in the remaining epochs.
5. Processing each epoch so the camera station locations are computed along with referenced points.
6. Assigning the same user names to the static points in the remaining epochs. When tracking is run, these points will be name matched and the static points will be used to ensure a common coordinate system.
7. Running tracking (see the *PMV Tracking Dialog*), this will match up the commonly named points and assign them the same point IDs across all epochs, the static points will then be used to bring the epochs into a common coordinate system; the remaining marks from the first epoch will then be tracked to the remaining epochs.
8. After tracking has been completed to your satisfaction, you can play back the results using the *PMV Auto Advance Dialog*, export the 3D data as an AVI, or write out multi-epoch 2D and 3D data using the *PMV Epoch Report Dialog*.

The PMV Images

PMV requires a sequence of frames from one or more cameras. As with a regular PhotoModeler project these cameras should be positioned to provide good angles (as close to 90 degrees as possible) and must not change their internal parameters (e.g. focal length due to zoom). Each camera can have its own calibration so they do not have to be the same camera type or have the same settings. It is recommended that you calibrate each camera before using them with PMV.

The image sequences that are loaded into PMV can be in one of three forms.

The first form is the AVI file. There will be one AVI file per camera. The AVI files contain the image frames for each epoch. Each AVI used in one PMV project must have the same number of frames. Both compressed and uncompressed AVIs are handled but which types of compressed types are handled depends on which codecs are installed on your computer. Also beware that highly compressed videos may have insufficient quality to get accurate results from. AVIs can be used only in type 1 (static cameras) projects.

The second form of image sequence is one image file per epoch per camera. These images must have file names in the form AAAATTTT.jpg where:

- AAAA is an arbitrary length string of characters that identifies the project and which camera the image was taken by (the last character must be non-numeric)
- TTTT is an arbitrary length string of numeric characters (0 to 9) that defines the time epoch of the frame (smallest valid value is 0)
- .jpg is an example file extension but the file does not need to be in JPEG format, it can be any format handled by PhotoModeler.

Example valid file names would be:

Project1_cam1_012.jpg and Project1_cam2_012.jpg would be two images from different cameras taken at the same time frame.

T533Right0000.jpg is also a valid example of a file name.

Files do not need to start numbered at zero, they can start and end at any number as long as each sequence is the same length, and no numbers are skipped. Note that AVI files are always assumed to start at epoch zero. This second form can be used in both type 1 and type 2 projects.

The third form of image sequence is where all the images for one epoch come from one sub-folder. So for example, the main project folder may be called "Project 1 Images" and it would have sub-folders called "Epoch 1", "Epoch 2", "Epoch 3" etc. the images would be located in the "Epoch N" sub-folders. This sub-folders form can only be used in type 2 (moving camera, some static points) projects.

The PMV User Interface

When a PMV project is loaded, one of the PMV Toolbars below will appear. There is also a corresponding PMV menu.

Type 1 toolbar:



- The first control brings up the *PMV Tracking Dialog*.
- The next six controls are for *switching between epochs*.
- The next control brings up the *PMV Transfer Marks Dialog*.
- The next two clipboard like controls do the 2D and 3D *PMV Data Export*.
- The next control brings up the *PMV Epoch Report Dialog*.
- The second to last control disables/enables automatic propagation of changes across epochs. See *Propagation*.

- The last control brings up the *PMV Auto Advance Dialog*.

Type 2 toolbar:



- The first control brings up the *PMV Tracking Dialog*.
- The next six controls are for *switching between epochs*.
- The next two clipboard like controls do the 2D and 3D *PMV Data Export*.
- The next control brings up the *PMV Epoch Report Dialog*.
- The next control disables/enables automatic propagation of changes across epochs. See *Propagation*.
- The next control brings up the *PMV Auto Advance Dialog*.
- The second to last control brings up the *Static Points Dialog*.
- The last control brings up the *Append Epoch Dialog*.

Note that one additional user interface item appears for PMV projects and that is a new page in the 3D Viewer Options Dialog called the *PMV 3D Viewer Animation Export*.

Switching between epochs

After loading a PMV project, the epoch designated as the starting epoch will be active and loaded. You can switch between epochs using the six switching tools on the PMV toolbar or their matching items on the PMV menu.



The controls are:

1. Go to first epoch. Pressing this button will jump to the lowest numbered epoch.
2. Go to previous epoch. Pressing this button will activate the epoch numbered one less than the currently active epoch.
3. Enter epoch number. This edit box will display the currently active epoch as you switch between them using the arrow controls, however you can also enter a specific epoch number into the edit and press the go to specific epoch button.
4. Go to specific epoch. Pressing this button will jump to whatever epoch number is listed in the Enter epoch number control.
5. Go to next epoch. Pressing this button will advance to the epoch numbered one more than the currently active epoch.
6. Go to last epoch. Pressing this button will jump to the highest numbered epoch.

Propagation

A PMV project is stored as a series of regular PMR projects, one for each epoch. To quickly examine a single epoch you can load the individual .PMR file and view it as you

would a regular PhotoModeler project, however it is recommended you do not edit or re-save the project.

Since each epoch is stored as a separate project, to have changes reflect across all (or some) epochs PMV has a propagation system. When a change that could be applied to multiple epochs is detected (such as changing the material of a point) the PMV Propagate Dialog will appear prompting you to select which epochs the change should be applied to.

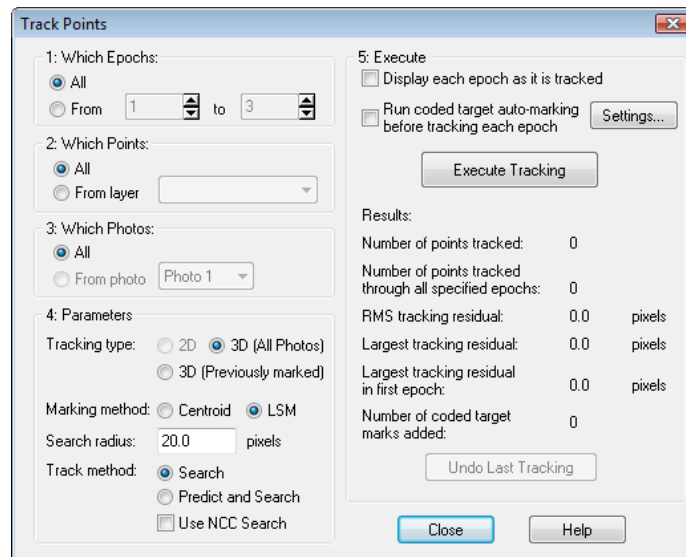
If you do not want any of your changes to propagate you can turn off propagation by pressing the Propagate button on the PMV toolbar or by choosing the Propagate item on the PMV menu.

Note: since there is no data in any epochs when you start a PMV project, propagation will be off by default until you perform tracking or switch to a different epoch.

Some settings propagate across all epochs regardless of the propagation setting and will not display the PMV Propagate Dialog. These settings are:

- Project units,
- the next point, curve, cylinder, edge and surface IDs
- the default material,
- the default layer,
- the Scale/Rotate set in the starting epoch, and
- the approximate size of the project.

PMV Tracking Dialog



The Track Points dialog can be accessed using the Track Points button, or from the "Track Points" item on the PMV menu.

The settings on the dialog control how and which points are tracked. The setup steps are:

1. Which Epochs. These settings control which epochs will be tracked. Using the All setting any points marked in the starting epoch will be tracked through to the ending epoch. By selecting "From" you can define a sub set of epochs to be tracked. The data from the epoch prior to the first selected epoch will be tracked through to the last selected epoch. (e.g. If you has selected to track from 10 to 20 the points in epoch 9 would be tracked to epoch 10 and through to epoch 20.)
2. Which Points. These settings control which points will be tracked. Selecting All will track points from all layers, selecting "From Layer" will only track points from the layer you select. Using this setting you can assign points to specific layers and just track a sub-set of your data.
3. Which Photo. These settings control which photos will be used during the tracking. Selecting "All" will track points on all photos in the project, selecting "From photo" allows you to pick a specific photo to track.
4. Parameters. These settings control how the tracking of targets is performed. See the *Tracking Methods* section for more information.
5. Press the "Execute Tracking" button to perform the tracking based on the parameters you set in the previous 4 steps. Once tracking is finished you will see an overview of the results in this section of the dialog. If the results do not seem correct you can use the "Undo Last Tracking" button. If the "Display each epoch as it is tracked" box is checked then each epoch will be opened in the user interface (as if you had hit the Next Epoch button on the PMV toolbar) before tracking into that epoch has begun. This option will use more memory and will slow tracking down but it does allow you to watch whether the tracking is successful or not. If the "Run coded target auto-marking before tracking each epoch" box is checked then Coded Targets will be auto-marked before other point tracking is begun in each epoch. See *Track Coded Target Settings* for more information.

Note that non-coded targets need to move slowly and/or in a predictable manner or the tracker will lose them between epochs. Also once a target has been lost (moves off a photo, moves too fast, or moves unpredictably) it will not be reacquired in later epochs. Coded Targets in PMV projects do not have this problem. As long as the code can be recognized, the coded point can move anywhere between epochs as well as it can be hidden in one epoch and be reacquired in a latter epoch if it reappears.

Tracking Methods

The type of tracking used will depend on the nature of the targets and the project. There are three stages to tracking: the initial placement in the image, the search, and the sub-pixel marking.

The initial placement can be done two ways: 2D-same and 3D projection. In 2D-same placement, the 2D location of the mark in the previous epoch is used in the epoch being tracked. In 3D projection, the 3D location of the point is projected onto the photograph being tracked and that 2D location is used as the initial position.

There are 2 types of 3D tracking '3D (all photos)' and '3D (previously marked)': the (all photos) option will try to track every 3D point on every photo, the (previously marked) option will only track 3D points on photos that the point was marked on in previous epochs.

PMV Type 2 projects must use 3D tracking because there is no relationship between photos between epochs in type 2 projects.

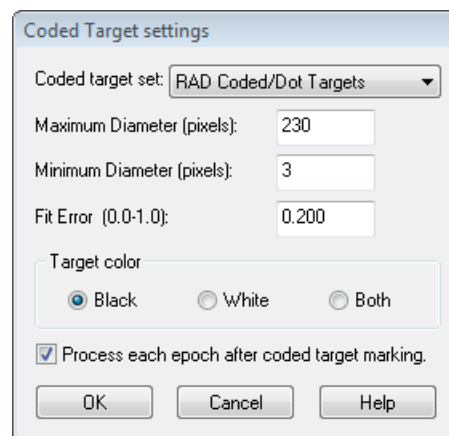
The search for the target is started at the initial position. It can be done two ways: spiral contrast search, and NCC (Normalized Cross Correlation) . The spiral contrast search spirals out from the initial position looking for the first pixel transition that is biggest than a

threshold. This method works well for high contrast targets with dark and low-noise backgrounds. The NCC method uses an image processing correlation method that is quite a bit slower but is also more robust. NCC works well with Template Targets and works well where there is a natural image or noisy background around the targets.

The marking can be done two ways: LSM (Least Squares Matching) and Centroid. See the *Automatic Target Marking* section for more information.

When a series of sub-pixel marked points are tracked, the Tracker determines which target type was used to initially mark the point. It then tracks these points into the selected epochs using the same template matching algorithm. For example, if epoch 1 had a number of Circular Targets and two types of Template Targets already marked, then when these points are tracked into epoch 2, the matching target type is used (that is after the search, the Circular Targets are sub-pixel marked with the Circular Target Marking Method, and the Template Targets are marked with the appropriate Target Template.

Track Coded Target Settings



This dialog appears when the “Settings...” button is pressed on the *PMV Tracking Dialog*. That button becomes available if, a) the *Coded Target* Module is installed, and b) the “Run coded target auto-marking before tracking each epoch” box is checked on the tracking dialog.

When there are *Coded Targets* in a PMV project it is a good idea to use the standard coded target automatic marking instead of standard tracking (because otherwise the code ring bits can get confused as targets to track). The advantage of using RAD or non-ringed coded targets in a PMV project is that as long as they are visible in two or more photos they will be computed and so they can be points that move farther, faster or more randomly than the standard target tracker can handle. In fact a PMV project can be done with 100% coded targets to get robust tracking of points.

When the option is used in the PMV Tracking dialog, the coded points will be searched before any standard tracking is done. This preliminary step is the same as is done in the Automatic Marking with whole image only coded target search. The settings needed for target searching as used in the *Automatic Target Marking Dialog* are needed here too. The purpose of this dialog is to get the appropriate parameters so the coded targets can be marked and identified.

The “Process each epoch after coded target marking” check box is useful for PMV Type 2 projects. In PMV Type 2 projects each epoch needs to be processed independently and with coded targets the marking, referencing and processing can all be done automatically using this method.

PMV Data Export

There are two reports that allow for data export from a PMV project: 2D and 3D. When you one of the two Export buttons, you will be prompted for a text file name, into which the data will be exported.

Data can then be used in a spreadsheet program for analysis, such as calculating differences in positions of points between epochs.

2D Report

The 2D report exports each point’s photo location (pixels), along with the point mark’s residual on that photo, for each epoch.

The file header shows: Project [C:\filepath] exported on “date&time” and Units: pixels

Report Data:

Point ID	Photo #	Epoch #	X	Y	Residual
1	1	0	220.0345	422.3665	0.2245
1	2	0	360.2356	125.2336	0.2760
...					

3D Report

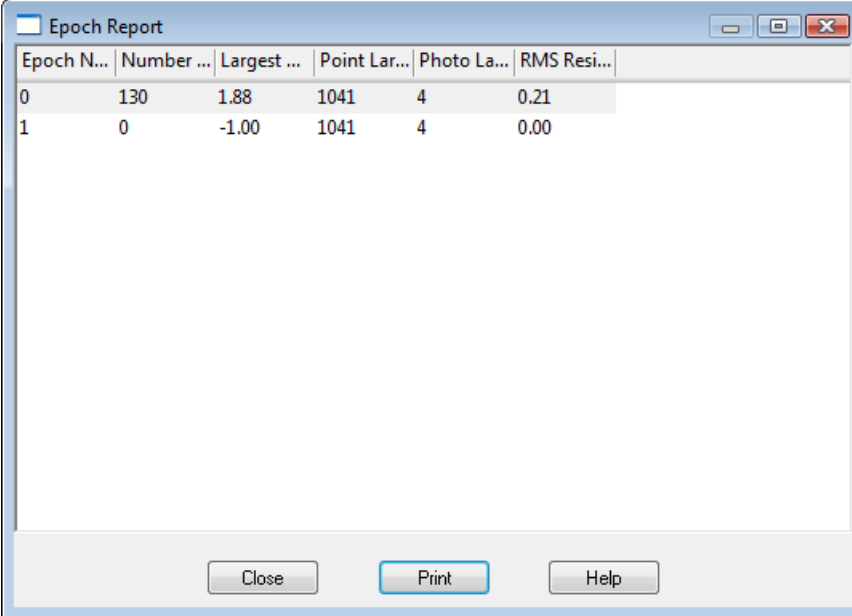
The 3D report exports each point’s 3D location (project units), along with the point’s tightness and precision values, for each epoch.

The file header shows: Project [C:\filepath] exported on “date&time” and Units: project units

The report data is shown as follows:

Pt. ID	Epoch #	X	Y	Z	Tight	X Prec	Y Prec	Z Prec
1	0	4.5462	9.2078	22.2722	0.005	0.0	0.0	0.0
2	0	6.4934	5.6513	23.9265	0.006	0.0	0.0	0.0
...								

PMV Epoch Report Dialog

The image shows a software dialog box titled "Epoch Report". It contains a table with six columns: "Epoch N...", "Number ...", "Largest ...", "Point Lar...", "Photo La...", and "RMS Resi...". There are two rows of data. The first row has values 0, 130, 1.88, 1041, 4, and 0.21. The second row has values 1, 0, -1.00, 1041, 4, and 0.00. Below the table are three buttons: "Close", "Print", and "Help".

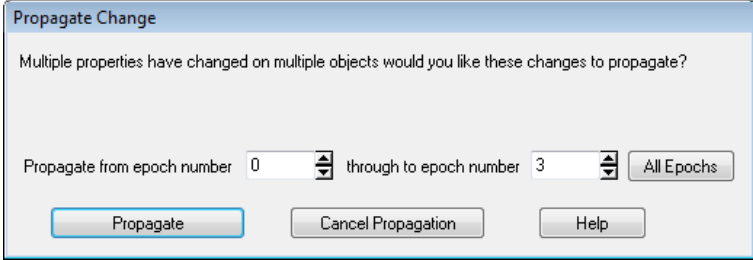
Epoch N...	Number ...	Largest ...	Point Lar...	Photo La...	RMS Resi...
0	130	1.88	1041	4	0.21
1	0	-1.00	1041	4	0.00

The Epoch Report dialog is accessed using the Epoch Report tool or by selecting "Epoch Report" from the PMV menu.

The Epoch report dialog displays a table giving a summary of data from all epochs. The columns in the report are: Epoch Number, Number of Referenced Points, Largest Residual (pixels), Point Largest Residual (which point has the largest residual), Photo Largest Residual (which photo the point is marked on giving the largest residual), the RMS residual of the epoch, the number of static points (used in type 2 projects), and the Common Coordinate System flag ("yes" means the epoch is in a common coordinate system (and hence you can compare xyz coordinates between epochs), and "no" means the common system has not been set up (in type 2 projects there are not enough static points that are 3D in this epoch)).

The report can be printed by pressing the Print button.

PMV Propagate Dialog

The image shows a software dialog box titled "Propagate Change". It contains the text "Multiple properties have changed on multiple objects would you like these changes to propagate?". Below this text are two input fields: "Propagate from epoch number" with the value 0 and "through to epoch number" with the value 3. There is a small up/down arrow icon between the two fields. To the right of the second field is a button labeled "All Epochs". At the bottom of the dialog are three buttons: "Propagate", "Cancel Propagation", and "Help".

Propagate Change

Multiple properties have changed on multiple objects would you like these changes to propagate?

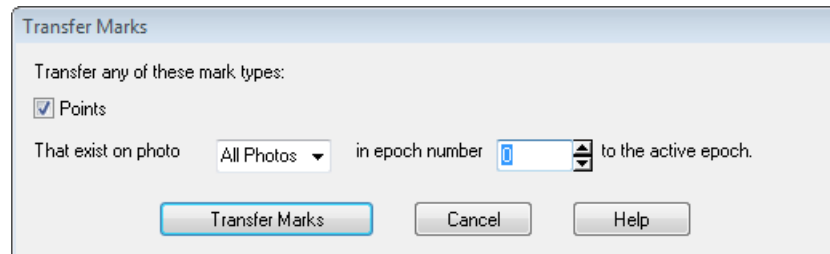
Propagate from epoch number 0 through to epoch number 3 All Epochs

Propagate Cancel Propagation Help

The propagation dialog allows you to control which epochs changes are propagated to. The top of the dialog describes what change will be propagated. The two spin controls determine which epoch to start and end the propagation at. These controls default to the current epoch through to the end of the project, the "All Epochs" button will set the controls to the starting epoch through to the end of the project.

Selecting "Propagate" will cause the change to take place in the selected epochs. Selecting "Cancel Propagation" will abort the propagation and the change will only take place in the active epoch.

PMV Transfer Marks Dialog



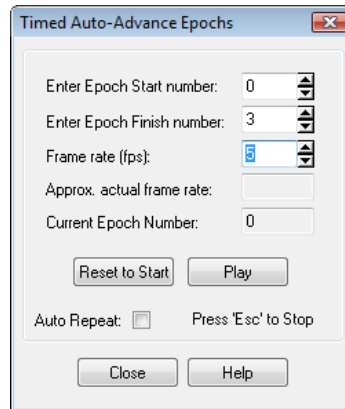
The Transfer Marks dialog comes up when the Transfer Marks tool, or the "Transfer Marks" item on the PMV menu is selected. The marks of the selected type(s) that appear on the selected (or all) photos in the epoch number chosen will be moved to the currently active epoch. If the marks already exist in the current epoch they will not be transferred.

The main use for this command is when some points fail to track you can transfer them and then manually mark them. The marks transferred will appear at the x,y location of the epoch they are coming from. Once they have been transferred you should manually move them to the appropriate location.

While this function is available in type 1 (static cameras) projects only, one can achieve a similar function with points by using the name matching facility in type 2 tracking.

Note: you can use the re-sub-pixel mark tool to manually identify targets.

PMV Auto Advance Dialog



The PMV Auto Advance Dialog provides a way to view your PMV project animated. Before opening the PMV Auto Advance dialog, open the photograph(s) or 3D Viewer that you want to monitor (you will not be able to open other photographs or 3D Viewers while the Auto Advance dialog is open).

There are various settings that you can set for project auto-advance:

Start Epoch: The first epoch of the animation.

End Epoch: The last epoch of the animation.

Frame Rate: The maximum frame rate per second (i.e. the number of frames/epochs displayed per second) at which your project will be animated.

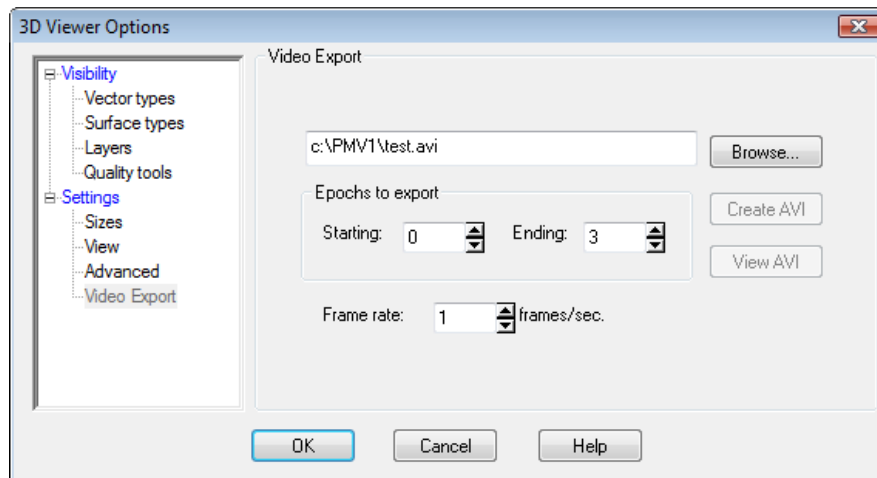
Auto-repeat: Select this checkbox if you want your animation to loop back to the starting epoch automatically, after the last epoch has been displayed.

Click Play to begin the auto-advance. Press Esc on your keyboard to stop the autoadvance. The frame rate that is currently being achieved will be displayed.

Note: this feature requires substantial computer processing power. If you are viewing a project that is complex, has a large number of 3D points, and you have 3D viewer(s) open, or you have several photos open, the actual frame rate may be lower than the frame rate that you set.

PMV 3D Viewer Animation Export

When the PMV Module is installed and a PMV project is loaded the *3D Viewer Options Dialog* shows another page called Video Export.



This page allows you to export a video sequence of the 3D Viewer over a specified epoch range. You set the 3D Viewer to have the view direction, size, contents, etc. desired and then with this page you produce an AVI animation video that shows this particular view for each epoch chosen.

The edit field at the top of the page displays the name of the file to be created or viewed. The browse button beside the edit field will allow you to choose a file using a standard windows file selection dialog.

The epochs to export fields allow you to choose the range of epochs that should be included in the video export.

The frame rate setting allows you to configure how many epochs will be displayed per second.

Pressing the Create AVI button will prompt you to choose which video codec to record the video with. Once a codec has been chosen each epoch in the selected range will be written to the file name listed at the top of the video export page.

Note: This button will not be enabled until a valid 3D scene is displayed in the 3D viewer.

Pressing the View AVI button will launch the player associated with the .avi extension and display the video listed in edit field at the top of the video export page.

PMV Type 2 Projects - Moving Camera

Many of the controls and the user interface is similar when working with type 1 (static cameras) or type 2 (moving camera) projects. The project types and their uses though are quite different.

Type 1 - Static Camera projects are used to watch moving points using static synchronized cameras. Typically we would see high speed movement. An example might be a fluttering flag with targets.

Type 2 - Moving Camera projects are used to watch shape and displacement change of objects that go through distinct and stable epochs. Typically only one camera is used and the object scene is re-photographed at each epoch. Typically we would see slow distinct

movements (perhaps minutes, hours or even days between epochs). An example might be a balloon that is inflated in distinct steps (that is does not move or change shape when each set of photos is taken).

The steps taken with type 2 projects were outlined above in the *The PMV Procedure - Type 2* section but here we describe steps again but with a typical operational scenario that might be easier to understand.

PMV Type 2 - Operational Scenario

This scenario assumes a set of images have been captured by one camera at each epoch of an inflating balloon. That is, the balloon is set up with some adhesive targets. Other adhesive targets are placed on a non-moving jig that surrounds the balloon. The balloon is partially inflated so the targets are all visible. A set of photographs is taken as if this were a standard PhotoModeler project.

- The balloon is inflated some more and allowed to stabilize. A new set of photos are taken (using similar camera positions but not exactly the same ones as the first set of photos). We are assuming the balloon does not change shape during the photo shoot.
- The process is repeated at each inflation level.
- The images are placed into sub-folders - one sub-folder per epoch.
- PhotoModeler is started.
- A new project is started using the project wizard, a PMV project type selected and then the 'Type 2 project' is chosen.
- A camera file (calibration data for the camera used) is chosen.
- The sub-folders with the separated epoch images are identified in the Wizard.
- Once the Wizard is complete, we manually mark, reference and process every epoch. Basically treating each epoch as a separate minimal regular PhotoModeler project. To minimize work we mark and reference only some key points - typically all or some of the static points (those on the jig surrounding the balloon). When done each epoch should have a valid 3d object (some points on the static jig).
- We manually name the static points (4 or more), that are common across the epochs, with common unique names (right click, enter User Name on the 3D Point Properties dialog). We use a naming system for the points on the jig so they are easy to identify.
- Using the 'Static Points' dialog we assign at least four static points from the first epoch that appear in or will be tracked to all epochs.
- In the first epoch, we complete the project by marking and referencing all the remaining points (the remaining targets on the balloon). We process the first epoch again to ensure it has a good solution and the balloon a good 3D shape.
- We run tracking with the appropriate options. All 3D points that exist in epoch 1 will be tracked to the specified epochs - including those on the balloon that is changing shape.
- Upon completion of the tracking, manually step through the epochs using the time line control to see if the 3D data makes sense and to ensure tracking was successful.
- We save the project.
- We perform measurements and use the epoch reports.

In a type 1 project one tends to collect all the images from all epochs at once and then set up a big project and track them all. While this can be done with a type 2 project, one can also build the project incrementally. You start with a one-epoch PMV Type 2 project. Then when you capture your next set of photos (there might be hours or days between the

epochs in your type 2 project), you append them using the *Append Epoch Dialog*. You set up the 2nd epoch project and the static points as described and track the remaining points from epoch 1 to epoch 2. This is repeated for each new epoch.

PMV Type 2 - Tracking

It is important to understand the steps taken during tracking in a type 2 project. The process for tracking type 2 projects is similar to type 1 projects except instead of relying on static cameras it relies on static points. There must be at least four 3D static points identified in the first epoch using the static point's tool. These same points should be marked and referenced in each destination epoch and then given the same user name as in the first epoch.

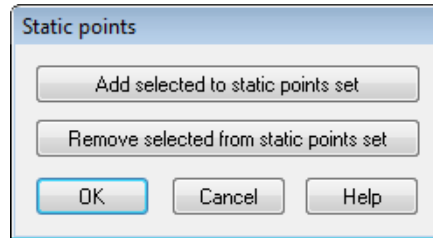
When tracking enters an epoch the first thing it will do is search the user names of the points in the destination epoch and if a match is found with the source epoch points, the points will be assigned a common point ID and will be linked between epochs. The four or more points are used to compute the coordinate system transformation between epochs. If four static points cannot be name matched during the tracking it will abort as a common coordinate system can not be calculated. Once the coordinate system is set up in the epoch being tracked, the remaining points will then be tracked as they would with a type 1 project (but always in 3D).

Differences between PMV Type 1 and Type 2 projects

Type 2 projects (compared to type 1 projects):

- can have a different number of photos per epoch,
- do not require the camera positions to remain static,
- need at least four (4) static points across all epochs,
- require that each epoch be manually oriented/processed before tracking,
- perform name matching as the first stage of tracking,
- cannot track using only a single photo since there is no correlation between photos in each epoch,
- perform tracking only in 3D,
- will close any open photo windows when the user switches between epochs,
- do not support the input of AVI files - only the image types available in standard projects are supported,
- specify only one camera during the Wizard setup (multiple cameras can be manually loaded and assigned in each epoch),
- have the Static Points mode (not available in type 1),
- have the Append Epoch function (not available in type 1),
- do not have the Transfer Marks function (instead manually marked points that are the same across epochs must be identified with the same unique user name and they will be matched up during tracking), and
- do not propagate Camera Station position data between epochs.

Static Points Dialog

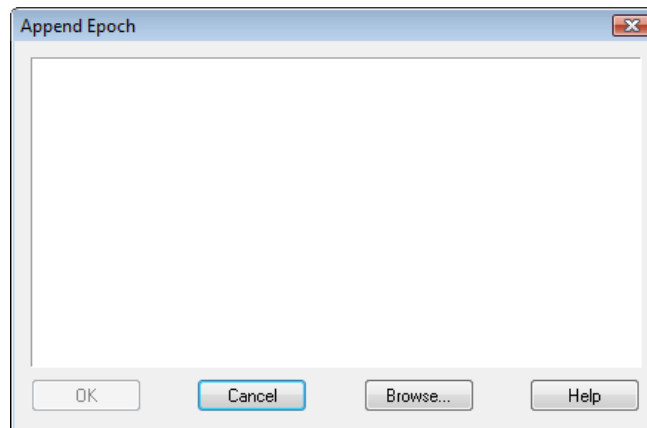


PMV Type 2 projects require designated static points to maintain a common coordinate system between epochs. The Static Points Dialog is used to add and remove points from the static set.

The dialog is opened by using the PMV menu, "Static Points ..." item. Similar to the scale/rotate dialog, when this dialog is open the static points will be highlighted in the secondary highlight color in all currently open windows. Pressing the add or remove buttons will add or remove the currently selected points to/from the static point set. You can only designate static points in the first epoch. If you open the Static points dialog in any other epochs the add and remove buttons will be disabled.

Static points should be named alike across all epochs or be trackable across epochs so the consistent coordinate system can be computed.

Append Epoch Dialog



The Append Epoch Dialog is used to add a new epoch to the end of a PMV Type 2 project.

The dialog is opened by using the PMV menu, "Append Epoch ..." item. The dialog shows a collection of thumbnails of the images which will be included in the appended epoch. When no images are in the new epoch this area will be empty. Press the Browse... button to get the photo import dialog, allowing you to import or remove images from the new epoch. When you close the Add/Remove Photographs Dialog the Append Epoch Dialog will update to show you all the images to be added to the appended epoch.

Coded Targets

Targets are high contrast circles placed in a scene or on an object to provide an accurate sub-pixel point marking. See *Automatic Target Marking* and *Sub-pixel Target Marking* for more detail.

Coded Targets are circular targets with some additional rings and bits that can be automatically recognized by PhotoModeler during the marking process.

This automatic recognition allows for automated referencing even before a project has been processed and in situations where the *Automatic Referencing* would not work (complex scene or shape). Since the point's ID is coded in its ring, the point can be identified in each photo that it is marked and therefore can be referenced automatically.

Coded Targets is an add-on module to PhotoModeler. The PhotoModeler Automation bundle is PhotoModeler plus the Coded Target module. For information on installing the Coded Target module see the *Modules and Licenses* section.

Coded targets can be in the form of *RAD Targets* (Ringed Automatically Detected Targets) and non-ringed coded targets. In this section we refer to both types of targets as Coded Targets, but where necessary we specify whether the target is a RAD Target or a non-ringed coded target.



One of the RAD targets



One of the 8 bit non-ringed coded targets

The four main reasons that Coded Targets are used in projects are: a) to fully automate 3d point measurement using *Automated Coded Targets Project*, b) to increase the speed at which projects can be completed, c) to improve the speed and robustness of the crucial orientation stage in projects that use a mixture of coded and manually marked targets, and d) to improve robustness and reduce the chances of misreferenced points.

Of the two types of coded targets, the *RAD Targets* would be preferred for most projects. The RAD targets have an additional outer ring allowing for much more robust detection, often quicker detection, and a larger target set allowing the use of more targets.

How to Use

To use Coded Targets in your scene or on your object to assist with automation of the marking and referencing process you would:

1. Study your scene or object and decide which points you want to be targeted and which should be coded (you can mix coded and non-coded targets in the same project and on the same image, but you cannot mix RAD Targets with non-ringed coded targets in the same project).
2. Estimate the scene size and determine the maximum distance between a camera and a target. This information together with your camera resolution and focal length of lens will tell you how big the center dot of the target needs to be. See *Target Size and Appearance*.
3. Print out a set of targets and cut them up. Perhaps mount them on cardboard. You can also send out the postscript file to get the targets manufactured out of more robust materials.
4. Place the targets in your scene at strategic locations and with good coverage. When placing targets on your object or in your scene, try to affix the targets so that they are as flat as possible. PhotoModeler can tolerate slight warp in the target, but if the inner dot's plane is too different from the outer ring plane, miscoding can occur. Using rigid paper or material can help maintain a flat target.
5. Photograph your scene so that each target appears in at least two photographs from good angles. Also, make sure that targets are placed in the scene such that they are not too distorted due to perspective. PhotoModeler can tolerate perspective distortion in circular targets, but the more perspective in the images' targets, the higher the likelihood of mis-codings/mismarkings. Try to include photos that are taken as directly towards the targets as possible to ensure they are recognized and coded properly.
6. Start a standard PhotoModeler project with a calibration camera and load your images.

7. Use Automatic Target Marking to automatically detect, sub-pixel mark and reference the coded targets in the image. You can also use the sub-pixel target marker to manually mark individual coded targets. See *Sub-pixel Target Marking*.
8. If sufficient points have been referenced (at least six targets recognized on two or more photos) you can then process the project.
9. Add additional points, targets and features using a combination of manual marking, sub-pixel marking, automatic marking, automated and manual referencing etc until your project is complete.

See also *Targets - Do's and Don't's* for tips on using targets in your project.

Coded Target Point Actions

Coded Target points act a bit differently than regular points in some areas of the program. As far as processing goes, coded target points are treated like any other sub-pixel marked point. Here are the areas where they act differently:

- Display: coded target points are displayed differently so they can be distinguished. They also have a unique way of using Point IDs. See the next section for more information.
- Modification: a) coded target point marks cannot be dragged on photographs, and b) they have an 'uncode' function on the *Object Point Properties* dialog.
- Referencing: a) coded target points can only be referenced to non-coded, sub-pixel marked points, b) the 'reference and mark' mode does not work if the source point is coded, and c) when a coded and non-coded point are referenced together the coded point's properties always prevail (with non-coded point referencing the source point's properties prevail).

Identifying Coded Targets

Coded Target points are displayed and represented a bit differently so that you can distinguish them. The following table describes how to identify a coded target in various parts of the program's user interface.

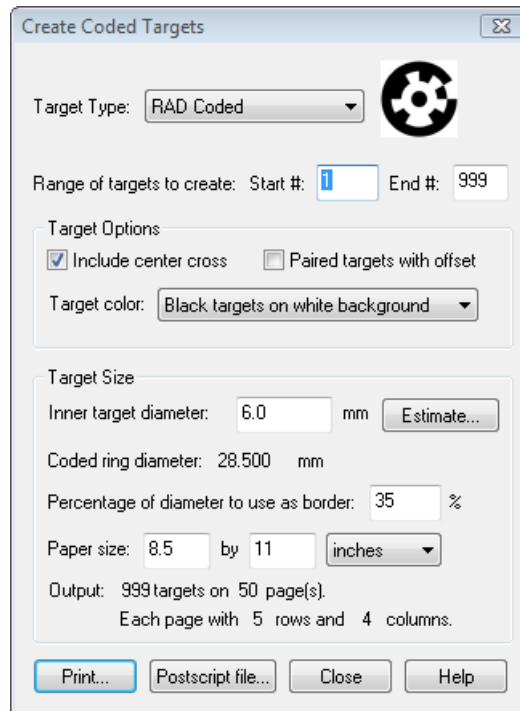
Area of User Interface	How to Identify Coded Targets
Photographs	Point symbol looks like a four piece coded ring
3D Viewers	Point ID is in square brackets []
Point Tables	The Target Code field is not "n/a"
<i>Status Bars</i>	The text "(coded)" appears.
Point Properties Dialog	The text "(coded)" appears.

Point IDs act a bit differently with Coded Target points. First, for any project with Coded Targets, there is a reserved block of one thousand (1000) IDs for the coded target points. This reserved block can start at 1, 1001, 2001, etc. Second, every Coded Target has a unique code (that number printed on the coded target by the *Create Coded Targets Dialog*) and there is a direct relationship between the target code and the point ID. If you recognize a point as coded remove the thousand's digit from the point ID to get the code. For example, a coded target with point ID of 2012 has code number 12.

Note: You can renumber points in your project using the *Renumber Dialog*.

Create Coded Targets Dialog

When the Create Coded Targets menu item (File menu) is clicked the Print Coded Target dialog appears:



The Create Coded Targets dialog is used to output *coded targets* (print or generate a Postscript file to be used in the printing or manufacture of the targets).

See *Targets - Do's and Don't's* for tips on using targets in your project.

Target Types

The first selector on the Create Coded Targets dialog allows you to select the type of targets to output. The choices are: 1) RAD Coded (Ringed Automatically Detected Coded), 2) RAD Dot, 3) Dots, 4) 8bit coded, 5) 10bit coded, 6) 12bit coded, and 4) the user defined set (as set up in *Preferences - Coded Targets*). When you select a Target Type, the image to the right of the selector will change to show an example target.

1. The RAD Coded target type is a robust target that is quickly and reliably identified when using sub-pixel target marking or automarking. A RAD target has a notched ring around a coded target which helps PhotoModeler distinguish it as a target even in noisy images. There are 999 unique RAD target codes.

2. The RAD dot target type is a plain circular dot with a ring around it. Like the RAD Coded target, the ring makes it more robust and helps PhotoModeler distinguish it as a target. You can output an unlimited number of these.
3. The dot target type is simply a circular dot. You can output an unlimited number of these.
4. The 8 bit set has 8 ring bits of 45 degrees each. There are 25 unique codes in this set. There is no outer ring on these types of targets, making them less easily detected than a RAD Target.
5. The 10 bit set has 10 ring bits of 36 degrees each. There are 45 unique codes in this set. There is no outer ring on these types of targets, making them less easily detected than a RAD Target.
6. The 12 bit set has 12 ring bits of 30 degrees each. There are 161 unique codes in this set. There is no outer ring on these types of targets, making them less easily detected than a RAD Target.
7. The user set can have 8, 10, 12 or 14 bits (note 14 bits generate 561 unique codes). The user set can be defined on the Preferences dialog (see *Preferences - Coded Targets*). There is no outer ring on these types of targets, making them less easily detected than a RAD Target. When the user set is chosen, extra information may need to be entered. See *User Set Parameters*.

The type of target detected in a project will depend on the first target marked. A project should therefore only contain one type of target. If you start a project using RAD targets, the other coded targets (ie either 8, 10, 12 or user set) will not be detected, though you can use a mix of RAD coded targets and RAD dots if need be.

The main reason for having the 8, 10 and 12 bit sets is for backward compatibility with pre-6.3 versions of PhotoModeler. If you are printing new targets for a new project to be marked by an up-to-date PhotoModeler, you would typically use RAD Targets.

Dot and RAD Dot targets are used to densify points without using the limited codes. Also non-ringed dots are smaller and can be packed closer together.

Coded (RAD and non-ringed) targets are used to get automatic and implicit referencing and greater automation. Non-coded dot targets can be marked by Automatic Marking and can be referenced manually or with Automatic Referencing. Projects can consist of only coded targets, a mixture of coded and non-coded targets, or a mixture of targets and manually marked natural points

When *Automatic Target Marking* is run it will default to the correct set based on the targets it detects during the marking process.

Target Options

The Target Options section controls the appearance of the target output.

The Start # and End # settings allow you to set the output to a certain range of codes, or in the case of non-coded targets, allow you to simply control the number of targets to be output.

The 'Include a center cross' option controls whether a small contrasting cross is printed in the center of the target dot. This is useful when targets are being used with an optical survey instrument, or it might help line the target up on an edge or corner.

The 'Target color' setting changes the target from being printed as black on a white background to a white target on a black background. Black targets on white background (default) are best suited to white or light backgrounds and objects (white walls, concrete,

etc). White targets on black background (inverted setting) are best suited to dark or black backgrounds (dark painted surfaces, flash lit retro-reflective targets in dark scene, etc). Note that black/white and white/black coded targets can be mixed in the same project and on the same images and the automatic marker will detect both. Maximum robustness is achieved though when only one target color is used in a project..

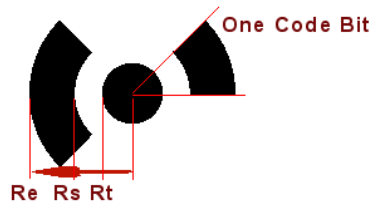
The “Paired targets with offset” option applies to RAD Coded targets only and only applies to sending the targets to Print... (ie you cannot create a postscript file of offsets). This setting will output RAD Coded targets in pairs with a graphical indicator for offset location. These RAD coded target pairs are used with ***RAD and Coded Target Offsets***. See the Offset Point section for an explanation on how to use and create offset points.

User Set Parameters

When User Set coded targets is chosen (on this dialog and in the Coded Target Preferences), you can control the specific shape of the target. Some applications may require specific settings. You can use these settings to balance overall target size against robustness and the ability to recognize targets at shallow angles (a larger space between target dot and code is needed).

The user settings are: start ratio, end ratio, and number of bits.

The number of bits determines how many code segments there are (or the number of degrees per segment (or bit)). The choice here is made between number of codes and robustness (lower number of bit codes tend to be more robust and mark more reliably but generate fewer unique codes).



The Start and End Ratio control the radius of the circle that defines the inner and outer boundaries of the code band. They are relative to the inner target circle radius - shown as R_t above. Start Ratio = R_s / R_t and End Ratio = R_e / R_t .

Note: You can use these settings to make large code rings or large gaps between center dot and the ring to improve automatic detection robustness in certain cases.

The User Set Parameters do not apply to RAD targets.

Target Size and Appearance

There are various settings on the Create Coded Targets dialog that allow you to control how the targets will appear.

Target Size

The values in the “Target Size” section of the Create Coded Target Dialog control the size of the targets and the number of targets placed on each page.

The 'Inner target diameter' controls the size of the target's inner dot (in millimeters) on the printed page (if printed to scale or at 100%). The size of this dot is important because this center dot needs to be recognized in the images by the Auto-Marker. You would typically set this value based on the target that will be farthest from the camera. A center dot of about 10 pixels in diameter or larger is best for naturally lit targets and a retro-reflective target can be a bit smaller down to 5 pixels in diameter.

The total size of target depends on the outer diameter of the code ring(s) and this is shown by the “Coded ring diameter”. The coded ring refers to the outermost ring around the target, and so the overall size can be displayed in millimeters. Do note though when applying targets to your object or scene you'll want white space around the target so that the outermost rings can be detected properly.

You can estimate the inner dot radius yourself or you can have an estimate computed using the 'Estimate' button and the *Estimate Coded Target Radius Dialog*.

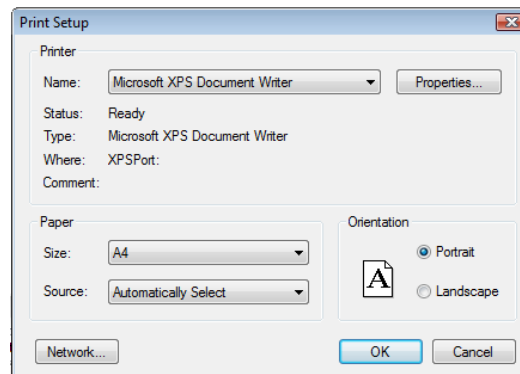
The 'Percentage of diameter to use as border' defines how much space will be left around each target. If the coded targets will not contrast with the object they are being applied to you should be sure to leave a reasonable border so the edges of the target can be detected. It is important to leave enough background around target if there is a big change of brightness. For instance if you placed a white target with black background (inverted setting) on a white wall and there was not much black between the white code areas and the white background then detection ability will be reduced.

The 'Paper size' is the size of the paper you will be printing the coded targets on; this is used to calculate the number of rows, columns, and pages and the spacing of the targets. This page size is also encoded in the .ps file as a level 2 Postscript command so that level 2 interpreters will know the page size.

The 'Output' tells you how many rows and columns of targets there will be per page and the number of pages. These values update as the settings above change.

Output Coded Targets

When the 'Print...' button is pressed on the Create Coded Targets dialog, Print Options dialog appears:

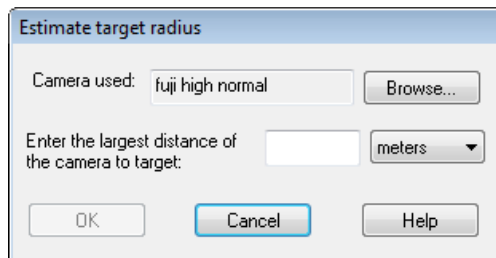


The standard print setup dialog allows you to select a printer, paper size and source and the paper orientation.

When the 'Postscript file...' button is pressed you'll be prompted for a .PS file name and location. The Postscript file will be created with one or more pages of targets. The targets also have crop marks so they can be cut apart easily. The Postscript file can be sent to any Postscript compatible printer, be sent out to a service house for printing or manufacturing, or can be converted to PDF format via Adobe Acrobat or online at <https://createpdf.adobe.com>. (Postscript and Acrobat are trademarks of Adobe).

Note: If you do not have the font 'Helvetica' (a standard post script font) installed with some post script interpreters (such as Distiller) you may see a warning about the font being replaced. This warning can safely be ignored.

Estimate Coded Target Radius Dialog



This dialog will calculate the recommended minimum size of a target. Select the camera you will be using for the project by browsing for a .cam or .pmr file. Then enter the approximate distance of the target that is farthest away from the camera. When you press OK the target size will be calculated and entered into the Create Coded Targets Dialog. The calculations done here are to obtain a minimum 15 pixel diameter target which is suitable for most naturally lit targets (that is targets printed out on a black and white laser printer). Retro-reflective targets taken with appropriate flash and exposure settings can often be smaller so use the computed value as a guide. Retro-reflective targets can be 50% to 90% smaller than this computed figure since they have higher contrast and are easier to detect.

If you wish to manually estimate the target size or check the calculations done by this dialog you can use one of two following formulas. For naturally lit targets, we suggest you do not use a target radius smaller than the figures computed here. As described above retro-reflective targets can be smaller than these figures.

The first formula is the coverage formula and is appropriate when most of the targets are a similar distance from the camera. This formula does not require as much knowledge of the camera.

Minimum target radius = $7.5 * w / pw$

where 'w' is the width of coverage of each image in real world space, and 'pw' is the number of pixels in the width of the image. For example, if on average each image will cover about 30 feet of the object horizontally and the camera has horizontal pixel resolution of 2048, we get:

Minimum target radius = $7.5 \text{ pixels} * 360 \text{ in} / 2048 \text{ pixels} = 1.31 \text{ in (or 33mm)}$.

The second formula is the "distance formula" and is appropriate when you know the approximate distance from the farthest coded target to a camera position. This formula does require more knowledge of the camera parameters and is the one used by the estimate dialog.

$$\text{Minimum target radius} = (7.5 * fw * D) / (f * pw)$$

where 'fw' is the format width of the camera, 'D' is the distance between the farthest target and a camera position, 'f' is the camera focal length, and 'pw' is the number of pixels in the width of the image. For example, if the farthest target is 8 m away, the camera has a 6.2mm lens, with a 6.0mm format width, and there are 2048 horizontal pixels, we get:

$$\text{Minimum target radius} = (7.5 \text{ pixels} * 6\text{mm} * 8000\text{mm}) / (6.2\text{mm} * 2048 \text{ pixels}) = 28.3\text{mm}.$$

With appropriate settings you can fit many targets on one page or just one target per page.

Automated Coded Targets Project

There is potential of fully automating a project when RAD Targets or non-ringed Coded Targets are used.

When the Coded Target module is installed there is an option on the *Getting Started Panel* to start a Automated Coded Target Project. When this option is chosen, the Wizard asks for the settings needed to execute the project with minimal operator intervention.

You have a choice to perform a fully automated 'RAD project', or a project using 'Automatic project with additional parameters' for a more interactive process of controlling some of the project parameters.

The RAD project uses only RAD targets (see *Create Coded Targets Dialog* and *Automatic Target Marking*) in the project setup. You select a set of photos in which RAD targets are used, then select a camera (if the camera associated with the photos is not stored in your *Camera Library*), and PhotoModeler will mark the targets, then process the project automatically. See *Getting Started Panel* or *New Project Wizard* for information on setting up these projects in the Wizard. You can control some aspects of a RAD project setup using the settings in *Preferences - Coded Targets*.

For a non-RAD automated project the program can automatically carry out target marking, processing, automatic referencing (for non-coded targets), and coordinate system affine setup. These settings can be saved in a file so that if you have similar projects they can be run quickly and automatically by loading just the one configuration file. Once the Wizard has been filled out and the Finish button pressed, the remainder of the processing is automatic. See *Getting Started Panel* or *New Project Wizard* for information on setting up these projects in the Wizard.

We strongly recommend you get used to successfully processing coded target projects with the manual process (standard project, running automatic marking, running processing, setting up scale/rotate, etc.) before embarking on fully automating the work so that you can be confident with the setting used.

While this system could be used for projects without coded targets it is not that useful because only automatic marking can be carried out. The power comes when sufficient coded targets are used so that 3D points can be calculated (via implicit coded target referencing).

For a non-RAD project, you set up your project such that all key points are coded targets. Key points are those that are used to orient all the cameras well and define your scale and

rotation. You record which code numbers define your scale and your coordinate system rotation. You then use the Automated Project Wizard to define your parameters, have all targets marked and referenced and have the project processed.

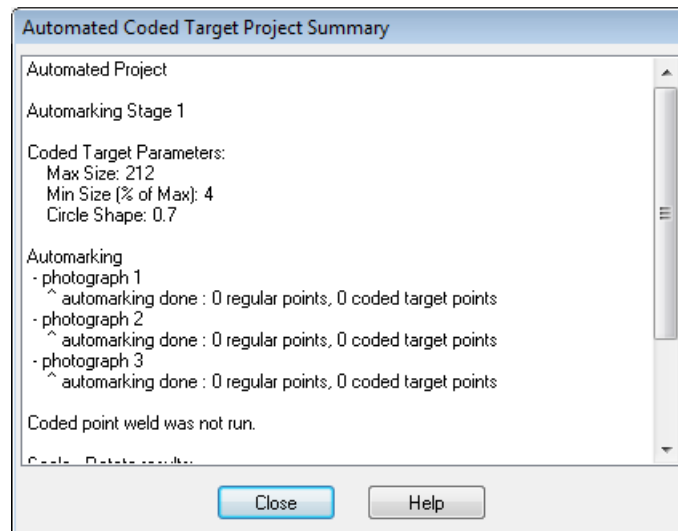
When placing targets on your object or in your scene, try to affix the targets so that they are as flat as possible. PhotoModeler can tolerate slight warp in the target, but if the inner dot plane is too different from the outer ring plane, miscoding can occur. Using rigid paper or material can help maintain a flat target.

Also, make sure that targets are placed in the scene such that they are not too distorted due to perspective. PhotoModeler can tolerate perspective distortion, but in an automated project, the more perspective in the images' targets, the higher the likelihood of mis-codings. Try to include photos that are taken as directly towards the targets as possible to ensure they are recognized and coded properly. See also *Targets - Do's and Don't's* for tips on using targets in your project.

There may be cases where a referencing error is made due to target mis-identification. In this scenario the processing stage may not complete (as with any other project that has a key point misreferenced). In this case you will need to study the codings made and unreference the offending point(s) before manually re-running Orientation and Global Optimization. A feature to assist you with projects that may have referencing or marking errors is the automatic point removal feature. During processing, if a point mark in the project has a high residual, PhotoModeler will attempt to make changes to the project by unreferencing the point. See *Preferences - Processing and Cameras*. This feature is turned on by default for Automatic projects. If it finds high residual points and makes a change, the *Total Error Dialog* will show a green bar. Any permanent changes it makes to the project are explained in the *Project Status Report*.

The *Automated Coded Target Project Summary* dialog appears at the start of automatic processing to provide feedback and is updated as the photos are marked and the project processed etc.

Automated Coded Target Project Summary



This dialog appears before automated processing steps have begun to provide feedback as those steps are run.

The first section of the report lists the coded target parameters. If this is a RAD project, these parameters are set internally, otherwise the parameters will be set during the wizard.

The next section shows which photographs were marked, how many new marks were added, and some status information. If the project was processed you may see either the largest residual (in pixels) of any Marked Point on that photo or the 'not oriented' text which indicates this photo failed to process (perhaps too few coded target points marked on this photo).

The next section of the report describes the status of the processing that can be optionally run after the automatic marking. The first two lines summarize the Processing Total Error Dialog by giving the number of iterations and the first and last iteration total error. This helps you identify if the processing was successful. See *Total Error Dialog* for more information. The total number of 3D points in the project is also listed.

The next section shows the results of the optional automatic referencing (used if the non-RAD project has non-coded targets as well and if the project was successfully processed in the previous stage).

The next section shows the results of the optional second processing which is useful if automatic referencing has added new points to the non-RAD project.

The last section of the report describes the status of the Scale and Rotation that can be optionally run after all steps are complete. If the scale, translate and rotation had been defined in the Wizard but they do not show as being setup here then perhaps one or more of the coded targets that defined the scale/rotate was not detected or could not be computed in 3D.

Programming PhotoModeler - DDE Interface

PhotoModeler can be controlled and have data fed to it by other Windows applications. PhotoModeler provides a DDE (Dynamic Data Exchange) interface and a set of simple DDE commands for this purpose.

PhotoModeler acts as a DDE server (a server accepts DDE commands and responds to them). To talk to PhotoModeler you will need to use a DDE client (a client initiates a DDE connection to a DDE server and sends commands to it).

DDE clients can be written in many Windows programming languages but one of the easiest is Visual Basic by Microsoft. Other programs like Microsoft Word, Microsoft Excel and Autodesk AutoCAD can act as DDE clients by using Visual Basic for Applications (VBA). Other programming languages like C, C++ and Java may also have DDE command interfaces.

Not every aspect of PhotoModeler can be accessed through DDE. The following subsections outline the DDE commands and provide an example using Microsoft VBA.

Note: DDE is a mechanism built into Microsoft Windows and is not a system developed by Eos Systems. To that extent, PhotoModeler's DDE capability is dependent on DDE functioning correctly on your machine.

Command Structure

PhotoModeler's DDE commands take a very simple form. Most of the complexity of DDE has been left off so we can concentrate on getting real work done. Only the "DDE Initiate", "DDE Request" and "DDE Terminate" messages are used.

All PhotoModeler DDE commands are ASCII text strings and are of the format: "commandName commandParam1 commandParam2 ...". All commands return values and a return code indicating success or failure. PhotoModeler's DDE commands are NOT case sensitive. For example, the commands "GetNextPoint", "getnextpoint" and "GETNEXTPOINT" are all equivalent.

To use the DDE interface of PhotoModeler:

1. Start PhotoModeler.
2. Start your DDE client program.
3. The DDE client opens a DDE channel to PhotoModeler using "DDE Initiate" with the server name: "PhotoModeler" and the topic: "Data".
4. The DDE client sends DDE commands using "DDE Request" to PhotoModeler.
5. The DDE client closes the DDE channel to PhotoModeler using "DDE Terminate".

Each programming or macro language has different syntax and methods for using DDE. Look into the manuals for your language for further instructions. As an example, using the Microsoft Word Visual Basic language step 3 above would be:

```
c = DDEInitiate(App:="PhotoModeler", Topic:="Data")
```

and a step 4. request to open a project would be:

```
DDERequest(Channel:=c, Item:="OpenProject d:\test1.pmr")
```

See the *Example Use* section for more detail.

Note 1: The command string sent to the DDERequest must not be longer than 254 characters or an error will result. The biggest problem this causes is with very long file names in the OpenProject and other file related commands. Also note that this limit was 49 characters before version PhotoModeler 4.0c.

Note 2: On some systems and with some languages the DDE command acknowledgment is not received back from PhotoModeler. As a result your client may give "time out" errors (or similar). You can usually get around this problem by "trapping" the Timeout error message and ignoring it.

Commands

The following subsections describe each of the available PhotoModeler DDE commands. The syntax of the passed-in strings and returned strings is shown for each command.

Following is a categorized list of the available commands, grouped by functionality:

Project set up:

NewProject
OpenProject
SaveProject
AddLayer
RemoveLayer
SetLayerByName
SetLayerByRegion
IdealizeProject

Camera/Photo:

AddPhoto
GetCamera
AddCamera
GetPhotoCamera
SetPhotoStation
GetPhotoStation
SetPhotoProcessing
GetPhotoList
SetPhotoSet
RemovePhotoSet
ShowPhoto

Object Information:

GetMarkedPoint
GetMarkedPointByIndex
GetNextPoint
GetNextPointID
GetNum3DPoints
GetNumMarkedPoints
GetPoint
GetUnits
GetNextCylinder
BoundingBox
ProjectPoint
ResetLists

Scale Rotate:

Scale
Translate
RotateAxes
RotateXYZ
ActivateTSR

Exporting:

Export
Export3DDXF
ExportOrthoFromPoints
ExportOrthoFromSurfaces
ExportTable

Automated Tools:

AutoMark
AutoReference
AutoReferenceByLayer
TwoPhotoAutoReference

Modeling:

MP
DeleteMarkedPoint
DeleteMarkedPointByIndex
MFP
Process
SetIterationType
SetPointToUseInProcessing
SetPointName
Show3Dviewer
CreatePointCloud
DefineControlPoint
ImportSilhouettes
AddLine

Following is a full list of commands, sorted alphabetically:

ActivateTSR

Description:	Activate the Translate Scale and Rotate.
Syntax:	"ActivateTSR translate scale rotate" where: translate, scale, and rotate are '1' to activate or '0' to deactivate
Return:	"1" if successful or "0" if not. Failure returns if: - Incorrect number of parameters - No project is loaded - No affine is set on the project
Example:	"ActivateTSR 1 1 1" return: "1"

AddCamera

Description:	Add a new camera to the project.
Syntax:	"AddCamera cName f fw fh pw ph xp yp K1 K2 K3 P1 P2" or "AddCamera cName f fw fh pw ph xp yp K1 K2 K3 P1 P2 photo" where: cName is a unique camera name (no spaces), "f" is the camera's focal length in mm, "fw fh" are the format size in mm, "pw ph" are the camera's expected image size in pixels, "xp yp" are the principal point in mm, "K1 K2 K3 P1 P2" are optional and are the lens distortion parameters, and "photo" is the optional photo number to which this camera is specifically assigned.
Return:	"1" if successful or "0" if not. Failure returns - insufficient number of parameters - no project is open - 'cName' already exists in project

Example:	"AddCamera kodak1 35.2 36.2 23.8 1280 1024 18.2 12.1" OR "AddCamera cam4 35.2 36.2 23.8 1280 1024 18.2 12.1 0.0003 0.000032 0.000012 0.002 -0.00005" OR "AddCamera cam4 35.2 36.2 23.8 1280 1024 18.2 12.1 0.0003 0.000032 0.000012 0.002 -0.00005 2" return: "1"
----------	--

AddLayer

Description:	Add a new layer to the project passing in the name of the new layer
Syntax:	"AddLayer layerName" where: layerName is a string for the name- cannot include spaces
Return:	"1" if successful, "0" if not successful. Failure returns - name if not unique
Example:	"AddLayer layerName" return "1"

AddLine

Description:	Adds a line between 2 existing points, and optional assigns the line to a given layer and/or material
Syntax:	"AddLine point1 point2 [LayerName] [MaterialName]" where: point1 is the id of the first point, point2 is the id of the second point, and LayerName is the optional layer name to which this line will be added, and MaterialName is the optional material name to which this line will be added. Note the layer and material names are case sensitive.
Return:	"1" if successful, "0" if not successful. Failure returns - Wrong number of parameters - No project loaded - Either point can not be found - The layer specified can not be found - The material specified can not be found
Example:	"AddLine 2 3 Default Red" return "1"

AddPhoto

Description:	Add a new photograph to the project.
Syntax:	"AddPhoto ID cName imageFile" where: ID is a unique identifier number for the photograph (≥ 1), "cName" is the name of the camera to be assigned to the photograph (must have already been defined by command above), and "imageFile" is optional and is a path name to an image file.
Return:	"1" if successful or "0" if not. Failure returns - insufficient number of parameters - no project is open - 'ID' photo already exists in project - 'cName' does not exist in project - 'imageFile' file does not exist on disk
Example:	"AddPhoto 1 kodak1" return: "1"

AutoMark

Description:	Perform auto-marking on the specified photo (or 0 for all) with the specified parameters.
Syntax:	<p>"AutoMark PhotoNumber(or 0 for all) X1 Y1 X2 Y2 MaxDiameter MinDiameter TargetType [FitError] [Layer] [Name]"</p> <p>where:</p> <p>PhotoNumber is the photo to mark or '0' for all photos in the project, X1 Y1 is the top left corner of the region to mark, Y1 Y2 is the bottom right corner of the region to mark (note the region is ignored when all photos are marked - the entire image is used in that case), MaxDiameter is the maximum size of the largest target in pixels, MinDiameter is the minimum size of the smallest target, TargetType is the type of target to mark, ie one of: -1 (not set, PhotoModeler will attempt to mark all targets types), 0 (RAD Coded Targets), 1 (RAD dots), 2 (dot targets), 3 (8bit set), 4 (10bit set), 5 (12bit set), 6 (User Set).</p> <p>The TargetType and remaining parameters are optional and are only valid if the Coded Target module is installed. If no module installed, TargetType will default to 2 for dot targets. FitError indicates the Fit Error threshold. Layer specifies the layer that automarked points are assigned. Name specifies the name to assign to points that are automarked.</p> <p>See the <i>Automatic Target Marking Dialog</i> for more background.</p>
Return:	<p>"1 NumNewMarks"</p> <p>where NumNewMarks is the number of new Marked Points created during this automarking run or "0" if this command failed.</p> <p>Failure returns</p> <ul style="list-style-type: none">- incorrect number of parameters- no project is open- the photo id number is invalid- automarking failed to run
Example:	<p>"AutoMark 1 0 0 2000 1500 40 10 0 0.1 layerName amPt"</p> <p>return "1 14"</p>

AutoReference

Description:	Performs automatic point referencing.
--------------	---------------------------------------

Syntax:	<p>"AutoReference SearchDistance SearchDistanceDoubling(1=Yes,0=No) MinNumPhotos SetToDoNoProcess(1=Yes,0=No) [Name of automatically referenced points]"</p> <p>where:</p> <p>SearchDistance defines how far apart the intersection of the light ray from one marked point and the light ray from another marked point can be before the points are determined to be unmatching (in project units), SearchDistanceDoubling is 1 to double the search distance and reiterate, MinNumPhotos is the minimum number of photos the referenced object point must appear on, SetToDoNoProcess is 1 for Yes and 0 for No and at the end of the command an option name for each point referenced. See the <i>Automatic Referencing Dialog</i> for more background.</p>
Return:	<p>"1 NumMarksReferenced"</p> <p>where NumMarksReferenced is the number of marks automatically referenced or "0" if this command failed.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open - autoreferencing fails
Example:	<p>"AutoReference 1.983 1 3 1 ar"</p> <p>or</p> <p>"AutoReference 1.983 1 3 1"</p> <p>or</p> <p>"AutoReference 1.983 1 3 1 Names can have spaces"</p> <p>return "1 14"</p>

AutoReferenceByLayer

Description:	Performs auto-referencing only on the layer specified
Syntax:	"AutoReferenceByLayer SearchDistance SearchDistanceDoubling(1=Yes,0=No) MinNumPhotos SetToDoNoProcess(1=Yes,0=No) [Name of automatically referenced points] LayerName" where: SearchDistance defines how far apart the intersection of the light ray from one marked point and the light ray from another marked point can be before the points are determined to be unmatching (in project units), SearchDistanceDoubling is 1 to double the search distance and reiterate, MinNumPhotos is the minimum number of photos the referenced object point must appear on, SetToDoNoProcess is 1 for Yes and 0 for No and at the end of the command an option name for each point referenced, LayerName is the name of the layer on which points will be autoreferenced. See the <i>Automatic Referencing Dialog</i> for more background.
Return:	"1 NumMarksReferenced" where NumMarksReferenced is the number of marks automatically referenced or "0" if this command failed. Failure returns - name of layer if not found
Example:	"AutoReference 1.983 1 3 1 layerName" return "1 14"

BoundingBox

Description:	Calculates the dimension of a 3D bounding box containing all the points with a specified user name.
Syntax:	"BoundingBox ptName" where: ptName is the user name of points to used in the bounding box calculation
Return:	"S width length depth"
Example:	"BoundingBox ar" return "1 100.3 250.04 300.33"

CreatePointCloud

Description:	Creates a point cloud surface from points with the specified user name.
--------------	---

Syntax:	"CreatePointCloud name u v" where: name=the user name assigned to points that are to be used, can be as long as 512 chars and have spaces optional: u = max u spans v = max v spans
Return:	"1" if successful or "0" if this command failed.
Example:	"CreatePointCloud ar" return "1"

DefineControlPoint

Description:	(Re)Define a 3D Control Point.
Syntax:	"DefineControlPoint importName ctlName x y z px py pz" where: "importName" is a unique name (no spaces and cannot start with underscore) for the name of the import object, "ctlName" is a unique name (no spaces and cannot start with underscore) for the control point, "x y z" are the coordinates of the control point, and "px py pz" are optional and are the standard deviation error of the point (if these are missing or any one of px, py or pz is negative then the whole point is considered fixed). If a control point with the same name already exists in the project, the values in the command will override it. Note that x,y,z and px,py,pz are in the current project units.
Return:	"1" if successful or "0" if not. Failure returns - incorrect number of parameters - no project is open - name starts with an underscore
Example:	"DefineControlPoint Box c1 23.2 355.4 234.1" return: "1"

DeleteMarkedPoint

Description:	Delete a mark from a photo.
Syntax:	"DeleteMarkedPoint OPID PhotoID" where: OPID is the ID number of the marked point and PhotoID is the ID of the photo on which the point is marked.
Return:	Return "1" if successful, "0" if not. Failure returns if - No project open - Point ID doesn't exist - Photo ID doesn't exist - The Point is not marked on the photo
Example:	" DeleteMarkedPoint 19 3" return: "1"

DeleteMarkedPointByIndex

Description:	Delete mark from a photo using its index on a photo.
Syntax:	"DeleteMarkedPointByIndex PhotoID Index" where: "PhotoID" is the ID of the photo on which the point is marked and Index ranges from 1 to the number of marked points on the photo (index is not the point ID). Note: deleting a point by its index will 'shuffle' any points with a larger index down by one.
Return:	"1" if successful or "0" if not. Failure returns: - No project open - Photo ID doesn't exist - There is no point at the index specified
Example:	"DeleteMarkedPointByIndex 4 25" return: "1"

Export

Description:	Export the current project using the settings specified.
Syntax:	<p>"Export formatType fileName points ids lines edges curves surfaces surfaceDraw cylinders textures textureSizeX textureSizeY mapFormat resampleType textureType surfaceAsNURBS cylindersAsLines cylindersAsTriangles cylindersAsSolid cylindersAsNURBS curveAsNURBS dxfVisibleFaces dxfPolyFaces dxfDecPlaces dxfClockwise dxfTwoDPlane cameraPositions shapeEdges shapeFaces importedPoints, importedLines importedSurfaces offsetPoints"</p> <p>where:</p> <p>'formatType' is the export format (0=3D DXF, 1=2D DXF, 2=3D Studio, 3=VRML 1, 4=VRML 2, 5=Wavefront, 6=Raw, 7=IGES, 8=Rhino, 9=STL, 10=Maya, 11=Google Earth (KML), 12 = Google Earth (KMZ)),</p> <p>'fileName' is the name and path for the export output (Note: no spaces are allowed in the file path or name),</p> <p>'points' is 1 to include points (when valid for the format) in the export 0 to exclude them,</p> <p>'ids' is 1 to include point ids (when valid for the format) in the export 0 to exclude them,</p> <p>'lines' is 1 to include lines (when valid for the format) in the export 0 to exclude them,</p> <p>'edges' is 1 to include edges (when valid for the format) in the export 0 to exclude them,</p> <p>'curves' is 1 to include curves (when valid for the format) in the export 0 to exclude them,</p> <p>'surfaces' is 1 to include surfaces (when valid for the format) in the export 0 to exclude them,</p> <p>'surfaceDraw' is 1 to include surface draw points and lines (when valid for the format) in the export 0 to exclude them,</p> <p>'cylinders' is 1 to include cylinders (when valid for the format) in the export 0 to exclude them, a mix,</p>

	<p>'textures' is 1 to texture exported surfaces and cylinders (when valid for the format) in the export 0 to not texture them,</p> <p>'textureSizeX' and 'textureSizeY' are the width and height of the texture file,</p> <p>'mapFormat' is the image format the texture should be (0 is the first item in the 'map file format' drop-down, 1 the second, etc. the available image formats depend on what 3D format is being exported),</p> <p>'resampleType' is the type of resampling used on the texture file (0=Nearest neighbor, 1=Bilinear, 2=Bicubic),</p> <p>'textureType' is the 0 if fast textures should be used or 1 if quality textures should be used,</p> <p>'surfacesAsNURBS' is 0 if surfaces should be exported as triangles 1 if they should be NURBS or 2 if they should be cylindersAsLines' is 1 if cylinders should be exported as center lines 0 if they should not,</p> <p>'cylindersAsTriangles' is 1 if cylinders should be exported as triangles 0 if they should not,</p> <p>'cylindersAsSolid' is 1 if cylinders should be exported as full cylinders 0 if they should not,</p> <p>'cylindersAsNURBS' is 1 if cylinders should be exported as NURBS surfaces 0 if they should not,</p> <p>'curvesAsNURBS' is 1 if curves should be exported as NURBS, 0 if they should not,</p> <p>'dxFVisibleFaces' is 1 if DXF surfaces should be a mesh 0 if they should not,</p> <p>'dxFPolyFaces' is 1 if DXF triangle edges should be visible,</p> <p>'dxDecPlaces' is the number of decimal places DXF files should be written to,</p> <p>'dxFClockwise' should be 1 if DXF surface vertex ordering should be clockwise 0 if it should be counter-clockwise,</p> <p>'dxFTwoDPlane' should be 0 for X=0, 1 for Y=0 or 2 for Z=0.</p> <p>cameraPositions is 1 to include (when valid for the format) in the export 0 to exclude them,</p> <p>shapeEdges is 1 to include Shape Edges (when valid for the format) in the export 0 to exclude them,</p> <p>shapeFaces is 1 to include Shape Faces (when valid for the format) in the export 0 to exclude them,</p> <p>importedPoints is 1 to include Imported Points (when valid for the format) in the export 0 to exclude them,</p> <p>importedLines is 1 to include Imported Lines (when valid for the format) in the export 0 to exclude them,</p> <p>importedSurfaces is 1 to include Imported Surfaces (when valid for the format) in the export 0 to exclude them,</p> <p>offsetPoints is 1 to include 3D Offset Points (when valid for the format) in the export 0 to exclude them</p>
--	--

Return:	"1" if export is successful or "0" if this command failed. Failure returns - incorrect number of parameters - no project is open - an invalid parameter - the export file could not be created
Example:	"Export 5 c:\temp\TestExport.obj 1 0 1 1 1 1 1 1 1 512 512 0 2 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1" return "1"

Export3DDXF

Description:	Export the currently loaded project as a 3D DXF file.
Syntax:	"Export3DDXF fileName points ids lines edges curves surfaces surfaceDraw cylinders cylLines cylTri decPlaces asMesh visibleEdges clockWise offsetPoints" where: filename is the full path and name of the export file (no spaces are allowed), points, ids, lines, edges, curves, surfaces, surfaceDraw and cylinders are set to "1" if that type should be included in the export or "0" if they should not. cylLines should be set to "1" to export cylinders as center lines, cylTri should be set to "1" to export cylinders as triangles, decPlaces should be the number of decimal places to include in the file, asMesh should be "1" to export surfaces as a mesh, visibleEdges should be "1" turn on the visible triangle edges option, clockwise should be "1" for the surface vertex order to be clockwise or "0" for it to be counter clockwise, offsetPoints "1" for the 3D offset points to be visible and "0" for not.
Return:	"1" if export is successful or "0" if this command failed. Failure returns - incorrect number of parameters (including spaces in file name) - the directory/folder where file is to go, does not exist - no project is open - the export file could not be created - the export failed
Example:	"Export3DDXF c:\output\House.dxf 1 0 1 1 0 1 0 0 0 0 6 1 1 1 0" return "1"

ExportOrthoFromPoints

Description:	Export an ortho photo based on a rectangular region defined by 3 points
--------------	---

Syntax:	<p>"ExportOrthoFromPoints photoID overScan PointID1 PointID2 PointID3 dominantAxis imageSizeX imageSizeY fileName"</p> <p>where:</p> <p>"photoID" corresponds to the photo from which the rectangle is defined, "overScan" corresponds to the % of extra photographic data captured (0-40), "PointID1", "PointID2", "PointID3" corresponds to the ID's of the three points defining the ortho region (ie "PointID1" and "PointID2" define the horizontal axis, and "PointID1" and "PointID3" define the vertical axis), "dominantAxis" corresponds to the dominant axis (ie 1-Horizontal, 2-Vertical), "imageSizeX" and "imageSizeY" correspond to the number of horizontal and vertical pixels respectively in the output, and "fileName" corresponds to the full path of the output file name (can have spaces in path). See also <i>Ortho-Photo Export</i></p>
Return:	<p>"1" if export is successful or "0" if this command failed. Failure returns</p> <ul style="list-style-type: none"> - one or more of the points are not valid 3D points - overscan out of range (ie outside 0-40) - dominantAxis out of range (ie outside 1-2) - fileName corresponds to an invalid path - projection plane cannot be formed internally
Example:	<p>"ExportOrthoFromPoints 1 10 1000 1010 1020 1 512 512 c:\orthophotos\fromPoints.jpg"</p> <p>return "1"</p>

ExportOrthoFromSurfaces

Description:	Export an ortho photo based on all photo textured surfaces in a project
Syntax:	<p>"ExportOrthoFromSurfaces planeType rotation overScan imageSizeX imageSizeY fileName"</p> <p>where:</p> <p>"planeType" corresponds to the plane type (1-6, where 1-TopXY, 2-BottomXY, 3-FrontXZ, 4-BackXZ, 5-RightYZ, 6-LeftYZ), "rotation" corresponds to the image rotation (1-4, where 1-0deg, 2-180deg, 3-90deg, 4-270deg), "overScan" corresponds to the % of extra photographic data captured (0-40), "imageSizeX" and "imageSizeY" correspond to the number of horizontal and vertical pixels respectively in the output, and "fileName" corresponds to the full path of the output file name (can have spaces in path). See also <i>Ortho-Photo Export</i></p>

Return:	"1" if export is successful or "0" if this command failed. Failure returns <ul style="list-style-type: none"> - planeType variable out of range (ie outside 1-6) - rotation variable out of range (ie outside 1-4) - overscan out of range (ie outside 0-40) - fileName corresponds to an invalid path - projection plane cannot be formed internally
Example:	"ExportOrthoFromSurfaces 1 0 0 512 512 c:\orthophotos\fromSurfaces.jpg" return "1"

ExportTable

Description:	Export the indicated table (by index) in the format specified to a text file.
Syntax:	"ExportTable tableIndex formatType fileName onlySelected" where: "tableIndex" corresponds to the index of the table in the ini file under the section [TableConfigurations] (see also <i>Table Layouts Dialog</i>), "formatType" is 1=comma separated (CSV), 2=tab separated, 3=fixedWidth, "filename" the full path of the file, and "onlySelected" controls whether only selected items or all items are exported 1=only selected items, 0=all items. Sample "ExportTable 5 1 c:\temp\TestExport.txt 1"
Return:	"1" if export is successful or "0" if this command failed.
Example:	"ExportTable 1 1 c:\temp\TableExport.txt 0" return "1"

GetCamera

Description:	Get the parameters for a camera.
Syntax:	"GetCamera cName" where: cName is the unique name of the camera.

Return:	<p>"1 f fw fh xp yp K1 K2 K3 P1 P2" if successful or "0" if not. where: "f" is the camera's focal length in mm, "fw fh" are the format size in mm, "xp yp" are the principal point in mm, and "K1 K2 K3 P1 P2" are the lens distortion parameters. Failure returns - incorrect number of parameters - no project is open - 'cName' does not exist in project</p>
Example:	<p>"GetCamera kodak1" returned "1 35.2 36.2 23.8 18.2 12.1 0.000023 0.000004"</p>

GetCylinder

Description:	Return a cylinder in with a specified ID.
Syntax:	"GetCylinder n" where: n is the Cylinder ID.
Return:	"1 n r x1 y1 z1 x2 y2 z2" where: n is the Cylinder ID, r is the radius, x1,y1,z1 and x2,y2,z2 are the coordinates of the ends of the cylinder centerline. Coordinates and radius are in project units and are affects by project current scale and rotations. "0" is returned if the command failed. Failure returns - incorrect number of parameters - no project is open - 'n' does not correspond to an existing cylinder
Example:	"GetCylinder 5" return "1 5 7.96 234.1 0.3 -984.2 235.2 456.2 -984.0"

GetMarkedPoint

Description:	Return a Marked Point's statistics by Object Point number.
Syntax:	"GetMarkedPoint OpID PhotoID" where: OpID is the id number of the object point and PhotoID is the id number of the photograph.
Return:	"1 X Y ResidualX, ResidualY, ResidualLength" where: X and Y are the image coordinates (in pixels) of the mark location, ResidualX and ResidualY are the X and Y values of the mark's residual and ResidualLength is the length of the mark's residual vector or "0" if this command failed. Note if the point is not 3D the residual values will be returned as 0. Failure returns - incorrect number of parameters - no project is open. - the photo number is invalid - the point number is invalid - the point is not marked on the photo
Example:	"GetMarkedPoint 1 2" return "1 815.0 49.0 -0.247 0.944 0.976 "

GetMarkedPointByIndex

Description:	Return a Marked Point's statistics by index.
Syntax:	"GetMarkedPointByIndex PhotoID Index " where: PhotoID is the id number of the photograph (≥ 1) and index ranges between 1 to N (N is number of marked points on photo). You use by looping, calling this command, and incrementing the index until a failure code is returned.
Return:	"1 X Y ResidualX, ResidualY, ResidualLength OpNum" where: X and Y are the image coordinates (in pixels) of the mark location, ResidualX and ResidualY are the X and Y values of the mark's residual, ResidualLength is the length of the mark's residual vector and OpNum is the id number of the mark's associated Object Point or "0" if this command failed. Note if the point is not 3D the residual values will be returned as 0. Failure returns - incorrect number of parameters - no project is open - the photo number is invalid - the index number is invalid
Example:	"GetMarkedPointByIndex 1 4" return "1 939.565 1115.64 -0.0688 0.0572 0.0895 9"

GetNextCylinder

Description:	Return a cylinder in sequence. See ResetLists and SetIterationType.
Syntax:	"GetNextCylinder"
Return:	"1 n r x1 y1 z1 x2 y2 z2" where: n is the Cylinder ID, r is the radius, x1,y1,z1 and x2,y2,z2 are the coordinates of the ends of the cylinder centerline. Coordinates and radius are in project units and are affected by project current scale and rotations. "0" is returned if the command failed. Failure returns - incorrect number of parameters - no project is open - the end of the list has been reached
Example:	"ResetLists" "GetNextCylinder" return "1 1 7.96 234.1 0.3 -984.2 235.2 456.2 -984.0"

GetNextPoint

Description:	Return a 3D Point in sequence. See ResetLists and SetIterationType.
Syntax:	"GetNextPoint"
Return:	"1 n p c x y z" where: n is the Point ID, p is the processed flag (1=point is processed, 0=point is approximated only), c is the control flag (1=point is a control point, 0=not a control), x is the X coordinate (in project units), y is the Y coordinate and z is the Z coordinate of the 3D point. "0" is returned if the command failed. Failure returns - incorrect number of parameters - no project is open - the end of the list has been reached
Example:	"ResetLists" "GetNextPoint" return "1 1 1 0 4.2 14.3 34.2"

GetNextPointID

Description:	Return the next available Point ID for marking points. This command also increments PhotoModeler's internal next ID to avoid Point ID overlap.
Syntax:	"GetNextPointID"
Return:	"1 n" where n is the next Point ID to be used with the MP command or "0" if this command failed. Failure returns - incorrect number of parameters - no project is open.
Example:	"GetNextPointID" return "1 12"

GetNum3DPoints

Description:	Return the number of 3D points in the currently open project. This includes processed points, approximated points and points with only 1 reference.
Syntax:	"GetNum3DPoints"
Return:	"1 n" where: n is the number of 3D points or "0" if the command was not successful. Failure returns - incorrect number of parameters - no project is open
Example:	"GetNum3DPoints" return "1 164"

GetNumMarkedPoints

Description:	Returns the number of Marked Points on a photo.
Syntax:	"GetNumMarkedPoints PhotoID" where: PhotoID is a unique identifier number for the photograph (>=1).
Return:	"1 Num" where: Num is the number of marks on the photo or "0" if this command failed. Failure returns - incorrect number of parameters - no project is open - the photo number is invalid

Example:	"GetNumMarkedPoints 4" return "1 10"
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GetPhotoList

Description:	Return a string list of Photographs numbers contained in currently open Project.
Syntax:	"GetPhotoList"
Return:	"1 n1 n2 n3..." where: n1, n2, n3 etc. are photograph numbers or "0" if this command failed. Failure returns - incorrect number of parameters - no project is open
Example:	"GetPhotoList" return "1 1 2 3 4"

GetPoint

Description:	Return the 3D position of a point with a specified Point ID.
Syntax:	"GetPoint n" where: n is the Point ID of the desired point.
Return:	"1 n p c x y z" where: n is the Point ID, p is the processed flag (1=point is processed, 0=point is approximated only), c is the control flag (1=point is a control point, 0=not a control), x is the X coordinate (in project units), y is the Y coordinate and z is the Z coordinate of the 3D point. "0" is returned if the command failed. Failure returns - incorrect number of parameters - no project is open - 'n' does not correspond to an existing point - the point has no 3D position.
Example:	"GetPoint 5" return "1 5 1 0 34.2 534.3 244.2"

GetUnits

Description:	Return the measurement units used by the current project.
Syntax:	"GetUnits"

Return:	<p>"1 xx"</p> <p>where:</p> <p>xx is the unit specifier (one of "km", "m", "cm", "mi", "yd", "ft", or "in"). Returns "0" if the command failed.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open
Example:	<p>"GetUnits"</p> <p>return "1 ft"</p>

GetPhotoCamera

Description:	Get the camera parameters for a particular photo (useful for self-calibration or if all you know is the photo number).
Syntax:	<p>"GetPhotoCamera ID"</p> <p>where:</p> <p>ID is a unique identifier number for the photograph (≥ 1).</p>
Return:	<p>"1 !camName! f fw fh xp yp K1 K2 K3 P1 P2" if successful or "0" if not</p> <p>where:</p> <p>"camName" is the name of the camera (which might have spaces), "f" is the camera's focal length in mm, "fw fh" are the format size in mm, "xp yp" are the principal point in mm, and "K1 K2 K3 P1 P2" are the lens distortion parameters.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open - 'ID' does not correspond to an existing photo
Example:	<p>"GetPhotoCamera 1"</p> <p>returned "1 !kodak1! 35.2 36.2 23.8 18.2 12.1 0.000023 0.000004 0.00003"</p>

GetPhotoStation

Description:	Get the computed station orientation for a particular photo.
Syntax:	<p>"GetPhotoStation ID t"</p> <p>where:</p> <p>ID is a unique identifier number for the photograph (≥ 1), and t is "0" to return angles as omega, phi, kappa Euler angles or "1" to return the rotation matrix form, or 2 to return the center point coordinates and roll angle.</p>

Return:	<p>"1 x y z w p k" or "1 x y z r11 r12 r13 r21 r22 r23 r31 r32 r33" or "1 x y z x2 y2 z2 roll" if successful or "0" if not where: "x y z" is the station perspective center, "w p k" are the station's Euler angles (in radians), or the r's are the values of the rotation matrix (eg. r21 is the element in the 2nd row and 1st column) or the "x2 y2 z2" are the center point coordinates and "roll" is the roll angle. Failure returns - incorrect number of parameters - no project is open - 'ID' does not correspond to an existing photo - photo is not oriented</p>
Example:	<p>"GetPhotoStation 1 0" returned "1 23.3 12.1 -1.3 0.0 1.4 -2.1" OR "GetPhotoStation 1 1" returned "1 23.3 12.1 -1.3 1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0" "GetPhotoStation 1 2" returned "1 23.3 12.1 -1.3 0.0 0.0 0.0 45.0"</p>

IdealizeProject

Description:	Idealize the open project. Photos in the specified photo set will be idealized. See <i>Idealize Project</i> .
Syntax:	<p>"IdealizeProject ps" where: 'ps' corresponds to the name of the photo set that contains the photos that are to be idealized (see also <i>SetPhotoSet</i> DDE command). The 'ps' parameter can have spaces in the name. (note that the maximum number of images to process will use the default number according to the amount of memory installed on your system)</p>
Return:	<p>"1" if successful or "0" if not Failure returns - incorrect number of parameters - no project is open - not enough disk space to store new idealized images - photo set not found</p>
Example:	<p>"IdealizeProject ps1" returned "1"</p>

ImportSilhouettes

Description:	Import silhouettes from the specified file.
Syntax:	"ImportSilhouettes fileName" where: fileName: dos path of the silhouette file, can be long and can have spaces
Return:	"1" if successful or "0" if this command failed.
Example:	"ImportSilhouettes c:\temp\sils.txt" return "1"

MP

Description:	Mark a point on a photograph. This command is also used to do implicit referencing by matching the Object Point IDs and Control Point marking.
Syntax:	"MP PhotoID 3DPointID x y importObjName ctlName" where: 'PhotoID' is a valid photograph number (≥ 1), '3DpointID' is a valid 3D Point ID (starting at value returned by GetNextPointID), 'x' is the X photo coordinate in pixels, 'y' is the Y photo coordinate (upper left is 0,0), and if optionally marking control 'importObjName' is the name of imported object and 'ctlName' is the name of a control point to assign to this point. Note that both the last 2 optional parameters must be included if marking control points.
Return:	"1" if the point was marked successfully. "0" if it was not successful. Failure returns - incorrect number of parameters - no project is open - 'PhotoID' does not correspond to an existing photo - the point is already marked on this photo - there is no control point named 'ctlName' in project - the point '3DpointID' is already assigned to a different control point
Example:	"MP 3 231 23.12 456.21" OR "MP 3 231 23.12 456.21 Box c1" return "1"

MFP

Description:	Mark a fiducial point on a photograph.
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Syntax:	"MFP PhotoID FiducialName x y" where: PhotoID is a valid photograph number (as returned by GetPhotoList), FiducialName is a valid name of a Fiducial for the Camera being used by this photo, x is the X photo coordinate (upper left is 0,0) in pixels, and y is the Y photo coordinate. Note: the FiducialName can have no spaces in it.
Return:	"1" if the point was marked successfully."0" if it was not. Failure returns - incorrect number of parameters - no project is open - 'PhotoID' does not correspond to an existing photo - the point is already marked on this photo - no match to fiducial name.
Example:	"MFP 1 UpperLeft 20.2 31.2" return "1"

NewProject

Description:	Create a new project (closing any currently open project (without saving it)).
Syntax:	"NewProject units [CTSet [numBits startRatio endRatio]]" where: "units" denotes the default units of the created project and of the 3D data to be passed in subsequent calls: 0-km, 1-m, 2-cm, 3-mm, 4-mi, 5-yd, 6-ft, 7-in. CTSet is the coded target set (1=8-bit, 2=10-bit, 3=12-bit, 4=User defined). If CTSet=4, the user settings for numBits, startRatio and endRatio are passed in. See <i>Coded Targets</i> section for more information.
Return:	"1" if successful or "0" if not. Failure returns - insufficient number of parameters - 'units' is out of range
Example:	"NewProject 3" return: "1"

OpenProject

Description:	Open a PhotoModeler project file, closing any projects that are currently open. Note the file name should be in DOS format (i.e., no long file or directory names, no spaces, and no double byte (Asian) characters).
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Syntax:	"OpenProject fullPathOfPmrFile" where: fullPathOfPmrFile is the DOS path of a PhotoModeler PMR file.
Return:	"1" if project was opened successfully or "0" if not. Failure returns - insufficient number of parameters - the named project could not be opened (illegal file name).
Example:	"OpenProject c:\data\projects\p1\first.pmr" return: "1"

Process

Description:	Process the project.
Syntax:	<p>"Process flag" or "Process flag pmq rca" where: "flag" is the sum of: - 1 for reorient all photos - 2 for reorient only unoriented photos - 4 for global optimize (bundle adjustment) - 8 for self-calibration during bundle - 16 for field calibration during bundle - 32 for constraints processing ('1' and '2' cannot be set at same time, '8' and '16' cannot be set at the same time, '8', '16' and '32' must be set with '4' also, and '16' only works if there is one camera in project assigned to multiple photos).</p> <p>If the project has more than one camera, '8' (self-calibration) is used by default as you cannot use 16 for a multiple camera project.</p> <p>Optional: pmq = Project Marking Quality (to enable Reference Checker), where -1 = off or > 0 as the marking residual threshold above which points will be processed (see rca variable) rca = 0,1,2 where 0 = do not run, 1 = unreference, 2 = set to do not use, 3 = rename name = name points to rename if rca= 3</p>
Return:	<p>"1 iter i.e. fe" if successful or "0" if not where: "iter" is the total number of iterations needed for solution, "i.e." is error in first iteration of processing and "fe" is the final error. Note if bundle is not run (i.e., only orientation) then "iter i.e. fe" will be "-1 -1 -1". Note this command can take some time to run as it waits to return until processing is complete.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - insufficient number of parameters - no project is open - 'flag' is malformed - project fails to process/orient

Example:	"Process 13" return "1 3 12.2 0.1" or "Process 13 1 3 rc" processes and each point with a marking residual above 1 will be renamed to rc and return "1 3 12.2 0.1"
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ProjectPoint

Description:	Return the 2D position of a 3D point on a photo.
Syntax:	"ProjectPoint PhotoID X Y Z" where: "PhotoID " is the id of the photo for the projection, x is the X coordinate, y is the Y coordinate and z is the Z coordinate of the 3D point (coordinates in project units).
Return:	"1 X Y" if successful or "0" if not where: X nd Y represent the 2D photo coordinates (upper left is 0,0). Failure returns - no project is open - invalid Photo ID - photo not oriented - point doesn't project onto the image
Example:	"ProjectPoint 1 10.5 20.8 -1.89" return "1 10.7 30.6"

RemoveLayer

Description:	Remove a layer by passing in the name of layer to be removed.
Syntax:	"RemoveLayer layerName" where: layerName is a string for the name
Return:	"1" if successful, or "0" if not successful. Failure returns - name of layer not removed
Example:	"SetLayerByName NewLayer 2 PointName" return 25

RemovePhotoSet

Description:	Remove a photo set by passing in the name of set to be removed
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Syntax:	"RemovePhotoSet psName" where: psName is a string for the name
Return:	"1" if successful, "0" if not successful. Failure returns Name of set not removed
Example:	"SetPhotoSet pset 2 4 8" return "1"

ResetLists

Description:	Reset the counters for the "Next" commands (e.g. GetNextPoint). This should be called before the "Next" commands are used and any time you wish to start getting the first item again.
Syntax:	"ResetLists"
Return:	"1" if successful, "0" if not successful. Failure returns - incorrect number of parameters - no project is open
Example:	"ResetLists" return "1"

RotateAxes

Description:	Set the rotate part of the project affine transform based on two sets of axes defined by points or camera stations.
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Syntax:	<p>"RotateAxes axesType axis1ID1 axis1ID2 axis2ID1 axis2ID2 item1Type item2Type item3Type item4Type"</p> <p>where:</p> <p>axesType = 1 for X&Y axes, 2 for X&Z axes, 3 for Y&Z axes</p> <p>axis1ID1 is the ID of the 1st item (point or camera station, see below) of the 1st axes</p> <p>axis1ID2 is the ID of the 2nd item (point or camera station, see below) of the 1st axes</p> <p>axis2ID1 is the ID of the 1st item (point or camera station, see below) of the 2nd axes</p> <p>axis2ID2 is the ID of the 2nd item (point or camera station, see below) of the 2nd axes</p> <p>and optional (default is point type):</p> <p>item1Type is the type of the 1st item of 1st axes - 1 for Point, 2 for Camera Station</p> <p>item2Type is the type of the 2nd item of 1st axes - 1 for Point, 2 for Camera Station</p> <p>item3Type is the type of the 1st item of 2nd axes - 1 for Point, 2 for Camera Station</p> <p>item4Type is the type of the 2nd item of 2nd axes - 1 for Point, 2 for Camera Station</p>
Return:	Returns "1" if successful or "0" if not
Example:	<p>"RotateAxes 1 38 30 42 15" would set up an X axes using points 38 and 30, and a Y axis using points 42 and 15</p> <p>"RotateAxes 2 1 30 2 3 1 2 2 2" would set up an X axes using camera station 1 and point 30, and a Z axis using cam station 2 and camera station 3</p>

RotateXYZ

Description:	Set the rotate part of the project affine transform based on an origin and two axes points.
Syntax:	<p>" RotateXYZ OriginPtId XAxisPtId YaxisPtId ZAxisPtId"</p> <p>where:</p> <p>xxxPtId are unique identifier numbers for existing Object Points. One of 'XaxisPtId', 'YaxisPtId', or 'ZaxisPtId' must be zero and the remaining two define the coordinate system being used. For example, "RotateXYZ 12 13 20 0" would set up an XY axis rotation using point 12 as origin, 13 as x axis and 20 as y axis points. Note that if any of the points is not 3D then the command still succeeds but the project will not be rotated until the points both become 3D.</p>

Return:	" RotateXYZ OriginPtId XAxisPtId YaxisPtId ZAxisPtId" where: xxxPtId are unique identifier numbers for existing Object Points. One of 'XaxisPtId', 'YaxisPtId', or 'ZaxisPtId' must be zero and the remaining two define the coordinate system being used. For example, "RotateXYZ 12 13 20 0" would set up an XY axis rotation using point 12 as origin, 13 as x axis and 20 and y axis points. Note that if any of the points is not 3D then the command still succeeds but the project will not be rotated until the points both become 3D.
Example:	"RotateXYZ 12 13 20 0" returned "1" OR "RotateXYZ 12 13 0 22" returned "1"

SaveProject

Description:	Save the currently open PhotoModeler project to disk.
Syntax:	"SaveProject fullPathOfPmrFile" where: fullPathOfPmrFile is the DOS path of a PMR file.
Return:	"1" if project was saved successfully or "0" if not. Failure returns - insufficient number of parameters - no project is open - the current project could not be saved (out of disk space, illegal file name, or no project open).
Example:	"SaveProject c:\data\projects\p1\second.pmr" return "1"

Scale

Description:	Set the scale part of the project affine transform. The scale distance should be in project units (which are set during NewProject).
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Syntax:	<p>"Scale pt1Id pt2Id distance"</p> <p>where:</p> <p>pt1Id and pt2Id are identifier numbers for the Object Points that scale is defined between.</p> <p>or</p> <p>"Scale id1 id2 distance type1 type2"</p> <p>The optional "type1 type2" variables control what object types are used to define the scale where 1=point, 2=edge, and 3=camera station.</p> <p>The project is scaled so that the distance between those two items becomes 'distance' (in project's default units). Note that if either of the items is not 3D or invalid then the command still succeeds but the project will not be scaled until the items both become 3D.</p>
Return:	<p>"1" if successful or "0" if not.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open - 'pt1Id' or 'pt2Id' do not correspond to existing points - 'distance' is zero or negative
Example:	<p>"Scale 12 13 22.34"</p> <p>or</p> <p>"Scale 1 2 22.34 1 3"</p> <p>return: "1"</p>

SetIterationType

Description:	Set the type of iteration done by GetNextPoint and GetNextCylinder. This call does an implicit "ResetLists".
Syntax:	<p>"SetIterationType n"</p> <p>where:</p> <p>n = 0 to make iteration through all points or cylinders and</p> <p>n = 1 to make iteration through only those points or cylinders selected by PhotoModeler user.</p>
Return:	<p>"1" if successful, "0" if not successful.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open - 'n' not in valid range
Example:	<p>"SetIterationType 1"</p> <p>return: "1"</p>

SetLayerByName

Description:	Set the layer on a group of points based on their name
Syntax:	"SetLayerByName layerName n ptName" where: layerName is the name of an already defined layer, n is the unique id of an existing photo, and ptName is the name assigned to points on the given photo
Return:	"1" and the number of points that had their layer set if successful, or "0" if not successful. Failure returns - name if not unique
Example:	"SetLayerByName NewLayer 2 mypoint" return "1 25"

SetLayerByRegion

Description:	Set the layer on a group of points based on a rectangular region
Syntax:	"SetLayerByRegion layerName n X1 Y1 X2 Y2" where: layername is the name of an already defined layer, n is the unique id of an existing photo, and the latter four parameters define a region within the given photograph. This command will bind all the points falling in the given region of the photo to the specified layer.
Return:	"1" and the number of points that had their layer set if successful, or "0" if not successful.
Example:	"SetLayerByRegion NewLayer 2 100 100 300 300" return "1 25"

SetPhotoProcessing

Description:	Set the inverse camera and processing type flags for a photo.
Syntax:	"SetPhotoProcessing ID in pr" where: ID is a unique identifier number for the photograph (>=1), "in" is the inverse camera flag and is a sum of 1=focal length solve, 2=principal point solve, and 4=format aspect solve (e.g. "7" would mean solve all parameters and "0" would mean solve none (the default)). "pr" is the processing type where 0=do not use, 1=use and adjust (default) and 2=use but don't adjust.
Return:	"1" if successful or "0" if not. Failure returns - insufficient number of parameters - no project is open - photo 'ID' does not exist in project - 'in' or 'pr' have improper values
Example:	"SetPhotoProcessing 1 1 1" return: "1"

SetPhotoSet

Description:	Create a photo set by passing in the name and list of photos to include
Syntax:	"SetPhotoSet psName p1 p2 p3" where: psName is a string for the name p1 p2... are photo id's of photos in the project
Return:	"1" if successful, "0" if not successful. Failure returns - missing photo's ID, - non-unique name.
Example:	"SetPhotoSet pset 2 4 8" return: "1"

SetPhotoStation

Description:	Set up a photo's station's orientation (because it is known or you are providing an approximation). Note that single photo orientation processing (eg InverseCamera) will ignore this approximation.
Syntax:	<p>"SetPhotoStation ID x y z 0 w p k"</p> <p>where:</p> <p>ID is a unique identifier number for the photograph (≥ 1), "x y z" is the station perspective center, 0 represents this call type (Euler angle form), and "w p k" are the station's Euler angles (in radians).</p> <p>OR</p> <p>"SetPhotoStation ID x y z 1 r11 r12 r13 r21 r22 r23 r31 r32 r33"</p> <p>where 1 represents this call type (rotation matrix form), the r's are the values of the rotation matrix (eg. r21 is the element in the 2nd row and 1st column).</p> <p>OR</p> <p>"SetPhotoStation ID x y z 2 x2 y2 z2 roll"</p> <p>where where 2 represents this call type (roll form), the "x2 y2 z2" are the coordinates of the camera center point and "roll" is the roll angle.</p> <p>Note, if the command is successful, it sets the photo to be "oriented".</p>
Return:	<p>"1" if successful or "0" if not.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - insufficient number of parameters - no project is open - photo 'ID' does not exist in project - the 6th parameters is not '0' or '1' - any one of the r's is larger than 1.0 or smaller than -1.0
Example:	<p>"SetPhotoStation 1 23.3 12.1 -1.3 0 0.0 1.4 -2.1" OR</p> <p>"SetPhotoStation 1 23.3 12.1 -1.3 1 1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0" OR</p> <p>"SetPhotoStation 1 23.3 12.1 -1.3 2 0.0 0.0 0.0 45.0"</p> <p>return: "1"</p>

SetPointName

Description:	Set the user name of the point with id specified
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Syntax:	"SetPointName PointID name" where: PointID is the ID of the point and name is the new user name of the point. The name can be any length and can have spaces.
Return:	"1" if successful or "0" if not.
Example:	"SetPointName 1 topLeftPoint" return: "1"

SetPointToUseInProcessing

Description:	Set the object point with id specified do not use in processing status to on or off.
Syntax:	"SetPointToUseInProcessing PointID state" where: PointID is the ID of the point and state is a 1 or 0 to turn the 'Do not use in processing flag on (1) or off (0).
Return:	"1" if successful or "0" if not. Failure returns - no project open, - no object point with specified id.
Example:	"SetPointToUseInProcessing 1 1" return: "1"

Show3DViewer

Description:	Show a 3D Viewer with requested options visible, optional to maximize
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Syntax:	<p>"Show3DViewer optBtn optDlg doRotate pts lines surfs cyls cyllines textures sd edges curves camstns perspective maximize"</p> <p>where:</p> <p>booleans are (1 for true, 0 for false):</p> <p>optBtn - show Options button</p> <p>optDlg - show Options dialog before 3D Viewer displays</p> <p>doRotate - apply Scale rotate to model</p> <p>pts - show points</p> <p>lines - show lines</p> <p>surfs - show surfaces</p> <p>cyls - show cylinders</p> <p>cyllines - show cylinders as centre lines</p> <p>textures - show photo textures</p> <p>sd - show surface draw</p> <p>edges - show edges</p> <p>curves - show curves</p> <p>camstns - show camera stations</p> <p>perspective - show perspective corrected textures (ie quality textures)</p> <p>maximize - maximize the window</p>
Return:	"1" if successful or "0" if this command failed.
Example:	<p>"Show3DViewer 0 0 1 1 0 1 0 0 0 0 0 0 0 1"</p> <p>return "1"</p>

ShowPhoto

Description:	Opens a photo with the ID specified in PhotoModeler in a certain view type
Syntax:	<p>"ShowPhoto photoID viewStyle"</p> <p>where:</p> <p>photoID is the ID of the photo to open, viewStyle is either 0 for a new photo window, 1 for replace active photo, or 2 for tab with active photo.</p>
Return:	<p>"1" if successful, or "0" if not successful.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - insufficient number of parameters - no project is open - photo 'ID' does not exist in project
Example:	<p>"ShowPhoto 1 1"</p> <p>return "1"</p>

Translate

Description:	Set the translate part of the project affine transform based on a location defined by a point or camera stations. The coordinates should be in project units (which are set during NewProject)
Syntax:	"Translate id X Y Z itemType" where: id is the ID of the translate item (point or camera station, see below) X,Y,Z are the 3D coordinates of the translation point (typically 0,0,0 but it could be any known 3D location) Optional: itemType (default is point) 1 - point 2 - camera station
Return:	Returns "1" if successful or "0" if not
Example:	"Translate 1 0 0 0" would set up translation using point#1 at (0,0,0) "Translate 1, 10.0 10.0 10.0 2" would set up a translation using a cam stn at (10,10,10)

TwoPhotoAutoReference

Description:	Performs automatic point referencing on two photographs. See Autoreferencing for conditions.
Syntax:	"TwoPhotoAutoReference SearchDistance SearchDistanceDoubling(1=Yes,0=No) MinNumPhotos SetToDoNoProcess(1=Yes,0=No) [Name of automatically referenced points]" where: SearchDistance defines how far apart the intersection of the light ray from one marked point and the light ray from another marked point can be before the points are determined to be unmatching (in project units), SearchDistanceDoubling is 1 to double the search distance and reiterate, MinNumPhotos is the minimum number of photos the referenced object point must appear on, SetToDoNoProcess is 1 for Yes and 0 for No and at the end of the command an option name for each point referenced. See the <i>Automatic Referencing Dialog</i> for more background.

Return:	"1 NumMarksReferenced" where: NumMarksReferenced is the number of marks automatically referenced or "0" if this command failed. Failure returns - incorrect number of parameters - no project is open - autoreferencing fails
Example:	"TwoPhotoAutoReference 1.983 1 3 1 ar" or "TwoPhotoAutoReference 1.983 1 3 1" or "TwoPhotoAutoReference 1.983 1 3 1 Names can have spaces" return "1 14"

Example Use

The following is a very simple Microsoft Word macro (Visual Basic) that uses the PhotoModeler DDE interface.

Word Macro for PhotoModeler DDE

Example program written in Visual Basic for Applications (i.e. VBA for Word and Excel).

```

Sub RunFullDDETest()
    '
    ' Test new DDE Commands in PhotoModeler
    ' Do a project with control points, inverse camera solution and
then add
    ' photo, reference points and do bundle adjustment
    '

    Dim ret As String
    ' Set up the DDE conversation with PhotoModeler's DDE Server
    ' (note, PhotoModeler program must already be running)
    c = DDEInitiate(App:="PhotoModeler", Topic:="Data")

    MsgBox "Starting Project Test"

    ' Create empty new project with inches as units
    If Not DDECommand(c, "NewProject 7", ret) Then GoTo Failure

    ' Add a camera with guessed at parameters
    If Not DDECommand(c, "AddCamera unknown 8.0 6.7 5.3 640 480
3.5335 2.65", ret) Then GoTo Failure

```



```

        If Not DDECommand(c, "GetCamera unknown", ret) Then GoTo
Failure
        MsgBox "Starting camera parameters " + ret
        ' Add a photo (no image)
        If Not DDECommand(c, "AddPhoto 1 unknown", ret) Then GoTo
Failure
        ' Set the photo to do inverse camera processing to solve for
focal length
        ' and format aspect ratio
        If Not DDECommand(c, "SetPhotoProcessing 1 5 1", ret) Then GoTo
Failure
        ' Define some fixed control points
If Not DDECommand(c, "DefineControlPoint Box cp1 0.0 2.95 2.9",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp2 0.0 0.0 2.9",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp3 0.0 0.0 0.0",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp8 0.0 2.95 0.0",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp18 2.8 2.95
2.9", ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp19 2.8 0.0 2.9",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint Box cp20 2.8 0.0 0.0",
ret) Then GoTo Failure
        ' Mark these control on photo 1
        If Not DDECommand(c, "MP 1 1 161.768 95.752 Box cp1", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 2 283.728 161.240 Box cp2", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 3 286.280 297.752 Box cp3", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 4 178.720 225.768 Box cp8", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 5 278.0 46.0 Box cp18", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 6 390.0 92.0 Box cp19", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 7 380.0 224.0 Box cp20", ret) Then
GoTo Failure
        ' Process the result to do an orientation and inverse camera
        If Not DDECommand(c, "Process 1", ret) Then GoTo Failure
        MsgBox "Orient / Inv. Camera return (should be -1 -1 -1)= " +
ret

        ' Show the results of the new camera parameters
        If Not DDECommand(c, "GetCamera unknown", ret) Then GoTo
Failure
        MsgBox "Solved camera parameters " + ret

        ' Add a new photo to use the newly solved camera
        If Not DDECommand(c, "AddPhoto 2 unknown", ret) Then GoTo
Failure

```

```

        ' Mark and reference some points onto photo 2 that appear as
        control on photo 1
        If Not DDECommand(c, "MP 2 1 294.24 53.68", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 2 400.272 124.76", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 3 408.760 227.26", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 4 285.288 152.232", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 5 218.0 138.0", ret) Then GoTo
        Failure

        ' Mark and reference some new points on photo 1 and 2 that are
        not control points
        If Not DDECommand(c, "MP 1 8 351.304 340.264", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 8 461.248 258.304", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 1 9 342.760 438.248", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 9 481.720 390.256", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 1 10 239.768 360.744", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 10 356.264 332.232", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 1 11 424.0 356.0", ret) Then GoTo
        Failure
        If Not DDECommand(c, "MP 2 11 376.0 442.0", ret) Then GoTo
        Failure

        ' Solve the project (which will orient photo 2 and do a bundle
        adjustment)
        If Not DDECommand(c, "Process 6", ret) Then GoTo Failure
        MsgBox "Processing return = " + ret

        ' Get the resulting camera station data
        If Not DDECommand(c, "GetPhotoStation 1 0", ret) Then GoTo
        Failure
        MsgBox "Station 1 orientation: " + ret
        If Not DDECommand(c, "GetPhotoStation 2 0", ret) Then GoTo
        Failure
        MsgBox "Station 2 orientation: " + ret
        If Not DDECommand(c, "GetPhotoStation 2 1", ret) Then GoTo
        Failure
        MsgBox "Station 2 orientation with rot matrix: " + ret
        MsgBox "Finished Project Test"
        GoTo Finished

Failure:
    MsgBox "Some part of test failed"

```

```

Finished:

    ' Terminate the DDE conversation with PhotoModeler
    DDETerminate c
End Sub

' Runs a dde command and returns true if is succeeded.
' If succeed the string ret contains the command return (with the
return code missing)
Function DDECommand(chan As Variant, command As String, ret As
String) As Boolean
    DDECommand = False

    If Len(command) > 254 Then
        MsgBox "<" + command + "> is longer than 254 characters."
        Return
    End If

    ' Set up an error handler to trap possible Windows/DDE problems
    On Error GoTo ErrorReturn

    ret = DDERequest(Channel:=chan, Item:=command)

    If Left(ret, 1) = "0" Then
        ' command failed
        MsgBox "<" + command + "> failed. Return was <" + ret + ">"
    Else
        ' command succeeded parse off return code
        ret = Mid(ret, 3)
        DDECommand = True
    End If

    GoTo OKReturn

ErrorReturn:
    MsgBox "<" + command + "> generated an error."

OKReturn:
    ' reset error handler
    On Error GoTo 0

End Function

```


Troubleshooting

The following sections deal with some problems which may occur as PhotoModeler is used. Each section discusses the problem and suggests solutions. The first section describes how to use the Tables to assess quality and find problems. The last section lists all the error and warning messages presented by PhotoModeler and explains what they mean.

Using the Point and Photo Tables for Troubleshooting and Assessing Quality

This section describes how to use the Point and Photo Tables to assess the quality and accuracy of the project and how to use them for troubleshooting.

Point Table Assessment

There are two non-column specific features that help when dealing with tables. These are dealt with in more detail in the Point Table chapter but as reminders we mention them here too:

- Use Table Configurations to get the specific columns you need for the job. You can use some of the configurations that come installed with the program but you can create your own or edit those pre-installed ones.
- When you find a suspect point and want to manipulate it or study it on its Photographs, first select it (or two or more points) and then use the "Open Photos Showing Selected" right click menu item. This will open all photos showing this point selected.

Here are a list of specific columns of the Point Table and how they can be used for project assessment:

- Photos – sort by this column to see which points are on only one or two photos. The one photo points will have no 3D position (unless they are control points or part of an Axes Constraint) and the two photo points have no redundancy so their accuracy is suspect.
- Tightness – sort by this column to find the points with the largest tightness values. Study how these points with large tightness are marked (or their photos are oriented). Also look at the values of the Tightness (unit) column to see if the values seem reasonable for your desired accuracy. E.g. if you want 1.0mm accuracy then you should have tightness that are no more than 3.0mm (and preferably less than 1.0mm).
- Angle - sort by this column to look for points with low maximum angles. Points with angles less than 15 degrees are suspect for good accuracy. If a large number of points in the project have low angles then the whole project accuracy is suspect.
- RMS Residual – sort by this column to verify average marking precision for the points. Points with the largest RMS *Marking Residuals* have the worst photo point marking.

- Largest Residual – sort by this column to look for points that may have a Marked Point that is incorrectly placed. You can use the "Largest Photo Residual" column to figure out which photograph has the worst mark for this Object Point. See *Marking Residual*.
- XYZ Precision – sort by this column to verify that the Processing has not flagged any points as low accuracy (usually due to poor photo angles or poor marking). Points with the largest precisions are the worst. Also look for the X, Y or Z precisions being largely different from the X, Y, or Z precision values (which may indicate a poor camera geometry). For further discussion of the meaning of precision refer to *Accuracy* and *Precision* in the Glossary.
- Precision Vector Length – sort by this column to view the points with highest precision vector lengths as an indicator of point quality. The Vector Length is the result of a point's X, Y and Z Precision.
- # Constraints – review this column to see if the point is constrained (which may lead to poor accuracy or inability to solve the point if the constraints conflict or over-specify the point).
- Use in Processing – review this column to ensure the point is being handled in Processing or not as desired.
- Frozen – review this column to ensure the point (or any points) are not frozen (unable to move in xyz) which may lead to the inability to process or may cause model warping if the project has changed considerably after the points were frozen.

Photo Table Assessment

There is one non-column specific feature that helps when dealing with tables. This is discussed in more detail in the Photo Table chapter but as reminders we mention it here too:

- Use Table Configurations to get the specific columns you need for the job. You can use some of the configurations that come installed with the program but you can create your own or edit those pre-installed ones.

Here are a list of specific columns of the Photo Table and how they can be used for project assessment:

- RMS Residual – sort by this column to find the photo with the worst/best markings. If one photo has significantly higher rms residual then the marking is on average poor on this photo (or the photo is not oriented well). See *Marking Residual*.
- Largest Residual – sort by this column to find single points on photos that may not be marked well. See *Marking Residual*.
- # Referenced – sort by this column to check to see if minimum requirements are met for multi-photo projects (i.e. at least six referenced points). Photos with low number of referenced points may also not be oriented that well.
- # Fiducials – sort by this column when using a fiducial camera to ensure sufficient fiducials have been marked on each photograph.
- Can be Processed – check this column when a photograph does not seem to be orienting. If it says "no" then some minimums are not being met (too few referenced points or too few control points, or too low photo coverage (i.e. all points in a small area), etc.
- Oriented – check this column to be sure every photo is *oriented* because no 3D data can come from an unoriented photo.
- Processing – check this column to remind you what processing status you have set for the photo (might help explain why it is not orienting or causing model distortion).

- Camera parameters – check over all these columns (focal length, principal point, format size, etc.) to ensure the camera parameters are consistent for all photos and they are what you expect. Also very important to check after self-calibration has been run to see how much the parameters vary photo to photo.
- Inverse flags – check these columns to remind you what camera parameters Orient/InverseCamera will be solving for.

Problems List

The sections below describe various problems and their solutions.

A Curve or an Edge does not appear 3D

After you have marked and referenced a Curve or an Edge and it does not appear in the 3D Viewer (i.e. its 3D position is not being calculated) then some of the requirements for Curves or Edges are not being met.

Note that the 3D status of an Edge or Curve is shown in the *Status Bars* when these objects are selected. See the *Status Bars* sections: "Curve - open Status Bar" and "Edge Status Bar".

Curves must be marked and referenced on two or more oriented photographs. Select the Curve and look at the number of oriented photographs listed on its *Status Bars*.

If an Edge is constrained in a single photo project it can become 3D, otherwise Edges must be marked and referenced on two or more oriented photographs. Select the Edge and look at the number of oriented photographs listed on its status bar. In the multi-photo case also study the angle shown in the Edge's status bar. If the value is too low (usually less than 10 degrees) then the Edge calculation will not work and the Edge will not become 3D.

You should study what photographs these marks appear on and whether they are suitable for that Edge or Curve. See the Quick Start Guide section Photography for Curves, Edges and Cylinders for more information.

Edges and relatively straight Curves can be modeled sufficiently by marking them on two photographs if those photographs rotate around the axis of the object. This is also described in the Quick Start Guide section - Photography for Curves, Edges and Cylinders.

Curves, on the other hand, if they are closed curves or change direction considerably will often have to be marked on three or more photographs. If you have a curve where only part of the curve appears in 3D this is most likely the problem. See the next section.

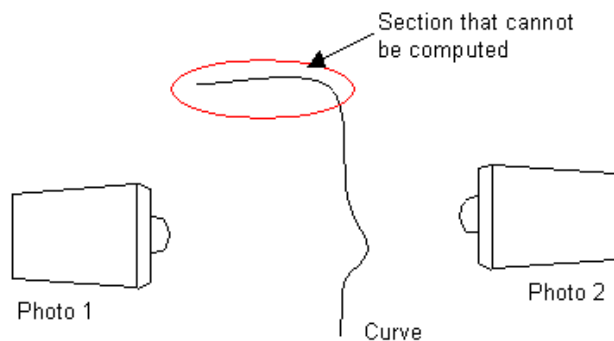
Another consideration with closed curves is that PhotoModeler assumes all marks "view" the curve from the same side. Imagine a horizontal metal ring that you will be modeling using a closed NURBS curve. If you photograph the ring from only one side (call it the upper side) then you will not encounter any problem. On the other hand, if you photograph the horizontal ring from below also and mark the ring on both the view-from-above and view-from-below photos PhotoModeler will not be able to disambiguate the orientation of the ring. The resulting 3D closed curve will lie in the wrong plane and may have the wrong shape. All closed curves must be marked on photographs that view the curve from the same side. See the Curve tutorial for an example.

Part of a Curve is missing or is not 3D

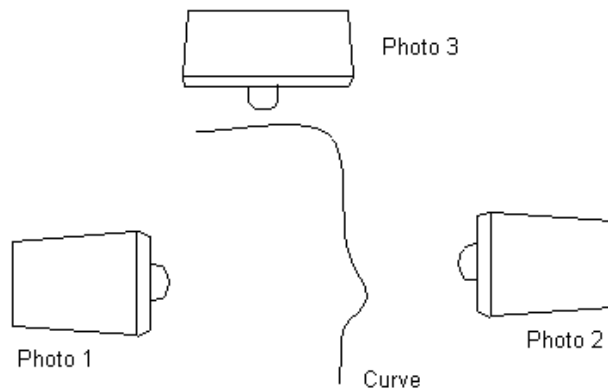
If the Curve is shown as "3D" in its *Status Bars*, does appear in the 3D Viewer and does export but is not complete then it is not possible for PhotoModeler to compute part of the curve.

You should first consider what photographs these marks appear on and whether they are suitable for that Curve. See the Quick Start Guide section Photography for Curves, Edges and Cylinders for more information.

If a curve changes direction considerably it will often have to be marked on three or more photographs. If you have curve where only part of the curve appears in 3D this is most likely the problem. Look to adding a mark for that curve on a photograph that better images that section that is missing.



A curve that changes direction with only two photos - upper section will be missing in 3D



Same curve but now on three good photos - will all be 3D

Each section of the curve needs to have a set of marks taken on photos with the appropriate rotations. Even closed Curves, or curves with 3D Object Points at both ends, that appear to be complete, may have sections that are inaccurate. Study the Curve Weak Area Display. For more information see *Curve troubleshooting*.

Only one Edge is 3D in a Single Photo Project

If you are doing a single photo project that uses Edges and Constraints, and after processing the 3D Viewer shows only one Edge, then you have not set up enough Constraints.

The Single Photo algorithm will arbitrarily pick a point to be called the origin (0,0,0). It then propagates the information along constrained objects (given the computed camera station and photograph marking data). Since Edges do not connect to other objects (unlike Lines which connect at Points) the only way to propagate information from them is to put them in a Surface Constraint.

Adding an Axis Plane Constraint, placing the desired Edges in that constraint and then processing will fix the problem.

When referencing seems confused

Occasionally referencing mistakes are made (i.e. a Marked Point is referenced to a Marked Point on another photograph but they do not correspond to the same point on the object) and are not noticed right away. At some later time, when trying to reference some other Marked Points, the connecting lines appear to be wrong or PhotoModeler will not allow two Marked Points to be referenced that are clearly the same point on the object.

The easiest way out of this problem is to select what you think to be the incorrectly referenced points, and choose "Unreference Selected Points" from the Referencing Menu. Once the points are unreferenced start referencing them again taking special care to reference correctly.

If the project is small or you have not proceeded far in the referencing stage you can select all points on all photographs and unreference all of them. This gives you a clean slate to start over again with referencing.

When processing fails or 3D results look bad

PhotoModeler completes the processing in one of two ways: It either succeeds in creating the 3D model or it fails. In either case PhotoModeler informs you at the end of processing what happened with a dialog box message.

If the processing failed, there a number of things you can do to correct the problem. Sometimes even if processing succeeded the results are obviously wrong (i.e. in 3D Viewer) that we consider that to be failed processing also. It is a good idea to always check the 3D Viewer right after a successful processing to make sure the model and camera positions are correct.

In case of some processing failure or excessive model distortion in the 3D Viewer, follow the *Troubleshooting Procedure* below to figure out how to fix the problems. See also *Processing Points-Based*.

Troubleshooting Procedure

Answer the following question, jumping to the appropriate section to get to the next question and then eventually to some suggestions for things to check or fix. Note: this procedure is quite a bit easier to follow in the Help file than in the printed User Manual.

Is this a new unprocessed project?

Yes - *New unprocessed project*

No - *Previously successful project*

New unprocessed project

Does this project have Constraints or Control Points?

Yes - *Control or Constraints have been used*

No - *Constraint-less project*

Control or Constraints have been used

Projects that use Constraints (axes constraints, multi-photo constraints or control points) can fail processing if the constraints are incorrectly defined or in the case of Control Points, incorrectly marked.

If this project has multiple photos and is using constraints, try reprocessing with Constraints turned off (second tab of the Processing Dialog). See the *Troubleshooting Constraint Processing Problems* section for more information.

If the project fails to process with Constraints off also, follow the questions in the *Constraint-less project* path of the troubleshooting.

The main reason control-based projects fail is because of incorrect control points. The problem can either be incorrect x,y,z values, incorrect marking of control or misreferencing of control to the wrong photo point.

Sometimes users can spend a lot of time trying to figure out why a control based or Inverse Camera project will not process because they adamantly assume that the input control points (perhaps supplied by a surveyor) are correct. Make sure you verify that all the x,y,z values of the control points are correct and that they are marked correctly on the photographs.

For Inverse Camera work also check the starting camera parameters. Perhaps they need to be closer to the final solution. Try changing the values of format size, principal point and format size a bit to see if it will solve. Also try solving for just one of the parameters instead of all of them.

Constraint-less project

Retry the processing of the project making and turn off Global Optimization and Self-Calibration in the *Processing Dialog*. If that completed without error, open the 3D Viewer window and turn on Camera Station display in the *3D Viewer Options Dialog*.

Did Orientation give an error message or were the results in the 3D Viewer obviously wrong?

Yes - *Orientation Fails*

No - *Orientation Succeeds*

Orientation Fails

Did this error message appear, "Unable to complete orientation. N photos have oriented correctly (#s:<photo list>) and M have not been oriented (#:<photo list>). Suggestion: try Point Audit Selected to see if 3 or more points are shared between the oriented set and the unoriented sets of photos."? If so then there is a scale failure.

Did this error message appear (i.e. scaling failed)?

Yes - *Scaling Failed*

If you did not get the scale error message shown above then the next step is to determine why orientation failed. The best way to do this is to reduce the project to orientations of sets of two photographs. You use the processing actions in *Photo Properties* to process only some subset of the photos. Process the new pair-photo project and check the result in the 3D Viewer. If the result looks OK, pick another pair and repeat. Note when you pick pairs, pick photos that share at least 6 points.

Did you find a pair of photographs that will not orient correctly?

Yes - *One or More Pairs will not Orient*

No - *All pairs Orient Successfully*

Scaling Failed

To orient one pair of photos together takes six common points. Not all photos need to share the same 6 common points. After a photo has been oriented against the current set of photos it must be scaled. This scaling requires at least one referenced point to appear on the photo being scaled and to appear also on at least two other photos in the project.

When this message appears it means that PhotoModeler could orient and scale the photos in the first list but it could not properly scale the photos in the second list to those in the first. These means that the photos in the second set do not share at least one point with two or more photos in the first set. Correcting this problem is accomplished by referencing more points in the second set of photos to points that appear on two or more photos in the first set.

You should also make sure that the photographs that do not orient properly have the correct camera assigned (i.e. the camera parameters, including zoom/focal length, match the photographs).

One or More Pairs will not Orient

If you have had just a single pair not orient the problem is probably one of a misreferencing of points between those two photographs (study them with Point Audit) but the problem could also be poorly defined control points on one of the photos (incorrectly marked control or 3D definitions of control points from CTL or DXF are incorrect) or *poorly defined camera parameters*.

Check the references with Point Audit and check any control points using the Imports Explorer (see *Imported Objects*) while turning off the "auto-advance" so the control points can be compared with their marks.

Another problem with a new pair of photographs that have not been successfully oriented is that the coverage might be too low. If your points in one or both of the photos cover only a small part of the photo then an instability can result which causes orientation to fail. Try

adding marking points to cover more area and reference them. Even if you do not need the points for your model or measurement they might help PhotoModeler solve.

You should also make sure that the photographs that do not orient properly have the correct camera assigned (i.e. the camera parameters, including zoom/focal length, match the photographs).

All Pairs Orient Successfully

It is possible that you can orient every pair of photos in the project successfully but all together they will not. The reason has to do with scaling. A scaling step is carried out when orienting three or more photographs that is not carried out when only two are oriented. So this failure is usually a failure to scale correctly. Scaling will fail because of one or more bad referenced points, because one of the camera stations has an incorrectly defined set of camera parameters or because there are insufficient points shared among a minimum set of photographs to affect a scale. This last problem is corrected by marking and referencing a few more points across as many photographs as possible. The other problems are resolved by studying Audit, Point Audit and the *Camera Viewer Dialog*.

You should also make sure that all the photographs have the correct camera assigned (i.e. the camera parameters, including zoom/focal length, match the photographs).

Orientation Succeeds

If your project fails global optimization but seems to orient OK, the probable problem is a bad referenced mark or two or a point marked in the wrong location. The reason is that one or more bad references (or inconsistent markings) can shift an orientation just a bit (still looks OK in 3DViewer but is wrong) and then the Global Optimization takes a step in the wrong direction and ends up failing (by moving the slightly bad camera station position a lot). Use Point Audit to carefully track down any marking or referencing errors.

Global optimization can also fail if control points have been marked incorrectly if this is a control based project. Check the control points using the Imports Explorer (see *Imported Objects*) while turning off the "auto-advance" so the control points can be compared with their marks.

Also see *Orientation Fails* above.

Previously successful project

Did you add any new photographs since the last successful processing?

Yes - *New Unoriented Photos Added*

No - *Same Oriented Photos as Last Time*

New Unoriented Photos Added

Does this new photo use the same camera as the other photos?

Yes - *All use same Camera*

No - *This has a new Camera*

All use same Camera

See the *Same Oriented Photos as Last Time* section below.

This has a new Camera

Make sure the new Camera defined for this new photo does indeed describe the camera that took the photo. See the *Poorly Defined Camera Parameters* section below for more ideas. If it is not a problem with the camera then see the *Same Oriented Photos as Last Time* section below.

Same Oriented Photos as Last Time

Try setting all the previously processed photos to "use but no adjust" in the *Photo Properties* and try to perform Orientation only in the processing.

Also if you had recently added Constraints or Control points follow the *Control or Constraints have been used* path in the troubleshooting.

Did the new photo orient correctly?

Yes - *New Photo Oriented when others Frozen*

No - *New Photo would not Orient when others Frozen*

New Photo Oriented when others Frozen

This means that there are some new points on the new photograph which cause the previously oriented and processed photos to now fail. This would usually be indicative of a few misreferenced points on the new photo. Study with Audit and Point Audit.

New Photo would not Orient when others Frozen

The most probable problem is a misreferenced or mismarked point. Perform a Point Audit on all points to make sure the newly marked points on the new photo are all correct. Also make sure there is good coverage of the new photo (i.e. not all points are in the middle of the photo (remember you can mark and reference points to help processing even if you don't need them in your final model)).

Poorly Defined Camera Parameters

If the camera parameters in the *Camera Viewer Dialog* do not match the real camera that took the photo(s) you can get some strange and/or poor results.

Sometimes it is not obvious that your camera parameters are wrong. Here are some cases of bad camera parameterization:

1. The photographs were taken vertically (i.e. in portrait mode) and then brought into PhotoModeler in an upright orientation (i.e. vertical - more tall than wide) but the Camera was defined for a landscape or horizontal photo (i.e. format size and principal points are set for the horizontal direction (x) being the widest one).
2. If you take photos with the camera oriented vertically (portrait orientation) either define your camera parameters with the h&w and x&y flipped or keep your photos in landscape

mode when you import them. We suggest you keep all your images in landscape orientation during import and then use the Photograph property for rotation to view portrait photos.

3. The photographs were printed cropped (how most photo labs do it) and then scanned on a flat-bed scanner. The problem here is that relative to the pixels in the image, the principal point (where the optical axis of the lens intersects with the film) is in a different place in every photo. If you have two or more of these types of photos assigned to one Camera then the principal point may not be correct on one or both.
4. One should either set up a camera per photo (and then probably use Inverse Camera), use the Eos Film Plane Insert or get full-frame prints so full-frame fiducials can be marked. Fiducials compensate for shifting principal points.
5. You are using an uncalibrated video or digital camera. It is very important with video and digital cameras that you have a good estimate of the format size (see *Camera Viewer Dialog*).
6. To get the most accurate format size you should do the full *Camera Calibration*. See *Determining Digital and Video Camera Format Size*.
7. You do not know the parameters of the camera that took the photos so you guessed or used one of the Default Cameras.
8. If you get bad results your guesses are too far off and perhaps Inverse Camera methods should be used.
9. You have a full set of parameters for your camera including lens distortion numbers. You enter these in and just do not get the accurate results you would expect.
10. Make sure the lens distortion numbers you are using are based on the same lens distortion math model that PhotoModeler uses (contact Eos Systems support for more information).

My 3D model is warped or has some points that seem to be in the wrong 3D location

Poor model shape usually results from one or more points that have been incorrectly located by PhotoModeler in 3D space. First, refer to the section of the Quick Start Guide called Guide For Taking Photos. Study the troubleshooting procedure in the above section *When processing fails or 3D results look bad* for further ideas.

Points that are improperly or inaccurately placed can be the result of:

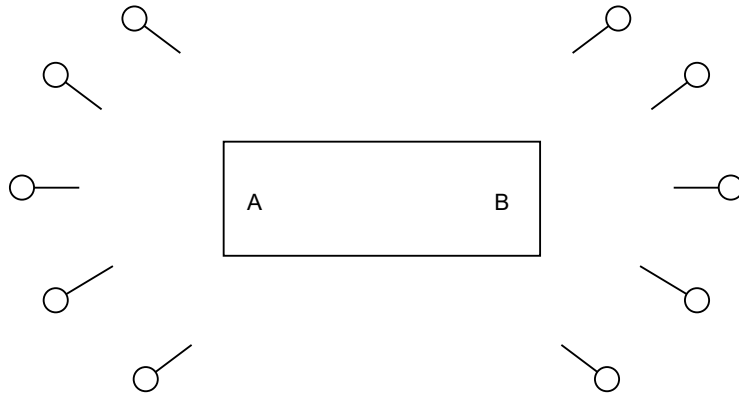
1. The point has one more incorrect references.
2. The point has been marked inaccurately in one or more photographs.
3. The point has been marked on only two photographs.
4. The point has a poor angle maximum (lower than 10 degrees).
5. There are too many points which are imaged on just two or three photographs.
6. There are sets of photographs that share many points between themselves but share few points with other sets of photographs in the project.

The following lists how you can determine if any of these are the problem and how to fix them:

1. To determine if a point is incorrectly referenced, find one marked version of the point on a photograph, select it and choose "Point Audit Selected" from the Referencing menu.

- Review where the point shows up on all photographs. If it is incorrect, fix it by unreferencing it and then referencing it correctly.
2. Review all marking on all photographs of the questionable point. Zoom in and make sure the point has been marked correctly.
 3. If a point is marked on only two photographs (which you would have determined in step 1 above) it will not be as accurate as if it were marked in three or more. Try to find the same physical point in other photographs in the project to mark and reference it there or add more photographs to the project and mark all visible points on the new photographs.
 4. Point Audit will show you if the point in question has a low angle maximum (i.e. the rays of light from the point to the images it appears on are too close together to get an accurate position in 3D). To fix this, the point must be marked and referenced on another photograph that is from a quite different view than the current photographs it is marked on.
 5. The *Audit Dialog* shows how many points have only two rays. If there are too many of these (over half the total points) then overall the model could be quite inaccurate. Try to add photographs to the project so more points are marked on three or more photographs.
 6. A careful review of the project through point audit will show if there are groups of photographs that share common points but do not share many of these points with other photographs in the project. When some photographs share few points with other photographs in the project, they become disassociated and form a little model unto themselves. In other words, the points shared by the set of photographs could be quite accurate internally but might be in the wrong location or orientation relative to other parts of the complete 3D model.

Ensure that there are no weak links with too few points among sets of photographs. For example, if we photographed a long building with the following set up:



Plan view of a poor camera layout

The two ends of the building at A and B might be accurately measured but might not sit correctly relative to each other because only a few points are shared between the cameras at the A end and the cameras at the B end. If the points shared between the two ends appear on only two photographs, the A and B ends might still not sit correctly relative to each other. In this case, more Camera Stations need to be added along the edge of the building to better tie the two ends together.

Note: Sometimes an object that you expected to be square may in fact not be square. We are used to seeing perfectly square and accurate models created by CAD programs and we are disconcerted when we see a real world object represented by CAD. A model with a bad shape may have some of the problems discussed above or the bad shape just might be the object's true shape.

My 3D model looks skewed and rotated when I get it into CAD

PhotoModeler generates its 3D models in an arbitrary coordinate system. When you export one of these models it will not lie perfectly flat on the drawing plane. To correct this use Scale/Rotate in the Project menu and define the coordinate system of your choice. See the *Adding Scale and Rotation* subsection for more information.

When a Photograph cannot be opened

PhotoModeler cannot open a photograph if it runs out of memory, the photograph is in an incorrect format or there was trouble creating the chip cache file (.cch). If a low memory message appears, release some memory by closing any open photographs and by closing running Windows applications.

If you get a low memory message repeatedly when nothing else is running and only one or two photographs are open, try one of the following:

1. Reboot your computer and restart Windows.
2. Study your autoexec.bat and config.sys to see if any unnecessary drivers, TSR's or expanded memory buffers are being used. Remove them and try again.
3. Add more RAM to your computer.

If you get a message about not being able to open the file, check to make sure the image file has not been corrupted or deleted.

If you get a message such as "Unable to write to disk" when Photographs are being loaded or displayed, the problem might be due to the image being on a read-only media. The image cache (.cch) file is being created at this time. To correct, remove the write protect from the disk or copy the images to a read/write hard-disk.

Accuracy and Overcoming Limitations

How Accurate is PhotoModeler?

No measurement technology can be perfect and all measurement involves performing approximations. PhotoModeler is no different.

PhotoModeler has been compared to other techniques of simple measurement such as using a tape measure for linear dimensions and a theodolite for 3D measurements. We have found that the accuracy of a Measurement Project is dependent on a number of factors:

- the quality of the calibration of the camera and digitizer used,
- the resolution of the camera and digitizer used,
- the geometry of the camera positions, and
- the precision with which the user marks object features as they appear in images.

For a project done with the high resolution digital camera and with reasonable user care, PhotoModeler has shown a relative accuracy in linear dimensions of around one part in five thousand (1:5,000) for man made objects (with 68% probability - the one-sigma accuracy). With higher resolution medium format metric cameras or high quality digital cameras accuracies as high as 1:30,000 have been demonstrated. Lower resolution cameras and imprecise marking can reduce the accuracy to one part in five hundred (1:500) or even lower.

Using the sub-pixel target marker greatly improves the last factor shown above (precision of marking). Given that the other factors are taken care of (good geometry, good camera calibration, etc.) one can achieve 1:30,000 or higher accuracy in a project that is all or substantially all done with sub-pixel circular target marking.

A relative accuracy of 1:5,000 means that for an object with a 10m largest dimension, PhotoModeler can produce 3D coordinates with 2mm accuracy at 68% (one standard deviation) probability.

Not all 3D coordinates that result will be of the same quality. PhotoModeler depends heavily on the user marking precise locations on the images. If a point appears in two photographs and the user guessed or approximated the location of the point in one or both of the photographs, then the resulting 3D coordinate will have low accuracy and will probably be incorrectly placed in 3D space. If there are too many points marked in this manner, other points marked precisely will be affected and the whole model will become inaccurate.

Checking Accuracy

One method of establishing the accuracy of your project is to use "check distances". You will need to obtain measurements for several items in a scene and compare these measurements with the measurements obtained from your PhotoModeler project.

For example: If you are measuring a road scene, and you need to determine the length of a set of skid marks, there may be a stop sign, the corner of an ambulance and a section of guard rail visible in 3 of your photographs. You visit the accident scene with a tape measure and measure the length of the guard rail and the height of the stop sign. You also determine from the manufacturer the height of the box on the ambulance. You then use PhotoModeler to measure these items and also the length of the skid marks.

Item	Tape measure	PhotoModeler measurement	Difference	%
stop sign	6.78'	6.73'	0.05'	0.7%
guard rail	10.2'	10.09'	0.11'	1.0%
height of ambulance	6.3'	6.21'	0.09'	1.4%
length of skid	n/a	32.34'	n/a	n/a

You could then state that your measurement of the skid mark length was likely within 2.0% of its actual value. In other words, the length of the skid is likely within 0.6' of the value derived with PhotoModeler.

Achieving the highest accuracy

If the user of PhotoModeler takes the following precautions, the errors will be minimized and measurement accuracy maximized:

- ensure that a well-calibrated camera is used for the project,
- maximize the number of photographs that each point is marked on,
- ensure that all points appear on three or more photographs,
- minimize the number of points that appear on only two photographs,
- ensure that the angle between the camera positions is as close to 90 degrees as possible,
- make sure the project has at least 25 points and the photographs have good coverage,
- ensure all point and line markings on the images are precise, and
- do not guess at a point location if it cannot be seen, is not distinct, is fuzzy or is hidden by some other object.

The highest level of accuracy can be achieved by using man-made targets and the program's special sub-pixel marking algorithms. These targets are typically high contrast circular dots. Also refer to the section *Using Targets*.

Our tests to date indicate that PhotoModeler is comparable in accuracy to most film-based small-restitution systems and other 3D triangulation equipment. PhotoModeler with sub-pixel target marking can be comparable in accuracy to high quality theodolites and total stations.

Accuracy Factors

There are a number of factors involved in determining the accuracy in photogrammetry.

Photo Resolution: The higher the resolution of the images, the better chance of achieving high accuracy because items can be more precisely located. Image resolution is defined by the capabilities of your digital camera or film scanner. Trying for the highest resolution you can or can afford is the best approach.

Camera Calibration: Calibration is the process of determining the camera's focal length, format size, principal point, and lens distortion. There are a number of ways of obtaining this camera information and using a camera fully calibrated in PhotoModeler will give the best results.

Angles Between Photos: Points and objects that appear only on photographs with very low subtended angles (for example a point appears in only two photographs that were taken very close to each other) have much lower accuracy than objects on photos that are closer to 90 degrees apart. Making sure the camera positions have good spread will provide the best results.

Photo Orientation Quality: During processing PhotoModeler computes the location and angle of the camera for each photo - this is called Orientation. One factor that contributes a lot to the accuracy of project is an accurate orientation for every camera position. The orientation quality improves as the number of well-positioned points increases and also as the points cover a greater percentage of the photograph area.

Photo Redundancy: A point's or object's position is usually more accurately computed when it appears on many photographs - rather than the minimum two photographs.

Targets: The accuracy of a point is tied to the precision of its location in the image as mentioned above with resolution. This positioning can be improved further by using targets. PhotoModeler uses the image data to sub-pixel mark the point and this increases the precision of its placement and then the overall accuracy of the point's computed 3D location.

The following figure illustrates this:

	Camera Resolution	Camera Calibration Method	Angles between Photos	Photo Orientation Quality	Photo Redundancy	Targets
Lowest Accuracy 1 part in 100	Video 640x480	no calibration ↓ Inverse Camera	most less than 15 degrees	few points per photo, low coverage	points mostly on only 2 photos	no targets, all user marked
Average Accuracy 1 part in 5,000	5-6 MegaPixel	Camera Calibrator	most between 20 and 90 degrees	15+ points/photo, 25 to 60% coverage	all points on 3+ photos	some naturally lit targets for key points ↓ many good quality naturally lit
Highest Accuracy 1 part in 30,000+	11 MegaPixel	Field Calibration*	most between 60 and 90 degrees	35+ points/photo, 50 to 80% coverage	most points on 8 or more photos	retro-reflective

* when field calibration photos are taken correctly (i.e. with rotated photos)

The accuracy figures "1 part in NNN" are the one-sigma standard deviation accuracies. At 1 part in 30,000 on a 3m object, point positions would be accurate to 0.1mm at 68% probability (one sigma).

Moving down each column one gets increasing accuracy given the other items remain constant.

So for example, the lowest accuracy with PhotoModeler is achieved with a low resolution uncalibrated camera, low angles between photos, low coverage of every photo, points only on two photos, and no sub-pixel targets.

Conversely the highest accuracy is achieved with a high resolution field calibrated camera, with strong angles between photos, most photos have good coverage, most points appear on 8 or more photos, and all points are retro-reflective targets.

Dealing with Measurement Problems

To use a photographic based measurement tool such as PhotoModeler one needs to be able to photograph what one wants to measure. This statement seems obvious but if we look more closely at it we can see some limitations.

First, every point you wish to measure and model should appear in at least two and preferably three or more photographs. Secondly, most of the points that appear in one photograph should also appear in the adjacent photograph (that is, the photographs need to overlap quite a bit). Thirdly, you have to positively identify the precise position of each point as it is imaged in each photograph.

The problems

Here are some examples where taking good photographs is difficult. Perhaps you can see or extrapolate your particular problem.

1. The building facade you are modeling has cars parked in front of it and you cannot see where the building meets the sidewalk.
2. The building you are modeling is surrounded by earth berms or uneven terrain and you cannot see the bottom edge of the building.
3. The process plant you are measuring has a large walk-way in between where you want to take photographs and all the boilers, pipes and valves you wish to measure,
4. The heritage school house you are modeling for your renovation project is surrounded by large old trees.
5. The tall tower you are measuring has a platform on top with some compressor housings that you need to measure but you want to take your photographs from ground level.
6. The automotive part you are modeling has many smooth curves and it is difficult to uniquely identify a single point on that surface in more than one photograph.
7. The object you are modeling has many curves and edges but not many good distinct points which you need to mark and reference so you can orient the photographs so that the Curve and Edge Tools can be used.
8. The building you are modeling is quite large and you want to get both an overall model but with lots of detail. When you take the overall photographs, the details are too fuzzy

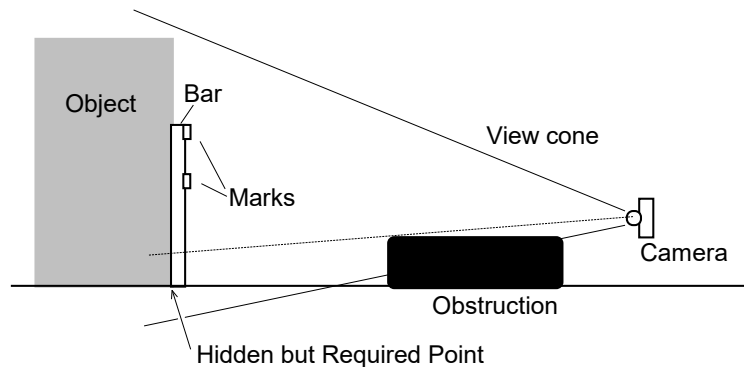
to mark but if you take lots of close-up shots it is hard to get an accurate consistent model.

9. The building you are modeling is quite large and due to the long focal length of your lens you cannot get photographs that encompass the whole structure.

On the other hand, there are many objects, both large and small, that you can take clear photographs of and in which you can identify each point precisely and uniquely. There are also many work-arounds for the problems listed above.

The solutions

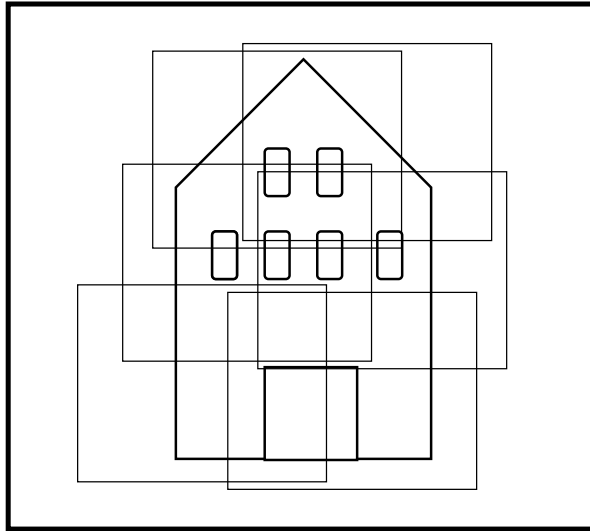
1. The following lists some of the methods that can be used to measure with PhotoModeler in difficult circumstances. The list corresponds by number to the set of example problems above.
2. Some projects require more planning than others. To remove the car problem, one needs to go out on a weekend and put out some pylons to stop cars from blocking the view of the bottom of the building.
3. Sometimes it is necessary to get the camera into a high position to be able to shoot down over obstructions like berms, hedges, etc. If there are nearby buildings one can use them and shoot from upper story windows or the roof. If there are no surrounding buildings one can sometimes use a tall step ladder, stand on top of a car or truck, or rent a lift for the day. Again some preplanning of the Measurement Project will let you know what restrictions you will have to overcome. It does not matter if photographs are taken from different elevations; in fact, that is preferred.
4. For some types of obstructions and some types of objects one can use extender bars. An extender bar is a long piece of straight wood or metal with three or four marks on it. They are measured with a tape measure so the distances between the marks are known. The bars are then placed in the scene being photographed so two or three of the marks can be seen by multiple shots of the camera. The last mark is placed beside or on top of the real feature you want to measure (for example, where the boiler meets the floor). In PhotoModeler you mark the points on the extender bar that can be seen in the photographs. In the CAD program you extend a line from those marks by the pre-known distance to the point you want the measurement for; see the diagram below:



The two upper marks can be seen and measured. The third mark can be projected from the positions of the other two and a known distance. This is quite easy to do in most CAD programs. You would not want to do this for very many points but when you are stuck it can be helpful.

Edges may also assist with this situation.

5. Trees and vegetation can sometimes be difficult . The best time to measure this sort of structure is in the winter because of the lack of leaves! Often you cannot wait that long. With careful layout and planning of the camera shots, use of extender bars or other object features, or the use of a wider angle lens one can often measure in these circumstances. The Edges feature is also very useful in this situation if you have the correct photography.
6. To measure the top of something, you will need to get above it; there are not many ways around this problem. You can try to get up on a nearby tower or building, you can use a airplane or helicopter, or you can use some sort of lift. We have had suggestions of using balloons and remote control model helicopters but these are only for the seriously adventurous.
7. Measuring and modeling surfaces such as milled and cast parts or terrain is a similar problem to the previous one. You need to provide a set of unique points that can be identified precisely in the photographs. With a small part you can project a pattern on to it (i.e. with a slide projector or laser) . With a larger part you can stick items to it or put on paint or wax marks. With a large surface (such as a pile of rubble) you might need to throw down some traffic cones with large numerals written on them. See the section *Using Targets* for more information on adding points to scenes.
8. Create a sheet of paper or other suitable platform with printed or placed circular targets under the object (or as a background). Then use the Sub-Pixel Marker to mark these targets (at least six per photo), reference them and then process. These points while not needed for the final model will produce accurate station orientations so that tools like Cylinder, Edge and Curve can be used to do the actual modeling.
9. Modeling a large object in which a lot of small detail is also required involves taking photographs at least two different scales. A few (3-4) photographs are taken encompassing the whole object or building. From these photographs an accurate but a model low in detail can be built up. At this stage one of two approaches can be taken:
 - i. If there is an overall higher level of detail required, take a set of overlapping close-up photographs. Mark and reference these to each other and to the overall photographs. Both the distance and close-up photographs can be combined in the same project.
 - ii. If small sections of very high detail are required you can do these areas as individual PhotoModeler projects. To tie the detail models together, use the overall low-detailed model as a source of control points to orient the detail models. That way all the detail models will sit in the same coordinate system as the overall model. The models can then be combined in CAD.
10. When a large structure cannot be photographed in whole then it should be photographed in pieces with good overlap between photographs. The more overlap usually the better as far as accuracy goes but the more pictures that need to be taken and the greater the amount of referencing. It is a trade off. Below is a diagram of a large facade and the light rectangles are the areas of the photographs taken.

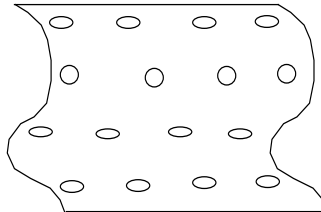


Using photograph overlap to capture a large structure

Using targets

Sometimes it is necessary and sometimes desirable to use man-made targets and place them on the object being measured. When a surface is curved or has an arch, targets allow you to identify points with greater ease in the photographs. Also, when you require maximum accuracy, targets are the way to go.

Targets can take two forms: the first is a small solid circle and is placed on curved surfaces to provide points for marking. For example, the following curved surface has rows of circular dot targets placed on it for marking purposes:



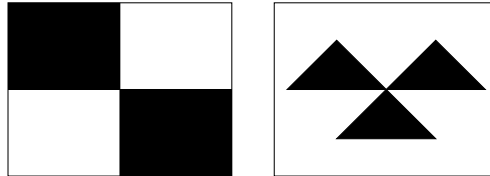
Any type of surface, from a car fender to a ship hull can be targeted in this fashion but some care has to be taken in deciding on the color and size of the targets. You can purchase various size dots in different colors from stationary stores. A calculation for the appropriate size for a dot target is shown below. The color chosen should contrast well with the surface being measured. Yellow fluorescent dots would work well on a black car fender but would not work well on a yellow car.

Circular targets are the highest precision in PhotoModeler because of the built-in *Sub-pixel Target Marking*. PhotoModeler uses two highly accurate algorithms for marking solid circular targets. As long as the target is relatively high contrast (black on white, white on black, dark on light, or light on dark) and shows up in the image ideally about 8-10 pixels across the sub-pixel marker will work well.

See also *Targets - Do's and Don't's*, *Coded Targets*, *Sub-pixel Target Marking*, *Marking Points*, *Automatic Target Marking*.

Manually Marked Targets

The other form of target could look like one of the following:



This type of target type (that uses straight lines as opposed to using a circular dot) can be manually marked or in some cases be marked by the Template Target sub-pixel marker. See *Template Target Marking* for more detail. These cannot be marked by the Circular Target Sub-pixel marker.

When one of these targets appears large enough in the photographs being marked you can zoom in and very precisely mark the center of the target. When targets such as these are marked with care on four or more photographs with good angle separation, the resulting 3D point location will be very accurate. Depending on the size required, these targets can often be created on 8.5"x11" paper in a laser printer.

Menu/Tool Reference

When you interact with PhotoModeler, you generally use menu items and toolbar tools. As many of the menu items also appear on the toolbar (they are in fact the same 'tool'), in this reference menu items and toolbar tools are collectively referred to as simply 'tools'. Note that you can also add, move, or remove tools to/from the menus and toolbars (see *Toolbar Customization*). What follows is a description of each tool categorized by the menu under which it appears when you first install PhotoModeler.

Tool Reference

File Menu

The File menu contains operations on projects and project files. Projects can be created, saved and loaded. Measurement data can be exported in various formats. The file menu is always accessible.

Getting Started...

This opens the *Getting Started Panel* from which a new PhotoModeler project can be created (see also *Creating a New Project*). This pane also provides access to recent projects, tutorial videos and projects, the help file, a check for program updates feature and links to useful pages on the PhotoModeler website.

This tool is always available.

Open Project...

Open an existing project from a disk file. PhotoModeler will display a File Selection dialog and allow the user to select the project to open, from the list of previously saved files in the current directory. The user may change directories and open any accessible project. See also *Opening an Existing Project*.

This tool is always available.

Open Merged Project...

Opens the *Project Merge Dialog* to allow the opening of multiple PhotoModeler projects all merged together.

This tool is always available.

Save Project

Save the current project as a disk file. The first time this is selected, PhotoModeler will display a File Selection dialog and allow the user to name the project. Once a project has been saved with a name, this menu item will save the project without asking for a name. Compare this with "Save Project As..." menu item.

This tool is only available after a project has been created or opened.

See also *Saving a Project*.

Save Project As...

Save the current project as a disk file. PhotoModeler will display a File Selection dialog and allow the user to name this project.

This tool is available only after a project has been created or opened.

See also *Saving a Project*.

Add/Remove Photos...

Opens a *Add/Remove Photographs Dialog*.

This tool is available when a project has been created or opened.

Edit Photo Sets...

Brings up the *Edit Photo Sets Dialog*. The user can add or remove photos from the project's photo sets from this dialog.

This tool is available only after a project has been created or opened.

Hide/Show Photo Control ...

Clicking this item will toggle the *Photo List Pane* visibility on or off. This selection is available when a project containing photographs is open.

This tool is available only when a project containing photographs is open.

Imports

Opens a file selector for you to select an import file. Once a valid import file is selected, the Import Options dialog appears. See *Imported Objects*.

This tool is available only after a project has been created or opened.

Exports

Shows a sub-menu from which you can choose to Export Model..., Export Ortho Photo..., or Export 3D Viewer Animation... .

This tool is only available when a project file is open.

Export Model...

Write out a 3D model in one of many 3D file formats. See also *Using your 3D Model with Another Program*.

This tool is only available when a project file is open.

Export Ortho-Photo...

Extract image data from a photograph under selected Surfaces. See *Ortho-Photo Export* and *Using your 3D Model with Another Program*.

This tool is only available when a project file is open.

Export 3D Viewer Animation...

Opens the *Animation Output Dialog* where you can set up an animation of your model or scene in a 3D view. See also *Using your 3D Model with Another Program*.

This tool is only available when a project file is open.

Print or Output Open View...

Opens the *Print and Output Options Dialog* where you can output an open window (e.g. a photo, table or 3D View) to printer, clipboard or file.

This tool is only available when a project file is open.

Create Coded Targets...

This tool is shown and enabled if you have the Coded Targets Module installed (see *Create Coded Targets Dialog* and *Modules and Licenses*).

Recent Projects

A list of recently opened projects appears at the bottom of the File menu. This allows you to quickly re-open a recent project without browse for the directory in which it is saved. The number of recent projects listed here can be set by changing the "Number of recent projects to display" setting in the Preferences Dialog on the General Page (see Toolbars and Menus section of *Preferences - User Interface*).

Exit

Leave the program. The program asks you to save any unsaved changes before exiting. See also *Saving a Project*.

This tool is always available.

Edit Menu

This menu contains commonly used editing operations. You can select all items in the active window, delete any selected items and undo any changes. The properties of objects can also be changed with this menu. This tools under this menu are only enabled when a project is open.

Undo / Redo

Reverse the effect of your last change to the project. Once reversed a change can be redone, by selecting this item a second time (will be called Redo).

See also *Undoing Changes*.

This tool is only available when your last change can be undone or redone.

Delete Selected Items

Remove all items that are currently selected in the active window.

If the active window is a photograph, then selected points, fiducials, lines, surfaces, surface drawings and cylinders are deleted. If the point being deleted is used to define scale or rotation, PhotoModeler show a warning.

This tool is only available when one or more items are selected.

Select Items Mode

Pick up the select tool. With this tool you can move items and select them for other operations. Either click on items to select or in photographs you can drag a rectangular region.

This tool is available when a Photograph, 3D Viewer or Table Window is open.

Region Select (Temporary)

Temporarily put the program into the polygon region select mode. With this mode you can define a closed region and all objects inside that region will be selected. Click down anywhere on a photograph or in a 3D Viewer, and then move the mouse to the next vertex of the polygonal area and click again. Repeat this to surround the objects to be selected. Click within ten pixels of the starting point and the region will close and the objects will be selected. Hitting the ESC key during the region definition will cancel it. Once the region has been defined, the previous mode reactivates.

This tool is available when a Photograph or 3D Viewer Window (see *Selection in the 3D Viewer*) is open.

Select All Marks/Objects in Active View

Select all items in the active window. If the active window is a Photograph Window, all points, lines, surfaces, surface drawings and cylinders will be selected. If the window is a Table then all Objects visible will be selected.

This tool is only available when in Select Mode or Referencing Mode.

Select Unreferenced Items

Select unreferenced items in the active window. If the active window is a Photograph Window, all unreferenced points, curves, edges, silhouettes, and cylinders will be selected. If the window is a Table then all Objects visible will be selected.

This tool is only available when in Select Mode or Referencing Mode.

Expand Selection to all Windows

This tool will search out all Marks on open photographs that are currently selected and all objects selected in 3D Viewers, and Tables and then add their associated objects to the selection. This applies to points, cylinders, edges, curves, and silhouettes.

Examples, Cylinder Mark selection expands to the same Cylinder in other photographs and in the 3D Viewer. Marked Point selection expands to all other photos, 3D Viewers and Point Tables that show this point. This is useful for relating object between different types of views. See *Universal Selection* for more detail.

This tool is available when a project is open.

Open Photos Showing Selected

This tool will open all photos on which the currently selected item is marked.

This tool is available when a project is open and an object is selected.

Create Photo Set From Photos Showing Selected

This tool will create a new photo set from all photos that display the marks from the currently selected object (see also *Edit Photo Sets Dialog*).

This tool is available when a project is open and an object is selected.

Materials...

Opens the *Materials Dialog* so the settings for existing Materials can be changed or new Materials created.

This tool is available when a project is open.

Layers...

Opens the *Layer Dialog* so the settings for existing Layers can be changed or new Layers created.

This tool is available when a project is open.

Tag Selected

Applies a "Tag" to all points that are currently selected. A "T" will appear next to the point if you have turned on the visibility of tags (see *Visibility Settings*).

This tool is available when points are selected on photographs.

Clear Selected Tags

Clear the Tag off all points that are currently selected.

This tool is available when points are selected on photographs.

Clear All Tags

Clear the Tag off all points in the Project.

This tool is available when a Project is open.

View Menu

This menu contains operations to show or hide panes or windows. See also *Paned Interface*.

Photo List

This tool shows (or activates) the Photo List pane if it has been hidden or tabbed out of view. The pane will open in the position that it was last shown. This pane contains 'chips' representing the projects photos and is where you open photos from. See also *Photo List Pane*.

This tool is only available when a project has been opened.

Visibility on Photos

This tool shows the Visibility on Photos pane if it has been hidden or tabbed out of view. The pane will open in the position that it was last shown. This pane has the controls to show or hide various items in photos. See also *Visibility on Photos*.

This tool is only available when a project has been opened.

Properties

This tool shows the Properties pane if it has been hidden or tabbed out of view. The pane will open in the position that it was last shown. This pane shows various properties of selected objects. See also *Properties*.

This tool is only available when a project has been opened.

Shapes Explorer

This tool opens the Shapes Explorer, if it has been hidden or tabbed out of view. The pane will open in the position that it was last shown. See *Shapes Modeling*.

This tool is only available when a project has been opened.

Imports Explorer

This tool opens the Imports Explorer, if it has been hidden or tabbed out of view. The pane will open in the position that it was last shown. See *Imported Objects*.

This tool is only available when a project has been opened.

Enhance Image...

This tool opens the opens the *Enhance Image* Pane if it has been hidden or tabbed out of view. With this dialog the brightness and contrast of a photograph can be modified to bring out hard-to-see features.

This tool is only available when a project has been opened.

Measurements

This tool opens the *Measurements* pane if it has been hidden or tabbed out of view. The pane shows real-time measurement information for selected items. See also *Processing Points-Based* and *3D Scale and Rotation Dialog*.

This tool is only available when a project has been opened.

Open 3D View

This tool opens a *3D Viewer* in the *3D View Windows* Pane using the visibility and other settings that were in use when the last 3D Viewer was opened. The 3D Viewer options dialog does not open. Note that you can open multiple 3D Viewer windows, each with different visibility settings.

This tool is only available when a project has been opened.

Open 3D View (show options)

This tool opens a *3D Viewer* in the *3D View Windows* Pane. The 3D Viewer options dialog opens first where you can set visibility and other display settings for the 3D Viewer. Note that you can open multiple 3D Viewer windows, each with different visibility settings.

This tool is only available when a project has been opened.

Generate a Table...

This tool opens a *Table Layouts Dialog* where you can configure and/or open a table. Tables will open in their *Table Windows* pane.

This tool is only available when a project has been opened.

Table 1

This tool opens the table that is listed 1st in the *Table Layouts Dialog*. Tables will open in their Table Windows pane. Note that the table name is listed in this menu tool when a layout has been configured.

This tool is only available when a project has been opened.

Table 2

This tool opens the table that is listed 2nd in the *Table Layouts Dialog*. Tables will open in their Table Windows pane. Note that the table name is listed in this menu tool when a layout has been configured.

This tool is only available when a project has been opened.

Table 3

This tool opens the table that is listed 3rd in the *Table Layouts Dialog*. Tables will open in their Table Windows pane. Note that the table name is listed in this menu tool when a layout has been configured.

This tool is only available when a project has been opened.

Table 4

This tool opens the table that is listed 4th in the *Table Layouts Dialog*. Tables will open in their Table Windows pane. Note that the table name is listed in this menu tool when a layout has been configured.

This tool is only available when a project has been opened.

Table 5

This tool opens the table that is listed 5th in the *Table Layouts Dialog*. Tables will open in their Table Windows pane. Note that the table name is listed in this menu tool when a layout has been configured.

This tool is only available when a project has been opened.

Additional Tables

This tool shows a sub-menu from which you can choose a table to open. The list matches the table layouts listed after the top 5 in the *Table Layouts Dialog*.

This tool is only available when a project has been opened.

Marking Menu

This menu contains operations used while marking points, edges, lines, curves, surfaces and fiducials on photographs.

Mark Points Mode

Pick up the point marking tool. With this tool you can mark points on an open photograph. See also *Marking Points*.

This tool is only available when a photograph has been opened.

Mark Lines Mode

Pick up the line marking tool. With this tool you can mark or create lines on an open photograph. See also *Creating Lines*.

This tool is only available when a photograph has been opened.

Mark Cylinders Mode

Pick up the Cylinder marking tool. With this tool you can mark the edges of a cylinder.

This tool is only available when a photograph is active.

Mark Curves Mode

Pick up the NURBS Curve drawing tool. With this tool you can draw curves on open photographs.

This tool is only available when a photograph is active.

Mark Edges Mode

Pick up the edge marking tool. With this tool you can mark edges on an open photograph.

This tool is only available when a photograph has been opened.

Mark Shapes Mode

Opens the Shapes Explorer and sets the Shape Marking mode. See *Shapes Modeling*.

This tool is only available when a project has been opened.

Sub-pixel Target mode

Modifies the Point Marking and Control Point Marking modes so that circular targets are marked by dragging out a region. See *Sub-pixel Target Marking* for more detail.

This tool is only available when a photograph is active.

Re-Subpixel Target mode

Allows you to re-mark a sub pixel marked point using the sub-pixel marker tool. This is useful if you find that you marked a point inaccurately on a previous attempt.

This tool is only available when a photograph is active.

Surfaces Sub-menu

The surfaces sub menu shows a list of the numerous surfacing tools (See also *Creating Surfaces*) as follows:

Path Mode

Pick up the Path Surface creation tool. With this tool you can create Path Surfaces from existing Points, Lines, Edges and Curves by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Triangle Mode

Pick up the Triangle Surface creation tool. With this tool you can create Triangle Surfaces from existing Points, Lines and Edges by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Loft Mode

Pick up the Loft Surface creation tool. With this tool you can create Loft Surfaces from existing Lines, Edges and Curves by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Sweep Mode

Pick up the Sweep Surface creation tool. With this tool you can create Sweep Surfaces from existing Lines, Edges and Curves by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Revolution Mode

Pick up the Revolution Surface creation tool. With this tool you can create Surfaces of Revolution from existing Lines, Edges and Curves by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Boundary Patch Mode

Pick up the Boundary Patch Surface creation tool. With this tool you can create Surfaces from a boundary of existing Lines, Edges and Curves by selecting them on an open photograph, 3D Viewer or table. This produces a Coon patch from three or four curves and so is different from the Path Model. See *Creating Surfaces*.

Cone Mode

Pick up the Cone Surface creation tool. With this tool you can create Conical Surfaces from existing Points and Curves by selecting them on an open photograph, 3D Viewer or table. See *Creating Surfaces*.

Mark Silhouettes Mode

Pick up the Silhouette Marking tool. With this tool you can mark the outlines (silhouettes) of objects, creating Silhouette Marks. These Silhouette Marks can be referenced to create a Silhouette Surface. See *Creating Surfaces*.

Create Point Cloud from selection

Creates a Point Cloud Surface from the selected Point set. See *Creating Surfaces*.

Automatic Surfacing/Triangulation...

Opens the *Automatic Triangulation Dialog*. This selection is available when a Project is open.

Reverse Last Object

Available when creating a surface, reverses the direction a surface interprets the last object added to its defining object set. See *Creating Surfaces*.

Finish Surface

Available when creating a surface, finish the current surface and resets the surface creation mode allowing you to begin creating another surface. See *Creating Surfaces*.

Close Surface

Available when creating a surface that can be closed, finish the current surface, close it, and resets the surface creation mode allowing you to begin creating another surface. See *Creating Surfaces*.

Flip Surface

Available when a surface is selected, this tool will flip or reverse the current surface. If your surface was created 'upside-down' and appears to be facing the wrong direction, use this tool to flip it. See *Creating Surfaces*.

Trim Surface

Available when a NURBS Surface is selected. Allows you to define a trim loop that is applied to the selected surface. See *Creating Surfaces*.

Create Hole in Surface

Available when a NURBS Surface is selected. Allows you to define a whole loop that is applied to the selected surface. See *Creating Surfaces*.

Select Defining Objects

Available when a surface is selected. Unselects the surface and selects the objects that define the surface.

Mark Surface Points Line Mode

Pick up the Surface Draw tool. With this tool you can draw points and lines on one or more Surfaces in a single photograph.

This tool is only available when a photograph is active.

Mark Surface Points Curve Mode

Pick up the Surface Draw Curve tool. With this tool you can draw points and curves on one or more Surfaces in a single photograph.

This tool is only available when a photograph is active.

Mark/Pin Imports Mode

Opens the Imports Explorer and sets the Import Point Marking tool. See *Imported Objects*.

This tool is only available when a photograph is active.

Uncontrol/Unpin Selected Point(s)

Turn any points in the current selection set that are Control Points back into normal Points.

This tool is available when control points have been selected on a Photograph, Table or 3D Viewer.

Fiducials List

Pick up the Fiducial Marking tool. This tool is used to mark Fiducial points on photographs that have been taken with a film camera. See *Using a Film Camera with Fiducials or Reseau* and *Fiducial*.

This tool is only enabled when the camera that is being used requires fiducial marks, and then it is only enabled when a photograph is open.

Automatic Target Marking...

Opens the *Automatic Target Marking* Dialog.

This tool is available when a Photograph is open.

Referencing Menu

This menu contains operations related to referencing points to one another.

Reference Mode

Pick up the referencing tool. With this tool you indicate common Marked Points, Edges, Curves or Cylinders imaged on more than one photograph. PhotoModeler needs to know which points are common to more than one photograph in order to build a 3D model. See also *Referencing*.

This tool is available when a project is open.

Quick Reference Selected

References all currently selected items together (if objects are of the same type and there are no conflicts). This is an “action” compared to the above which is a “mode”.

This tool is available when one or more objects is selected.

Unreference Selected

Breaks the association between the selected Points, Edges, Cylinders, Curves or Silhouettes on the Active Photograph, 3D Viewer or Table and any objects they have been referenced to on other photographs. When the selected object is “mark” (that is selected on a photo) then only that mark is unreferenced. When the selected object is a “3D object” (that is selected in a Table or 3D Viewer) then all associated marks are unreferenced. See also *Referencing*.

This tool is only available when one or more Marked Points, Edges, Curves, Cylinders or Silhouettes are selected on the active photograph, table or 3D Viewer.

Weld Unreferenced Points...

Open the *Unreferenced Point Weld Dialog*.

This tool is available when a Project is open.

Automatic Referencing...

Open the *Automatic Referencing* Dialog.

This tool is available when a Project is open.

Project Menu

This menu contains operations for configuring a project, solving a project to produce a three dimensional model and examining the solved model.

Process...

Attempt to build a three dimensional model. PhotoModeler will first display the *Audit Dialog*. This dialog displays statistics about the points that have been marked. See *Processing Points-Based*.

This tool is available when a project has been created or opened.

Undo Process

Reverts the project data back to the state just before the last processing was done. If the processing succeeds (i.e. no error messages) but the result is not correct (i.e. orientation had a poor solution and the model looks corrupted) or you are not happy with the result you can reverse all the changes made during processing.

Note that if processing did not give you the expected result, using "Undo Process" does not fix the underlying problem (which might be a referencing error, wrong camera

parameters etc.) it just returns the project to a state that is probably easier for finding and fixing the problem.

This tool is available after a successful processing until the next action that changes the model (e.g. moving a point).

Project Status Report...

Displays the *Project Status Report* which allows you to examine the state of your project and statistics on the overall project, marked points, photographs and cameras.

This tool is available when a project has been created or opened. A report will be displayed if processing has been attempted at least once.

Audit/Statistics...

Displays the *Audit Dialog*. Examine statistics related to the Marked Points and Photographs in this project.

This tool is available when a project has been created or opened.

Point Audit All...

Display a *Point Audit Dialog* and display information about all points in turn.

This tool is only available when a project is open.

Point Audit Selected...

Display a *Point Audit Dialog* and display information about each selected point in turn.

This tool is only available when a project is open.

Scale/Rotate...

Apply a scale to this project. Optionally the user may choose to rotate the project in 3 dimensional space and set its origin. Scale can be applied to a project at any time, but is only used for export and measure once a project has been successfully processed. See also *Adding Scale and Rotation*.

This tool is available when a project has been created or opened.

Cameras...

Opens the *Camera Viewer Dialog* which allows you to create new Cameras, load Cameras from disk and save Project Cameras to disk.

This tool is available when a Project is open.

Camera Calibration...

Opens the *Camera Calibration Dialog* which allows you to calibrate your camera.

This tool is enabled only when a Calibration Project is open.

Project Information...

Displays information about the current project. Allows editing of this information, including changing units, camera type and project name. See also *Project Information Dialog*.

This tool is available when a Project is open.

Open Constraints Dialog...

Displays the *Constraints Dialog* so all defined constraints in the project can be viewed.

This tool is available when a project has been created or opened.

Constraint Definition mode

Enters Constraint Definition mode. See *Working with Constraints*.

This tool is available when a photo or a 3D Viewer window is active.

Post Processing Modification...

Open the *Post Processing Modification Dialog*.

This tool is available when a project is open.

Renumber...

Open the *Renumber Dialog* where you can reset the numbering of various objects in the model.

This tool is available when a project is open.

Window Menu

This menu provides operations for manipulating document windows. Windows can be positioned, sized, and zoomed in and out. A list of open windows (Photographs, 3D Viewers, or tables) is shown at the bottom of this menu.

Tile Active Pane

Position and size all panes within a top level pane so that they do not overlap. See *Paned Interface*.

This tool is available when a photo, table or 3D view is active.

Maximize Active Pane

Maximizes the active pane in it's parent pane so that all other panes become tabbed beneath. This applies to photos, tables or 3D views. See *Paned Interface*.

This tool is available when a photo, table or 3D view is active.

Split Active Pane Horizontally

When more than one pane visible, this tool splits the pane so that two appear stacked on top of each other, while the rest are tabbed beneath. This applies to photos, tables or 3D views See *Paned Interface*.

This tool is available when a photo, table or 3D view is active.

Split Active Pane Vertically

When more than one pane visible, this tool splits the pane so that two appear side by side, while the rest are tabbed beneath. This applies to photos, tables or 3D views See *Paned Interface*.

This tool is available when a photo, table or 3D view is active.

Photo Window

Shows a menu on which are tools for use specifically with photo windows. See below for each.

Zoom To Fit

Return the active window to its default unmagnified state. See also *Changing the Magnification of a Photograph*.

This tool is available when a photo window is active.

Zoom To Fit All

Return all windows to their default unmagnified state. See also *Changing the Magnification of a Photograph*.

This tool is available when a photo window is active.

Zoom In Mode

Pick up the zoom-in tool. With this tool you can magnify the contents of a window. See also *Changing the Magnification of a Photograph*.

This tool is available when a photo window is active.

Zoom Out Mode

Pick up the zoom-out tool. With this tool you can shrink the contents of a window. See also *Changing the Magnification of a Photograph*.

This tool is available when a photo window is active.

Zoom To Area Mode

Pick up the zoom-area tool. See also *Changing the Magnification of a Photograph*.

This tool is available when a photo window is active.

Pan mode

Pick up the pan tool. With this tool you can move the contents of a zoomed-in Photograph Window.

This tool is available when a project is open.

Zoom 1:1

Immediately zoom the currently active photograph to a scale of one image pixel = one screen pixel.

This tool is available when a photo window is active.

Zoom Previous

Immediately zoom the currently active photograph to the zoom and pan setting before the most recent zoom change.

This tool is available when a photo window is active.

Manage Main Pane Layouts

Shows a menu of Main pane management tools (i.e. the layout of all panes in the application, see *Paned Interface* such as photo, table, 3D views etc.)

These tools are only available when a project is opened:

Manage Layouts

Brings up the *Manage Layouts Dialog*, where you can set the default layout and add/remove alternate layouts.

Save Current Layouts

Stores the current Main pane layout. A name dialog appears prompting you for a name to store it as. If the name is not unique, you will be asked whether you wish to overwrite.

Various Main Pane Layout Menu Items

When you have created new layouts a list is shown, from which you can select to load into the current application window.

Manage Photo Pane Layouts

Shows a menu of Photo pane management tools (i.e. the layout of just the photo panes in the Photo Windows main pane, see *Paned Interface*).

Manage Layouts

Brings up the *Manage Layouts Dialog*, where you can set the default photo pane layout and add/remove alternate photo pane layouts.

Save Current Layouts

Stores the current Photo pane layout. A name dialog appears prompting you for a name to store it as. If the name is not unique, you will be asked whether you wish to overwrite.

Various Photo Pane Layout Menu Items

When you have created new photo pane layouts a list is shown, from which you can select to load into the current Photo Windows pane.

Options Menu

This menu contains selections to change various PhotoModeler user interface options, program settings and module installation.

Preferences...

Opens the *Preferences* Dialog so various settings can be changed.

This tool is always available.

Check for Updates...

When tool is clicked, PhotoModeler will update itself if required. (see also *PhotoModeler Online Update*).

This tool is always available.

Licenses...

PhotoModeler has add-on Modules that can be purchased from Eos Systems or your dealer. These modules require a special license key to enable them. Use this tool to open the *License Management Dialog* and view currently installed module licenses.

This tool is always available.

Customize Toolbars...

Opens the *Toolbar Customization* Dialog which enables you to show hide and move PhotoModeler tools to/from toolbars or menus .

This tool is always available.

Help Menu

This menu contains information about how to use the PhotoModeler product. Help is available for all PhotoModeler features as well as on the theory of measurement.

Help Topics

Displays the Table of Contents of the on-line help for PhotoModeler.

This tool is always available.

Tutorial Videos

Run the Tutorial Video Launcher. This program provides access to the tutorial videos.

This tool is always available.

PhotoModeler on the Web...

Shows a sub menu of quick links to the PhotoModeler website: 1) A link to the main PhotoModeler website for general information about the program; 2) A link to the Support FAQ (frequently asked questions) section of the PhotoModeler website which should be referenced first if you are having problems with PhotoModeler; 3) A link to the section of the PhotoModeler website that shows a list of modules available for purchase from Eos Systems; and 4) A link to the Registration page on the PhotoModeler website.

This tool is always available.

About PhotoModeler...

A summary of information about the PhotoModeler product, the version you are running and various copyright information.

This tool is always available.

Tools not appearing under a Menu

Two tools that do not appear under a menu are the Current Layer and Current Material drop-down tools. These tools are on a stand-alone toolbar called Layers and Materials.

Current Layer Tool

The Current Layer tool provides ways to set the current project Layer, to view a selected object's Layer and to change a selected object's Layer. See also *Layer Dialog*.

To set the current project Layer (the layer to which any newly created items will be assigned), make sure nothing is selected, click the down arrow on the tool and select a Layer. Any new items created will be assigned the selected Layer. When you select an object or several objects on a photograph, in a 3D Viewer, or on a table, the object's Layer will be shown in the Current Layer tool. If you select multiple objects and not all of the selected objects share the same Layer, the Current Layer tool will not show a Layer – it will be blank.

When you select an object or several objects on a photograph, in a 3D Viewer or on a table, and if you change the Layer in the Current Layer tool, the newly selected Layer will be assigned to all of the selected object(s).

Current Material Tool

The Current Material works the same way as the Current Layer tool, except it works on Materials. The tool provides ways to set the current project Material, to see an object's Material and to change an object's Material. See also *Materials Dialog*.

To set the current project Material (the Material to which any newly created items will be assigned), make sure nothing is selected, click the down arrow on the tool and select a Material. Any new items created will be assigned that selected Material.

When you select an object or several objects on a photograph, in a 3D Viewer, or on a table, the object's Material will be shown in the Current Material tool. If you select multiple objects and not all of the selected objects share the same Material, the Current Material tool will not show a Material- it will be blank.

When you select an object or several objects on a photograph, in a 3D Viewer or on a table, and if you change the Material in the Current Material tool, the newly selected Material will be assigned to all of the selected object(s).

Keyboard Shortcut Reference

The complete list of default keyboard shortcuts is given below in two forms: first in menu order and second in key order. The keys can be customized and so might not match the list shown here. See *Toolbar Customization* (Keyboard tab) for more information.

File Menu	
Getting Started...	Ctrl+N
Open Project	Ctrl+O
Save Project	Ctrl+S
Save As Project	Ctrl+Shift+S

Edit Menu	
Undo	Ctrl+Z
Delete Selected Items	Del
Enter Select Mode	1
Enter Region Select (Temporary) Mode	D
Select All in Active View	Ctrl+A
Expand Selection to all Windows	W
Materials	Ctrl+M
Layers	L
Tag Selected Items	T
Clear Selected Tags	Shift+T
Clear All Tags	Ctrl+ Shift+T

View Menu	
Properties	Ctrl+P
Measurements	M
Open 3D View	F7

Table 1 (see <i>Table Layouts Dialog</i>)	Shift+1
Table 2 (see <i>Table Layouts Dialog</i>)	Shift+2
Table 3 (see <i>Table Layouts Dialog</i>)	Shift+3
Table 4 (see <i>Table Layouts Dialog</i>)	Shift+4
Table 5 (see <i>Table Layouts Dialog</i>)	Shift+5

Marking Menu	
Enter Mark Point Mode	2
Enter Mark / Create Line Mode	4
Enter Mark Cylinder Mode	8
Enter Mark Curve Mode	7
Enter Mark Curve Through Points Mode	Alt+7
Enter Mark Edge Mode	3
Enter Sub-pixel target sub-mode	S
Enter Re-sub-pixel target sub-mode	Shift-S
Enter Path Surface Mode	5
Automatic Surfacing	N
Flip Surface	Ctrl+F
Enter Mark Surface Points – Line Mode	6
Enter Mark/Pin Imports Mode	0
Automatic Target Marking	Alt-A

Referencing Menu	
Enter Reference mode	R
Quick Reference	Shift+Q
Unreference selected items	Ctrl+U

Project Menu	
Process	F5
Audit/Statistics	Shift+F5
Point Audit All	Ctrl+Q
Point Audit Selected	Q
Constraint Definition mode	C

Window Menu (Photo Windows sub-menu)	
Zoom to Fit all Photos	Shift+F
Zoom to Fit	F
Enter Zoom In mode	I
Enter Zoom Out mode	O
Enter Zoom Area mode	U
Enter Pan mode	P
Zoom Previous	Y

Help Menu	
Open Help File	F1
Tutorial Videos	F12

Non-Menu Keys	
End current operation (or skip point in Referencing and Control Point modes)	ESC
Zoom in photograph (or 3D viewer) under cursor	+
Zoom out photograph (or 3D viewer) under cursor	-
Bring up temporary zoom window	ALT
Enter into temporary zoom-area, pan mode.	CTRL

In key order:

Numbers	
1	Enter Select Mode
Shift + 1	Open Table 1
2	Enter Mark Point Mode
Shift + 2	Open Table 2
3	Enter Mark Edge Mode
Shift + 3	Open Table 3

4	Enter Mark / Create Line Mode
Shift + 4	Open Table 4
5	Enter Create Surface Path Mode
Shift + 5	Open Table 5
6	Enter Surface Draw Line Mode
7	Enter Mark Curve Mode
Alt + 7	Enter Curve Through Points Mode
8	Enter Mark Cylinder Mode
0	Enter Mark Control Points Mode

Letters	
Ctrl+A	Select All in Active View
C	Constraint Definition mode
D	Enter Region Select mode
F	Zoom to Fit
Shift+F	Zoom to Fit all Photos
I	Enter Zoom In mode
L	Flip surface
M	Measure mode
N	Automatic Surfacing/Triangulation
Ctrl+N	New Project
O	Enter Zoom Out mode
Ctrl+O	Open Project
P	Enter Pan mode
Q	Point Audit Selected
Shift+Q	Quick Reference
R	Enter Reference mode
S	Enter Sub-pixel target sub-mode
Shift+S	Enter Re-sub-pixel target sub-mode
Ctrl+S	Save Project
Shift+Ctrl+S	Save As Project
T	Tag Selected Items
Shift+T	Clear Selected Tags
Ctrl+U	Unreference selected items
U	Enter Zoom Area mode
W	Expand Selection to all Windows

Y	Zoom Previous
Ctrl+Z	Undo

Function Keys	
F1	Open Help File
F5	Process
Shift+F5	Audit
F12	Tutorial Videos

Misc. Keys	
ESC	End current operation (or skip point in Referencing and Control Point modes)
ALT	Bring up zoom window
CTRL	Enter into temporary zoom-area, pan mode.
+	Zoom in photograph (or 3D viewer) under cursor
-	Zoom out photograph (or 3D viewer) under cursor
Del	Delete Selected Items

Mouse Button Reference

Most mouse devices now have at least two buttons and a scroll wheel. PhotoModeler utilizes the left and right buttons and the scroll wheel:

Button	
Left	Used for typical windows application interaction and the method of selection of items in photos, tables and 3D Viewers. Can also be used in combination with the keyboard, eg Shift+Left Mouse will allow multi-select. See also <i>Selection and Visibility</i> .
Right	Generally used to bring up context menus in various views, also called right-click menus.
Scroll Wheel	Scrolling the wheel will zoom the active photo or a 3D Viewer in and out.

Glossary

This section lists some commonly used terms in this User Manual and in 3D measurement and modeling in general.

3D Face

Three connected points which define a triangular surface. This is the term used in AutoCAD to describe surface patches.

3D Model

A connected set of 3D points, lines, curves, and surfaces which can be used to represent an object or scene.

3D Point

A point with a location in space. Using *Cartesian coordinate axes*, a 3D point has values along the X, Y and Z axes. These values uniquely define one point.

Absolute measurement

A measurement of some quantity taken relative to a standard. A unit of time is considered an absolute measurement since it is implicitly relative to the time standard set up by the world standard organizations with their highly precise cesium clocks. Contrast with *relative measurement*.

Accuracy

The degree of conformity with a standard, or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result and is distinguished from *precision* which relates to the quality of the operation by which the result was obtained.

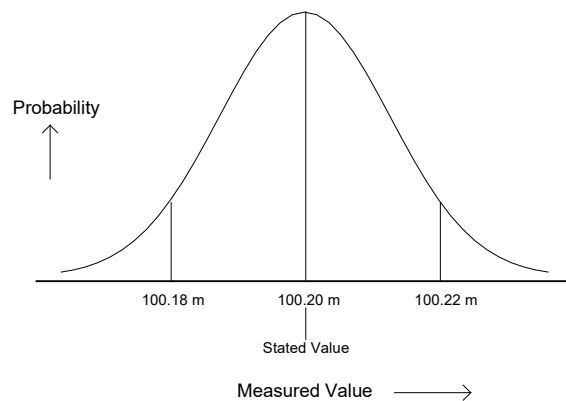
Accuracy refers to the closeness between measurements and their "true" values. The farther a measurement is from its expected or true value, the less accurate it is.

Precision pertains to the closeness to one another of a set of repeated observations of a random variable. Thus, if such observations are closely clustered together, then these observations are considered to have been obtained with high precision. A measurement that is precise is not necessarily accurate.

The "true" value is usually defined by some standard. A measured length of 1.1m of an actual length of 1.0 is accurate to 0.1m. If there are no systematic errors the accuracy usually falls within the precision of the measurement. The term accuracy is often incorrectly used interchangeably with the terms *repeatability*, *resolution* and *precision*. See the *precision* definition for an example.

Statements of accuracy need to be tied to statements of probability. If someone is stating how accurate a measurement is they should also be stating to what probability it is that accurate. Some background might clarify the relation of probability to accuracy.

Imagine that we have measured the length of an object. We measure this object repeatedly using the same instrument and record all the measurements. We then plot the number of times we obtained a certain measurement. We would normally get a graph something like this:



Most of the measurements were around 100.20m. We did get some measurements up near 100.22m and some down near 100.18m. We were measuring this length with a device that was calibrated to a known international standard. Relative to the standard we can say the most probable measurement for that length is 100.20m. When we state the accuracy of the measurement we can say that to 95% probability the accuracy is $\pm 0.02\text{m}$ (or 2cm).

The curve shown above is called a normal or Gaussian distribution and most accuracy curves look like this unless there are problems with the measurement technique.

This accuracy can also be stated with respect to one of the parameters of the normal distribution curve called the standard deviation. There is a 68% probability that the 'true' measurement lies within one standard deviation of the stated value and there is a 95% probability that the 'true' measurement lies within two standard deviations of the stated value. The graph above shows lines at 100.18m and 100.22m which are approximately at the two standard deviation marks. This measurement then might also be stated as: $100.20\text{m} \pm 0.02\text{m}$ at two standard deviations.

When the accuracy is not stated with a probability, then it is common to assume a 95% probability. That is, it is assumed that the 'true' value lies within the stated error range with a 95% probability. Unfortunately you cannot always assume this fact since it is easy to make a measurement appear more accurate by stating it at 50% (called probable error) or at 68% (called mean error) probability levels. When reading accuracy figures it is "reader beware"!

For example, a length measurement might be stated as 12.34m \pm 0.01m. The author of this figure has not stated a probability. It would be incorrect to assume that the 'true' value is between 12.33m and 12.35m with 100% certainty. The following table shows how the 95% probability level error (which is an accepted international standard for stating accuracy) changes with different assumptions on the measurement taker's part:

Probability Level Actually Used but Not Stated	Stated Error	Actual Error at 95% Probability
50% (Probable Error)	0.01 m	0.03 m
68% (Mean Error)	0.01 m	0.02 m
95% (Standard Error)	0.01 m	0.01 m

The accuracy of a complete Measurement Project or a set of measurements usually refers to the worst measurement in the set but can sometimes refer to the average or root mean square (RMS). Surveying standards are always based on the worst measurement in the set. For example, a survey done to 1:5,000 means that the worst measurement in the set is accurate to one part in 5,000 of the largest dimension in the set.

For other discussions on accuracy and how to improve it in PhotoModeler see the [Accuracy and Overcoming Limitations](#) section.

Accuracy standards

A standard is something established by authority as a rule for the measure of quantity, weight, extent or quality. Accuracy of measurements should be stated as a probability relative to an accuracy standard. For example, this length measurement has a 95% probability of falling within one centimeter of exactly one meter as given by the ISO standard meter length. Some people might state this as 1.0m \pm 1.0cm but this discounts the probability value which can make a big difference in the perception of accuracy as discussed above.

Active Photograph

The photograph in PhotoModeler, to which user interaction is currently directed.

Affine Transformation

A mathematical transformation of all the coordinates in the model that does not affect the shape of the model. Affine transformation can affect the size, position, and rotation of the model.

Angle Maximum

A value used to indicate the best angle between the photographs that image an Object Point.

The 3D position of an Object Point is computed by intersecting light rays from photographs. When the light rays intersect at a small angle the accuracy of the computed point tends to be less accurate because it is more susceptible to small errors.

If we call the angle between light rays j and k that are used to compute point i as A_{ijk} then the angle maximum is computed as:

Angle maximum for point i = maximum (A_{ijk} for all j and k on point i)

Approximate Camera

A Camera used by PhotoModeler that has not been calibrated but has had approximate parameters set in the Camera Calibration. Often all that is needed for a quick project is an Approximate Camera. For the highest accuracy a Calibrated Camera can be generated.

Approximated 3D Point

A 3D Point in PhotoModeler that has had its position in 3D space approximated but not processed by the 3D Processing algorithm. Under some circumstances (Camera Station have been successfully processed and have not been moved, and the point markings are accurate) an Approximated 3D Point will be quite accurate. Generally processing a project and turning all Approximated 3D Points into Processed 3D Points will improve the accuracy of these points.

3D Points are "approximate" when newly marked and referenced. Processed Points can become "approximate" if an associated Marked Point is moved, if the associated Camera Station is moved, if any fiducials on any photos containing the associated Marked Points are moved, or the associated Camera is changed in some fashion. Approximate Points become "processed" after successful 3D Processing (Project Menu).

Boundary Patch Surface

A *Surface* created from three or four boundary curves. Also called a Coons NURBS patch.

CAD

Computer Aided Design, or Computer Aided Drafting. CAD refers to the use of a computer program to model something in two or three dimensions.

Camera Calibration

A process of accurately determining the internal parameters of a camera (such as its focal length, principal point, format aspect, and lens distortion). There are a number of ways of doing camera calibration in PhotoModeler. The main method is the New Project Wizard - Calibration path. The other common method is *Field Calibration*.

Camera Station

A Camera Station is the location and orientation of a photograph at the time of exposure. Each photograph used in PhotoModeler has a Camera Station.

See *Orientation* for further detail.

Cartesian Coordinate Axes

The set of three axes (defined by one origin point and three points in space) that define the position and orientation of a Cartesian coordinate system. These axes are at right angles to each other. A Cartesian coordinate is represented by three values that designate a position. The point is located by measuring its distance from each axis along a parallel to the other axis.

See *Orientation* for further detail.

CCD

CCD is an acronym for Charge Coupled Device. CCDs are used in a video or digital camera to capture and record light as film does in a film camera. Another modern device for capturing images in digital camera is a CMOS device. While a CMOS device is not a CCD, we use CCD here to mean any digital imaging chip in a digital still or video camera.

Chip

See *Photo Chip*.

Coded Target

A *target* that has a unique code ring around it that PhotoModeler can automatically recognize. Four coded targets are used in Camera Calibration and the *Coded Targets* Module provides the ability to automatically mark, recognize and reference targets in a scene. A coded target looks like this:



The Coded Target Module is required to generate these targets, and to allow PhotoModeler to recognize them. See *Sub-pixel target marking*, *Automatic Target Marking Dialog*, *Coded Targets*, *RAD Targets*.

Confidence Region

Also the Error Ellipsoid. When 3D Points are solved in the processing algorithm, a precision is estimated for them. See *Precision*. The precision is known in three dimensions. In the table these are shown as precision along axes and in the 3D Viewer they are shown as an ellipsoid. Use the 3D Viewer Options to turn on Confidence Region display. Technically these ellipsoids are iso-surfaces of constant probability error. Every point on the ellipsoid is a constant one sigma probability of point position.

These ellipsoids are useful when you look at a) their shape, or b) their relative size to other point ellipsoids. If an ellipsoid is a sphere then the point's position is equally likely in all directions. If it is a strong oval shape then the point is less accurate in one direction (i.e. the longest dimension of the ellipsoid is the axis of most probable error of point). This is useful to see if for example that direction is very important for your measurement task. The relative size of the ellipsoids gives a very quick visual way to see if some points are more accurate (or inaccurate). The larger the ellipsoid the greater probability that point is inaccurate.

See also *Confidence Regions in the 3D Viewer*.

Control Point

A point with some known quantities that is used to control some other quantities. In general surveying and photogrammetry, a Control Point defines a known or pre-measured location in a 3D coordinate frame.

Coordinate system

A set of numbers used to identify the location of a point on a line, on a surface or in space. A 3D coordinate system has three such numbers used to identify a location in space.

Curve

See *NURBS Curve*.

Datum

The reference to which some quantity is measured. Also called the origin of a coordinate system. For example, any stated tidal sea level is implicitly stated relative to a datum that has been fixed at some known value. There is usually some large rock or piece of concrete with an embedded metal rod that precisely defines some coordinate in a reference frame that is used to measure sea heights. All sea height measurements in tide tables are relative to this datum mark.

Datums are also defined for measuring quantities on topographic maps such as the positions of roads and heights of mountains.

Whenever you see a single valued measurement (such as a height, a distance, a longitude or a latitude) it will be relative to some datum.

Docking Context Stickers

When moving panes graphical symbols appear to guide you in positioning panes. As you drag the panes over these stickers panes will snap into position. For example, you can dock a pane to the left edge by placing it over the leftmost arrow context sticker; or you can tab a pane by dropping it on the tab sticker in the center.

Dense Surface Model

A Dense Surface Model is a digital representation of a shape and is used in any application where a large number of 3D points (a point cloud) is needed. The DSM process creates a dense set of points called a *PointMesh*. See *Dense Surface Modeling / PhotoModeler Scanner*.

Sometimes also referred to as Digital Terrain Model or Digital Elevation Model.

DSM

See *Dense Surface Model*.

DSM Trim

A polygonal region used to limit the extents during the *Dense Surface Model* creation process. See *DSM Trims*.

DXF File Format

The DXF file format is a data exchange standard defined by AutoDesk, Inc. Many CAD and rendering packages can import DXF data files. PhotoModeler can create a 3D or 2D DXF file containing the solved 3D model.

Edge

A line-like structure that denotes a straight edge in the 3D model. An Edge is different than a *Line* in that 1) it does not connect Object Points (it is an entity unto its own), and 2) its end-points do not need to match when it is referenced across photographs.

Epoch

A period of time. Used in context of PhotoModeler Video (PMV) module. In PMV an epoch is a time when the moving and changing object/scene is considered to be stationary. For fast moving objects the epoch would be a very short time interval and if captured by a video camera there might be 15 epochs per second. For slow moving objects or objects that change shape slowly epochs might be minutes, hours or days apart and last for many minutes.

EXIF

Short for EXchangeable Image File. This is a file format that is a standard for storing information in digital photography image files. Almost all new digital cameras use the EXIF format, storing information in the image such as shutter speed, F number, focal length, date/time, resolution, etc. JPEG EXIF files can be read by any application supporting JPEG. Not all programs read the EXIF header information though (as PhotoModeler does).

The EXIF format is being replaced by DCF (Design rule for Camera File systems). DCF merges the CIFF and EXIF digital image file formats. Where PhotoModeler refers to EXIF, DCF can be used interchangeably.

Feature

A distinguishing mark on an object or in a scene. We talk about marking and measuring features. Whether something is a feature or not is in the eye of the beholder. The edge of a window frame would be a feature to someone modeling window positions on the facade of a building.

Fiducial

A fiducial is a physical point in a camera that is positioned such that when a photograph is taken, it is imaged on the film at the same time as the image coming through the lens. Fiducials are attached to the body of the camera so the images of the marks leave a frame of reference on the film image that ties the image to the camera. So no matter how the image is cropped, enlarged, shifted or scanned, PhotoModeler can still reconstruct accurately how the image was placed in the Camera at the time of the exposure.

Fiducials in PhotoModeler are defined by an x,y position in mm in a coordinate system placed on the film image plane. This fiducial coordinate system must be positive x from right to left and positive y from bottom to top on the image surface. Because a lens flips the picture, this will be positive x from left to right and positive y from top to bottom in the final image as seen in PhotoModeler.

Fiducials also each have a name so the user can identify them later during marking. For the Eos Insert the two fiducials have the names "Upper" and "Lower". For a frame fiducial set (where the frame of the focal plane opening is being used as a set of four fiducials) the fiducials have the names, "UpperLeft", "UpperRight", "LowerLeft" and "LowerRight". If you are defining you own Camera you can name the fiducials as you wish. If you are marking a *reseau* you may wish to name the fiducials by their grid position, for example, "r1c1", "r1c2",..."r2c1", "r2c2" etc.

Contrast this with *Fiducial Mark*.

Fiducial Mark

A Fiducial Mark is a point on a Photograph marked by a user to indicate the position of an imaged Fiducial. The combination of Fiducial Mark positions and the physical Fiducial positions give PhotoModeler the information to reconstruct where each photograph was at the time of exposure and to compensate for scale, rotation and skew changes introduced during printing and/or scanning.

Contrast this with *Fiducial*.

Film Plane Insert

A small piece of film with two *fiducial marks* provided with PhotoModeler to be used with 35mm cameras.

Field Calibration

A type of *camera calibration* where the camera internal parameters are solved at the same time as a standard project is being solved. If the project is set up well (for example, with good camera angles, rotated photos and sufficient good points) a field calibration will often produce the highest accuracy results.

Fit NURBS Surface

A *Surface* fit through a number of 3D points approximating a 2.5D surface, created with the Fit NURBS Surface to Selected Points tool.

Focal Length

The distance measured along the optical axis of a lens from the rear nodal point to the plane of best focus for an object a great distance away. The nominal focal length is an approximate value of the focal length that is printed on lens housings and in some lens specification sheets. The calibrated focal length (the value PhotoModeler uses) is an adjusted value of focal length that describes the distance from the perspective center of the camera to the image plane of the camera.

Highlight

verb: To bring to the user's attention by changing the intensity or color of some user interface object (such as a point, line, photo chip or button). noun: An attribute of a user interface object when it has been flagged for special user attention.

PhotoModeler uses various highlight colors:

red - indicates that the object has been selected

yellow - indicates that a point is referenced or about to be referenced

green - indicates that the point defines the origin, axis or scale point of the model.

Note these colors can be changed in *Preferences - User Interface* on the Colors page.

ID

A unique identification number for an object. 3D Object Points, Edges, Cylinders and Surfaces all have independent IDs. See *Point ID* for more information.

Image

An image is an optical representation of a scene. It consists of a raster of pixels (either monochromatic or color). We differentiate this from a photograph in PhotoModeler by saying the photograph has more knowledge about the camera and time of exposure. A photograph is like a image together with the information about how the image was captured.

Least Count or Least Reading

The reading of an instrument without interpolation of values. That is, if the smallest marking on a tape measure is one millimeter, then the least count is one millimeter. Often through interpolation, one can be more precise than that and get to 0.2mm or 0.5mm. Compare with *resolution*.

Line

The connection of two 3D *Object Point*s by a straight segment.

Lofted Surface

A *Surface* constructed from a series (two or more) of ordered Curves or Lines such that the surface goes through these curves and is smooth between.

Machine ID

A 'fingerprint' value to represent various hardware pieces of the computer during activation. The Machine ID is stored in the License file and is used to make sure the installation is valid. There is no personal information stored in the Machine ID.

Mark

A location on a single photograph representing the image of some physical feature.

Marking

The process of drawing and placing points or lines on a photograph to denote the boundary of some object. I.e. When the user outlines a door in a picture of a house with a set of four lines, that would be called line marking.

Marking Residual

A Marking Residual is a *residual* error relating to an object marked, by the user, on a photograph. It is the difference between where the user marked it and where the program expects it to be.

The most common marking residual is the Marked Point Residual. When a point has a 3D position, PhotoModeler can project it back onto the photograph (along its light ray) to

determine where, in the ideal case, that point should be on the photograph. Due to various errors and averages etc. the x, y point that the user marked and this projected x,y position will not be the same. The difference between these two is called the Marking Residual for the point. You can see the projected location by turning on Projections. You can also see the residual in its vector form by using the *Marking Residual Display* setting (see *Visibility on Photos*). The residuals can be seen in numeric form and summarized on the *Point Table*.

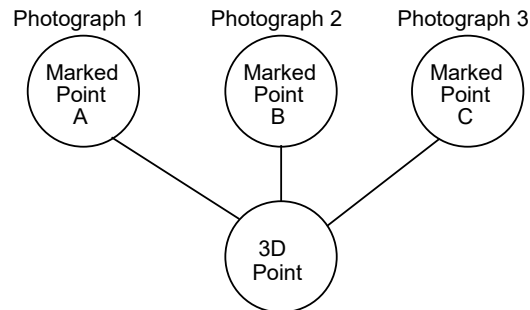
Marking residuals are one of the best indicators of project quality and should always be checked after processing. All projects should have the largest point marking residual of under 10 pixels. For projects with known and calibrated cameras the largest residual should be less than 3 pixels and for projects done with all sub-pixel targets, the largest residual should be less than 1 pixel and smaller if possible.

A large marking residual means that the 3D location of the point and the mark position of the point do not “agree”. The lack of agreement points to problems in the project that should not be ignored. If there are only a few points with high residuals then they are probably not marked well (or misreferenced). If there are many points with high residuals then perhaps there is a camera calibration (or parameterization problem) or one or more of the camera stations are not *oriented* correctly.

Marked Point

A point visible on a photograph that has been marked by a user. A Marked Point is shown on a photograph with an "X" like symbol.

This document refers to Marked Points, 3D Points and Points. A Marked Point is on a photograph, a 3D Point is on an object or in a 3D scene and a Point refers to some location in space and is usually synonymous with 3D Point. Marked Points are associated with 3D Points on a many-to-one basis. As Marked Points are referenced together they become to share the same 3D Point. The figure below illustrates this conceptual relationship:



Marked Points A, B, and C are marked on different photographs and are all referenced together. This implies that they mark the image of one point in 3D object space. When you see the term "point" used without the qualified "Marked" or "3D" this refers to either a multiple of referenced Marked Points or one 3D Point (which are really the same). See *3D Point* definition. The point identifiers displayed and exported by PhotoModeler are associated with and are unique to all 3D Points.

Measurement Project

The set of information PhotoModeler works with to produce a 3D model.

Network

A set of Camera Stations used in a Measurement Project and their positional relationship.

Network Strength

A qualitative measure of how well a network of Camera Stations will produce an accurate 3D model.

NURBS Curve

A 2D or 3D curve in space. NURBS = Non-Uniform Rational Bezier Spline. There are two forms of NURBS Curve in PhotoModeler - the *Curve from Marks* and the *Curve from Points*.

NURBS Surface

A 3D surface with usually a smooth curved shape. NURBS = Non-Uniform Rational Bezier Spline. There are a number of ways to create NURBS Surfaces - see *Creating Surfaces*.

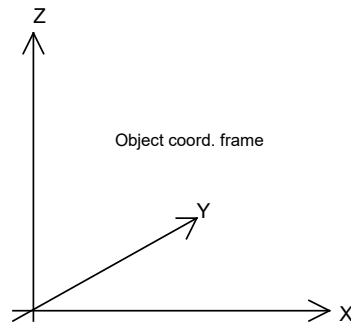
Object Point

A *3D Point* that is created by referencing two or more Marked Points across photographs. 3D Point and Object Point are used interchangeably.

Orientation

The position and angles of a *Camera Station*. The orientation of a Camera Station defines the position of and the pointing direction of the camera at the time of exposure of a photograph. Orientation can also refer to the process of determining the orientation of one or more Camera Stations.

The following sections describe the orientation angles and coordinate system.



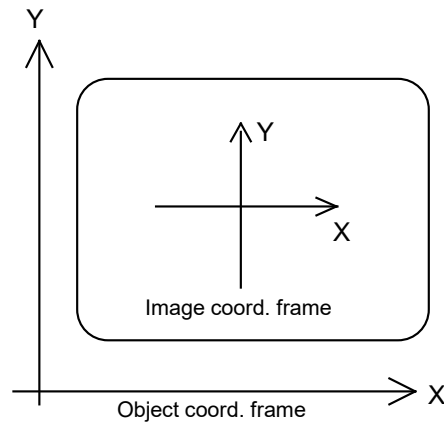
Euler Angles: Omega, Phi, Kappa

The direction of view and rotation of each Camera Station is defined by three Euler angles called omega ω , phi ψ , and kappa κ . These angles define the rotation of the camera from a default position. These positions and angles are defined in terms of a right-handed coordinate system.

Imagine the object you are measuring is sitting on the XY plane of a Cartesian coordinate system. Imagine the film or CCD that is used to image the object also has a coordinate system in which the XY plane lies on the imaging surface and the Z axis lies along the optical axis of the camera.

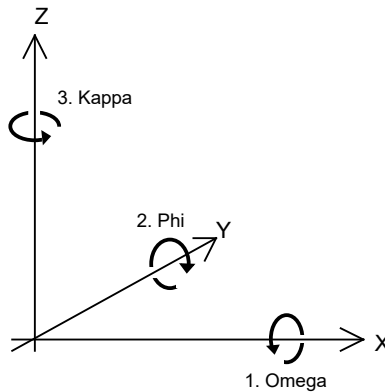
If you line-up the coordinate system of the camera with the coordinate system of the object you have the camera's default position.

In the following figure, you are looking through the back of the camera towards the object coordinate frame when the camera is in its default position (that is omega, phi and kappa all equal zero) :



The Z axis is pointing up out of the page in both coordinate frames.

To rotate the Camera into the desired orientation in the object coordinate frame, we rotate omega degrees about the X axis (right-handed again, in other words, positive rotation rotates the Y axis towards the Z axis), then phi degrees about the Y axis (positive rotates the Z axis towards the X axis) and the kappa degrees about the Z axis (positive rotates the X axis towards the Y axis). The following figure shows the rotation of the positive values of each angle:



Oriented

Oriented is the term applied to a *Photograph* or *Camera Station* to mean that it has been solved and we know where it is located in space and how it is pointing. Photographs cannot be used in PhotoModeler to compute 3D data until they are oriented. See *Orientation* for more detail.

Pane

A window within the PhotoModeler user interface that can be docked, floated, resized positioned relative to other panes.

Paned User Interface

A user interface system of pane windows displaying data and tools that can be docked, tabbed, floated, hidden, sized, moved etc to facilitate workflow and maximize screen real estate. See *Paned Interface*.

Path Surface

A *Surface* constructed by choosing a closed loop of 3D objects such as points, lines, edges, and curves. The loop becomes the outer boundary of the surface and the interior is interpolated.

Perspective Center

A point through which all light rays pass in a camera/lens system. This point is used to define the 3D position of Camera Stations.

Perspective Matching Definition

Perspective Matching is the process of determining the position of a camera when it took a photograph so that 3D graphics can be combined with that photograph. To combine 3D

graphics with a photograph you have to tell the 3D rendering program where to place the camera, how to orient the camera, and the specification for the camera's internals so during rendering the 'perspective matches'.

See *Perspective Matching* and *Using Camera Station Information, Imported Objects* and *Idealize Project*.

Photo

Short for *Photograph*.

Photo Chip

A scaled down version of a photograph used for indexing of the photographs. Photo Chips appear in the *Photo List Pane*, the *Photo Table*, and the *Add/Remove Photographs Dialog*.

Photo Set

As set of photographs used by PhotoModeler to help reduce clutter and control certain operations. See *Photo Sets*.

Photo Texture

A mapping of a photograph onto a surface during 3D rendering to increase the realistic look of that rendering.

PhotoCD

A product developed by Eastman Kodak and trademarked by them. This product provides high resolution digital images in CD-ROM format from film negatives. A user can take their film to the PhotoCD producer and get the film placed on a PhotoCD. The user then reads those images into the computer on a CD-ROM using PhotoCD access software.

Photograph

A 2D projection of a scene captured by a camera. In PhotoModeler, a 'photograph' often refers to the window that displays the image.

Photogrammetry

The art and science of making measurements from photographs.

Pixel

A pixel is the smallest unit of resolution in a digital image or on a CCD. It stands for "picture element".

Point

Refer to definitions of *3D Point*, *Marked Point* and *Referenced Point*.

Point ID

A unique number identifying each 3D model point in the project. This number stays the same for the life of a point. Point IDs are displayed on the *Status Bars* when points are selected, are displayed on Photographs and 3D Viewers when they are set to be visible, are shown in the Point Table and the Point Audit Dialog, and are exported with those formats that support text identifiers. Note that when two 3D points are referenced, one 3D point lives and gets all the other 3D point's marks, while the other 3D point is deleted - this makes some IDs on some point marks change.

Point IDs act a bit differently with *Coded Target* points. First, for any project with Coded Targets, there is a reserved block of one thousand (1000) IDs for the coded target points. This reserved block can start at 1, 1001, 2001, etc. Second, every Coded Target has a unique code (that number printed on the coded target by the *Create Coded Targets Dialog*) and there is a direct relationship between the target code and the point ID. If you recognize a point as coded (in a photograph the coded target has a different symbol, in a 3D viewer the id is surrounded by square brackets [], in a point table by the Target Code column, and on the status bar by the word (coded)), remove the thousand's digit to get the code. For example, a coded target with ID of 2012 is a mark of code #12.

PointMesh

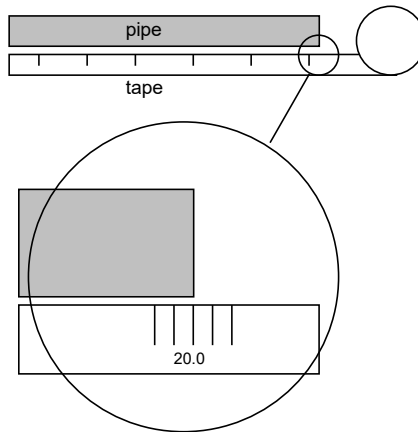
A PointMesh is a dense set of 3D points with optional triangles connecting them. A point mesh is created by the *DSM* process and can be just a cloud of 3D points or it can be a full mesh/triangulated surface. See also *Meshing Tools*, *Dense Surface Modeling / PhotoModeler Scanner*.

Precision

A quality of a measurement. The amount of care taken when a measurement is performed. A quality associated with the refinement of an instrument.

Accuracy refers to the closeness between measurements and their "true" values. The farther a measurement is from its true value, the less accurate it is. Precision, on the other hand, pertains to the closeness to one another of a set of repeated observations of a random variable. Thus, if such observations are closely clustered together, then these observations are considered to have been obtained with high precision. A measurement that is precise is not necessarily accurate.

Example: We are measuring a length of pipe with a tape measure:



We get three groups of four people each to take the measurements and we get the following results:

Group	Measurement 1	Measurement 2	Measurement 3	Measurement 4
No. 1	20.1	20.0	19.9	19.95
No. 2	18.95	19.02	19.0	19.05
No. 3	18.8	21.2	19.5	30.3

Groups 1 and 2 had relatively precise measurements with variations of 0.2 and 0.1 respectively. Group 3 has lower precision with a variation of 2.4. We discount the group 3's measurement number 4 at 30.3 because that clearly seems wrong. This last measurement is called a gross error.

Notice that group 2's measurements have small variation so were precise but the values are wrong (let's say the true value is 20.0). Their measurements center around 19. So group 2 has precise measurements but not very accurate measurements. Group 1 has both precise and accurate measurements.

Group 2 perhaps had a tape measure that was not manufactured properly. This would be called a systematic error.

The random errors affect the precision of the system. The precision, gross errors and systematic errors all affect the accuracy of the system. So if the gross errors and systematic errors are small, the precision should be close to the accuracy.

In the output of PhotoModeler (i.e. the *Measurements Pane*, *Point Table*, *Project Status Report*), precision refers to the expected spread of the value about its estimated value (just as with the random errors shown with the tape measure above). A precision of 0.1 mm refers to the width of the spread of one standard deviation of a normal Gaussian probability curve. The "true value" may or may not fall within the precision of the estimated value and so precision is not a measure of accuracy. These precision numbers can be used as estimates of accuracy if the gross errors and systematic errors can be assumed to be negligible.

Note that after version 5.2.3 all output precisions in PhotoModeler are scaled by the a posteriori sigma0. There is some debate in the photogrammetry community whether this is correct but if the a posteriori sigma0 (see *Final Total Error*) is different than 1.0 then scaling the precisions makes the precisions more useful (and independent of the input precision values). There is an ini setting for turning this precision scaling off (contact technical support if you feel this is required).

The precision values will give you good estimates of how well the project is solving and also the relative precisions give good feedback. For example, if the Z coordinate precisions on Object Points in the project are all ten times as big as the X and Y coordinate precisions then you can see there is some weakness in the project and the Z values cannot be depended on as much.

One more example comparing accuracy and precision: The project is the measurement of a road accident scene. The project solves well and the point precisions come out to around 0.5 inches. This means that if there are no gross or systematic errors in the project then the accuracy could be around 0.5 inches (this is the one sigma 68% probability). But let's say the tape measure that was used to measure the project scale was off by 25%. The project is still precise but it is not accurate. All the measurements are scaled the same in this project and hence will be off 25% from their "true" values.

Precision Vector Length

The Precision Vector Length is the result of a point's X, Y and Z Precision values and serves as a useful indicator of point quality. An object point's Precision Vector Length can be displayed in the Point Table. The *Confidence Region* can be more useful if the axis of largest error does not line up with the coordinate axes.

Principal Point

The location in a camera where the optical axis of the lens intersects the imaging plane.

Project

See *Measurement Project*.

RAD Targets

Ringed Automatically Detected Targets. These types of targets provide the ability to automatically mark, recognize and reference targets in a scene. A RAD target is a *coded target* with a ring around it, for example:



The Coded Target Module is required to generate these targets, and to allow PhotoModeler to recognize them. See *Coded Targets*, *Automatic Target Marking Dialog*, *Sub-pixel Target Marking*.

Reference Frame

A *coordinate system* with a defined *datum* and standards for the units and types of measures used for the individual coordinate values.

Reference Photograph

The Photograph you have selected to pick points on for referencing to points on other photographs. In the course of referencing a project, each photograph in turn may be selected as the reference photograph.

Referenced Point

A *Marked Point* that has been identified as referring to the same *3D Point* imaged in another photograph.

Referencing

The process by which you identify to PhotoModeler all the marks, on all the photographs, that refer to the same physical point on the object you are measuring.

PhotoModeler then treats referenced marks as one 3D point and solves for the coordinates of this point in the model.

Relative measurement

A measurement of some quantity taken relative to a stated reference measurement. For example, this door is twice as high as it is wide is a statement of relative measurement. Contrast this with *absolute measurement*.

Repeatability

A measure of how capable an instrument is of providing the same reading for the same quantity as the measurement is repeated. For example, if a caliper is used to measure the

thickness of a steel plate many times (opening the caliper and restarting the measurement each time), the repeatability is a measure of how different the measurements of thickness are.

Reseau

A means of imaging a grid of points or crosses onto film during exposure of a photograph. The reseau can be in the form of a glass plate with a grid of crosses that cover the image area or it can be a set of LEDs or lights that shine through the back of the film in a grid pattern. Reseaus are used to calibrate and remove the effects of film distortion and can also be used as fiducials. See *Fiducial*.

Residual

A residual is an amount of difference between an expected and calculated value. For example, if you expected a certain measurement to come to 2.55mm but the actual final result was 2.52mm then the residual (or residual error) would be 0.03mm.

The most important residual in PhotoModeler is the *Marking Residual*.

Resolution

A measure of the smallest "feature" that can be resolved by an instrument. In photography, the measure of resolution relates to the distinguishing of two black bars. As the bars get closer and closer together on the film or in the digital image, they get increasingly difficult to separate. Eventually they look like one bar and not two. The point at which they just turn from looking like two bars to looking like one bar is called the resolution of the imaging system.

Retro-reflective Target

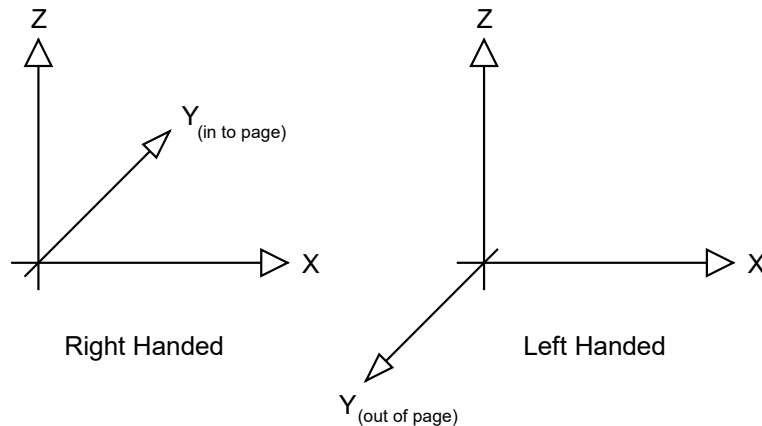
A type of *Target* made from retro-reflective material. Retro-reflective material is a type of sheet that reflects light back in the direction of the light source (unlike a diffuse material that reflects light in all directions (white paper is diffuse) and unlike a mirror that reflects light at opposite to the angle of incidence). Retro-reflective material is useful in photogrammetry because if you place a strong light source at the camera (such as a flash) then regardless of the angle of the target, the target will strongly reflect this light.

With targets made from retro-reflective material and a flash on the camera, you can change the camera exposure settings so that the targets in the scene are considerably brighter than the scene. This high contrast makes retro-reflective targets easier to identify and more precise. They are also suited to working at night or in other darkened environments.

Many road-side signs are made with retro-reflective lettering so that when you car headlights illuminate the sign, you can see the letters clearly and brightly. Many shops that make signs can also make retro-reflective targets.

Right Handed Coordinate System

A Cartesian coordinate system in which the location of the third axis may be inferred from the location of the two other axes, by using the right hand rule. This rule states that, if you form the first three fingers of your right hand into three perpendicular vectors, and point your thumb in the direction of the X axis, and your index finger in the direction of the Y axis, your middle finger will point in the direction of the Z axis.



Scanner

PhotoModeler Scanner is a set of tools used to create a *Dense Surface Model*. See *Dense Surface Modeling / PhotoModeler Scanner*.

Silhouette

An outline of an object in a 2D view that separates it from the background.

Smoothing Group

An user assigned grouping of surfaces that will appear to be smoothly rendered across their shared boundaries.

Surface

The outer most layer or boundary of an object. In PhotoModeler surfaces can be constructed from a closed loop of objects such as points, lines, and curves (a *Path Surface*), from a set of curves (a *Lofted Surface*, a *Surface of Revolution*, a *Boundary Patch Surface*, or a *Swept Surface*), or from a set of points (a *Fit NURBS Surface*). A Surface looks solid or opaque in the 3D Viewer and can be assigned Materials such as color and *photo texture*. See *NURBS Surface*.

Surface of Revolution

A *Surface* created by revolving a curve around an axis.

Swept Surface

A *Surface* created by moving a curve (a profile) along another curve (a rail).

Target

A target is a point in a scene or on an object that can be easily identified and easily marked when viewed in an image. Typically, a target is a high contrast dot or filled circle. Such a target can be marked with high precision with the sub-pixel marker (manual or automatic). Also see *Coded Target*. Targets can be other shapes too when Template Targets are used. Also see *Template Target Marking*.

Texture

See *Photo Texture*.

Tightness

Tightness is a value that indicates how well an Object Point's marks agree.

The tightness of a point relates to how well its defining light rays intersect. The better and closer they intersect in 3D space, the smaller the tightness value.

Take for example a point marked on only two photographs. Once the orientation and 3D solution is complete, the light rays from the two camera locations, through the marks, and out to the 3D point in space can be computed. If everything is perfect (perfect camera orientation, camera calibration, and mark positions) then the two light rays will intersect in 3D space perfectly - and this is the position of the computed 3D point. In this case the tightness value for this point would be zero.

In real-world situations neither the markings, nor the calibration, nor the orientation are perfect and these two light rays will not intersect - they will graze by each other - there will be a small gap between them (at the point they are closest to each other). The size of that gap is the tightness value. The larger the tightness, the larger the gap between the light rays.

When a point is marked on more than two photos, the tightness value shown is the largest gap between all light rays for that 3D point pair wise.

Tightness can be displayed in the *Point Table* as either an absolute value in scaled project units, or as a percentage (percent of the size of the project (the maximum diagonal extents of the 3D data in the project)). A tightness of 1.0% would mean that the light rays for that point miss each other in 3D space, and the size of the gap at the closest approach is 1% of the project extents. Note the 'Tightness as a percentage' column in the Point Table is not displayed by default but can be easily added.

In a high accuracy project the tightness values should generally be under 0.01%. A tightness of 0.01% means the gap between the light rays is one ten-thousandths of the largest project extent ($0.01 / 100 = 0.0001 = 1 / 10,000$).

In a good quality project with many manually marked points (not subpixel targets), the tightness values can reach 0.1% which translates into one one-thousandths of the project size.

Large tightness values can be due to imprecise marking or poor camera calibration.

Comparing tightness to marking residuals (see *Residual* and *Marking Residual*) - residuals relate to the error of an individual mark (how far is the 2D mark on the photo from the projection of the 3D point on that photo) and are measured in pixels, whereas tightness relates to the error of the intersecting light rays in space, as a 3D distance measure, and is displayed as a percentage of the project extents or as an absolute value in project units. See also *Precision* (which is another estimate of error that is computed by the processing algorithm).

Tool

A mode in a program used to accomplish a narrowly defined task. Tools exist for, among other things, panning a photograph, magnifying a photograph and marking points.

Toolbar

A set of tool buttons organized and displayed as a bar along the top of an application window.

Trim

A Trim is a curve loop that is used to cut away a part of a NURBS Surface. A Trim can be an outer trim (cuts away the outside edge of the Surface) or a hole (cuts a hole in the Surface).

Not to be confused with a *DSM Trim*, which is used to limit the search extents in the *Dense Surface Model* creation process.

Unused Point

A 3D point on the object being measured that is imaged on only one photograph, that is imaged on photographs that are too close together or that is incorrectly marked. An unused point will not be used in the 3D processing stage.

Unused Photograph

A photograph with too few Marked Points, too little point coverage or with no fiducials marked. An unused photograph will not be used in the 3D processing stage.

Weak Point

A 3D point on the object being measured that is imaged on too few photographs (usually less than three), that is imaged on photographs that are too close together or that is incorrectly marked. Weak points are difficult to solve for with any degree of accuracy and so they are brought to the user's attention. The user should aim at having very few weak points in a project.

Weak Photograph

A photograph with too few Marked Points or too little point coverage. A photograph that has only a few points imaged on it or is not covered very well with points can cause troubles in the 3D processing stage. The user should aim at having no weak photographs in a project.