
User Manual

PhotoModeler Pro 5

Eos Systems Inc.

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Welcome to PhotoModeler Pro

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 a lot of accurate detail in a very short time. It then organizes the model building process as you trace over photos on the screen.

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 **Video Tutorials** are the best way to learn PhotoModeler. There are a few concepts in PhotoModeler that are unique and it is best to read the help overviews and watch the tutorials before embarking on your first project. See the *Help* section. The *How do I start?* section has useful information that is project-type and application-area specific.

New for PhotoModeler Pro 5

This section provides a quick overview of the major new features in PhotoModeler Pro 5 since the Pro 4.0g 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 also read the *Upgrading to PhotoModeler Pro 5* section.

Improved Modeling

Improved Surfaces and Curves

- PhotoModeler 5 extends the NURBS curves capabilities to NURBS surface construction for modeling complex curved surfaces.
- NURBS surface construction techniques are: a) from point cloud, b) loft through curves and lines/edges, c) surface of revolution, d) sweep of curve or line/edge along curve or line/edge path, e) cone, and f) boundary patch. PhotoModeler Pro 4.0's ability to create surface triangles and surfaces from an outlined path of 3D objects remains and has been improved.
- NURBS surfaces can be extended a user specified amount and trimmed with outer and inner loop curves and paths.
- NURBS curves and surfaces are parametric (any change to the underlying defining objects automatically recomputes and reshapes the NURBS).
- NURBS surfaces can be textured from photos.
- A new 'flip' surface command has been added which makes it easy to change the direction a surface is facing.
- Surfaces now display in 3D as they are created, giving instant feedback on the 3D shape of a surface.
- Surfaces can now be created on and across any view, you are no longer restricted to having all defining objects on one photo.
- A new "Curve from Points" mode provides a quick way to create NURBS curves when the object has many distinct marks.

Silhouettes Solids

- An advanced method that produces a solid shape (polygonal based or NURBS surface based) from marked and referenced silhouette curves on photos.
- Provides the ability to quickly model complex and organic shapes without targets, curves, etc.
- A silhouette curve is the boundary between an object and its background in a photograph. Silhouette curves have a special mode for drawing and editing.
- Silhouette solids can be textured from photos.

Redesigned Photo-Texturing system

- Photo texturing now has the new ability to assign multiple photographs to one surface.
- The choice of which photograph to use for a surface or section of a surface can now be made automatically (at user choice).
- Texture maps can be in two forms now: one per photo (as in PhotoModeler 4.0), or all photo data optimized into one image map.
- Improved quality including blending/feathering between photographs.

- An improved and vastly more powerful ortho-photo generator.
- Cylinders are treated like surfaces and hence can be textured.

Improved Exports

- New export formats: OpenNURBS/Rhino (3dm) and Stereo Lithography (stl).
- IGES and OBJ now export NURBS Surfaces.
- New options to export curves and surfaces as tessellated/polygonal or NURBS form.
- Export of smoothing groups.
- Improved texture output (option of all photographic data in one texture map of a given size (e.g. 512x512)).
- Improved and re-written ortho-photo export that is easier to use and allows multiple source photos.

Efficiency and Ease-of-Use Improvements

New 3D Photo Projection system

- 3D Projections are now a fully rendered 3D model merged into the photographs
- The user has control over transparency of the 3D model projection onto the photo (from fully opaque to fully transparent).
- Objects appearing in projections can be selected with the mouse (similar to selecting 3D objects in the 3D Viewer).
- Projections are still sub-pixel accurate (background 3D model re-renders as you zoom in) and account for lens distortion and the camera characteristics.
- Surface Draw and photo-texturing now use projected surfaces.
- Projections can now display cylinders and camera stations.
- Projections optionally render with the object's assigned material.

Improved New Project Wizard

- Creating new PhotoModeler projects has been improved and streamlined.
- There is a new automated focal length detection system which will improve the cases where the user does not wish to do a full calibration.
- There is new support for digital cameras that support the EXIF image file format (most digital cameras). EXIF focal length is checked and camera setup is improved with these cameras. This makes the "change of zoom" problem less likely to go unrecognized.

New Status Report and post-processing review

- The Status Report provides a tree-view overview of the status of your project. It alerts you to possible problems and provides suggestions for improvements.

Improved User Interface

- New tools, new toolbar, new graphical menu, and more tools directly accessible (such as materials and layers via toolbar dropdown lists).
- User configurable toolbars and menus (also create you own toolbars and menus). User configurable short cut keys in 5.0.4.
- Easier and more capable Scale/Rotate of the 3D model (affine transforms).
- New Photo Control – a new control docked on left side of application window that replaces previous photo chip dialog. This new control still opens photographs but also controls item visibility, projections, and photo sets. It also provides feedback on the state of each photo (whether oriented, set to “do not use”, etc).
- Rewritten and improved Tables (better look, select faster, secondary sort, draggable columns, split viewing, etc.).
- New Quick Reference command that provides a quick way to reference marks without entering Reference Mode.
- New controls over whether objects get computed or not. Turn off their 3D calculations to save time or remove an object that is not solving well without actually deleting the objects or marks that define it.

Rewritten 3D Viewer

- The 3D Viewer now uses OpenGL instead of DirectX (better aligned with high end CAD and graphics packages)
- Lines and points now display as true vector items.
- Surfaces can be displayed as points, wire frame, shaded or textured.
- Faster switching of types displayed and faster response to changes.
- Point ID's, tags, control points, and control lines are now displayed.
- User can view the model from the same vantage as any one of the photographs.

Improved Help System

- Uses the modern HTML help format which is more versatile and easier to navigate.
- New Instruction Bar that provides step by step instructions for each mode and tool.

Automated upgrade patching from internet

- PhotoModeler 5 is able to automatically visit, download and install upgrade patches so your program remains up to date at all times (this is optional and the user has full control)

Accuracy Improvements

New Camera Calibrator

- Completely rewritten and is now integrated into PhotoModeler (no longer a separate program).

- Fully automated (a new grid pattern means the user does not need to manually mark the four control points on each photo).
- Uses circular targets and sub-pixel marking making the calibrator more robust and more accurate.
- Addition of the K3 lens distortion parameter for very wide angle lenses [5.0.4]

Improved Large Project Handling

Layers

- Layers are far more powerful in Pro 5.
- Objects in user assigned layers can be hidden on photographs and in the 3D Viewer making it easier to handle large complex projects.
- Layers also work with the new 3D photo projection system.

Photo Sets

- Photo Sets are user and program defined subsets of photographs in the project.
- The user can create new photo sets in a number of ways (manual choice or from photos showing particular objects).
- The Photo Control (on left side of window) or the Photographs Dialog can be told to display only those photos in a photo set. This is ideal for projects with large number of photographs.
- Photo Sets are also used in the new multiple-photo texturing system, and in referencing.

Advanced Industrial Measurements

Automated Segmentation in Automarking

- Automatic marking has an optional automated segmentation and target search routine so the manual (and more time consuming) method of identifying the threshold can be omitted if desired.

New Measure tools

- Measure length of a curve and the shortest distance from point to a curve using the Measure tool.

New DDE Commands

- A number of new DDE commands provide for even greater control by outside programs. Fully automated and externally controlled projects are now possible.

PMV Module

- PhotoModeler Video (PMV) adds the ability to handle image sequences from stationary cameras (and moving cameras in 5.0.6).
- PMV tracks targeted points automatically between frames in 2D or 3D.

- PMV is aimed at those applications of industrial measurement where circular targets can be placed or projected on an object and then two or more stationary cameras set up to image the movement or change in shape over time.
- Main output is in the form of a table export that shows the 3D and 2D location information of point movement over time. There is also a 'Timed auto-advance' tool to animate the model. A user can 'play' a specified sequence of frames and view the changes to the model over time.
- An add-on (extra cost) module. Note: PMV module is independent of the Coded Target module.

Coded Target Module

- *Coded targets* are high contrast circular dots with a special circular code around them. PM 5 can automatically search and identify coded targets in the photographs thereby further automating the marking and referencing process in certain circumstances.
- The Coded Target modules adds the ability for the auto-marker to identify, mark and reference these targets and it also adds a generate function to create coded targets of user specified size in a Postscript file. This file can be sent to a Postscript printer or into Adobe Acrobat to generate a PDF file.
- In 5.0.6 version and later, the coded targets provide for fully automated projects (carry out special set up Wizard and press "Go").
- An add-on (extra cost) module. Note: Coded Targets module is independent of the PMV module.

Rewritten Sub-Systems

- The following parts of PhotoModeler Pro 5 have undergone complete rewrites since the Pro 4.0g release to improve functionality and robustness: Camera Calibrator, NURBS Curve Algorithm, 3D Photo Projections, 3D Viewer, Photo-texturing system, Ortho-photo export, Tables, Menus, and Toolbars.
- Plus many other changes to improve robustness and efficiency (see changes.txt for a complete list)

Upgrading to PhotoModeler Pro 5

This section is for those customers that will be loading project files (.pmr) created with PhotoModeler versions before 5. There are some important changes that may affect how your project / model will appear and act.

If your old project has **Surfaces**:

- One of the biggest changes you will notice is that Surfaces no longer have "marks" and hence no longer appear on photographs. When you open your first photograph you may think that all your surfaces have been deleted - they haven't. Surfaces are much more advanced in Pro 5 and as a result do not require photographic marks. Surfaces in Pro 5 are 3D-only objects. You can see

your Surfaces in the new *Surface Table*, or if they are 3D, in the 3D Viewer or with *Photo Projections*. The *Old Surface Warning* Dialog appears when you load an old project to remind you of this change.

- Each Multi-point (more than 3 points) Surface is now loaded as a “*Path Surface*”. They also triangulate differently and so you may find some of your surfaces have changed shape. You may also find that surfaces that did not triangulate before (i.e. were not 3D) will now be 3D and in rare cases visa versa. You may need to replace your surfaces that have changed shape a lot with one of the Pro 5 advanced surfaces. See *Creating Surfaces*.
- If any of your Surfaces are attached to edge points you may see one of two changes: a) if attached to both edge points of one edge in sequence the surface might be flipped or distorted at that edge; b) if attached to only one edge point of an edge the surface will be deleted. You may need to recreate these surfaces.
- If the old project had surfaces in Layers that were smoothed you should note that the surfaces will be placed in a *Smoothing Group*. Smoothing Groups and Layers are distinct and orthogonal concepts now.

If your old project has **Photo Textures**:

- The method for assigning photographs to surfaces during photo-texturing has changed quite a bit. The selection of photo data is no longer based on Surface Marks (since they no longer exist - see above). This means that some old projects when loaded in Pro 5 will not texture the same way. These projects can be corrected by using the new Pro 5 texture tools and/or by changing the photo assignments. Also see the *Photo Texture* definition.

If your old project has **Surface Draw**:

- In Pro 4.0 the Surface Draw algorithm decided which surface and which surface triangle to use for the surface intersection by searching for Surface Marks on that photo. Since there are no longer any Surface Marks, Surface Draw now does the calculation based on the best projected surface on that photo.

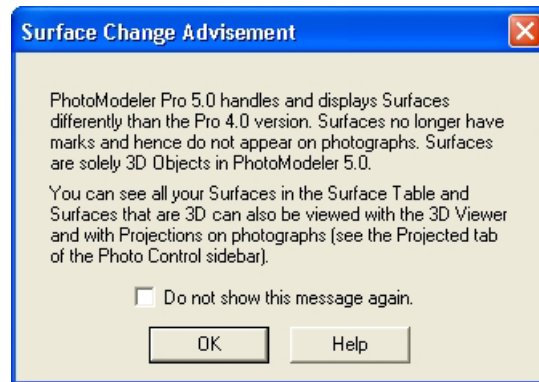
If your old project has **NURBS Curves**:

- The Curve algorithm has been rewritten and is based on a new NURBS library. This may result in some curves changing shape.

If your old project uses images from a **digital camera with EXIF**:

- Pro 5 uses the EXIF focal length information stored by some digital cameras to check for inadvertent focal length changes and hence improve project robustness. Old projects that use EXIF encoded jpeg images will also be checked but in a slightly different way. The first image in the project becomes the base EXIF focal length and all other image's EXIF focal lengths are compared to this one. If they are the same nothing will happen, but if they are different a warning dialog will come up. This warning should not be ignored. See the *Image Check Dialog* for further information.

Old Surface Warning



One of the bigger changes that Pro 4.0 users will be confronted with is that Surfaces no longer have a photograph mark. That means Surfaces will not appear on a photograph by default. To see Surfaces on a photograph in Pro 5 will require turning on Photo Projections.

The important tools for Surfaces are: the *Surface Table*, *Photo Projections*, and the *3D Viewer*. If you are creating a surface by selecting objects on photographs alone you may want to turn projections on (see *Projected Visibility Tab*) so you can see the result right away.

When a Surface is not 3D (it cannot be computed because one of its defining objects is not 3D or it has an unusual or illegal shape or definition) it cannot be seen in the 3D Viewer or Projections. The Surface Table is the only place that non-3D Surfaces will appear to the user. One of the columns in the Surface Table is the '3D' status of each Surface so you can find these non-3D Surfaces easily.

This warning will appear every time a Pro 4.0 project with Surfaces is loaded. You can check the box "do not show again" and this warning will not reappear. We suggest you leave it on until you are completely used to the way Surfaces work in Pro 5.

Technical Support

“We will make sure you succeed”

It is very important to us that all PhotoModeler customers are satisfied. We want to ensure every customer is able to 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 trouble shooting section of the manual and help 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. PhotoModeler support (serial) number (from the Help / About menu or inside cover of manual), and
4. For phone calls, have PhotoModeler running and use a telephone beside your PC.

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.

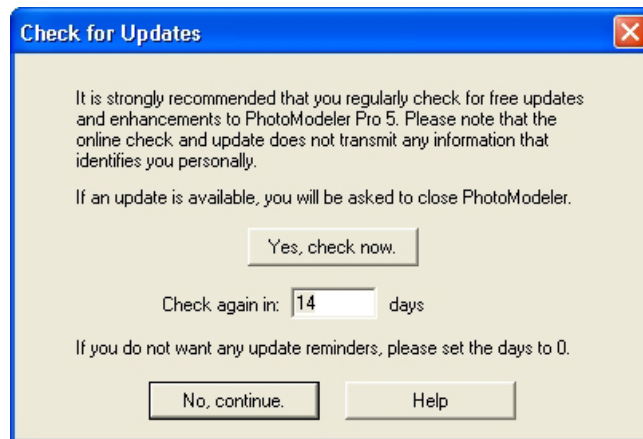
Support Contacts:

Internet E-Mail: support@photomodeler.com

Web: www.photomodeler.com/support.htm

Update Check Reminder

It is important to keep your PhotoModeler Pro up to date. Eos Systems releases free upgrades often 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 a regular intervals to ask if you want to check for a more recent version of PhotoModeler Pro. 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.

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' tab of the Preferences dialog box. 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.

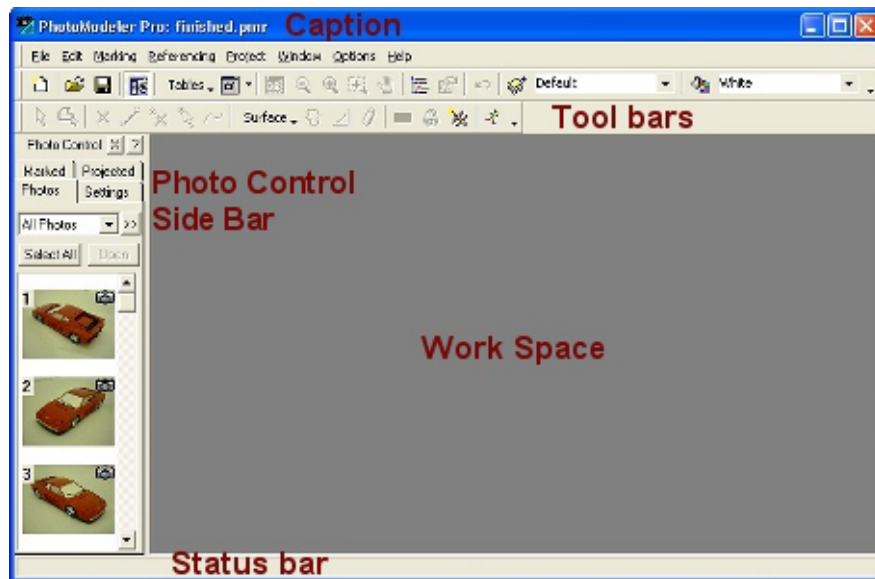
Please note that no personal information is transmitted during the update check procedure. Only the version number of your PhotoModeler is sent online for comparison (the version number is set during installation or update).

User Interface

PhotoModeler is a program that runs under Microsoft Windows (NT 4.0, 2000, and XP). It will run with most Windows 98 and Me systems also. PhotoModeler follows the user interface conventions established by this operating environment.

Elements of the PhotoModeler Screen

PhotoModeler's screen contains: a caption, a main menu, toolbars, a work space, and a status bar (see references below). Optionally there can be the Photo Control Side Bar.



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 Pro" and the name of the active project. If a PhotoModeler document window is maximized in the workspace, its name appears in brackets in the title also.

The caption area can be used to move the entire application around the windows 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 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 first button at the right of the caption area is the minimize button. Clicking on it turns PhotoModeler into a minimized icon on the desktop.

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 have not imported photographs, the Open Photo Control 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 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*.

Toolbars

Under the main menu bar are toolbars containing a series of tools. These graphical buttons initiate commonly used PhotoModeler tasks. See also *Menu/Tool Reference*.

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*.

Like the main menu bar, you can dock and undock toolbars. If you move your mouse over the left edge of a toolbar 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.

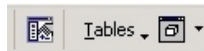
When you first install PhotoModeler, the Standard Toolbar and Modes Toolbar will be visible. Other toolbars will be hidden (hidden toolbars can be made visible using Toolbar Customization).

Standard Toolbar

The first one is the Standard Toolbar which contains commonly used tools such as Save or Open.



The first three buttons control project and file operations (New Project, Open Project and Save Project).



The next three buttons control the views within PhotoModeler (Show/Hide Photo Control, Show Tables, and Show 3D Viewer).



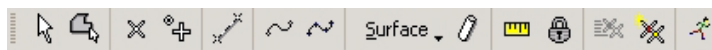
The next five buttons control window operations (Zoom to Fit, Zoom Out, Zoom In, Zoom Area, and Pan).



The remaining tools are commonly used tools that you will likely use repeatedly (Processing Report, Properties of Selected, Undo/Redo, Layer Dialog, Current Layer, Materials Dialog, and Current Material).

See also *Current Layer Tool* and *Current Material Tool*.

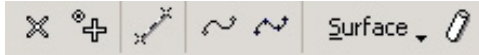
Modes Toolbar



Below the Standard Toolbar is the Modes Toolbar which contains various tools that put PhotoModeler into one of several modes, such as Select Mode or Line Mode.



The first two tools are used for selection (Select and Region Select).



The next series of tools are used for various commonly used marking modes (Point Mark, Sub-pixel Mark, Line Mark, Curve Mark, Curve Through Points, Surface submenu and Cylinder Mark).



The next three tools are used to initiate Measure Mode, Constraint Mode and Referencing Mode. The Quick Reference tool is not a mode but an action (references together all selected items).



The last tool on this toolbar is the Process tool.

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 (found in Windows or WinNT directory). 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

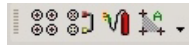
Other toolbars are available but are hidden from view – Surfaces, Tables, and AutoTools Toolbars.



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 Tables toolbar includes all tools found under the Tables submenu. This toolbar provides quick access to the various Table views in PhotoModeler (such as Photo Table or Point Table).



The AutoTools toolbar includes tools commonly used for PhotoModeler's automated features such as AutoMarking, AutoReferencing).

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

Tools

A tool is used to accomplish a task. Tools are represented by graphical buttons on the Toolbar or menu items under the menus. Once a tool is selected it is used by clicking the left mouse button, or clicking and dragging a selection with the left mouse button.

The type of tools available at any one time depends on the project being worked on and the type of window that is active.

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.

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 bar 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.

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 a file called PMToolsLayout.atb. If you delete this file after you close PhotoModeler, your user interface settings will be restored to their original factory settings.

The toolbar customization dialog has three tabs: Toolbars, Commands and Options.

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 or menu 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. Note that Camera Calibration and Mark Fiducials tools are not on the list because they depend on project type.

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.

Options

This tab allows you to set various personal options for the look of your toolbars. You can set whether icons are large (i.e. double the normal size), whether to show "tool tips" (called ScreenTips) on toolbars (i.e. a small text message appearing at your mouse cursor when your mouse is over a tool briefly indicating 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).

Photo Control Side Bar Area

The Photo Control Side Bar contains the main buttons, tools, controls, etc you use regularly to view and work with Photographs. See the *Photo Control Side Bar* section in this document for more detail.

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 *Document Windows* or icons.

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 or help on the tool button or menu item the cursor is over.

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: "Selected - marked points:3, lines:12" means that currently 3 marked points are selected and 12 lines are selected.

Marked Point Status Bar

Photo Mark: x:<x>, y:<y> pixels, residual:(<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.
- <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)
- <num> is the number of photos this point is marked on
- <photos> 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 Control Points dialog
- <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 (ie 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
- <nt> 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 "Point Cloud", 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

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: <p1> unused <p2>.

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

User Interaction

The user interacts with PhotoModeler by using a mouse to point at things and the keyboard to enter information.

The Mouse

The mouse is a mechanical pointing device. It 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.

Keyboard Shortcuts

Keyboard shortcuts are one or two 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.

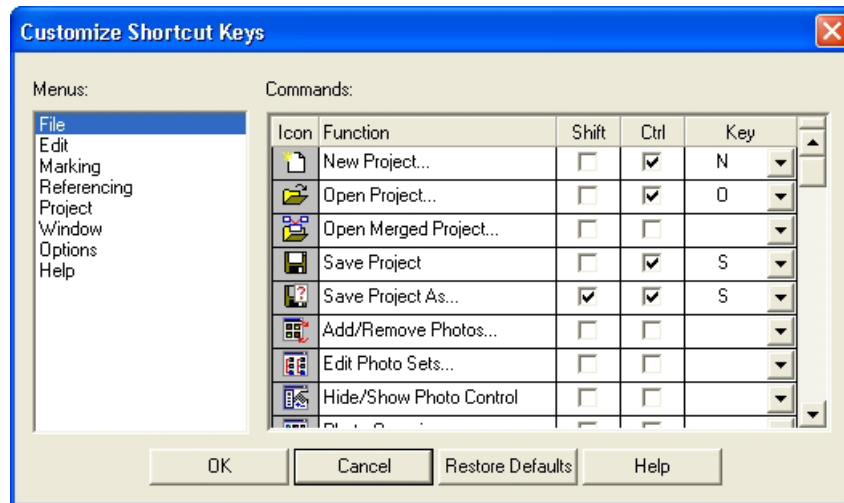
For instance, if you wish to undo your last action you can hold down the control key while pressing the letter "z".

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. The next section describes how to do that.

The complete list of default (before customization) shortcut keys is given in the section *Keyboard Shortcut Reference*.

Shortcut Key Customization



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. The Customize Shortcut Keys Dialog is where the defaults can be changed (or reset).

Most menu commands in PhotoModeler can be found in the Commands list. You find the command you wish to have a shortcut for by first selecting the Menu name in the left list, and then finding the particular menu item in the right list. These are similar to the *Toolbar Customization* lists. Note that Camera Calibration and Mark Fiducials tools are not on the list because they depend on project type.

Add a new keyboard key assignment (or change the current one) by selecting the key from the drop down list in the Key column. You can then choose that this key be active when the Shift or Ctrl key modifiers are pressed.

For example, the default shortcut key for Save Project is Ctrl S. So the Ctrl check box is checked and the "S" key is chosen for that row in the table. Whenever the "S" key is pressed along with the Ctrl key on the keyboard the Save Project command is then executed.

If a key is chosen that is already used by another menu item there will be a warning message and the change will not take place. If you want to have that particular key for that function you will need to find the other function that uses it and change it first to something else and then try your change again on the original command.

You can reset the shortcuts to the defaults (same as when PhotoModeler was first installed) by pressing the "Restore Defaults" button and then the "OK" button. These custom key assignments are saved from session to session in the program's ini file.

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.

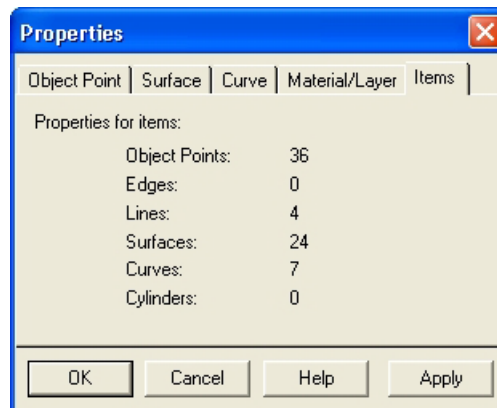
See the section, *Selection and Visibility*, for more detail.

Property Sheets

A number of the objects in PhotoModeler have properties that can be viewed or modified by the user. Generally these items are available on Property Sheets. These Property Sheets are available when the item (or items) is selected and "Properties of Selected" tool, the "Properties of Selected" item on the Edit menu, or the right mouse menu "Properties of selected..." item is used.

Which Property Sheets appear on the dialog depends on what types of objects were selected at the time. The manual section, *The Objects That Make Up A Model*, describes the Property Sheets for specific object types, the section, *Material/Layer Properties*, describes the Material and Layer sheet, and the following section, *Selected Items Sheet*, describes the Items sheet.

Selected Items Sheet



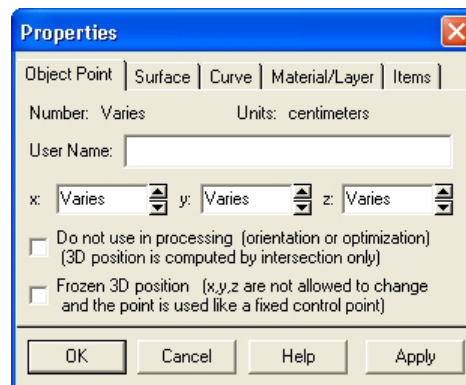
Whenever one of the *Property Sheets* is opened, the last tab in the dialog is the "Items" tab. This tab displays what objects types and the number of objects that are being reflected in the display of the other tabs.

For example, in the dialog above, there were two Object Points, one Line and one Surface selected. The contents of the other tabs reflect the properties of those four objects. Lines do not have a Property Sheet of their own and all three types have Materials and Layers. The end result is that there are tabs called "Object Point", which will show the common property of the two Object Points, "Surface", which will show

the properties of the one Surface, and "Material/Layer", which will show the common properties of all four objects.

Viewing and Modifying Properties

Individual tabs on the *Property Sheets* will show all properties that are common to the selected items (and if only one item of that type is selected then the tab shows the properties for just that one item). Where a property differs between objects, the field will either be blank or will say something similar to "varies". For example, in the following picture, two object points have been selected. Their XYZ coordinates are not the same, so those fields show "Varies" but they are both "frozen" so that check box shows the common property.



Furthermore, when multiple objects are selected you can change the properties of all selected objects to the same value. For instance we could force both Object Points in the example above to have the same x value.

Any changed properties can also be applied right away without closing the Properties dialog by hitting the Apply button. In some cases this will provide immediate feedback on the change. Note that after the Apply has been pressed, a press on Cancel does not undo that change. Think of Apply as the equivalent of pressing the OK button on the dialog and then immediately bringing the Properties dialog back up again.

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. Selecting undo a second time 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

Working with Windows is basic to using PhotoModeler. PhotoModeler uses the Multiple Document Interface (MDI) standard, but behaves differently in some key areas. MDI is the set of Windows standards that describe how an application should behave when the user has opened more than one document window inside an application.

PhotoModeler differs from other MDI applications in three ways. First, some PhotoModeler operations involve cooperation between two open document windows. Second, PhotoModeler does not save the contents of each document window separately, but instead saves the state of a *Measurement Project* as one file. Third, not all of PhotoModeler's document windows are the same type. You may open several *Photograph Windows*, *3D Viewer* windows, and Table windows as document windows in PhotoModeler.

Please refer to your Windows documentation for further information about working with windows.

Document Windows

Three kinds of document windows are used in PhotoModeler: Photograph, 3D Viewer and Tables. Much of the interaction between the user and PhotoModeler will take place through document windows.

- A *Photograph Window* displays one photograph. It is used to mark the features of the 3D model.
- A *3D Viewer* is used to display the processed 3D data in graphical form.
- *Tables* are used to display the processed 3D data in spread-sheet form.

Each of these windows can be turned into an icon with the minimize caption bar button. Windows can be turned into icons to reduce the visual clutter of the workspace.

Photo Control Side Bar



The Photo Control Side Bar sits on the left side of the window by default and contains a number of useful controls relating to photographic data.

This side bar is made up of four tabs: *Photo Chips Tab*, the Marked Visibility Tab, the *Projected Visibility Tab*, and the Settings Tab. The Marked Visibility Tab and the Settings Tab are described in the section *Visibility Tabs*. This side bar can be closed to gain more work space. To reopen it use the Photo Control menu or toolbar toggle.

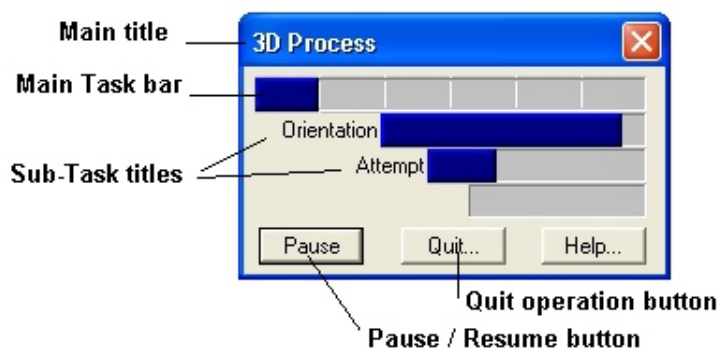
Progress Dialog

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 colored 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.

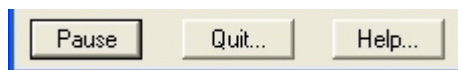
So to complete 3D Process from the state shown in the diagram above would require that the bottom sub-task, "Solve Equations" complete, then the remaining "Solution Steps", then the remaining "Attempts" and then the remaining steps in "3D Process" all complete. At any time, a glance at the Progress Dialog 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 go and 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

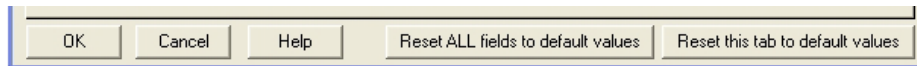
The Preferences dialog provides the user a way to change program options that are saved from session to session. These settings are saved in the PhotoModeler ini file in the Windows directory.

Each tab 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.

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

Preference Dialog Controls



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

When the 'OK' button is pressed any changes you have made to settings on any or all tabs 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 tab will be ignored.

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


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



When the "Reset this tab to default values" button is pressed, all the preferences settings shown on the active tab 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 - General

The General tab controls those options that do not fit into other categories.

Field	Description
Open Photo Control Side Bar when Project opened	If checked, the <i>Photo Control Side Bar</i> opens automatically when a project is opened.
Surfaces default to double sided	If checked, all new Surfaces have their "double sided" property turned on.
Acknowledge DDE commands	 If checked, commands sent to PhotoModeler via DDE will be acknowledged so the sending program knows they have been received.
The "Open Photos showing selected items" option closes all windows	If checked, the right-click menu item "Open Photos showing selected items" will display only those photos showing the selected item and other windows will be minimized.
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.
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.
Show User Names as well as point ID	When Point ID display is on (<i>Visibility Tabs</i> or <i>3D Model Export Dialog</i>) and this item is checked then a point's user name will be shown also.
Tools and toolbars have the 'Windows XP' Look	If checked the menus and toolbars have the XP look, otherwise the slightly older 2000 look is used.
Show shortcut keys in menus	If checked, shortcut keys for the actions will appear in menus beside the action.

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.
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.
Default Control point import precision (% of project size)	Controls the default value used for Control Import precision.
Maximum backup versions (_verN)	Controls the number of backup version pmr files that are saved.
Number of recent projects to display	Controls how many recent projects are listed at the bottom of the File menu.
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).
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.
Image Chip Size	Image Chips are the small images shown in the Photo Control Side Bar, the Photo Import Dialog, the Photo Overview Dialog, and the Photo Table. 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).
Memory Check Settings	
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).

Preferences - Colors

The Colors tab controls the colors used in the user interface.

Field	Description
Selection Color	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.
Projection Colors	
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.
Points/ Lines/ Surfaces/ Cylinders/ Edges/ Curves	The color of points, lines, surfaces, cylinders, edges and curves when projected onto photos if the above check box is not checked.
Control Point and Line Colors	
Control points & lines	The color of Control Points and Lines when displayed in the Control Point 3D View, 3D Viewers, and Photo Projections.
3D Viewer Colors	
Ambient light	The RGB setting for the ambient light in the 3D Viewer scene.
Headlight	The RGB setting for the light located at the view camera for the 3D Viewer scene.

Background	The RGB setting of the window background.
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Preferences - Referencing

The 3D Viewer tab controls those options to do with the viewing of the model in the 3D Viewer, Projections and the 3D View in the Control Point Dialog.

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-Tile is on when application starts	If checked the referencing auto-tile-windows option is on for the first referencing.
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.
Close old photo when switching photos during referencing	If checked, photographs that are no longer needed by referencing will be automatically closed when advancing to the next one. Use if you have many photographs and step through large sets during referencing (esp. if projections are on - which can be slow with many photos open).
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.
Photos to show in reference lists	Controls which photographs are listed in the referencing drop down lists. Setting this to '0' means that all photos in the project will be shown, '1' means that only photos that are currently open will be shown, and '2' means only those photos in the currently active <i>Photo Set</i> will be shown.
Potential reference highlight threshold (pixels)	Controls the distance from the epipolar line that a candidate item for referencing will be highlighted during manual referencing.

Preferences - 3D Viewer

The 3D Viewer tab controls those options to do with the viewing of the model in the 3D Viewer, Projections and the 3D View in the Control Point Dialog.

Field	Description
Texture Settings	
Texture quality while moving or resizing model	Controls the quality and rendering speed of the 3D Viewer when textures are displayed and the view point is being manipulated. 0 means no texture (which is the fastest) and 1 means use the best possible method.
Texture quality while model is stationary	Controls the quality and rendering speed of the 3D Viewer when textures are displayed and the view point is stationary.
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.
Tessellations	
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 mean more triangles and a finer tessellation. 25 degrees works well for cylinders but a smaller value (such as 10 degrees) works better for surfaces.

Control Point 3D Viewer	
Point Size	The 3D Viewer in the <i>Control Points Dialog</i> displays its points with this many pixels. Note that some video cards (esp. in accelerated mode) handle only a limited set of point sizes.
Line Width	The 3D Viewer in the <i>Control Points Dialog</i> displays its lines with this many pixels. Note that some video cards (esp. in accelerated mode) handle only a limited set of point sizes.
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.
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.

General	
Show dark back faces of single sided surfaces	If checked, the back faces of all surfaces are rendered in a dark flat shaded mode. If off the back faces are culled and you can see right through the back of surfaces. This does slow the 3D Viewer and Photo Projections down but it makes non-solid models easier to understand and view. Note: this is the setting for all Projections but just the default for 3D Viewers (since each 3D Viewer can be adjusted independently in the Advanced Tab of the 3D Viewer Options Dialog).

Preferences - Export / Textures


The Export / Textures tab controls the export of 3D models, texturing and ortho-photos.

Field	Description
Format specific	
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.
VRML 2: Place viewers in 'Examine' mode	If checked, VRML 2 exported files will be placed in Examine mode (suitable for viewing objects but not all VRML browsers handle it properly).
VRML 2: Faces should be smoothed with crease angle.	If checked, VRML 2 exported files will have their surfaces smoothed using the 'creaseAngle' option.
Shininess Conversion Factor settings in export	These values control how the PhotoModeler Material Shininess value converts to each format's value for shininess, which is usually non-linearly defined.

General Texture Settings	
Perspective correction in quality textures	Controls whether an advanced perspective correction technique is used when quality textures are created (Export, 3D Viewer, Projections). This will be most noticeable for surfaces at a large angle to photo.
Transition feathering in quality textures	Controls whether an advanced feathering/blending technique is used to smooth transitions between textures from different photographs. Used when quality textures are created (export, 3D Viewer, projections).
Transition feathering in ortho photos	Controls whether an advanced feathering/blending technique is used to smooth transitions between textures from different photographs. Used during ortho-photo creation.
Feathering Distance (pixels)	The approximate blend distance during feathering. The distance on either side of the edge that the other photograph data is bled or blended. The larger the value the smoother the transition. A large value does not work well though if the triangles are small.

Preferences - Image

The Image tab controls the display of images and the model data on them.


Field	Description
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 display	
Point IDs font size	Controls the font size, in 'points', of the ID's that display on photos.
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 Photo Control <i>Visibility Tabs</i> .
Display accuracy of Curves on photos (screen pixels, 0.1-10.0)	Controls the tessellation threshold for 2D Curve Marks. The smaller the number the more accurate the display but also slower.







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 is a larger value makes the program more responsive when projections are turned on.
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).
Projections	
Use 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.
Image Zoom Levels	Controls the zoom levels used by zoom tools in photo display.
Resampling Type	Controls the type of resampling done during image display. It can be set to Nearest Neighbor (default), BiLinear or BiCubic.

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.
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.
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.
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.
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.

Preferences - Camera Calibrator


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

Field	Description
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.

Targets and Sub-pixel Marking	The following controls are similar to those in <i>Automatic Target Marking</i> .
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 subpixel marking	 If checked the auto-marker uses the accurate Least Squares Matcher in calibration.
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.

Preferences - Audit

The Audit tab 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 Tab 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 - Process

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

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
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.
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> .
Camera Calibration	
Calibrate when greater than these number of good points on all photos	 When there are more than this many 'good' points (see <i>Preferences - Audit</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).

Standard Deviations	
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	 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.
Post processing report	
Only report parameter correlations over this %	Controls which correlation values are shown in the <i>Project Status Report</i> .

Preferences - Orientation








The Orientation tab controls the Orientation stage of Processing


Field	Description
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.
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.
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Preferences - Control Orient & Inverse Camera

The Control Orient & Inverse Camera tab controls those options to do with the processing of projects with control points and dealing with Inverse Camera.

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.
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 values 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.
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Preferences - PMV

This tab has the preference for the *PMV PhotoModeler Video* Module.

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 - Target Marking

This tab has the preference for *Automatic Target Marking*.

Field	Description
Edge Filter Sigma	 The edge detector used in the automatic segmentation 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).
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.
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).
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.
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.
Subpixel 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."

Show Target Template Toolbar	When checked and at least one template target has been imported into the project, the Target Sub-Toolbar will automatically appear when entering Sub-pixel Marking mode. When not checked, this sub-toolbar does not appear but the marking that gets done is still of the default target (whatever that might be).
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Preferences - Coded Targets

This tab has the preference for the *Coded Targets* Module.

Field	Description
Target Set	Determines the default set of targets detected by the <i>Automatic Target Marking Dialog</i> and created by the <i>Create Coded Targets Dialog</i> .
Disk Check	
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.
Coded 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.
User Set Parameters	
Start of code band ratio	If set #4 is chosen above, the user can enter in the code ring start band ratio.
End of code band ratio	If set #4 is chosen above, the user can enter in the code ring end band ratio.
Number of code bits	If set #4 is chosen above, the user can enter in the number of bits in the code.

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.

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.

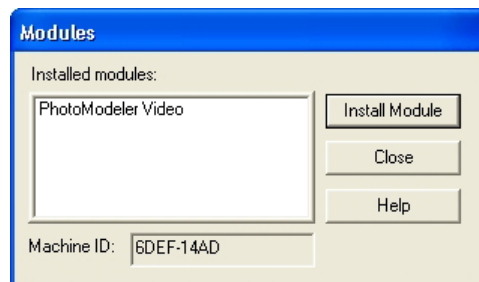
Training

In addition to help there are extensive video tutorials. You can access these tutorials from the Help menu. 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.

Modules

Modules are add-on, extra-cost components for PhotoModeler. The two add-on modules at this time are *PMV PhotoModeler Video* and *Coded Targets*.

Modules Dialog



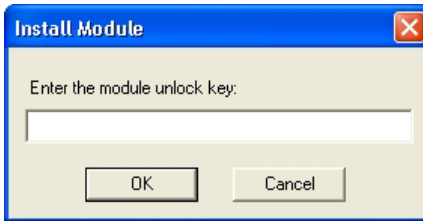
This dialog can be accessed through the Modules item on the Options menu. It shows a list of the installed modules. An empty list indicates no modules are installed.

The install module button brings up the *Install Module Dialog* that will allow you to install new modules.

The Close button closes the dialog.

The Machine ID field is required for certain modules - when ordering a module you may need to provide the code displayed.

Install Module Dialog



To install a module enter the license key provided by Eos or your reseller in the edit box and press OK. When a valid key is entered the message "Module added successfully" will appear. You will need to restart PhotoModeler before you can access the module.

PhotoModeler Online Update

Eos Systems is constantly working to improve PhotoModeler by adding new features and improving existing features. Eos Systems regularly posts PhotoModeler 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.

Overview of Producing a 3D Model

A 3D model is a set of connected 3D points, edges, curves and cylinders 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 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.

The sub-section, *How do I start?*, is a good place to review application-specific guidelines for creating and executing projects.

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. The *Taking Photographs* section of this manual provides some guidelines. When you become more familiar with the technique you will be able to plan the camera positions on the spot.

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.

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. See the *Taking Photographs* section of this manual for further 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.

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 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. If you have been reasonably careful in your work, PhotoModeler will work on the data for a few minutes (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 manual section on *Processing* for further details.

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. 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.

How do I start?

PhotoModeler Pro is a flexible, powerful, and feature-packed program. You may be wondering with all that PhotoModeler Pro has to offer, "How do I start my type of project?"

The following sections are broken down by application area. Each has the following sub-sections:

Typical PhotoModeler projects in this application area

- lists some of the specific types of projects suited to PhotoModeler

What you need to do a particular type of project

- outlines what is required in terms of photographs and preparation before starting the PhotoModeler work

How you start this type of project

- outlines the steps you will take to begin the project and get you on your way

What PhotoModeler features you will use

- outlines some of the special PhotoModeler features you might use in this type of project (it does not list all the features you will use).

The descriptions are kept brief so as to give you a quick overview of all the steps. The detailed descriptions can be found elsewhere in the manual / help file / tutorials.

Once you have a grasp of the overall process, visit the links (in the help file) or search for more information on topics where you need further guidance.

Visit one of the sections below most related to your field:

Accident Reconstruction Projects- How Do I Start?

Typical Projects:

- Measuring skids and road positions with a single photo, from an unknown camera, when a map or control point survey is available.
- Measuring vehicle crush or shape from photos taken with an unknown camera.
- Mapping an accident scene with my own camera.

Measuring skids and road positions with a single photo, from an unknown camera, when a map or control point survey is available.

What you need:

- a single photo capturing visible skid mark and / or road information
- six or more control points (known x,y,z positions) from the scene that also appear on your single photo

Steps to take:

1. Set up an Unknown / Inverse Camera project using the Setup Wizards
2. Open the photo in PhotoModeler and import and mark the control points
3. Process the project and solve for Inverse Camera
4. Add surfaces with the Surface tools
5. Use Surface Draw to trace the skid mark
6. View skid mark shape in 3D Viewer
7. Use the Measure tool to measure skid distance
8. Export the result as an ortho-photo
9. Export to CAD for further work

What features of PhotoModeler will I need to use?

- Control Point Marking
- Inverse Camera
- Surface Draw
- Ortho-Photo Export
- Measure Tool

Measuring vehicle crush or shape from photos taken with an unknown camera.

What you need:

- two or more photos of the crushed vehicle taken from an unknown camera(s)
- a PhotoModeler project of an exemplar vehicle- this project will provide a)
control points to help rebuild the camera information for the crush photos, and
b) a set of measurements from the exemplar vehicle (to compare with crush vehicle)

Steps to take:

1. Do an exemplar undamaged vehicle project in PhotoModeler, using your own calibrated camera to model the vehicle and generate control points
2. Import the unknown photos of the crushed vehicle
3. Mark and reference frozen (or control) points from the exemplar vehicle onto matching points on the crush vehicle
4. Use Object Properties to help visualize the differences between the projects; for example, the lines on the crush vehicle can be assigned different colors
5. Use Projections to help check how project information ties together
6. Use the Measure tool to perform displacement measurements

What features of PhotoModeler will I need to use?

- Control Points
- Inverse Camera
- Measure Tool
- Object Properties
- Projections

Mapping an accident scene with my own camera.

What you need:

- two or more photos of the scene taken with your calibrated camera
- control points from a total station survey are not required but may be used if needed to improve accuracy in large/long projects
- at least one known physical measurement between 2 points that appear in the photo

Steps to take:

1. Set up the camera and a new project using the Setup Wizards

2. Using Point, Line and Edge tools, mark and reference common features across the photos
3. Process the project
4. Add surfaces and use Surface Draw if necessary
5. Do point, distance and area measurements of the scene using the Measure tool

What features of PhotoModeler will I need to use?

- Camera Calibration
- Constraints and/or Control Points
- Surface Draw
- Ortho-Photo Export
- Measure Tool
- Projections

Forensic Projects- How Do I Start?

Typical projects:

- Documenting and measuring a crime scene with your own camera
- Doing measurements of a scene with a single photo from an unknown source

Documenting and measuring a crime scene with your own camera.

What you need:

- multiple photos of a scene taken from different angles
- photos should have good coverage of important evidence
- at least one known physical measurement between 2 points that appear in the photo (for scale and measurement purposes)
- a calibrated camera

Steps to take:

1. Scan or download the photos into your computer
2. Start a new project using PhotoModeler Pro's Setup Wizards
3. Using Point, Line and Edge tools, mark and reference common features across the photos
4. Process the project
5. Add more detail if necessary
6. Perform measurements of the scene within PhotoModeler, or export to CAD programs for further work

What features of PhotoModeler will I need to use?

- Camera Calibration
- Measure Tool
- Projections
- Edges

Doing measurements of a scene with a single photo from an unknown source.

What you need:

- a single photo capturing visible scene evidence and other items
- constraints on lines/edges to form parallel and perpendicular relationships along with one known scale distance, OR six or more control points (known xyz) from the scene that also appear in the photograph

Steps to take:

1. Set up an Inverse Camera project in PhotoModeler using the Setup Wizards
2. Define Constraints such as parallel or perpendicular lines or import or mark the control points
3. Process the project
4. Add surfaces using the Surface tools
5. Do Surface Draw to add detail
6. Perform measurements within PhotoModeler, or export to CAD for further work

What features of PhotoModeler will I need to use?

- Inverse Camera
- Constraints
- Configurable Tables
- Measure Tool
- Surface Draw
- Edges

Architecture / Preservation Projects- How Do I Start?

Typical projects:

- Measuring, modeling, and surveying a structure for 3D modeling or conservation

- Creating a rectified photo of a facade
- Modeling a structure from one or more historical or archived photos

Measuring, modeling, and surveying a structure for 3D modeling or conservation.

What you need:

- a calibrated camera
- multiple photos of the building or structure taken from different angles
- at least one known physical measurement between 2 points that appear in the photo (for scale and measurement purposes)
- possibly a network of 3D control points to help "solidify" the geometry if the photos have sub-optimal coverage or angles

Steps to take:

1. Start a new project using PhotoModeler Pro's Setup Wizards
2. Set up Constraints such as parallel or perpendicular lines
3. Import control points if necessary
4. Using Point, Line and Edge tools, mark and reference common features across the photos
5. Process the project
6. Add more detail, such as Curves, if necessary
7. Add surfaces using Surface tools
8. Use Surface Draw to add detail on flat surfaces
9. Work with xyz data in the Point Properties table
10. Measure and view the model in the 3D Viewer
11. Export to CAD for further work

What features of PhotoModeler will I need to use?

- Constraints
- Surface Tools
- Surface Draw
- Measure Tool
- Spreadsheet Tables
- Camera Calibration
- Control Point Marking

Creating a rectified photo of a facade.

What you need:

- one or more photos of facade with good resolution taken at not too sharp an angle
- a source of 3D control points, either from a standard multiple photo PhotoModeler project or from a survey, that have good coverage of a facade, OR
- sufficient pairs of parallel and perpendicular lines/edges in the photo(s)

Steps to take:

1. Set up a new project in PhotoModeler using the Setup Wizards (set up an Unknown / Inverse Camera if using a single photo)
2. Mark the control (or simply use the points in a multi-photo project)
3. Process the project
4. Add surfaces using Surface tools
5. Add facade detail using Surface Draw
6. Add photo-textures
7. View model in the 3D Viewer
8. Perform measurements with the Measure tool
9. Export as an ortho-photo

What features of PhotoModeler will I need to use?

- Control Points
- Surface Tools
- Surface Draw
- Ortho-Photo Export
- Measure Tool
- Object Properties

Modeling a structure from one or more historical or archived photos.

What you need:

- one or more photos that have good coverage of the structure
- sufficient pairs of parallel and perpendicular lines/edges in the photo(s), OR
- six or more control points from the scene that appear in the photo(s)

Steps to take:

1. Set up an Unknown / Inverse Camera project in PhotoModeler using the Setup Wizards
2. Define Constraints such as parallel or perpendicular lines, or
3. Import and mark the control points
4. Process the project
5. Add detail with Point, Lines and Edges if using multiple photos
6. Add surfaces using the Surface tools
7. Do Surface Draw to add detail to facades
8. View and measure in the 3D Viewer, or export for use in CAD or VRML
9. Export as an ortho-photo

What features of PhotoModeler will I need to use?

- Control Points
- Constraints
- Inverse Camera
- Ortho-Photo Export
- Measure Tool
- Surface Tools
- Surface Draw

Archaeology / Anthropology Projects- How Do I Start?

Typical projects:

- Measure and model an artifact
- Document dig sites
- Measure shipwrecks

Measure and model an artifact.

What you need:

- multiple photos of the artifact taken from different angles
- at least one known physical measurement between 2 points that appear in the photo (for scale and measurement purposes)
- a calibrated camera for precise accuracy

Steps to take:

1. Start a new project using PhotoModeler Pro's Setup Wizards
2. Using Point, Line and Edge tools, mark and reference common features across the photos
3. Process the project
4. Add more detail, such as Curves, if necessary
5. Add surfaces using the new Surface tools
6. Add photo-textures
7. View the model in the 3D Viewer
8. Perform measurements with the Measure tool and view xyz data in the Point Table
9. Export for use in CAD, Animation, Rendering or VRML

What features of PhotoModeler will I need to use?

- Surface Tools
- Measure Tool
- Curves
- Spreadsheet Tables
- Projections
- Object Properties

Document Dig Sites.

What you need:

- multiple photos that have good coverage of the scene
- at least one known physical measurement between 2 points that appear in the photo
- calibrated camera for precise results
- a set of control points from a total station survey done at the dig site (not necessary, but can be useful for tying PhotoModeler data into a known coordinate system and for piecing together projects over larger sites)

Steps to take:

1. Set up a normal project in the PhotoModeler using the Setup Wizards
2. Import and mark control points if necessary
3. Using Point, Line and Edge tools, mark and reference common features across the photos
4. Process the project
5. Add more detail such as Curves and additional points, lines, and edges

6. Add surfaces and photo-textures if necessary
7. Measure and view the model in the 3D Viewer, or export to CAD for further work
8. Export for use in CAD, Animation, Rendering or VRML

What features of PhotoModeler will I need to use?

- Control Points
- Surface Tools
- Spreadsheet Tables
- Measure Tool
- Camera Calibration
- Object Properties

Measure shipwrecks.

What you need:

- multiple photos that have good coverage of the shipwreck
- at least one known physical measurement between 2 points that appear in the project
- calibrated camera (preferably calibrated underwater) for reliable results
- xyz control points may be used for tying together small projects done when visibility is low

Steps to take:

1. Set up the camera and project in the PhotoModeler
2. Set up Constraints and / or import control points if necessary
3. Using Point, Line and Edge tools, mark and reference common features across the photos
4. Process the project
5. Add more detail, such as Curves, if necessary
6. View the model in the 3D Viewer
7. Perform measurements with the Measure tool and view xyz data in the Point Table
8. Export to CAD for further work

What features of PhotoModeler will I need to use?

- Control Points
- Constraints
- Measure Tool

- Spreadsheet Tables
- Camera Calibration
- Curves

3D Modeling Projects- How Do I Start?

Typical projects:

- Creating a 3D model using multiple photos from your own camera
- Creating a 3D model with a single photo

Creating a 3D model using multiple photos from your own camera.

What you need:

- consistent lighting when taking the photos (for better photo-texturing)
- multiple photos of the object taken from different angles

Steps to take:

1. Set up a new project using PhotoModeler Pro's Setup Wizards
2. Using the Point, Line, and Edge tools, mark and reference some common features across the photos
3. Process the project to create a 3D result
4. Add more detail if needed, including Curves
5. Add Constraints (optional) if you know certain relationships, such as parallel lines, to be true
6. Using the Surface tools, add surfaces to your 3D model
7. Using Object Materials, add photo-textures to your model
8. View your model in the 3D Viewer or export model for use in animation, VRML, rendering or CAD

What features of PhotoModeler will I need to use?

- Surface Tools
- Curves
- Constraints
- Export Functions
- Object Properties

Creating a 3D Model with a single photo.

What you need:

- one photo of the object
- at least 6 control points or photo must show object relationships (parallel edges / lines etc.)

Steps to take:

1. Set up an Unknown / Inverse camera project in PhotoModeler using the Setup Wizards
2. Set up Constraints such as parallel or perpendicular lines and / or import and mark control points
3. Process the project
4. Add surfaces using the Surface tools
5. Mark detail using Surface Draw
6. Add photo-textures using Object Materials
7. View your model in the 3D Viewer or export model for use in animation, VRML, rendering or CAD

What features of PhotoModeler will I need to use?

- Inverse Camera
- Constraints
- Control Point Marking
- Surface Draw
- Surface Tools
- Export Function
- Edges
- Object Properties

Industrial Measurement Projects- How Do I Start?

Typical projects:

- Measure industrial structures.
- Measurements in a process plant.
- Measure and model mechanical parts.

Measure industrial structures.

What you need:

- multiple photos of the structure taken from different angles
- at least one known physical measurement between 2 points that appear in the photo (for scale and measurement purposes)
- a calibrated camera for precise accuracy
- circular targets placed on the structure before taking photos
- if necessary, a set of control points to tie sub-projects together or overcome poor camera placement geometry problems

Steps to take:

1. Start a new project using PhotoModeler Pro's Setup Wizards
2. Import and mark control points
3. Using Point, Line and Edge tools, mark and reference common features across the photos
4. Use Sub-Pixel-Target marker to accurately mark targets
5. Process the project
6. Add more detail, including cylinders and additional points, lines, and edges
7. Work with xyz data in the Point Properties table
8. View and measure your model in PhotoModeler, or export to CAD for further use

What features of PhotoModeler will I need to use?

- Measure Tool
- Spreadsheet Tables
- Projections
- Edges
- Control Point Marking
- Sub-pixel Target Marking
- Camera Calibration
- Cylinder Tool

Measurements in a process plant.

What you need:

- multiple photos that have good coverage of the scene

- at least one known physical measurement between 2 points that appear in the photo
- calibrated camera for precise results
- circular targets placed on the structure before taking photos
- if necessary, a set of control points to tie sub-projects together or overcome poor camera placement geometry problems

Steps to take:

1. Set up a normal project in PhotoModeler using the Setup Wizards
2. Import and mark control points if necessary
3. Using Point, Line and Edge tools, mark and reference common features across the photos
4. Use Sub-Pixel Target marker to accurately mark targets
5. Process the project
6. Add more detail, including cylinders and additional points, lines, and edges
7. Work with xyz data in the Point Properties table
8. View and measure your model in PhotoModeler, or export to CAD for further use

What features of PhotoModeler will I need to use?

- Measure Tool
- Spreadsheet Tables
- Projections
- Control Point Marking
- Sub-pixel Target Marking
- Camera Calibration
- Cylinder Tool

Measure and model mechanical parts.

What you need:

- multiple photos that have good coverage of the object
- at least one known physical measurement between 2 points that appear in the project
- calibrated camera for reliable results

Steps to take:

1. Set up a normal project in PhotoModeler using the Setup Wizards
2. Using Point, Line and Edge tools, mark and reference common features across the photos
3. Add Constraints if you know relationships of features (e.g. parallel lines)
4. Process the project
5. Add more detail, including cylinders and additional points, lines, and edges
6. View and work with XYZ data in the Point Properties table
7. View and measure your model in PhotoModeler, or export to CAD for further use

What features of PhotoModeler will I need to use?

- Curves
- Constraints
- Cylinders
- Measure Tool
- Spreadsheet Tables

Taking Photographs

PhotoModeler depends heavily on the nature and quality of the photography used for measurement. This chapter describes the appropriate method for taking these photographs. For more information on the types of cameras that can be used with PhotoModeler see the chapter *Camera Background*.

This chapter 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..

Generating 3D Points from Photographs

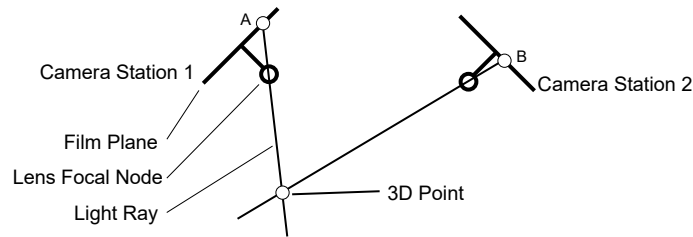
For best results some guidelines should be followed when positioning the camera during photography. The following is a summary of some guidelines for how photographs should be taken. These guidelines are each discussed in detail in this chapter.

Photography guidelines:

- try to get the angles between the shots as close to right angles (90 degrees) as possible,
- take at least three photographs,
- 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
- measure the distance between two clearly visible points.

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

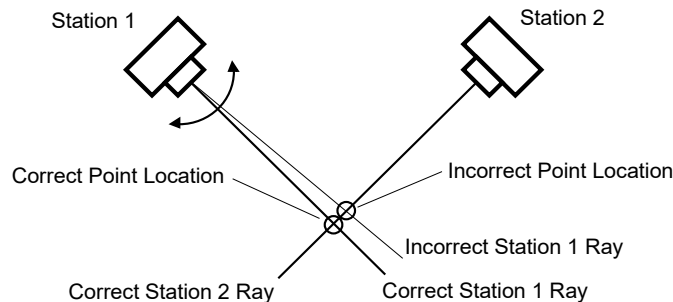
Representations of two *Camera Stations* are shown in this figure. Each of these show the position of the film or the *CCD* and the focal node of the lens at the moment the picture was taken. These representations are simple two dimensional drawings but are sufficient to describe the method.

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 to calculate the 3D Point location by intersecting the two straight lines.

Guidelines

Guideline 1: Get Good Camera Angles

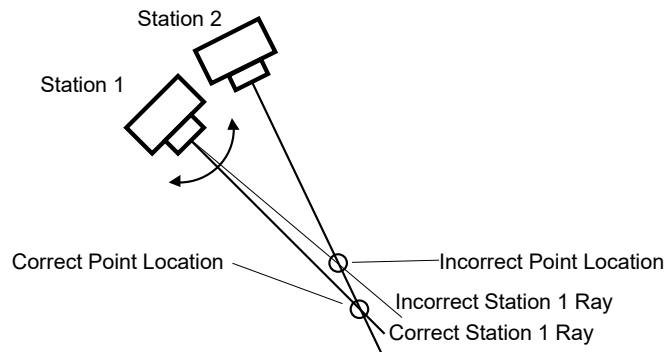
The process of measurement is never perfect. Measurement is instead the process of reducing and minimizing errors so as to maximize accuracy. If PhotoModeler has incorrect camera positions or orientations, it will generate an incorrect position for the 3D point. The figure below shows such a case. It 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. This small error is 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.



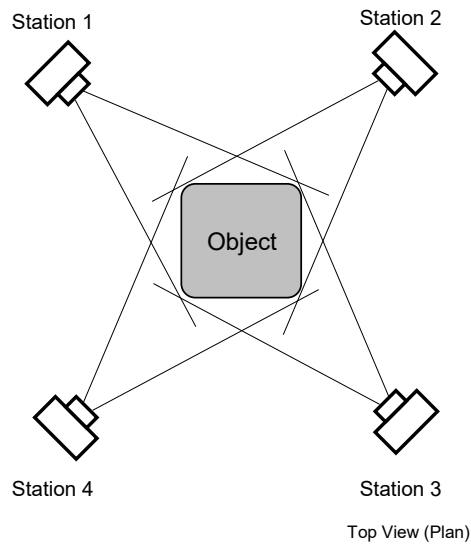
Point Location Error with Bad Camera Positions

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

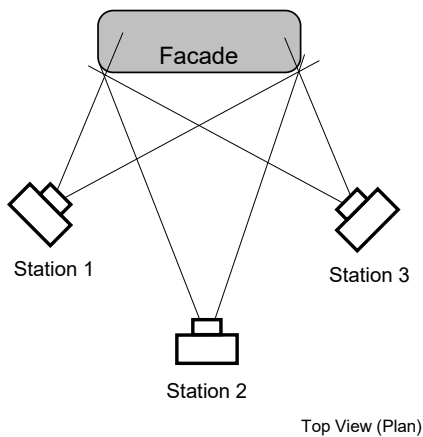
If you are measuring a box shaped object and you are using four photographs, take the photographs off the four corners of the object. All the photographs can be taken at the same level but one or two sides of the box will not be photographed. Often missing a side is not important. The figure below shows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



Camera Station Positions for an Object

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

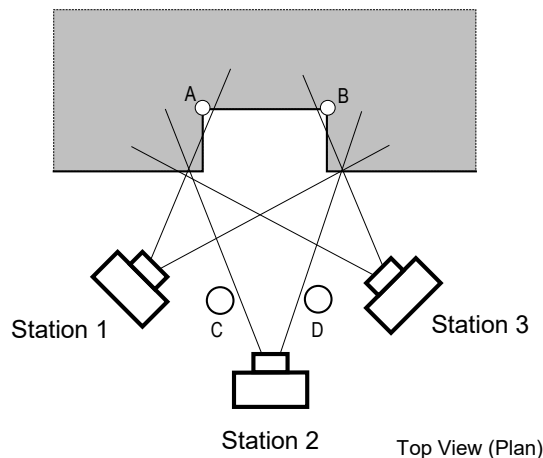
All of the points on the face of the object show up in three photographs. The Camera Stations are not all at right angles (station 1 and 3 are close to this ideal) but they are in good positions none the less.

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.

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 or a dent in some object. 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.



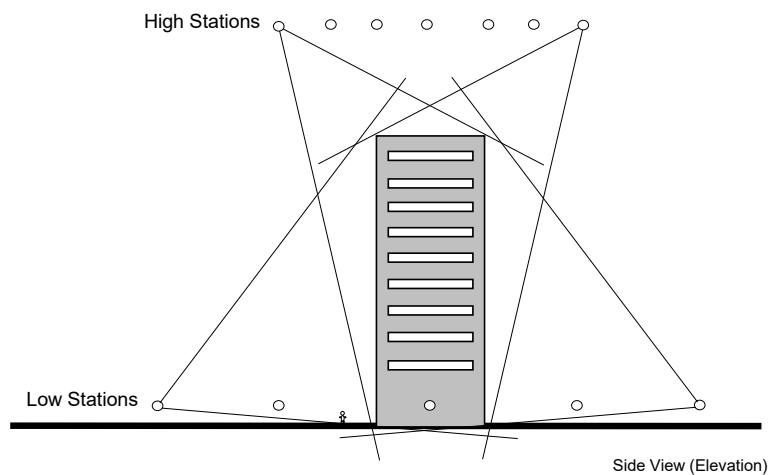
Camera Station Positions for an Alcove

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 a 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.



Positioning Camera Stations for a Tall Object

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.

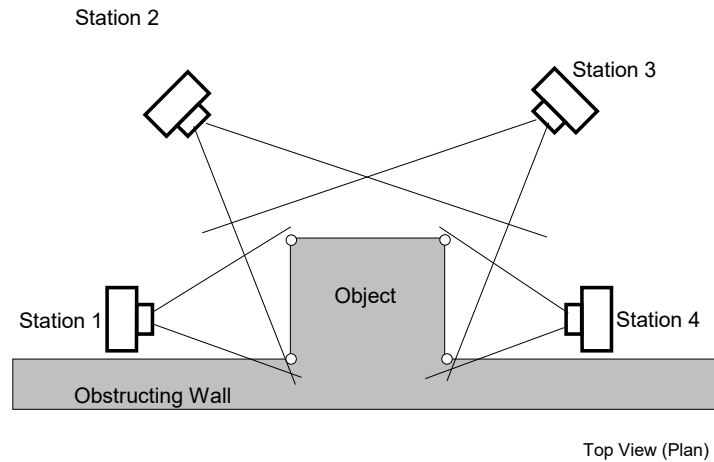
Guideline 4: Get Good Photograph Overlap

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, 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 of it, 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. Measure or estimate by some means the distance between them. Make sure that you will be able to identify 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 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.

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 also *Adding Scale and Rotation*.

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.

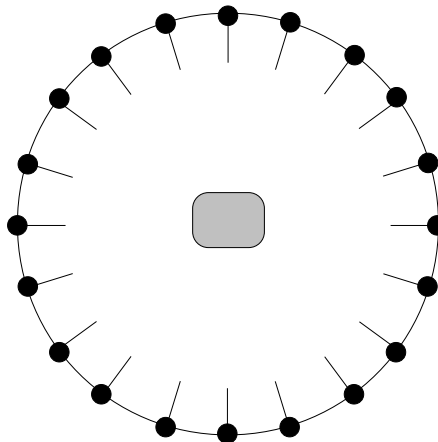
You do not need to follow these guidelines strictly, but you should be aware of them. The closer you come to meeting these guidelines, the easier the measurement process will be and the more accurate the measurements.

The Ring Method

A good method for taking photographs in many situations that covers all 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.

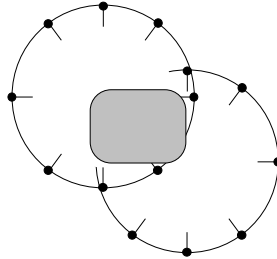
Photographing an object using "rings" is quite easy:

1. 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:

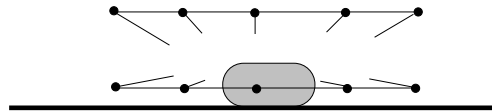


Top View of Camera Positions in a Ring around Object

2. 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.



3. 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

4. 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 too 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!

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 Pro 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 Constraints. These Constraints can be either Axes Constraints or Control Points.

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:

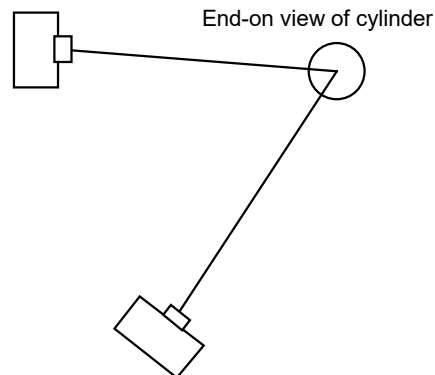
- the photographs be clear and in focus,
- the constrained items (edges, lines, control points) be clearly visible and spread out over the photograph, and
- if trying to recover all the camera parameters in an *Inverse Camera* procedure, the photograph should be in three point perspective (i.e. have three vanishing points).

Photography for Curves, Edges, Cylinders and Automatic Referencing

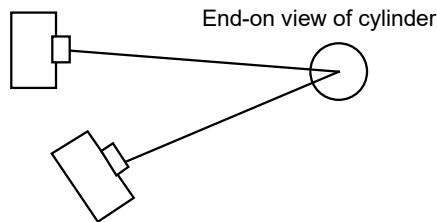
There are some slightly different requirements when taking photographs when you know you will be modeling with curves, edges and or cylinders. These requirements are similar when you wish to use the *Automatic Referencing* feature.

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

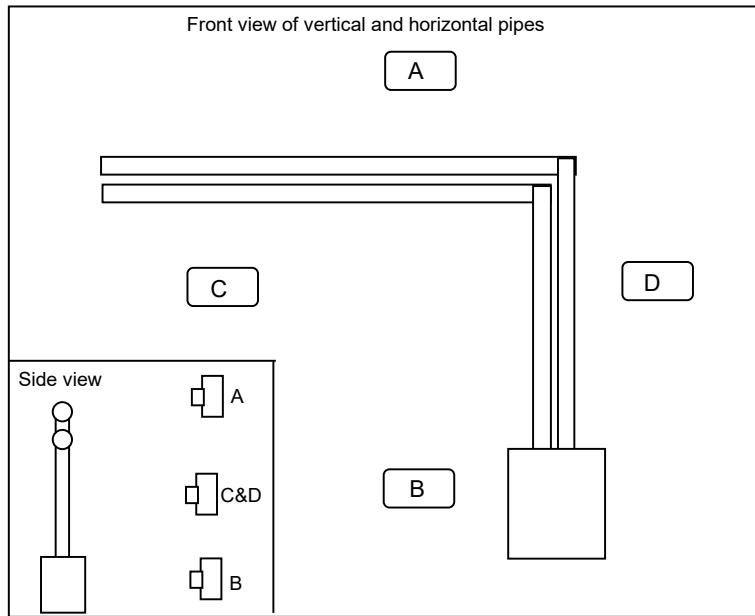
A Curve has similar requirements but the issues are more complex because a curve can be both horizontal and vertical within the same curve. This means you need both vertically separated photos and horizontally separated ones and the curve has to be marked and referenced on all of them.

Using cylinders as an example again we show an example 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.

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.



Field Collection Form

When you are learning PhotoModeler you might find it useful to take along a form to fill out with pertinent information. The following form contains information that would be useful when running PhotoModeler and setting up a new project. This form can also be used by field crew for surveying or by the police at accident scenes.

Date/Time of collection:	
Location of collection:	
Camera name and/or manufacturer:	
Camera serial number:	
Lens manufacturer and serial number:	
Lens focal length:	
-if a zoom, what focal length was it set to:	
Approx. distance of camera to object(s):	
Dimension of know object: object name:	
dimension:	
Number of camera positions:	
Number of photos taken:	

Height of camera operator or tripod height:	
Were pictures taken at different angles?	
Were pictures taken at different distances?	

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

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

PhotoModeler will start the *Project Setup Wizard*. The Wizard takes you through project setup, the *Camera Setup Wizard*, and the *Photo Import Wizard*.

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*.

Project Setup Wizard

When you select New Project from the File menu or press the New Project toolbar button, the Setup Wizard will start. This wizard is composed of three chained wizards, the *Project Setup Wizard*, the *Camera Setup Wizard*, and the *Photo Import Wizard*.

Each pane of the Wizard is described below.

Project Wizard: Choose Project

The Choose Project pane is the first wizard pane to appear when the New Project toolbar or menu is chosen.

It gives between three and five choices depending on what modules are installed:

Choose "A Standard PhotoModeler project" when you are carrying out most PhotoModeler projects including single and multiple photo projects.

Choose “A PhotoModeler Calibration project” when you are calibrating a camera. See the *Camera Calibration* section for more detail.

Choose “A Quick-Setup PhotoModeler project” when you wish to quickly review some photographs but not carry out a real project. See *Quick Setup Project Warning* for more information.

Choose “An Automated Coded Target project” when you have a set of photos taken using coded targets that you wish to fully automate. This option allows for automatic marking, referencing and processing of all photographs. To further automate these projects a settings file can be optionally entered or browsed for. Check the box to activate the settings file edit box and Browse button. For more information on the settings file see *Photo Import Wizard: Finished (Automated Coded Targets Project)*. [This project type is available only if the Coded Target Module is installed].

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

Quick Setup Project Warning

This warning is presented when the Quick Setup path is chosen on the first Wizard pane. This path through the wizard is designed to be fast and minimize the number of panes to go through. On the other hand it does not set up the project fully and hence should not be used for doing PhotoModeler work (marking, processing, modeling etc).

If you are a PhotoModeler expert you may use this path for quick startup but you will need to a) set up and load your cameras manually, and b) set up your project units and rough size.

Project Wizard: Welcome

The Project Wizard welcome screen lists the steps required to complete a standard PhotoModeler 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.

Project Wizard: Welcome (Calibrator)

The Project Wizard welcome screen lists the steps required to complete a PhotoModeler calibration 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.

Project Wizard: Welcome (Automated Coded Targets Project)

This Project Wizard welcome screen lists the steps required to complete an automated coded target 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 *Automated Coded Targets Project* section for more information on how to set up an automated coded target project. The next screen to collect information for an automated project is the *Photo Import Wizard: Automated Project Stages (Automated Coded Targets Project)*.

Project Wizard: Units and size

This wizard screen prompts for the units of measure you would like for data entry and data display as well as a rough object/project size. This rough size is used as a base estimate for sizes and measurements reported by PhotoModeler. To increase the accuracy of these measurements you will have to scale your project precisely later - see *Adding Scale and Rotation*. In addition if you are using *Coded Targets* in this project you can define which set of targets is used.

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.

Camera Setup Wizard

See *Working With Cameras* for more detailed information about camera types etc.

The Camera Setup Wizard asks you a set of questions so PhotoModeler can set up the camera for optimal use and accuracy. Each pane of the Camera Setup Wizard is described below.

Camera Wizard: Welcome

The Camera Setup Wizard guides 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.)

If the camera you are creating has already been used in a PhotoModeler project (and you have a copy of this project) you should select the "A camera used by PhotoModeler previously" radio button and press Next> to load the camera from that project. If this camera has not been used in a PhotoModeler project or you do not have a project file that contains the camera you should select the "A new camera" radio button.

If you are starting with prints or images from an unknown camera (e.g. in forensics, accident reconstruction, or historical architecture) you will choose "An Inverse Camera Project".

Depending on what type of camera you are using the wizard will prompt you for different information, some of these steps require you to have images/prints ready. The table below lists what items will be required to finish the wizard based on what type of camera you are using:

Your camera is a:	Items required:
Digital/Video	<ol style="list-style-type: none">1. The camera2. The camera manual/specification sheet3. A piece of paper4. Tape (or something to stick the piece of paper to a wall with)5. A ruler or tape measure6. Any device needed to extract images from your camera to your hard drive. (e.g. a digitizing board, floppy adapter, interface cable, etc.)
35mm/Polaroid/Other film based Camera	<ol style="list-style-type: none">1. The camera manual/specification sheet.2. A print created with this camera.3. A digital image scan of the print.4. A ruler or tape measure.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Name

Enter a description for your camera in the edit box provided on this screen. Make the name as descriptive as possible to help identify the camera at a later date. This name can be changed again later using the *Camera Information Dialog*.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Camera Type

When you are using a camera for the first time with PhotoModeler you have four options:

1. Digital/Video cameras: You can get reasonable results using a digital or video camera even without calibrating it. Choose this option if you do not want to calibrate your camera at this time and you want to use estimated but reasonable camera parameters. This is a quick process that will involve taking a picture of a single piece of paper and marking the corners of it. The wizard then estimates your camera's focal length and other parameters.
2. Camera Calibration: Choosing this option will take you through a process of calibrating your camera. See *Camera Calibration*. Note that this option is not available if the Camera Wizard was started from the Wizard button in the *Project Cameras Dialog*.
3. 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
4. Quick-Setup: 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. You can set up a camera at a later date and assign it to your photographs.

Camera Wizard: Film Camera Type

When you are using a film camera, select the camera's film format. Your options are: a 35mm camera or a medium/large format camera.

Camera Wizard: Type of Camera

Choose what type of camera you are configuring by clicking on the appropriate radio button, this selection will determine what information the rest of the wizard will need to acquire.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Inverse Camera Type

This dialog is similar to *Camera Wizard: Type of Camera* dialog but is specifically for the case where you are doing an *Inverse Camera* project. That is, you have prints, negatives or images from a camera for which you do not know the parameters (focal length, etc.).

You may know a little bit about the camera even if you do not know the exact parameters. That is, someone might have told you the photos were from a 35mm camera, or from a video camera. In this case you pick the camera type from the list. If you have no idea what type of camera took the photographs, then choose the last option "I don't know."

Camera Wizard: Focal length

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.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: How do you digitize your prints?

Choose the method you use to get your film/prints into digital form. This selection will determine what information the wizard will need next.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Variable focal length?

This screen asks if your camera has a zoom or interchangeable lenses. If you have a zoom or use different lenses with this camera select yes, if not select no. You must have a different camera configured for every zoom/lens setting you use.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Variable Focal length discussion

If your camera has a zoom or interchangeable lenses this screen explains that you must create a camera for every setting you use.

Press the Next> button to advance to the next wizard screen.

Camera Wizard: Measure print size

The wizard needs to know the size of the prints you are scanning in. Using a ruler (or other measuring device) determine the exact width and height of your prints. If your prints have borders do not include it in your measurements, and if they do not have a border ensure you measure all the way to the edge. The precision of this measurement will affect project accuracy.

Enter the width and height you measured in the edit boxes provided. The combo boxes beside the edit boxes allow you to choose what units the measurements were made in.

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Paper method

To configure your digital or video camera PhotoModeler needs to determine the relationship between the actual physical size of the imaging area and the focal length. You need to carry out some simple steps:

1. Take a picture of a piece of paper at 45 degrees.
2. Measure or take note of the dimensions of the piece of paper.
3. Import and then mark the corners of this piece of paper using the wizard.

This screen outlines these steps and shows a typical setup for taking the photograph of the paper.

Once you have reviewed the steps press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Paper information

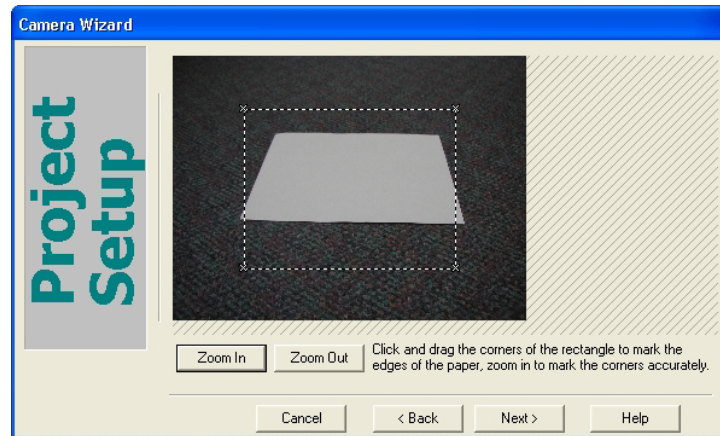
This screen prompts you for two pieces of information.

1. The file name of the image of the piece of paper.
2. The size of the piece of paper.

Note: the more accurately you enter the information for 2 above the better the camera will be set up (hence more accurate 3D models).

Once you have entered the information requested by this screen press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Mark image corners

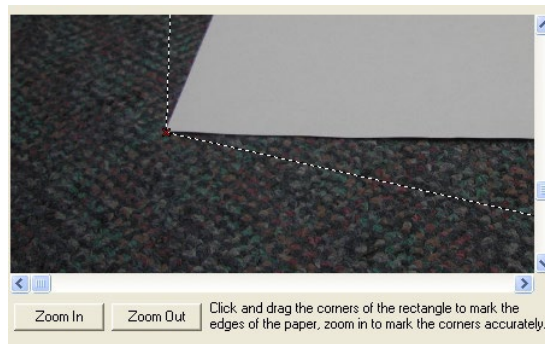


This screen displays the image you selected on the previous wizard screen, with a rectangle outline drawn on top.

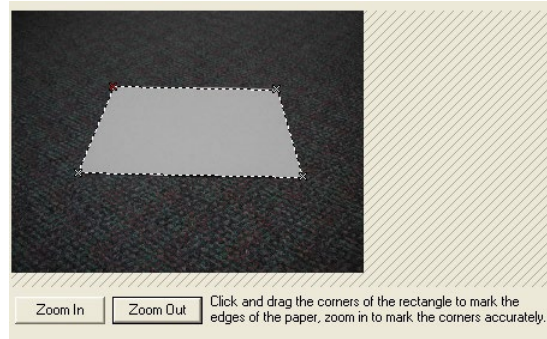
You must drag the corners of the outline rectangle to the corners of the paper you photographed. It is important to mark the corners accurately as the precision of your camera configuration affects the accuracy of your 3D models. To ensure you are marking the corner of the paper to the closest pixel use the zoom buttons in the lower left corner. Once you have zoomed you can use the scrollers to move the image around.

Once you have moved all four points of the rectangle to the four corners of the paper press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

The following figure show the bottom left corner being marked at a higher zoom.



The following figure shows the marking complete (at which point you can click Next>).



Camera Wizard: Paper Rotation Error

This pane indicates that the picture you took of the paper has too much rotation or you have improperly marked the corners of the piece of paper.

For the program to properly determine the focal length and format size the paper has to have little or no rotation relative to the camera (but the camera is still tilted for perspective as shown above).

If the paper was incorrectly rotated, please retake the picture and re-import it. If the corners are incorrectly mark, please remark them before continuing.

You should press the <Back button on this pane. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Image size

You must enter the resolution of images created by this camera. If you have an image file created with this camera it is recommended that you use the browse button to load the image and the wizard will determine the resolution for you.

Once the resolution has been entered press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Loading from an existing Project

If this camera has already been used in a PhotoModeler project you can load its configuration from a .PMR or .CAM file. There are two choices. The first provides a list of all the projects on the Most Recently Used list (same as the list appears at the bottom of the file menu). The other options allows you to choose the file with a file browser. Click the Browse... button to select the file or enter the name and path of the file in the edit box provided. Once the camera is chosen (from a project or camera file) click the Next> button to load the camera. If the project has multiple cameras, a dialog will appear allowing you to choose which one you want loaded.

Camera Wizard: Scanned file load

PhotoModeler must now load the scanned image of the print you previously measured. Click the Browse... button to select the file or enter the name and path of the file in the edit box provide. PhotoModeler will compare this image with the measurements of the physical print to see if your scanner distorts the image size.

When you have entered the file name press the Next> button to advance to the next wizard screen. If you wish to make a change to a previous question use the <Back button. You can use the Cancel button to abort the Camera Wizard at any time.

Camera Wizard: Format Size

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. Note that all the settings are for landscape formats (i.e... wider than tall). If all your photos are in portrait you can choose "Other" and enter in the format size reversed.

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 scanning method and exact format size are critical to getting good measurements.

Camera Wizard: Print Available?

If you are doing an *Inverse Camera* type project, this pane will appear asking whether you have a physical photograph in terms of a print or if all you have is a digital image. If you have a print then sometimes a more accurate estimate of the format size can be done (which will improve accuracy).

Camera Wizard: Focal Length Estimate

If you are doing an *Inverse Camera* type project, this pane will appear with an estimate for the focal length of the camera. This estimate is based on the camera type. The Inverse Camera process uses this focal length as a starting point for its calculations. If this estimated focal length is very different than the real focal length (e.g. a wide angle 28mm is entered here but the real lens was a 110mm), the Inverse Camera processing might not succeed (depends on the number and quality of the *Control Points*). If you can update the estimate with a better guess then enter it here, otherwise just click Next>.

Camera Wizard: Square Pixels Assumed

If you are doing an *Inverse Camera* type project, this pane will appear if PhotoModeler is assuming the imaging device (scanner, CCD etc.) has square pixels. Most devices have pixels that are close to square but sometimes they are a bit off. This assumption affects PhotoModeler calculation of the format size. An accurate format size is important for the highest accuracy. If you have enough control points it might be a

good idea to try at least one Inverse Camera round while solving for format size. This will make sure the pixels are square (or not) and give you the best accuracy.

Camera Wizard: Negative Scanner

A negative scanner is a type of film scanner that scans slides and negatives directly without going to print. Good negative scanners have the potential for higher accuracy than scanning from prints because one optical path is removed from the whole process. Good negative scanners usually move the scan head and not the film, are high resolution, are repeatable, and are geometrically stable. Good negative scanners are quite expensive.

A negative scanner has a fixed horizontal resolution defined by the CCD scan head and a variable vertical resolution defined by the steps taken by the stepper motor (which moves the film or the CCD head). If the scanner has perfectly square pixels then the spacing between the CCD imaging cells is the same as the stepper motor steps. If they are not then each pixel will cover a different amount of the film vertically versus horizontally.

PhotoModeler, given an image from a negative scanner, will assume the pixels are square. If they are not then the accuracy will be affected. You can get around this problem by using 4 or more *fiducials*. It is also recommended that for good accuracy that you calibrate the camera and the negative scanner with the Camera Calibration.

Camera Wizard: Does Camera have Fiducials?

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: Eos supplies the two point insert and the full frame 9 point insert, 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 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 pick Yes here and choose the appropriate type.

Camera Wizard: Full Frame Fiducials

You have specified that this film camera has fiducials and they are 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. 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 Information Dialog*.

Camera Wizard: Add 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.

Choose a name for the fiducial that will be obvious when you are marking the fiducials on the photos.

Camera Wizard: Principal Point Offset

If you are using a film camera with non-frame fiducials, you will have to specify the position of the upper-left image fiducial relative to the format frame. Note that the fiducial that appears in the upper left in an image is the fiducial that appear at the bottom right of a physical camera that is upright and the back is facing you.

This measurement is used to compute the correct principal point (which is assumed at the start to be in the middle of the format) but is specified relative to the fiducial coordinate system (i.e. 0,0mm for the upper-left fiducial).

Camera Wizard: Review

This screen gives you an overview of the information the Camera Setup Wizard has gathered and calculated. If any of the information is incorrect you may use the back button to fix it now or you can use the *Camera Information Dialog* to edit the values directly once your project has been created.

Press the Next> button if these values look correct to advance to the photo import wizard.

Photo Import Wizard

The Photo Import Wizard assists you with choosing the starting images for the project. Photos can always be added or removed later using the *Add/Remove Photographs Dialog*. Each pane of the Photo Import Wizard is described below.

Photo Import Wizard: Importing images

This screen shows a collection of thumbnails of the images which will be included in this project. When no images are in the project this area will be an empty white rectangle. If you press the Add/Remove Image(s)... button the photo import dialog will open allowing you to import or remove images from the project. When you close the Add/Remove Photographs Dialog the import images wizard screen will update to show you all the images currently in the project.

If you do not want to import images at this time you can skip this step and import later using the *Add/Remove Photographs Dialog*.

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.

Photo Import Wizard: Finished

You have reached the end of the 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, reference and process your project to create a 3D model.

Photo Import Wizard: Finished (Calibration Project)

You have reached the end of the setup of your calibration project. When you press the Finished button a new project will be created based on your answers to the wizard's questions and then *Camera Calibration Dialog* will appear. If you wish to change any of your settings you may use the back button.

Photo Import Wizard: Review (Quick-Setup Project)

The Quick-Setup PhotoModeler project is intended mainly for reviewing photographs. While a new camera has been created and assigned to your photographs, the project will likely not process or produce a reliable 3D model.

However, if at a later date you calibrate the camera that took the photos in this project, or you learn of the camera's parameters, you can assign the new camera to the photos, and treat the project like a standard PhotoModeler project.

Photo Import 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: *Photo Import 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: *Photo Import 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: *Photo Import 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: *Photo Import 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: *Photo Import 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 to 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 *Preferences – Coded Targets*.

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 a Point Cloud 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:

```
[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

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.

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

Photo Import 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.

Photo Import 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.

Photo Import 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 cannot be left at the default of 0.0 and should be set to the expected average *tightness* of points (in absolute units not percentage) after the first coded target marking and processing.

Photo Import 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. (eg. 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: *Photo Import 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*.

Photo Import 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 (*Photo Import 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.

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.

Photo Import 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 *Photo Import 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.

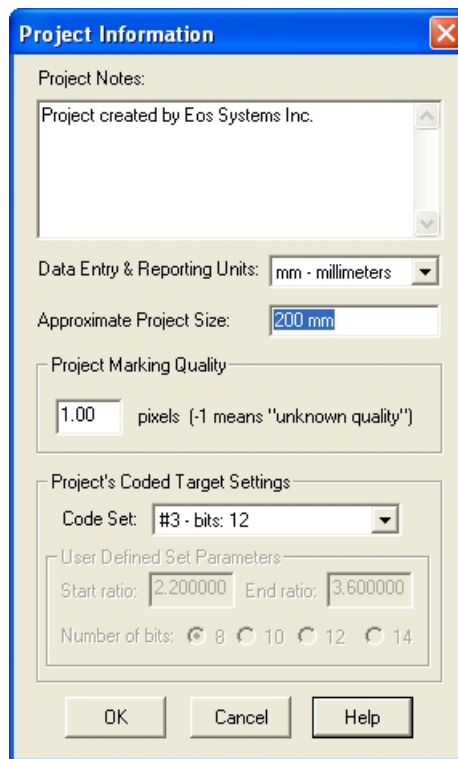
Photo Import Wizard: Finished (Automated Coded Targets Project)

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 of which some was first collected by the *Project Setup Wizard*.

The first Project property is 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.

The second property is the Data Entry & Reporting 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.

The third property is the approximate size of the object or scene. This value allows PhotoModeler to get the approximate dimensions correct when no Project Scale/Rotation has been set. This size should be set to approximately the largest dimension (a diagonal for example) of your object or scene. A very approximate number or even a complete guess is fine here. This is also used for computing the tightness percentage.

The fourth property is the 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 subpixel 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.

The fifth set of properties relate to the Coded Target Set used by the project. This is available if you have the Coded Target Add-On module installed. See *Coded Targets* 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 in the Preferences dialog.

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 *Upgrading to PhotoModeler Pro 5* for further information. In some cases you may see the *Image Check Dialog*.

Merging Projects

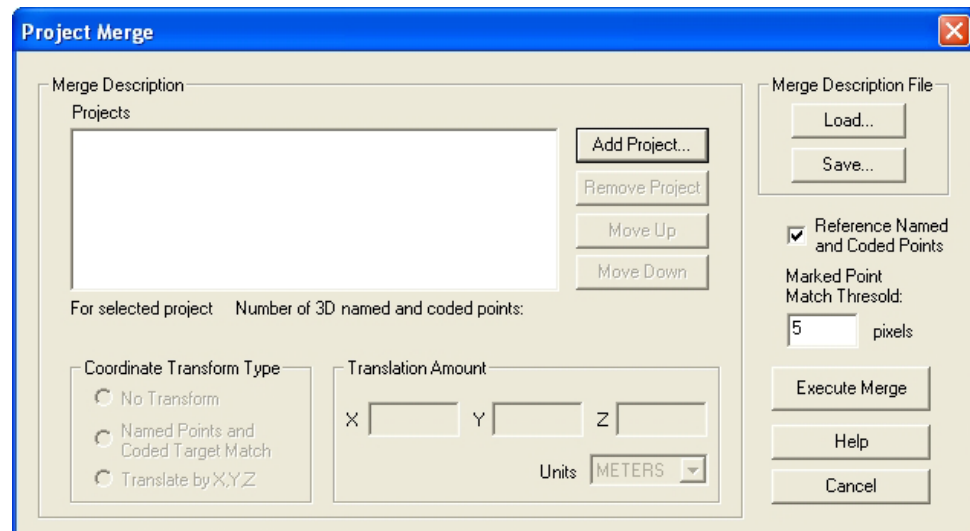
There are some circumstances where a larger project will be broken down into smaller projects. When the smaller projects are complete you may want to combine the projects together to complete the model, view the completed model, reprocess etc.

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 Pro 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

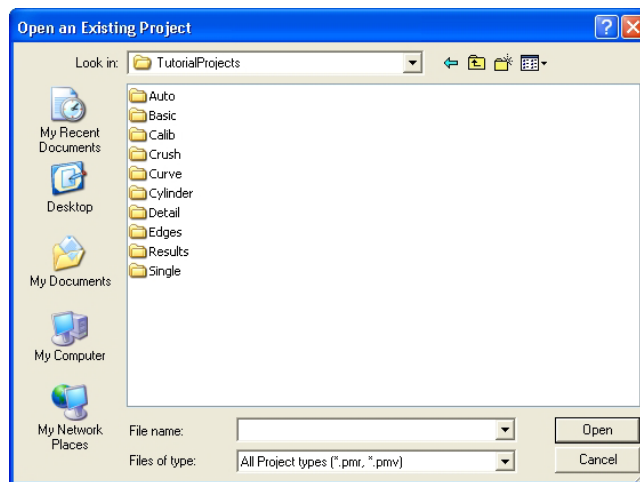
crttut_ver3.pmr - the oldest version

If you would like PhotoModeler to save more or fewer versions you can change the value "MaximumVersions" found in the Preferences dialog.

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.

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.

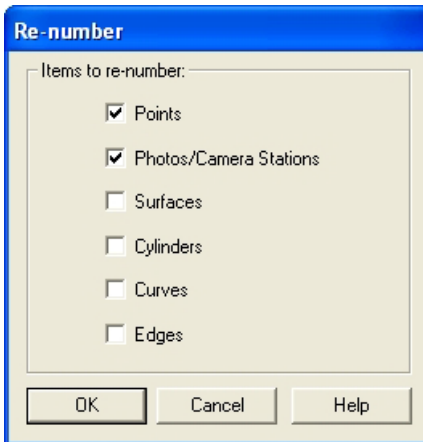
During normal operation of the program the user will not even be aware of the functioning of Check and Repair. Check and Repair only becomes visible when an error has been detected in the project. A Check and Repair report dialog will first appear stating how many errors it has found and asking if it 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.

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 your 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 Reseau

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.

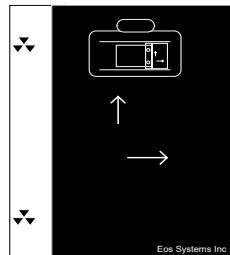
Using a scanner (such as PhotoCD) is best done with a fiducial insert. If the scanner is very consistent (the PhotoCD auto-gate scanner is sometimes this way) you can forego fiducials and use the PhotoCD with no fiducial camera type.

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:

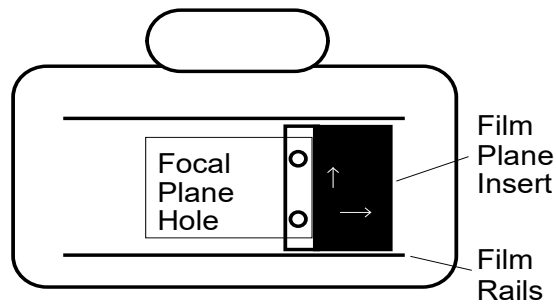


This item may be purchased as an option – contact your dealer or the Eos Systems sales department. To use this insert glue it into the camera between the film rails projecting out into the imaging area.

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.

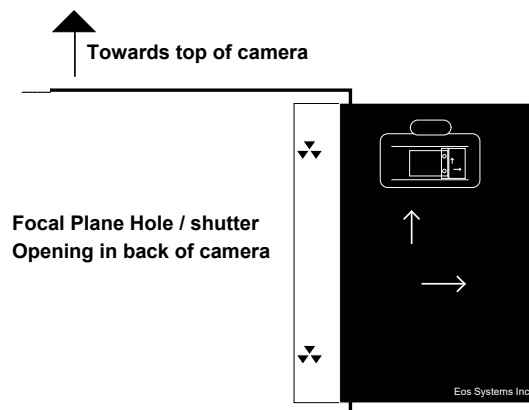
To modify the camera, follow these steps:

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

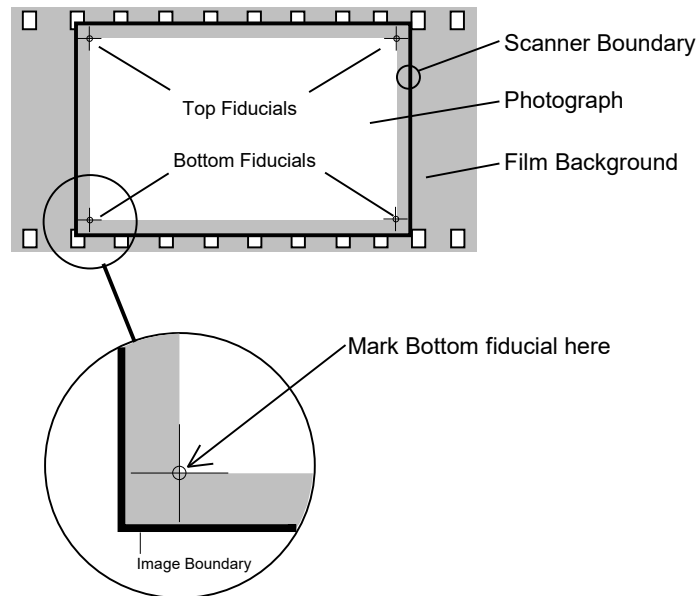
You may have a number of photographs of an object taken before you obtained PhotoModeler, before you inserted the Film Plane Insert in your camera or you may not wish to use the insert. Can you use these with PhotoModeler? The answer is "yes", but a few conditions must first be met if you want *high* 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.

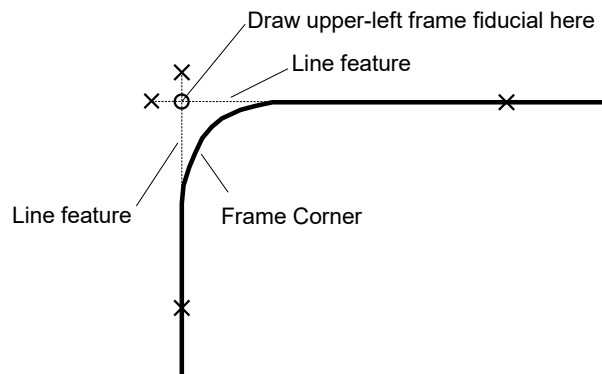
If these conditions are not met you can still get reasonable results by using the appropriate non-fiducial camera type or by using the *Inverse Camera* procedure.

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.

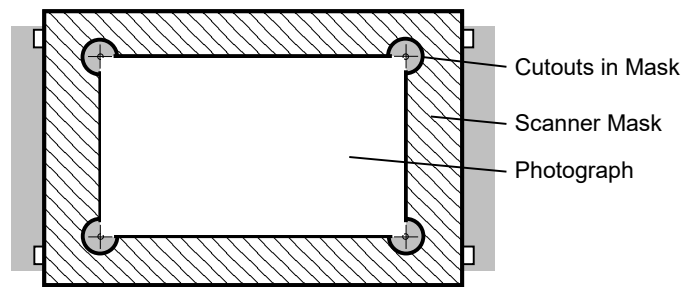


Modifying the Scanner Mask

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.

The easiest way to create a camera is to use the *Camera Setup Wizard* which gets called automatically as part of setting up a new project or can be called from the *Project Cameras Dialog*.

Cameras can also be created by typing in parameters into the *Camera Information Dialog* or by getting a camera from another project.

There are two ways to build a Camera Description for your camera. If you want to get started quickly and you are not that concerned about accuracy at the start, you can create an approximate camera.

If you want higher accuracy or if you have a camera that does not work well in approximate mode (such as a video camera where little is known about the internal CCD or a film camera with fiducials) then a full calibration should be done.

Do I need to calibrate my camera ?

It depends on the project you are working on and the type of camera you use. If you want the highest accuracy we suggest you calibrate your camera. On the other hand we also recommend that you start working with PhotoModeler with an approximate camera first. Then at a later date when you want to improve the accuracy of your project(s) you can switch to a calibrated camera easily.

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 will often work with the approximate values given by the camera manufacturer and the 3D data produced will look reasonable. 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.

Approximate camera descriptions

When we use a camera in PhotoModeler that is not calibrated we call it an "Approximate Camera". The next section describes how to build the camera description file for an Approximate Camera. Certain types of cameras and scanners are not easy to set up as "Approximate Cameras" and sometimes PhotoModeler will fail trying to use such a camera. Examples of hard cameras to approximate are: video cameras with digitizer boards where little is known about the CCD chip and film cameras with flat bed scanners.

Building an Approximate Camera using the Dialog

Approximate Cameras can be built by hand or by the *Camera Setup Wizard*. If doing it by hand you may not know these camera numbers exactly so provide the best numbers you can. To enter these parameters you will fill in the Camera Information Dialog (shown below). The type of camera you use, dictates how the numbers are entered. Tables later on in this section describe how to come up with these numbers for your camera/scanner combination. Study the following steps and the dialog below and then find the table that describes your camera.

1. To create an Approximate Camera using the Camera Dialog:
2. Start PhotoModeler.
3. Select the "Cameras..." menu item from the Project Menu.
*The **Project Cameras Dialog** will appear.*
4. Click on the "New..." button to create a new Camera.
5. Fill out the Camera Information Dialog as discussed in the tables below.
6. Click on "OK".
7. You can save this Camera to disk using the "Save..." button in the Project Cameras Dialog or if you want to use it just in this project press "Close" on the Project Cameras Dialog.

Your camera description is now built and can be used in PhotoModeler for doing projects.

Camera Information Dialog

Camera Name: Toshiba PDR-M4

Focal Length: 7.1577 mm

Format Size W: 6.0001 H: 4.5000 mm

Principal Point X: 3.0986 Y: 2.1920 mm

Lens Distortion K1: 2.030e-003 P1: -3.143e-004

K2: -5.025e-005 P2: -7.658e-007

K3: 0.000e+000

Image Size: 1600 x 1200 Set from file

Fiducial type: No Fiducials

Fiducials: mm

Modify...

Calibrated: yes ☐ Make copy for Inverse Camera

OK Cancel Help

Camera Information Dialog

The Camera Information 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:

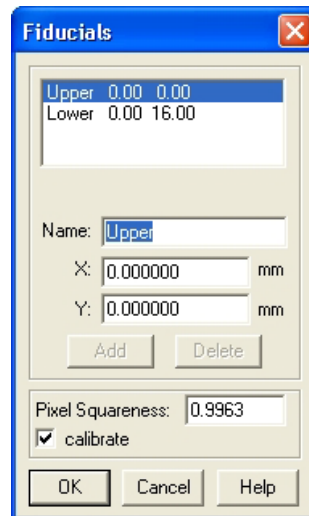
Camera Name:	Provide a name for the camera to help you identify it.
Focal Length:	The focal length of the lens of the camera being calibrated. A PhotoModeler Camera can have only one focal length. Set this to the figure printed on the lens or in the camera specification sheet. See note below regarding 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> .
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.
Calibrated:	A flag that indicates whether this Camera has been calibrated or not. It is set by the Calibrator after a successful calibration.
Make copy for Inverse Camera:	If checked, this camera is used for Inverse Camera processing (in other words, the camera parameters are not that well known). This box is used to control only whether this camera will get copied when it is assigned to a new photograph. It is copied because it is assumed to have different parameters for each photograph.

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).

Fiducials Dialog

The Fiducials Dialog is used to add, remove or modify *Fiducials* associated with a film camera. This dialog is entered from the "Modify..." button on the *Camera Information Dialog*.



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.

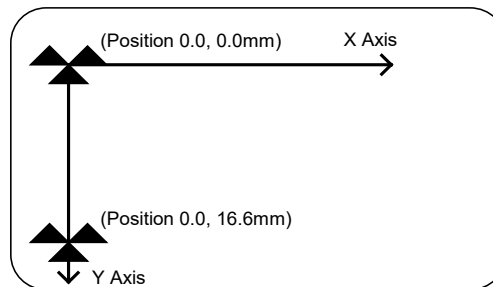
Fiducials cannot be removed from the Camera types, "35mm film w/ Eos Insert" or "35mm film w/ frame edge fiducials". Fiducials also cannot be removed if they have been marked on any Photograph in the project. If you wish to remove a fiducial that

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.

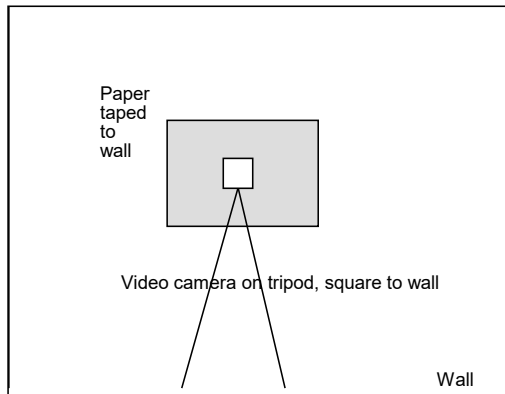
The best way to set up digital and video cameras is to use the *Camera Setup Wizard*. If you want to do the format size calculations yourself or check the wizard's results you can follow the method below.

You will need

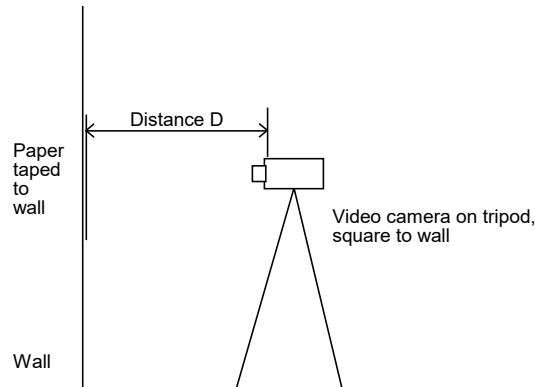
- the video or digital camera
- a tripod (or camera support of some form)
- a sheet of 8.5"x11" paper (or A4 sheet)
- a measuring tape
- a small portion of a flat wall
- a good estimate of the focal length of the camera (the focal length you are going to use)

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.



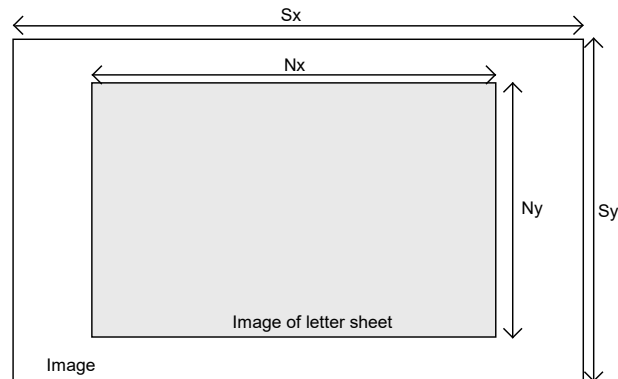
Back view of camera setup



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 D1, 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 -> $D = D1 - f$.

Lens Distortion Formulation

PhotoModeler uses a standard lens distortion formulation with four parameters as seen in the Camera Information 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:

$$x_c = x + drx + dpx$$

$$y_c = y + dry + dpy$$

where x_c, y_c is the corrected image point,

drx is the x component of the radial lens distortion correction,

dry 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:

$$x_c = x * (1 + drb / r)$$

$$y_c = y * (1 + drb / r)$$

If you pre-divide the radial distortion formulas by r you have:

$$dr = drb / r$$

$$x_c = x * (1 + dr)$$

$$y_c = y * (1 + dr)$$

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 Information 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 found in the Windows directory:

```
[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.

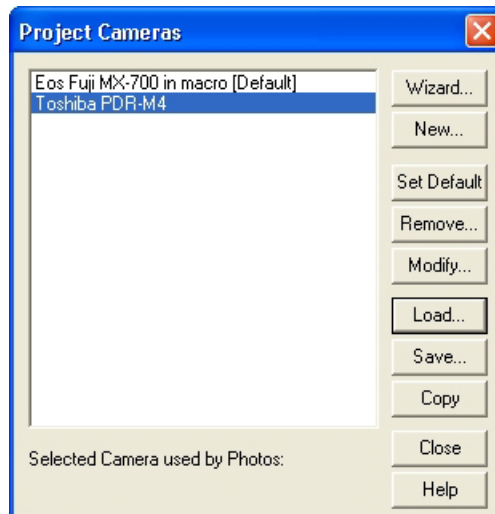
Sometimes when you are using the camera with an outside program that does not understand lens distortion (such as most animation and rendering packages) you will want to calibrate it with no radial or decentering distortion compensation. Set all the lens distortion parameters to zero in the Camera Information 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.

Project Cameras Dialog



The Project Cameras Dialog is used to manipulate the cameras used by the current project. You can create new cameras (using Wizard or Camera dialog), copy a camera, modify camera parameters, load cameras from disk, save cameras and remove cameras from the project. This dialog is accessed through the "Cameras..." menu item, and the Photograph Properties Dialog "Cameras" button.

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 list on this dialog. If this list is empty, there are no cameras used anywhere in this project.

When a Camera is selected in the list, the numbers of the Photographs that use this Camera are shown at the bottom of the dialog. When a Camera is selected, the Modify and Remove buttons also become active. Double clicking a Camera brings up the Camera Information Dialog which allows you to modify the camera's parameters.

When you are finished manipulating or loading Cameras you click the Close button. You will be returned to the dialog you came from. If the dialog you came from had no Camera selected in its drop down list, the last Camera selected in the Project Cameras Dialog will appear in that dialog as the selected Camera.

Creating a new Camera

To create a new camera in a project, click on the "Wizard..." button to go to the *Camera Setup Wizard* or on the "New..." button to go to the *Camera Information Dialog*. You can

also copy a Camera by selecting it and pressing the Copy button (then you will probably modify the camera as described below). When you are done with the Wizard or the Dialog you will be returned here and the new camera will appear in the list. This camera can then be assigned to a Photograph.

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. 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 Default" button.

Modifying a Camera

To modify a Camera in a project select it in the project cameras list and click the "Modify..." button in the Project Cameras Dialog or double click on a Camera. The Camera Information Dialog will appear. Modify the parameters of the Camera and when finished click OK (see the *Camera Information Dialog*). There are some modifications that are not allowed when the Camera has been assigned to Photographs.

Loading a Camera from disk

To load a Camera from disk into the current project, click the "Load.." button in the Project Cameras Dialog. 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.

Saving a Camera to disk

To save a Camera contained in the current project to disk, first select it from the project camera list, then click the "Save.." button in the Project Cameras Dialog. A standard Windows file dialog will appear. Choose the location and a name for the Camera and click OK. The Camera will now exist on disk and can be used in other PhotoModeler projects. It will have the file extension .CAM.

Removing a Project Camera

To remove a Camera from a Project first select it from the project camera list, then click the "Remove.." button in the Project Cameras Dialog. A Camera cannot be

removed from a Project if it is being used by a Photograph. If the Camera can be removed, a warning dialog will appear confirming that you want the Camera to be removed from the Project. Note that if this Camera has not been saved to disk then all record of this Camera will disappear.

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.

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).

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, then you probably do not need to calibrate your camera.

You can create an approximate (non-calibrated camera) directly in PhotoModeler. 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. You use the project and camera wizards to create an approximate camera. See *Camera Wizard: Paper method*.

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 reproducible. For zoom lenses only calibrate at most-wide angle or more 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.

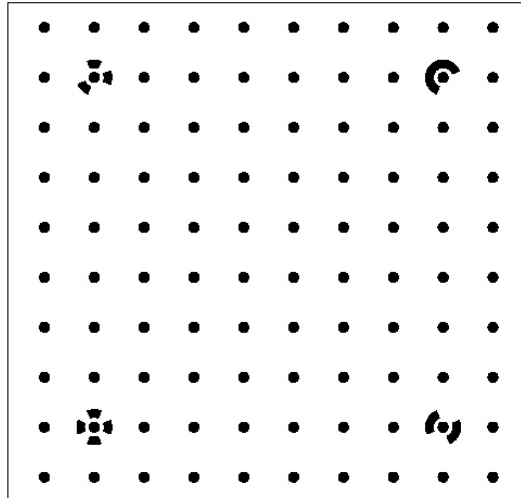
When using Kodak PhotoCD, you will need to calibrate the film, lens, PhotoCD scanner combination at one particular resolution. If you intend to use PhotoCD at different resolutions you will need to calibrate at each resolution. You only need to take one set of calibration photographs, though, since all 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 Pro 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. If the calibration fails see *Camera Calibration Troubleshooting*.
10. 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 the grid in two forms: a) a PDF file (PhotoModelerCalibrationGrid.pdf - in the install directory), and b) a 35mm slide. Optionally you can also purchase a plotted sheet from Eos or your dealer (approx. 1 meter square).

The first consideration is size. Ideally you calibrate your camera at the same focus setting (so the same distance) 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 large objects or large scenes try to make the calibration grid as large as is practical.

If you are modeling smaller objects (or you just want a quick way to test calibration) you can print the grid on a standard piece of paper.

There are some advanced ways to use the Camera Calibrator that do not use this exact grid. Contact Eos Support for more information.

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 included 35mm slide.

If you need a larger grid, do not have a room suitable to projection and a size of 1m is suitable, you can get the PDF file plotted 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 stand piece of paper (8.5"x11" or A4).

For extremely small grids (extreme close up work of 50mm or smaller objects) you can use the 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.

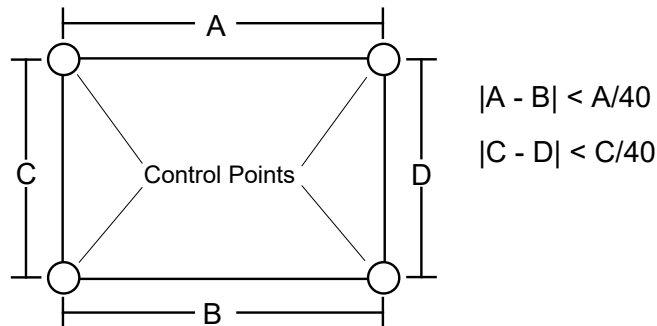
Taking Photos of the Slide

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.

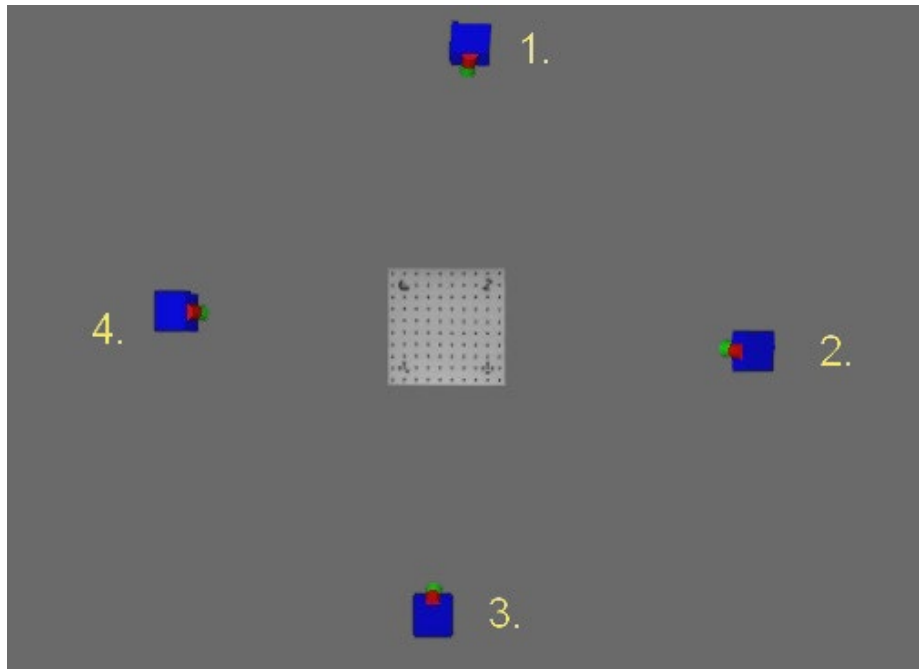
Important note 2: Certain digital cameras perform automatic sharpening on the images they take. This is done because humans like looking at sharp pictures even if they are artificially sharp. On the other hand, image processing algorithms like the Auto-marker in the Calibrator do not work well with sharpened 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.

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:

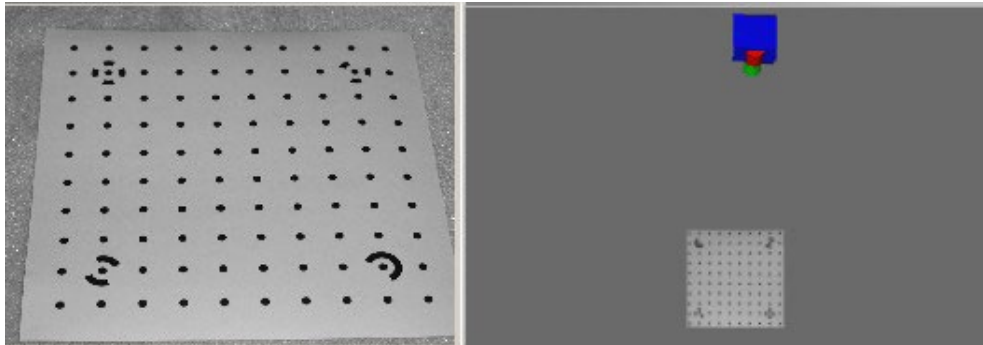
- if you are photographing a grid lying on the floor, then these are top down views (viewer is above grid looking down at floor),
- if you are photographing a grid projected on the wall, then these are front views (viewer is in front of wall looking straight at it).

“ccw” in the section titles below means rotation counter clock-wise and “cw” means rotation clock-wise.

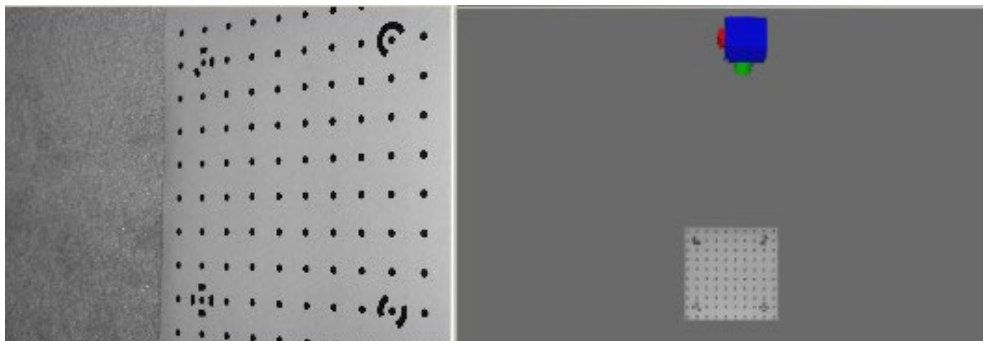
Note 1: the actual orientation of the calibration grid is not important. These illustrations are solely to guide the photography relative to the edges of the grid.

Note 2: the calibration grid should not be moved but instead should be static and rigid - move the camera instead.

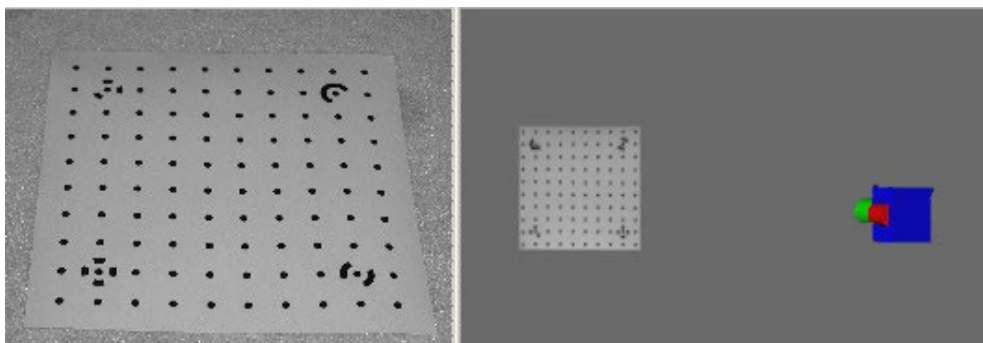
Position 1 - normal



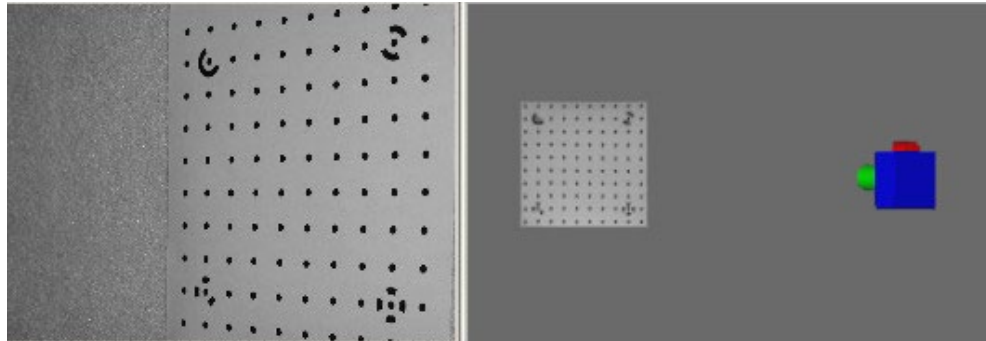
Position 1 - Roll 90 degrees cw



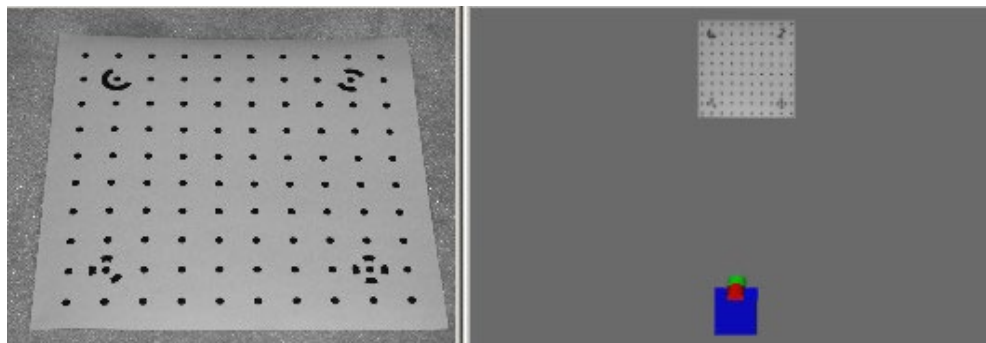
Position 2 - normal



Position 2 - Roll 90 degrees cw



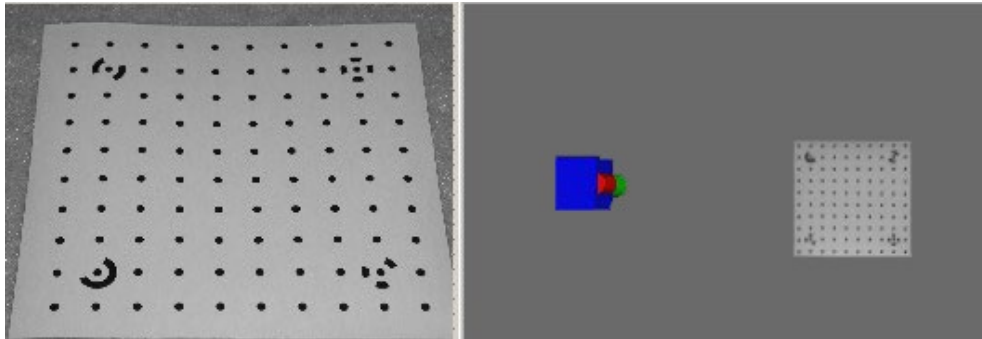
Position 3 - normal



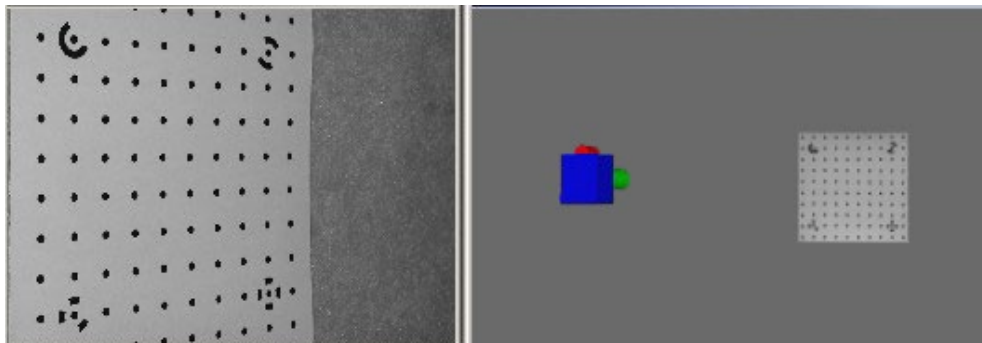
Position 3 - Roll 90 degrees ccw



Position 4 - normal



Position 4 - Roll 90 degrees ccw



Additional Positions and Slide Grid

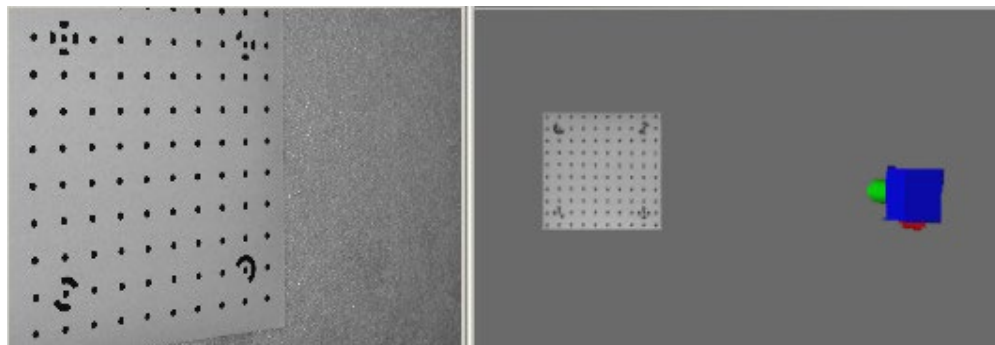
In addition to the eight positions shown above you may want to add one more roll angle at each position bringing the total to 12 photos. These four additional photographs ensure a better coverage and a complete set of roll angles. While they are not necessary, if you are striving for the highest accuracy 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*.

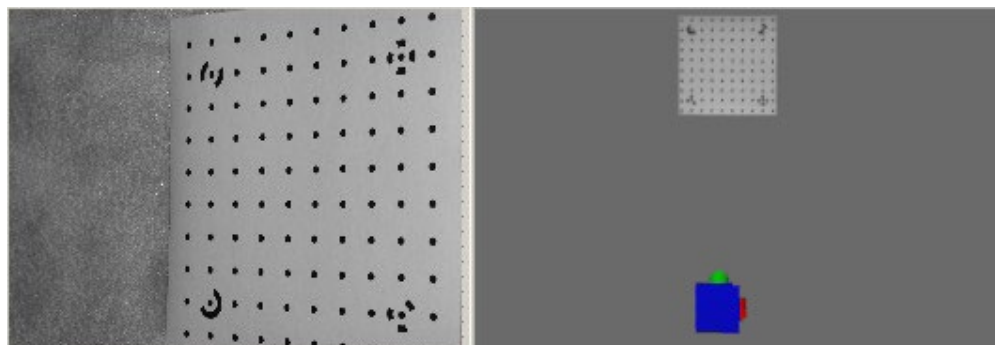
Position 1 - Roll 90 degrees ccw



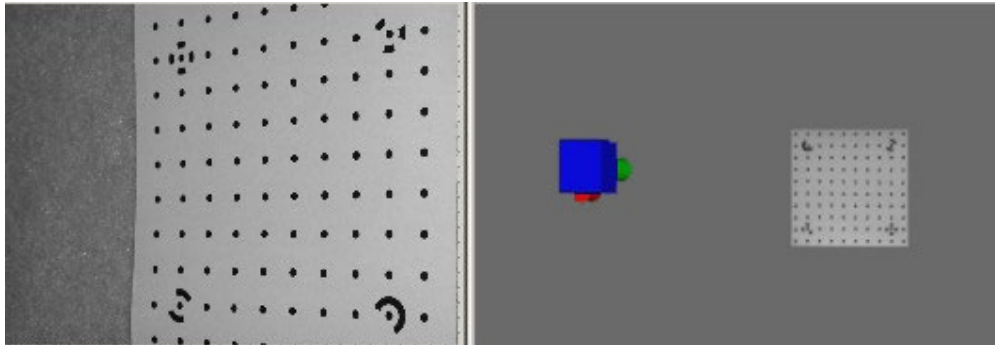
Position 2 - Roll 90 degrees ccw



Position 3 - Roll 90 degrees cw

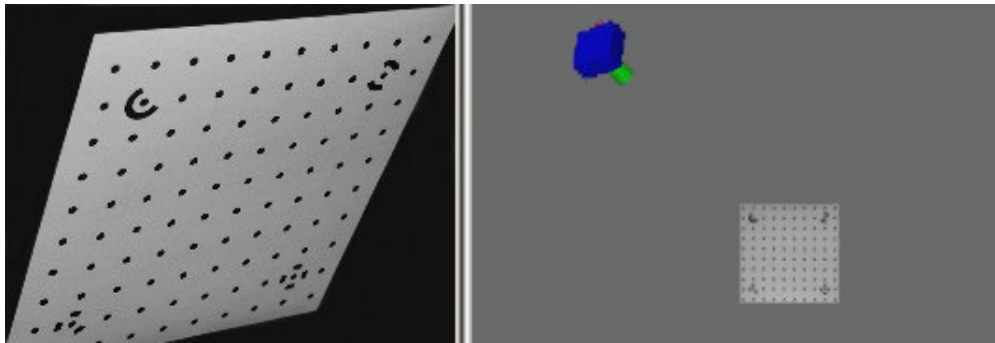


Position 4 - Roll 90 degrees cw



Position 5 - angled

Alternate for slide project grid.

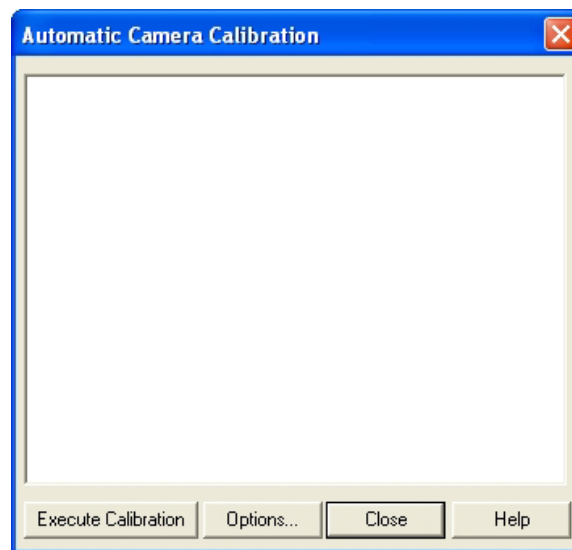


Position 6 - angled

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.

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. When you close that dialog, the calibration will be complete.

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 Dialog / Process) and these values here assume the default values (0.1 pixels for subpixel 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* (on the *Marked Visibility Tab*) 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.

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 (eg Focal Length, Format Size Width, Principal Point and K1) and the rest in Stage 2 (eg 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.

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. 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 *Preferences - Camera Calibrator*, "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 "Image Enhance" under the Edit 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.

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 *Preferences - Camera Calibrator*). 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, 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 *Preferences - Camera Calibrator*). 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.

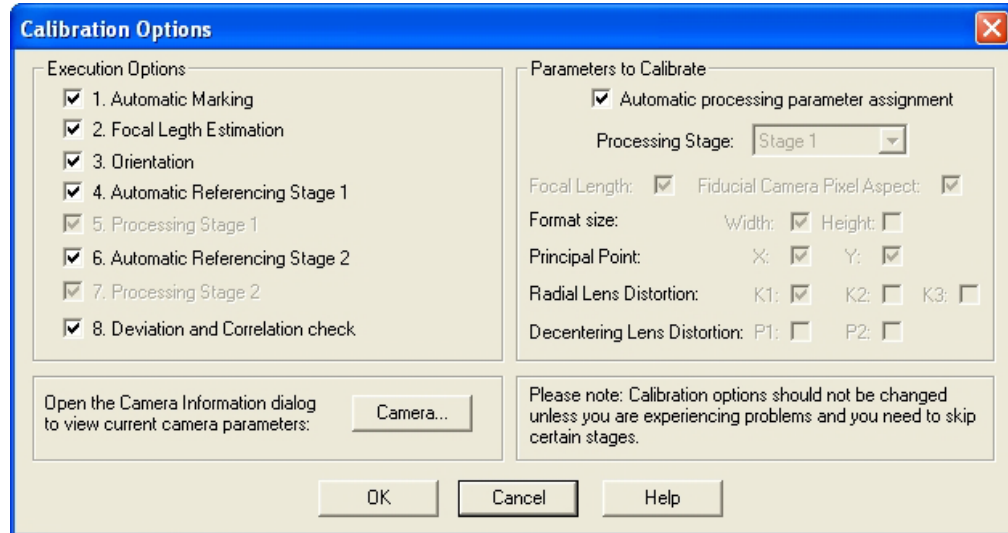
The Marking Residuals are high after Calibration processing.

A good calibration will have marking residuals all under 1.0 pixels. 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).

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.

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 Information 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 Information 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 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 pixels¹).

¹ A pixel is the smallest unit of resolution in a digital image or on a CCD. It stands for "picture element".

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.

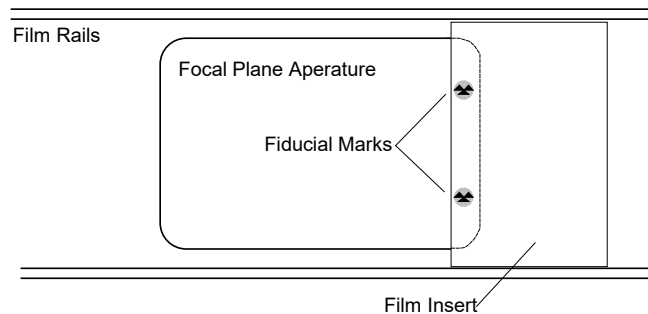
On the other hand, in a film camera, the film is removed from the camera for processing and digitization. By the time we are locating points on the film image in PhotoModeler, we have little idea where that point was relative to the lens / camera body at the time of the exposure.

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).

Importing and Using Photographs

After a Project is created with the Setup Wizards the next step is to import Photographs (note photograph import can be accomplished in the Import Wizard which is part of the standard Setup Wizard chain).

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.
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 Camera 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

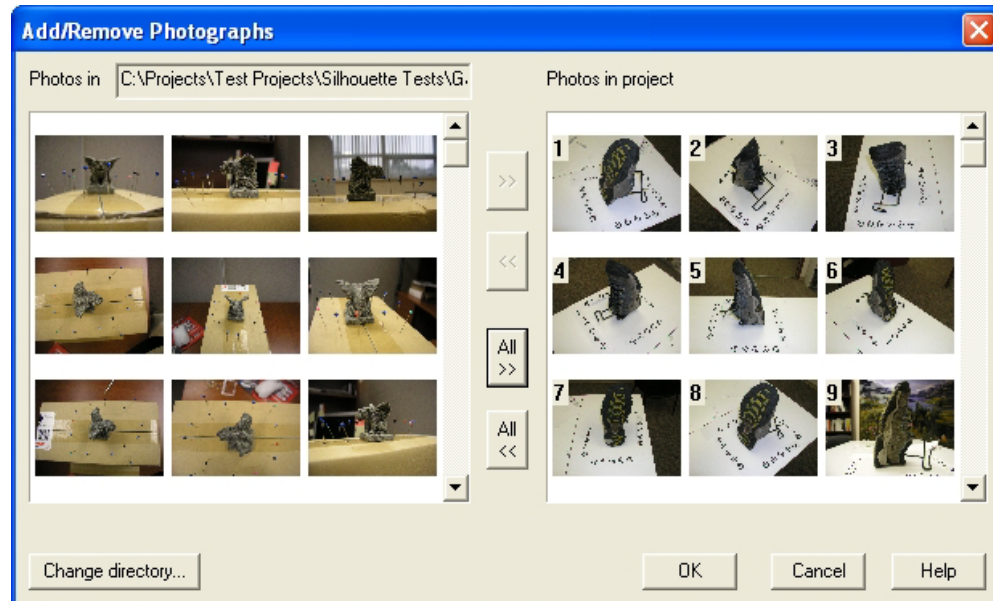
The photographs for your Measurement Project are now stored in your computer in one of the acceptable formats.

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 to remove Photographs from the current Project.

If part of your photo directory path is truncated, you can scroll the "Photos in" textbox to bring text into view by either clicking and dragging on the text box, or using the arrow keys on the keyboard when the text is selected.

The dialog is composed of two large regions that show a *chip* of each photograph in the current directory (on the left) and in the current project (on the right). Below each of these areas are text boxes that show the location and file name of the currently selected photo chip above.

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

To load Photographs into a project, click on the "Change directory..." button on the Add/Remove Photographs Dialog. A directory selector dialog will appear. Change to the directory where the images that you wish to use in the project are located. Select any one of the image files and click OK. The photo chips for all recognized image formats will be loaded and displayed in the Directory Photographs area.

Select an photo chip to see its file name at the bottom. 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 "Choose directory..." button) and moving some more images. Repeat this as necessary.

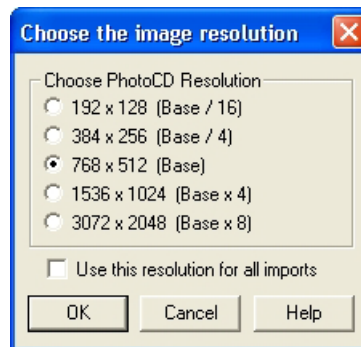
Any photograph additions to the Project can be canceled by hitting the "Cancel" button on this dialog.

Removing Photographs from a Project

To remove a Photograph from a Project first select the photo chip of the required Photograph (its file name will 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: 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.

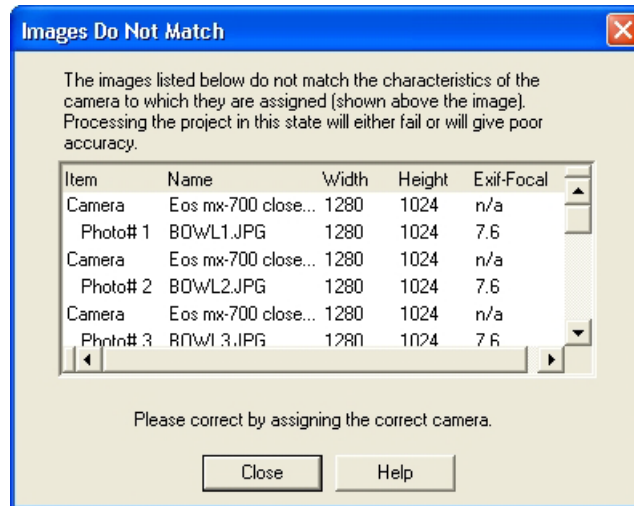
Image Resolution Dialog



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 size and **EXIF** Focal length (if available). This dialog appears only when there is a mismatch.

Image Size: The number of pixels in the image. The Photograph's image size is read from the image file on disk. The Camera's image size is stored by PhotoModeler when the Camera is first created. The Image Sizes for the Camera the Photographs must match. For example if the image was taken at 640x480 resolution, the stored Image Size in the Camera must be 640x480 also.

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). 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 with 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 Chips Tab* of the *Photo Control Side Bar*. Photographs can also be opened from the *Photo Overview Dialog* and the *Photo Table*.

Photo Chips Tab



The Photo Chips Tab is a tab in the *Photo Control Side Bar*.

This tab has five controls:

- Photo Set list,
- Photo Set Edit button,
- Select All button,
- Open button, and
- Photo Chip area.

The most important and most used will be 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 work space. Double clicking on a chip is a short cut to using the Open button.

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.

If the photograph you wish to open is not in this list see *Adding Photographs to Your Measurement Project*.

Each chip shows two pieces of information. The photograph number (which uniquely identifies a photograph in a PhotoModeler project pmr) is show 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".

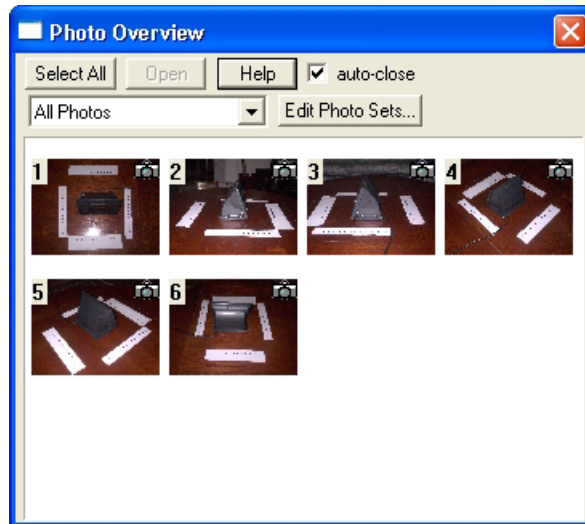
You can use the right-mouse button when the cursor is over a photo chip and you will get a pop-up menu with "Photo Properties..." and "Add/Remove Photos..." items. The first brings up the *Photograph Properties Dialog* for the selected image and the second brings up the *Add/Remove Photographs Dialog*. You can also create a Photo Set from the currently selected set of photo chips.

The two top controls have to do with *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. The >> button brings up the *Edit Photo Sets Dialog*.

Note: PhotoModeler has an automated mechanism for creating smaller versions of each image. These smaller versions are used in the Photo Chip Tab, the Photo Overview Dialog, 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 you're 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 *Preferences - General*.

Photo Overview Dialog



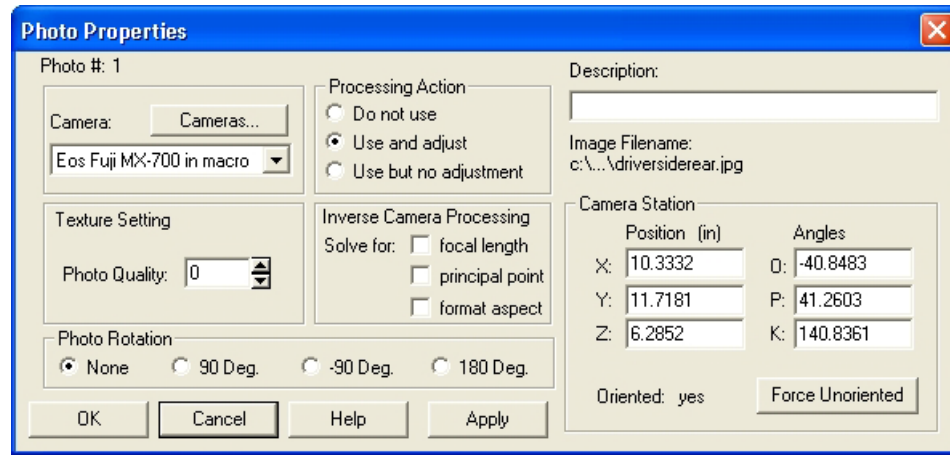
The Photo Overview Dialog is similar to the *Photo Chips Tab* of the *Photo Control Side Bar*. It shows multiple photo chips, shows Photo Sets, and can be used to open photographs.

This dialog is opened by the 'Photo Overview...' menu item in the File menu.

The main difference between this dialog and the Photo Chips Tab is that it is sizable and can be made very large. By dragging on any corner of the dialog window with the mouse you can size it as small or large as you want. If you have many photographs in your project this is a great way to see all or at least many more of them at once.

The 'auto-close' check box on the dialog controls whether the dialog automatically closes/hides when a photograph is opened from this dialog.

Photograph Properties Dialog



The Photograph Properties Dialog displays properties of one or more photographs in the project and provides the facility for modifying these properties. 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.

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. Starting at the top left of the dialog and going clockwise there are sections for the Photograph's Camera, how the data on the Photograph is processed, the Photograph's user name, the associated image file name, the information about the Camera Station orientation, the InverseCamera settings, the rotation of the image on the screen and the quality setting used in texturing.

These are described in the sections below:

Camera

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 button on list box to pick a new camera. If the Camera does not appear it means it is not loaded into the project. In this case press the "Cameras" button to bring up the *Project Cameras 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*.

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 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 trouble-shooting.
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 trouble-shooting.

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.

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.

Image Filename

This is a non-editable field that shows the full disk path name of the image associated with this Photograph.

Camera Station

The Camera Station part of the dialog gives information on the orientation of the Photograph's Camera Station (i.e. where the camera was at the time the photo was taken).

The position of the perspective center of the camera at the time of exposure of the corresponding photo 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*.

The angles O stands for Omega and is the rotation about the X axis, P stands for Phi and is the rotation about the Y axis, and K stands for Kappa and is the rotation about the Z axis.

This dialog has a button called "Force Unoriented" which is available when the Photograph has been processed and oriented. Pressing this button (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.

Note: the values for orientation of the Camera Station can be changed here - you should be quite confident in your coordinate systems and Euler angles 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).

Inverse Camera Processing

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.

This property has three check-box controls: focal length (check when you want to solve for the focal length of the camera that took this photo), principal point (check when you want to solve for the x,y principal point of the camera that took this photo), and format aspect (check 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.

Photo 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.

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.

Texture Setting

This area of the dialog contains the Photo Quality control.

The Photo Quality 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 where 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.

Photograph Window

Photographs are displayed in a Photograph Window. 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 by using the System Menu in the upper left hand corner of the Photograph Window. The System Menu looks like a short white dash in a box. Double clicking on the System Menu will close the window. Single clicking will bring up the menu which allows you to minimize, maximize, resize, move and close the Photograph Window. Photographs can also be closed using the "X" button in the upper right of the window. Photographs can be minimized and maximized using the other buttons in the upper right of the window, can be moved by dragging the caption bar, and can be resized by dragging the window borders. See Windows documentation for more details on interacting with windows.

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.

There are a number of ways to magnify (or "zoom") a photograph. There are:

- three mode button on the toolbar (in, out, area),
- an action button on the toolbar (default zoom),
- actions available through right-mouse menus,
- actions available through the Window menu,
- actions available through a wheel mouse, and
- actions available through keyboard commands.

The sections below describe each of these.

Zoom Modes

The following steps describe how to use the toolbar zoom modes.

To magnify a photograph:

1. Pick up the Zoom-In tool from the toolbar (the magnifying glass with a "+").
2. Click this tool on the Photograph Window you wish to magnify.

PhotoModeler will magnify this window each time you click the mouse button. The photograph 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.

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.

To decrease the magnification of a photograph:

1. Pick up the Zoom-Out tool from the toolbar (the magnifying glass with a "-").
2. Click this tool on the Photograph 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.

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. See the next section for more information.


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.

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 tab) 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 tab. 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.

Zoom Menus

The main Window menu and many of the right-click menus provide access to magnification functions. These are:

Zoom to Fit	Makes the active photograph fit completely within the current window.
Zoom to Fit All	Does Zoom-to-Fit on all open photographs.
Zoom 1:1	Set the active photograph's magnification such that one image pixel is displayed for each screen pixel.
Zoom Previous	Makes the active photograph return to the most recent zoom and pan settings.

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 settable 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 Tabs*.

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.

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:

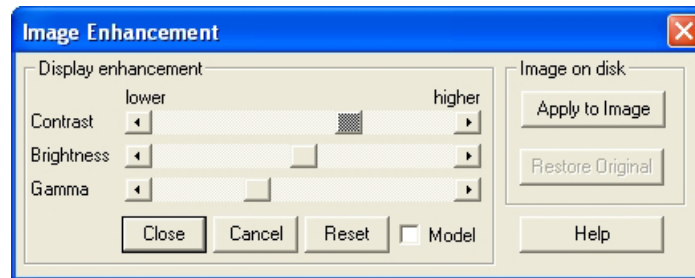
+ key	to zoom in quickly while in any mode
F key	to fit whole photo to the window
Fit toolbar button	to fit whole photo to the window
Ctrl right mouse button	to pan while in any mode
Right click menu	to access zoom 1:1
Alt key	to access zoom window to get quick magnify
Mouse wheel	to make rapid changes 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 "Image Enhance..." from the Edit Menu. Modify the values in the Brightness and Contrast Dialog.

Image Enhance Dialog



This dialog is opened with the Edit menu / "Image Enhance..." item. The purpose of the dialog 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.

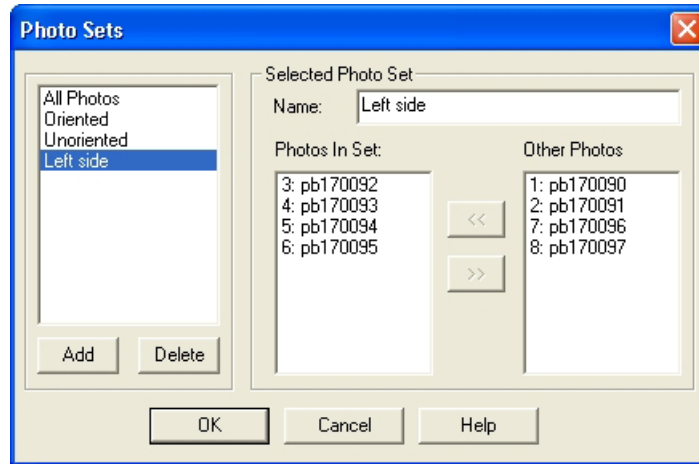
Outside of the three default sets, the user can create their own Photo Sets in a number of ways:

- By selecting one or more Photo Chips in the *Photo Chips Tab*, 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 Chips Tab 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. The Referencing Drop down lists can be set to use the active Photo Set also - see Preferences.

Edit Photo Sets Dialog



The Edit Photo Sets Dialog is used to create, delete and modify *Photo Sets*. It is opened from the *Photo Chips Tab*, 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 placeholder 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 with appear as a solid color only.

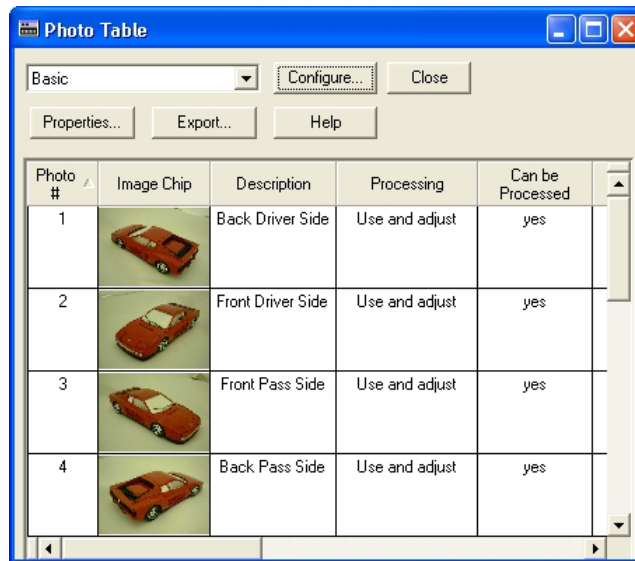
You want to switch a project from TIFF to JPEG images

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.

Photo Table



The Photo Table is a key capability of PhotoModeler for reviewing photograph, camera and camera station data. The Photo Table can be opened from the Project Menu / "Open a Photo Table" item, or from the Photo Table toolbar button.

See the sections below called *Tables* and *Table Top Dialog* for more background on tables and how the controls at the top of the table work.

The properties of Photographs and Camera Stations can be modified by selecting one or more of them in the table and pressing the Properties button. This brings up the *Photograph Properties Dialog*.

There are numerous columns and properties that can be displayed in the Photo Table. They are:

Property	Type	Description
Image Chip	image	Small version of the photograph. See <i>Photo Chip</i> .
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

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.
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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 H, W	# 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 the *Photo Table* Export.

You would set up a Table Configuration with the columns you need in your external program. PhotoModeler ships with a typical configuration called "Perspective Match" which you can modify.

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. There are a number of issues with doing very accurate matching so if this is your interest please contact Eos Systems for more information.

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.

Building a 3D Model

This chapter describes how to build a 3D model in PhotoModeler Pro. 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:

- Object Points,
- Lines,
- Curves,
- Edges,
- Cylinders, and
- Surfaces.

The following sections describe each of these types and how they are typically used. How each object gets a computed 3D position is also discussed. Sections later in the manual discuss how to create and manipulate each of these objects.

Object Points

Object Points are one of the most important items in PhotoModeler. Most if not all projects will contain Object Points. An Object Point is a 3D location (X,Y,Z).

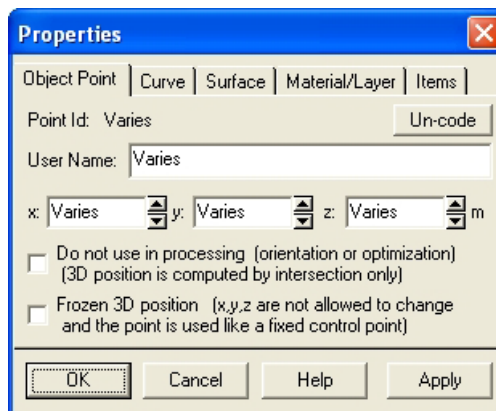
Object Points are central to camera station orientation and overall processing. The only type of project that may not have any Object Points is a single photo constrained project using Edges.

Object Points are created by placing Marked Points on Photographs. These Marked Points are then referenced together (in a multi-photo 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 *Control Points Dialog*. 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. You can see how many objects have been selected in the Items tab.

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,
- 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 'Unicode' 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 'unicode' the point(s) happens on the OK or Apply button presses.

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.

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 Tab of the *Preferences* dialog).

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*.

Edges

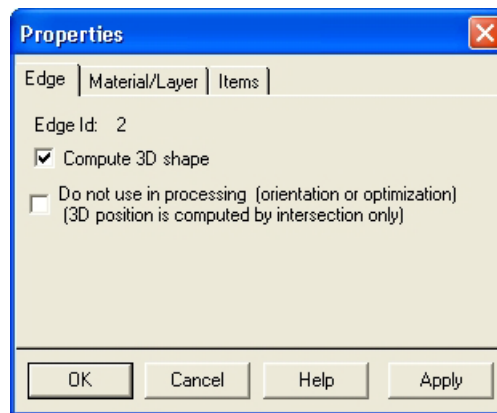
An Edge is a line segment between two 3D positions. The most important aspect of Edges is that when referenced their end points do not need to match across

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.

Edges do not have their own Property Sheet.

How Edges become 3D

Edges are assigned 3D position:

- during global optimization

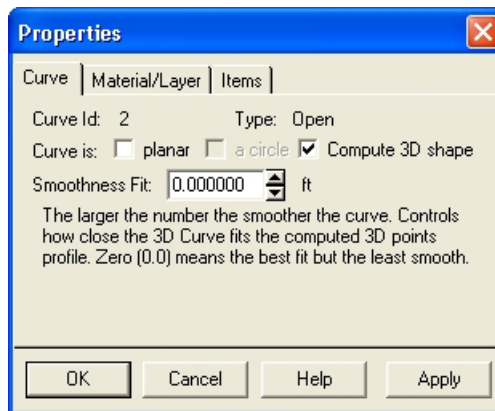
- from intersection math when the edge is referenced on two or more oriented photos
 - fires when an edge has marks referenced/dereferenced
 - fires when an edge point is moved
 - fires when one of the photos its mark appears on is oriented, reoriented or forced unoriented
 - fires when the user changes 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 section *Photography for Curves, Edges, Cylinders and Automatic Referencing*.

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. You can see how many items have been selected in the Items tab.

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.

How Curves become 3D

Curves get 3D position:

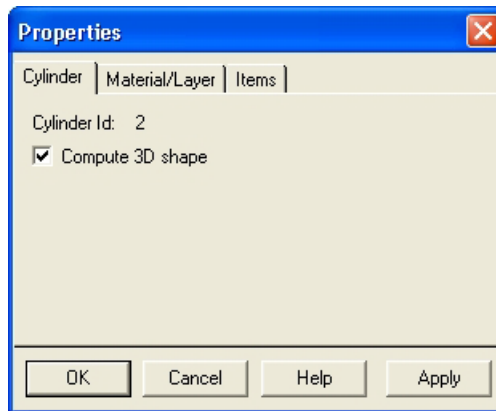
- from the curve projection algorithm when the curve is referenced on two or more oriented photos
 - fires when a curve has marks referenced/dereferenced
 - fires when a curve point is added/removed/moved in a curve mark
 - fires when one of the photos its mark appears on is oriented, reoriented or forced 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 section *Photography for Curves, Edges, Cylinders and Automatic Referencing*.

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.

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/dereferenced
 - 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 section *Photography for Curves, Edges, Cylinders and Automatic Referencing*.

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 bar.

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.

How Lines become 3D

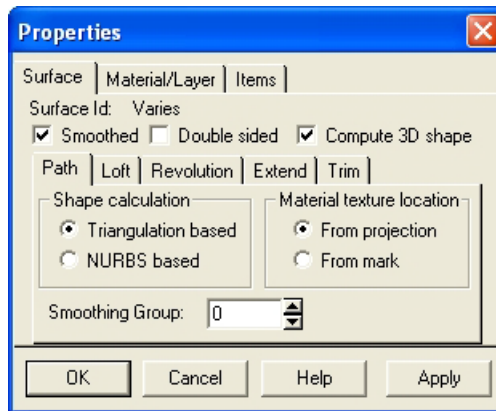
Lines get their 3D position solely from the 3D positions of their end Object Points.

Surfaces

A Surface is an object that helps make the 3D model look "solid". Surfaces are applied Materials such as 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 point clouds. 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. You can see how many items have been selected in the Items tab.

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 on the Extend sub-tab), and
- Trim/hole settings (displayed on the Trim sub-tab).

Each surface type also has the following unique properties displayed as sub-tabs within the surface properties tab. Except silhouettes which have their own main tab.

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 tab 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.

Point clouds:

- Max Spans U and V - Controls how well a point clouds fits to a set of points.

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).

Marking

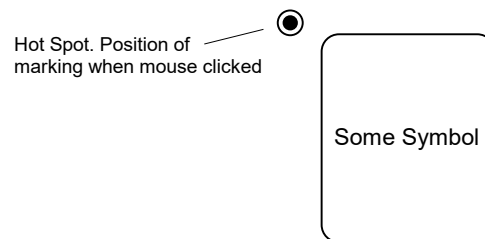
Marking is the process of creating and positioning an object on a photograph. Points, edges, curves, cylinders, silhouettes and fiducials are items marked on photographs.

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.

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.

Generic Marking

To Mark Objects on Photos:

1. Open the photograph you need by double clicking on the photo chip in the *Photo Chips Tab*.
2. Pick up the desired tool (point, edge, curve, etc.) from the toolbar or select the appropriate mode from the Marking menu.
3. Click the mouse in the desired location in the photo to start the object. A point requires one click, an edge requires two, a cylinder four, and a curve a variable number of clicks.


4. For specifics on marking edges, cylinders, curves and silhouettes see the sections below.
5. 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.

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. Pick up the fiducial tool from the toolbar  or select "Mark Fiducials" from the Marking menu.
2. The Fiducial Toolbar will appear.
3. Choose the name of the Fiducial you wish to mark on the Photograph from the drop list on the Fiducial toolbar.
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.

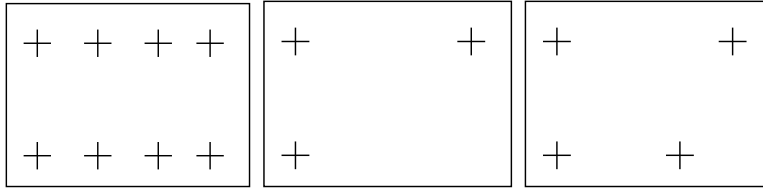
Hint: It is important to mark each fiducial as precisely as possible. Zoom the photograph in and be as careful as possible when marking fiducials.

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.

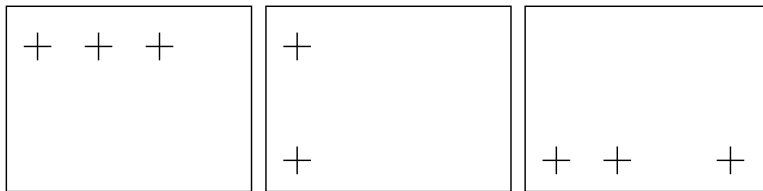
On some photographs it may not be possible to see each fiducial mark. This may be the case if the fiducial mark was positioned over a dark object in the scene you photographed. If this is the case, mark only the fiducials you can see. You must mark both fiducials if you are using a two fiducial camera (such as the Eos Film Plane Insert) or at least three if you are using a camera with three or more defined.

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:

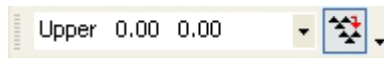


but these are not:



Fiducial Toolbar

When Fiducial Marking mode is entered, the Fiducial Toolbar first appears:



The drop down list contains each fiducial defined in the camera associated with the current photograph. The button beside 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 drop down list box in the dialog 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 fiducial to be marked.

You should zoom up the Photograph to mark the Fiducial to get as much precision as possible. When you select any of the zoom modes you will automatically exit Fiducial Marking Mode and the Fiducial Marking Toolbar will disappear. To get back to marking the Fiducial, reenter Fiducial Marking Mode by using the toolbar button or menu item.

If the "Auto-advance" button is pressed, as each Fiducial is marked, the drop down 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 drop down list will show the first unmarked Fiducial on this Photograph and will be blank if none are to be marked.

During marking you can also skip over a fiducial and advance the drop-down 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, and 3D Viewer windows.

Mouse selection

To select an item with the mouse, move the cursor to the item in a window. Click the 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 move 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.

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 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 and the region will close and the objects will be selected. Hitting the ESC key during the region definition will cancel it.

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, will select all visible objects in the view (photographs, table, and 3D view) that is currently active in the workspace.

The right click menu for Select mode while in a Photograph Window or a 3D View Window, has the item, "Select All (in this window)". 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 Tabs*.

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, and the Silhouette Mark. An Object is something that exists globally to all photographs. The Objects in PhotoModeler are Object Point, Edge, Curve, Cylinder, Line, Silhouette, and Surface.

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 and Cylinder).

Photographs display these Marks: Marked Point, Edge Mark, Curve Mark, Silhouette Mark and Cylinder Mark and these Objects: Line and Surface (projections). All of these can be selected.

3D Viewer windows display these Objects: Object Point, Edge, Curve, Cylinder, Line, Silhouette and Surface. All of these can be selected.

Point Table windows display Object Points only. Object Points can be selected.

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, object properties, tag, point audit, etc.) can be done by selecting objects in 3D Viewer, Point 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 Point or Other Table	Select in a 3D Viewer or Photo Projection
Point Mark	yes		
Object Point		Yes (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

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.

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 bar 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 and cylinder 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, 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 Tabs.

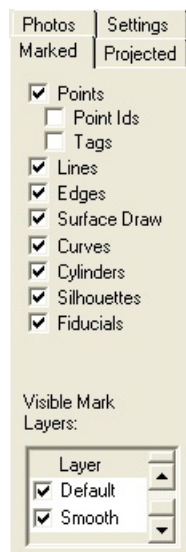
Visibility Tabs

The Visibility Tabs are part of the *Photo Control Side Bar*. They have controls for setting what is displayed and how it is display on Photograph Windows.

When a check box is “on” in one of these tabs then that particular type of object will be visible on the photographs. Also an object has to be visible to be selectable.

There are four tabs: Marked, Projected, Settings and Photos. Photos tab is described in the *Photo Chips Tab* earlier in this document.

Marked Visibility Tab



The Marked Visibility tab controls which 2D objects (marks on photographs) are visible on the open photographs.

When a check box is empty the corresponding item type is hidden. The type will also not be selectable. For example, if Lines 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.

When PhotoModeler is in a marking mode its corresponding type is forced to be visible. For example, if you are in Line marking mode then Line visibility is forced to be on and cannot be turned off.

Beside the ability to make marks visible by type (i.e.. turn off all cylinder marks), you can also control which layers are visible. For example, if you assigned 10 lines of a 20 line project to the Smooth layer and then turned that layer off (by unchecking the box beside the word “Smooth” in the Visible Mark Layers box) then those 10 lines would not be visible or selectable on any photograph. This is very useful for large and complex projects. This is similar to how layers work in CAD programs.

Point ID Visibility

When Points are visible as Marks or Projections on a photograph, the Point ID’s Visibility option becomes available. Control Points have a similar setting in Projections.

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
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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 on the Preferences Dialog. See *Preferences - General*.

Note: You can renumber the points in your project using the *Renumber Dialog*.

Residual Errors

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.

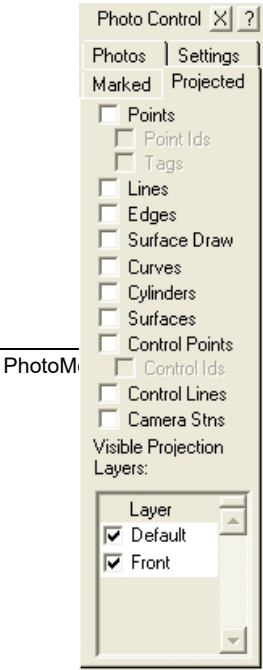
Target Areas

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.

Projected Visibility Tab

The Projected Visibility tab controls which 3D objects are visible on the open photographs as projections.



Note: projections are displayed on oriented photographs only.

See the section on *Photo Projections* for more information.

You may find that Surface projection display is quite useful since surfaces do not appear on photographs as marks.

See also *Point ID Visibility*.

Control Projections

The bottom two check boxes on the *Projected Visibility Tab* do not control a type of object in the current 3D model but instead the data that has been imported for *Control Point* use.

After a DXF or CTL text file have been imported, PhotoModeler knows all the 3D locations of the control points and any lines that join those points. When the Control Points check box is checked on the Projected Visibility Tab, all the imported control points will be projected onto all open photographs. Similarly with the Control Lines check box.

Control points do not need to be marked on any photographs for projections to work. The key is that the project must be in the same coordinate system as the control file or the projection will not be useful. The typical way of ensuring this is to mark three or more control points from the imported control file on some photographs and do an orientation and processing. Then the Control projections will all project onto all oriented photographs (even those that have not been marked yet).

Control projections are useful for a number of functions but one that might not be obvious is for marking control that are not visible:

There are situations when you need to draw a surface to a point on a photograph that is not visible on the photograph. An example of this is setting up surfaces for texturing, surface draw or ortho-photo extraction of a road surface where you have control points from a survey of the road surface and you have been able to mark and process enough of these control to get the photograph oriented (and possibly InverseCamera done also) but the point you need is not visible in the photograph (perhaps poor angles, an object obscuring it, point or mark on the road did not exist when this photo was taken etc.). In this situation, you turn on control projections and

then mark the control point on the projection location. With this 3D control point in a reasonable location you can then draw surfaces to it. Note this method should be used only if you cannot see the point and you require it to create surfaces or other objects.

See also *Point ID Visibility*.

Settings Tab

Marked | Projected
Photos | Settings

Mark Settings:
Thick lines ☐

Projection Settings:
Projections selectable: ☒
Highlight when selected: ☒
Use object's material: ☒

Sizes:
Points: 1.0
Lines: 1.0
Camera Stations: 7.0

Surfaces display:
Shaded

Transparency:
Solid Clear

The Settings tab controls a number of viewing and selection parameters on Photograph Windows.

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*.

The top two Projection settings control whether you can select items projected on the photos and whether items that are selected (perhaps in other views) are shown as highlighted on photos. The update of the selection can be slow (since it involved a new 3D rendering, projection, and image blending) and you may wish to uncheck both of these items to improve the speed of selection on photographs.

The next four controls (sizes, and surface display type) 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 and Surfaces.

The Transparency slider controls how opaque the projected 3D model is. 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.

Referencing

Referencing is the process of telling PhotoModeler that marks on two or more different photographs represent the same physical object in space.

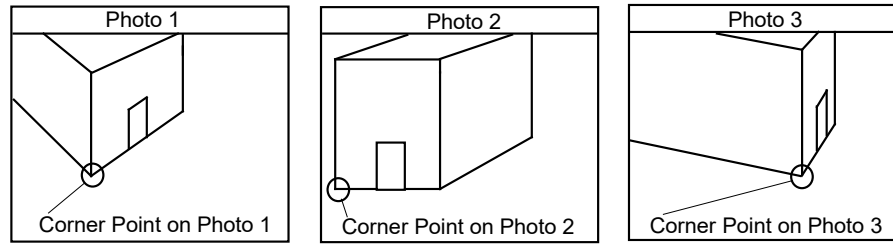
Photograph Marks (user identified positions on photographs) such as Point Mark, Edge Mark, Curve Mark, Cylinder Mark and Silhouette Mark, should be marked and referenced in each photograph that the object appears in.

Referencing is not used in single-photo projects.

In a multi-photo project, referencing is the key step needed to ensure the project will process properly and to ensure objects get computed with 3D positions.

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, select the source and destination photos, enter the single point sub-mode, mark a point in the source photo, and immediately mark same point in reference mode. 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. So a 3D Curve is created from two or more Curve Marks. So a 3D Cylinder is created from two or more Cylinder Marks. So a 3D Edge is created from two or more Edge Marks. So 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 it's color changes to white on photos. Representative colors can be selected on the *Preferences – Colors* tab.

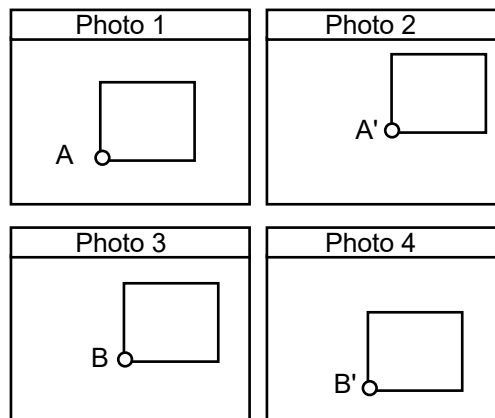
Referencing is Additive

- 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.

Referencing Marks

There are two methods for referencing Marks. There is the Reference Mode which is entered into using the *Reference Toolbar* 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 also drives you through referencing (mark by mark, and photo by photo) so there is less chance a mark will be missed (i.e. remain

unreferenced). Quick Reference 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 items marked on the same photograph, you can select and Quick Reference a marked item and a projection item on the same photo as long as that projected item does not already have a mark on the photo. Using projections allows you to do single photo referencing! The item must be 3D already for the projection to appear though.


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 Toolbar

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 Toolbar will appear.



The Referencing Toolbar controls how photographs are handled during the referencing process.

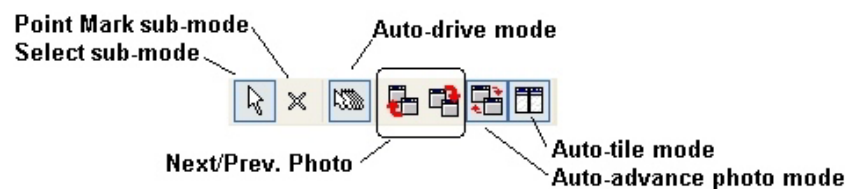
While objects are usually referenced across multiple photographs, all referencing actions take place between two photographs. These two photographs are called the "Source Photo" and the "Destination Photo".

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.

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 in the two drop down lists to the left of the Reference Toolbar - the source photo number on top and the destination photo number on the bottom. The drop down lists (once expanded) will either show all photos in the project or only the photos that are currently open depending on a setting in preferences. This option can be set under the general tab in preferences, by checking the "Show Only Open Photos in Referencing lists" checkbox.

There are seven buttons to the right of the photo lists.



They are:

- Selection Sub-mode: the default mode for referencing allows you to select objects in the Source Photo.
- Point Sub-mode: an optional sub-model that allows you to mark a single point in the Source Photo so it can be immediately referenced to the Destination Photo(s).
- Auto-drive: speed up the referencing process on oriented photos. See Auto-drive Referencing section below.
- Next Photo: Opens the next photograph in the Destination Photo drop-down list and makes it the Destination Photo.
- Previous Photo: Opens the next photograph in the Destination Photo drop-down list and makes it the Destination Photo.
- Auto-advance Photo: turns on auto-advance photo mode which will automatically advance to the next Destination Photo when there are no more objects remaining to be referenced.
- Auto-tilde: Automatically tiles the Source and Destination Photo beside each other (Source on the left). If you wish to view other windows (3D Viewer for example) or if you wish to quickly reference an object in multiple Destination Photographs you will want to turn this mode off.

Note 1: Auto-drive, Auto-advance, and Auto-tilt can be set to be off by default by settings on the General tab of the Preferences Dialog.

Note 2: If using Auto-advance Photo, a setting on the General Tab of the Preferences dialog controls whether photos are automatically closed when advancing to the next destination photo. This automatic photo closing can help save memory and time if you are stepping through many destination photographs.

Auto-drive Referencing

Auto-drive is a form of semi-automated referencing. It can improve efficiency considerably.

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.

When a Marked Point, whose underlying Object Point has no 3D location, is highlighted in the Source Photograph, a Reference Helper Line will appear in the Destination Photograph. The technical term for this line is the epi-polar line. The point you are referencing to should be somewhere along this line in the Destination Photograph. When referencing points or silhouettes, the potential matches are highlighted (see *Reference Helper Highlight*).


When a Marked Point, whose underlying Object Point is 3D, is highlighted in the Source Photograph, the cursor and image in the 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 recenter to the expected point location.

Reference Helper Highlight

During Referencing Mode when a point or silhouette is selected on the source photo, the best potential match(es) will highlight in the destination photograph. The color of the highlight can be set in *Preferences - Colors* tab with the “Potential Reference” color setting.

Referencing Steps

To reference objects across photographs:

1. Start Reference mode by selecting "Reference Mode" in the Referencing menu, or by pressing the Reference Toolbar button .
The Reference Toolbar will appear.
2. Pick the photograph which will act as the source of objects you will be referencing from. If this photo is not yet open, you may need to select it from the Source Photo drop-down list.
The source photo will be open and tiled on the left side of the work space.
3. Pick the photograph which has the marks you wish to reference to. Select it from the Destination Photo drop-down list.
*The destination photo will be open and will be tiled on the right side of the work space.
Note they will be automatically tiled only if Auto-tile is on.*
4. In the Source Photograph select any marks (Marked Points, Edge Marks, Curve Marks, or Cylinder Marks) that should be referenced. The Select All menu items may be used for this. See the section on Selection above.
The selected objects will become highlighted.
5. Move the cursor over to the Destination Photograph.
*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 Photograph, 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). When referencing points or silhouettes, PhotoModeler also highlights the most likely match using a **Reference Helper Highlight** color.*
6. 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 the 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.*
7. If the object that is highlighted in the Source is not visible in the Destination, click the right mouse button and pick "Next 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.
8. Continue step 6, until all the marks that are highlighted on the Source Photograph and are visible on the Destination Photograph, have been referenced.

9. Repeat steps 3 through 7 for different Destination Photographs. You may use the Destination Photo advance buttons on the Reference toolbar.

Note: 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*.

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 and Cylinders.

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.
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 Referencing 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 Reference 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 tab of *Preferences* Dialog) 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 bar 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" from the Marking menu.
2. Click this tool on the location to be marked.

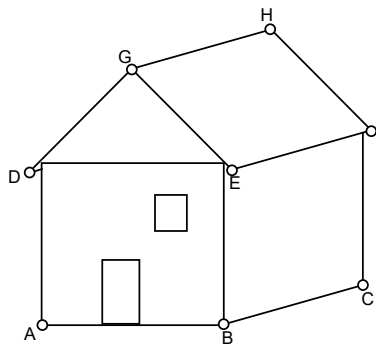
A Marked Point symbol will appear at the location marked. Each additional click will produce a new Marked Point symbol. The photograph being marked may be magnified to allow more precise marking.

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.

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 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. Much of the background covered here applies to the automatic case also.

Target Shape

The Sub-pixel Target Marker works with two different types of targets: Circular Targets and Template Targets. Circular Targets are solid circles or dots of contrasting color to the background (white dot on dark background for example). 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 a bit 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 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.

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.

The sub-pixel marker will accept a target down to five pixels in diameter in the digital image. For good accuracy you will usually want the target to be eight or more pixels across. You will need to plan how big to make the physical targets. Here is a calculation you can do to get an estimate:

min. target diameter = $8 \text{ pixels} * \text{maxDistance} * \text{formatSize} / (\text{imageSize} * \text{focalLength})$

where 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, and focalLength is the focal length of the lens. Making sure your units are consistent, let us do two examples:

I. Laser Printed Targets on a Building using a Digital camera

- maximum distance from camera: maxDistance = 15m = 15,000mm
- formatSize = 12mm
- focalLength = 15mm
- imageSize = 1200 pixels

therefore minimum target diameter = $8 * 15000 * 12 / (1200 * 15) = 80\text{mm}$. Print out a 16cmx16cm black area with a 8cm 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 sticky dots on a Car using a Film Camera and PhotoCD

- maximum distance from camera: maxDistance = 7m = 7,000mm
- formatSize = 36mm
- focalLength = 50mm
- imageSize = 3600 pixels

therefore minimum target diameter = $8 * 7000 * 36 / (3600 * 50) = 11\text{mm}$. So use the 0.5" circular stickable stationary labels (contrasting color to the car).

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.

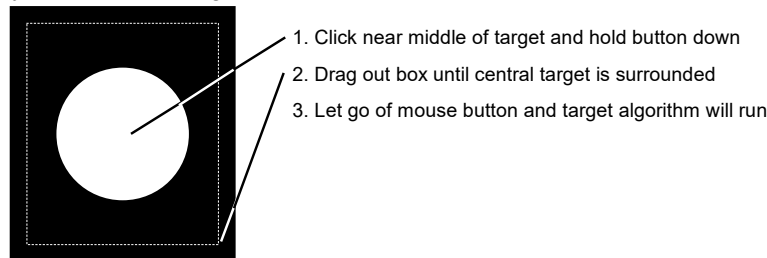
How to use the Sub-pixel Target Marker

There are two methods for manually marking of sub-pixel targets. The first is the Sub-pixel Target Mode found on the Marking menu and the second is the Target Mode on the *Control Points Dialog*. The Sub-pixel Target Mode is described here but much of this applies to how the Control Point marking works also.

When in Sub-pixel Target Mode the marking cursors (point and control) will look different.

To use either of 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.

Typical Circular Target



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 on the *Marked Visibility Tab* of the *Photo Control Side Bar* 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 looks like a plus sign (+) and the sub-pixel Control 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*.

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" tab, "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" tab, "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 subpixel marking is done on the green channel for colour images):

[General]

SubPixelMarkingColourChannel=1

(where 0=RED, 1 = GREEN, 2 = BLUE, -1 = convert colour 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.

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.*

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

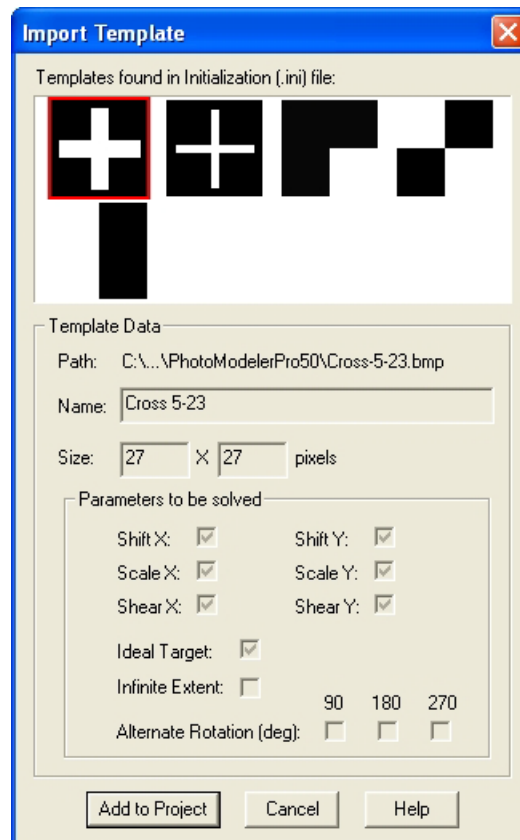
Natural targets are assumed to be already imaged by a typical camera. That is they have blur and maybe a bit of noise. In other words they are not ideal. The program marks natural targets a bit differently as it does not need to solve for the amount of blur nor will it solve for large changes in size 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 Define Project Target Templates dialog (which is opened from the Define Targets item on the Marking menu).

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.

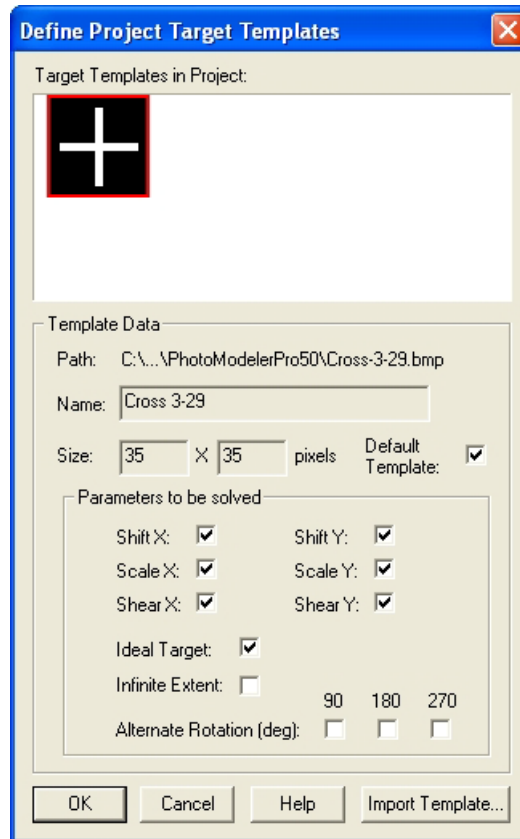
To import a template into a project, select a template image and click “Add to Project”.

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 from the Sub-Pixel Marking Mode sub-toolbar (if displayed) or from “Define Targets” under the Marking menu. The dialog shows all target templates loaded in a 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).

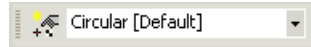
Some target shapes do not need to solve for all parameters. For example the Infinite Edge does not solve for any parameters in the direction of the infinite shape (e.g. the Y direction on a non-rotated infinite vertical edge template) because its shape does not change if you adjust it (i.e. scale or 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 tab) 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.

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 (PhotoModeler .ini file usually in the Windows directory).

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. The .ini file is stored in the Windows directory (e.g. c:\WinNT or c:\Windows) and it 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 Taking Photographs chapter - *Photography for Curves, Edges, Cylinders and Automatic Referencing*.

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 referecing Curve Marks on Photographs.

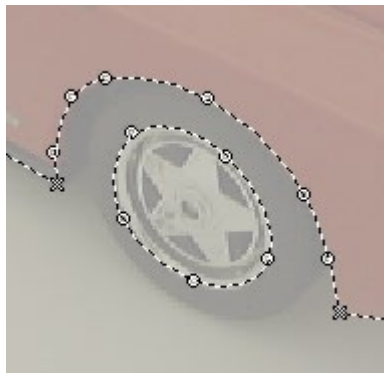
Marking Curves

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.

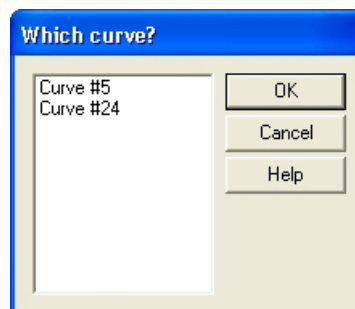
The Curve Right Menu will appear.

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 bar.

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 Taking Photographs chapter - *Photography for Curves, Edges, Cylinders and Automatic Referencing*.

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 through 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 Pro 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.

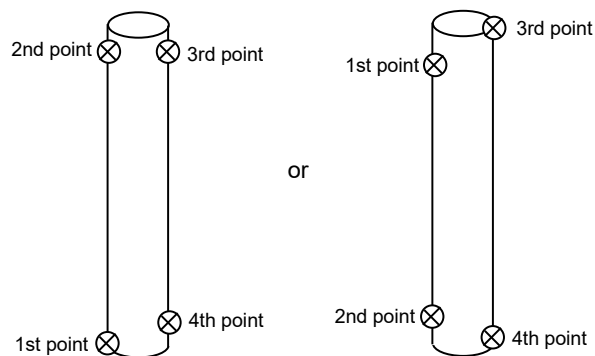
One cylinder point will be drawn and you will get a rubber band line.

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 Tabs* 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 point cloud 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
Point Cloud	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](#).

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 Point Cloud 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 "Create point cloud from selection" from the Surface sub menu or the Create Point Cloud 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: point clouds 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 a point cloud 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:

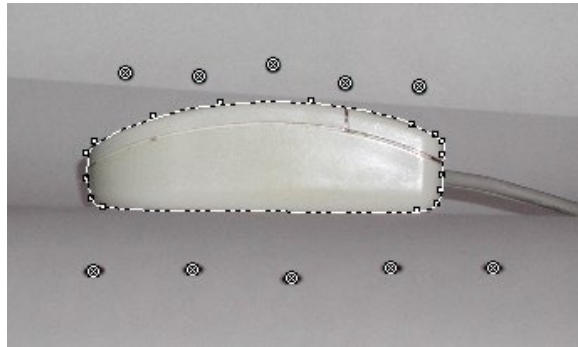
A silhouette surface is created from referenced marks and not from 3D objects like other surfaces. You draw a mark that defines the *silhouette* of the object in two or more photographs, and reference the marks together. If the photographs are *oriented* the surface will be computed and can be seen in 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, on the Surface sub-menu of the Marking menu (below the Mark Silhouette 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 (eg. 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 Tabs 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 trim sub-tab on the *Surface Properties* tab.

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 sub-tab of the *Surface Properties* tab. 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 and Using the Model

Processing


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

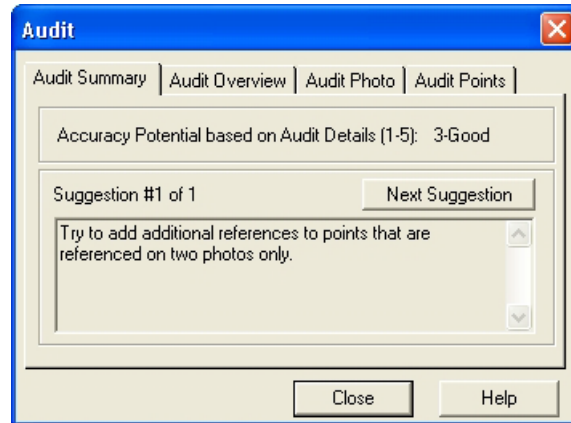
Auditing is the process of reviewing the project data that is important to the generation of the 3D model. The information provided by the Audit step can be instrumental in tracking down problems and in predicting the success of the processing stage. For identifying error in referencing specific points 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. See the section called *Taking Photographs* 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. See <i>Taking Photographs</i> section 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

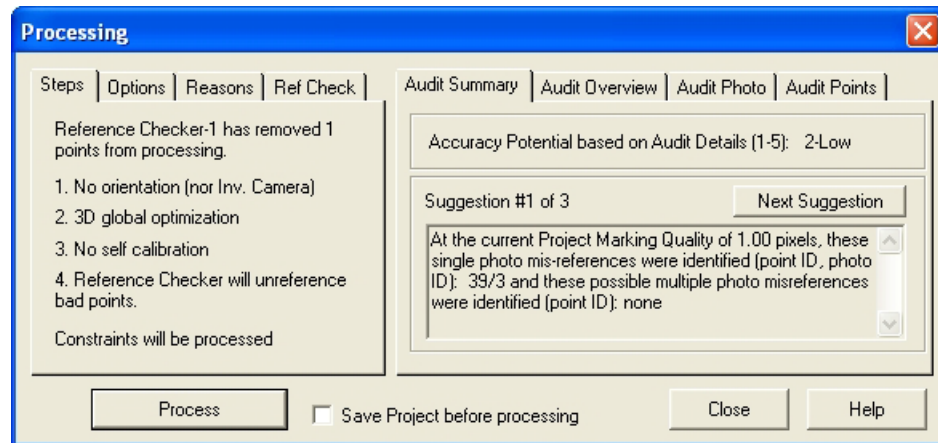
Adjustment and Processing

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.

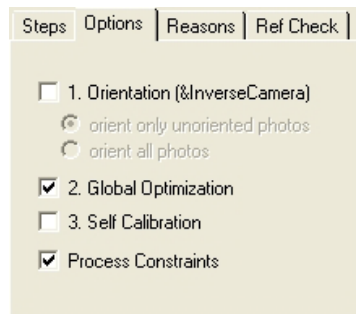
This dialog is split into two sections. The section on the right contains Audit information and is identical to that found in the *Audit Dialog* so it is not described here further.

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.
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.

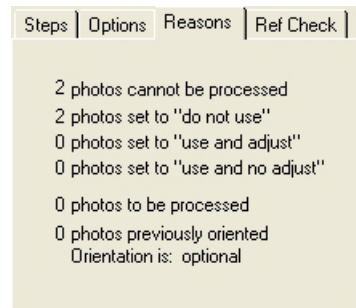
In most normal circumstances you can leave the default settings of this dialog and press the "Process" button to start the 3D Processing. There are various circumstances when you may want to do an Orientation only, a Global Optimization only, or ask for Self-Calibration or Field-Calibration.

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.

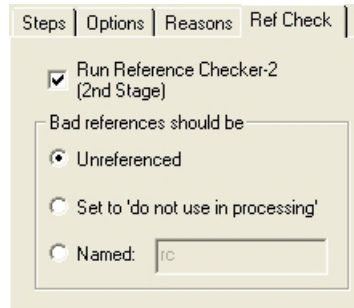
Global optimization and self-calibration can also be turned on and off. For single photo projects, only the first orientation stage is done so the later two stages will be off and disabled.



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.
- 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. 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

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 the *Preferences - Process* dialog 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.

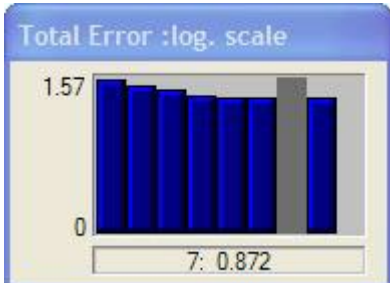
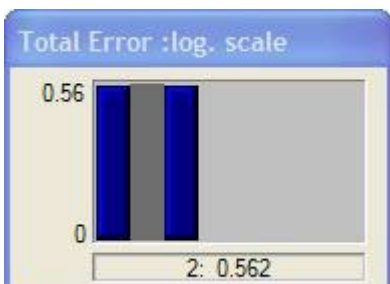
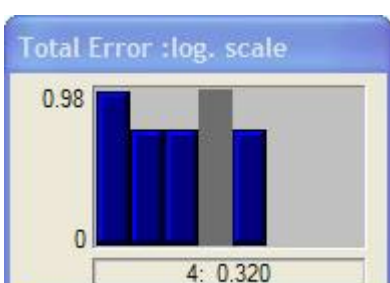
If the bars get bigger instead of smaller or if there are more than ten vertical bars of the same height, then PhotoModeler is having trouble solving. A few bigger bars are generally OK as long as the bars start to get smaller. If the bars do not get smaller then the processing is failing. In this case 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.

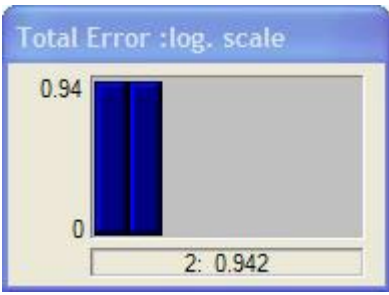
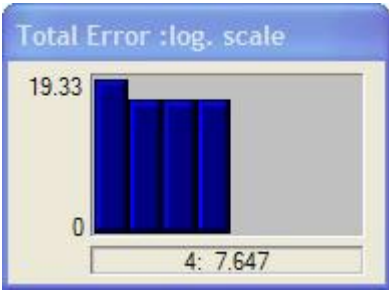
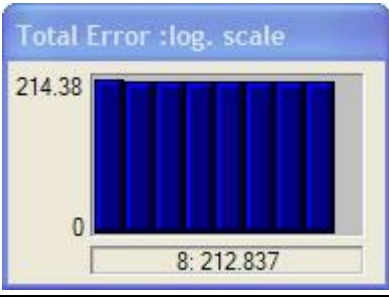
The Total Error Dialog will usually show two sets of bars separated by a gray area. The first set corresponds to the first Optimization phase and the second set of bars to the second Optimization and Self-Calibration phase. Sometimes the first vertical bar

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 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 screenshot shows a bar chart titled 'Total Error :log. scale'. The y-axis ranges from 0 to 1.57. There are seven blue bars of varying heights, with the last bar being the tallest. Below the chart, it says '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 screenshot shows a bar chart titled 'Total Error :log. scale'. The y-axis ranges from 0 to 0.56. There are two blue bars, both of similar height. Below the chart, it says '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 screenshot shows a bar chart titled 'Total Error :log. scale'. The y-axis ranges from 0 to 0.98. There are four blue bars. The first bar is the tallest, followed by three bars of decreasing height. Below the chart, it says '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>The dialog shows a single blue bar representing the total error. The y-axis is labeled 'Total Error :log. scale' with a maximum value of 0.94. The x-axis shows '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>The dialog shows four blue bars of varying heights. The y-axis is labeled 'Total Error :log. scale' with a maximum value of 19.33. The x-axis shows '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>The dialog shows eight blue bars of varying heights. The y-axis is labeled 'Total Error :log. scale' with a maximum value of 214.38. The x-axis shows '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>

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*.

In bundle adjustment processing we need to set a scaling value for all expected parameters precisions. This value is called sigma0 (σ_0) (or more properly a priori sigma0). In PhotoModeler we set this value to 1.0. When all input assumptions of the adjustment are met, the output sigma0 should be 1.0 also. This means that the total error value on the last iteration should be 1.0 if everything is perfect. What does it mean when the final total error is not 1.0?

Generally 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

input assumption. This assumption is given by the Preference Process / Default Point Standard Deviation Weights. For example, if the standard deviation for sub-pixel marked points is 0.1 pixels and the final total error of processing 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 the default in the Preference dialog. 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 0.1 (meaning the marking precision was actually 0.01 pixels). So this is similar to an upper limit.

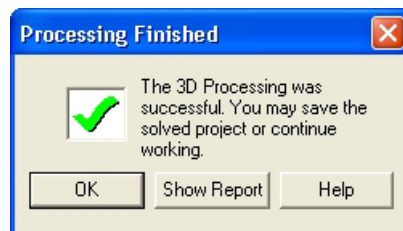
When the final total error is over 1.0 then some of the initial assumptions are incorrect. Those incorrect assumptions could be that the camera was properly calibrated, or that the marks are marked to the assumed precision (defaults are: 1.0 pixels (one standard deviation) for manually marked points 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 misreferenced 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 (but it does not mean that it can't be improved further), when the final error is between 1.0 and approximately 5.0 then perhaps our marking precision assumption is wrong or the camera is not well calibrated, and when the final error is 5.0 or greater we may have a poor camera calibration but as well possibly some gross errors such as misreferenced points or edges (or badly defined constraints). High total errors should usually be investigated (look for gross errors and consider how the camera was calibrated).

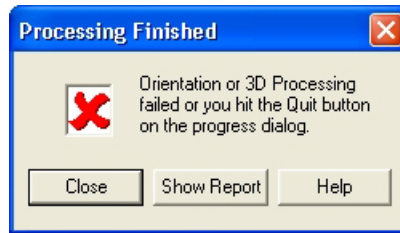
See also *Total Error Dialog*.

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.

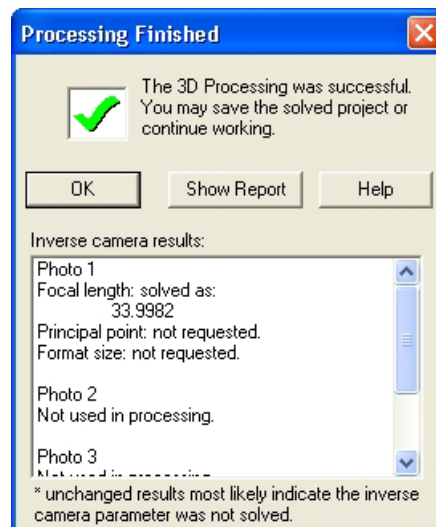


The dialog above appears when the processing was successful. When the OK button is pressed, this dialog and the Total Error dialog will close. If the Total Error Help button is pressed the *Total Error Dialog* help section is opened. When the Show Report button is pressed the *Project Status Report* will open.



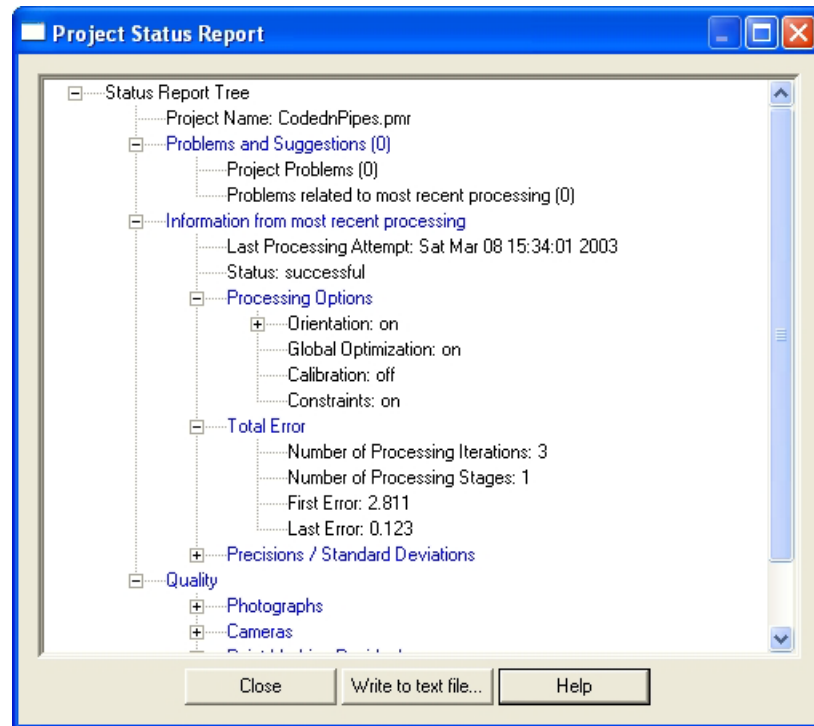
The dialog above appears when the processing was unsuccessful. When the Close button is pressed, this dialog and the Total Error dialog will close. If the "Troubleshooting Help" button is pressed the help file will open at the *Processing Troubleshooting* section. When the Show Report button is pressed 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 the *Photograph Properties Dialog*) 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*, *Advanced Troubleshooting Tools* 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.

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.

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 *Project Cameras Dialog*.

The Point Marking Residuals node (see also *Marking Residual Display* and *Marked Visibility Tab*) 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 Information Dialog* to review the parameters on individual cameras.
- *3D Viewer* to check currently oriented Camera Stations to see if they "make sense".
- *Photograph Properties Dialog* to temporarily remove one or more Photographs from processing.
- *Object Point Properties* to temporarily remove one or more Object Points from processing.
- *Constraint Edit 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 *Trouble-Shooting 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.

Advanced Troubleshooting Tools

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 Photo Control (see *Marked Visibility Tab*) 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, the *Marked Visibility Tab* provides a way to set exaggeration factor. 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.

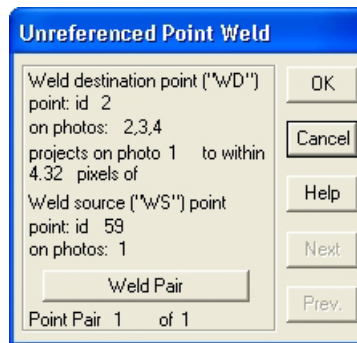
b) Referencing errors: if you have misreferenced a point (for example referenced the right headlight point on photo 1 to the left headlight on photo 2), the Marking

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 Point Projections in the *Projected Visibility Tab*, 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.

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):

1. no applied affine transform (project will be in an arbitrary coordinate system after processing),
2. 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
3. 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.

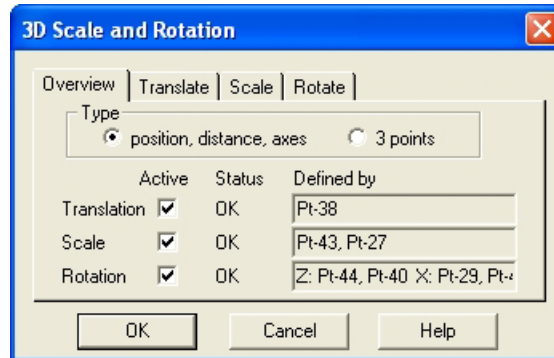
Scale: the scale component is used to define a known distance between two Points, between one Point and one Edge, between two Edges, between a Point and a Camera Station, or between two Camera Stations, so that you can determine absolute measurements in your model. The scale is arbitrary in PhotoModeler 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.

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.

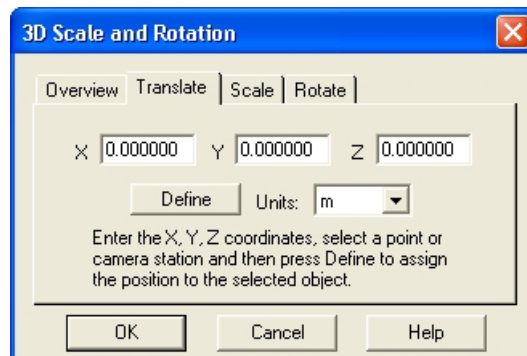
Note: If text is truncated in any of the text boxes, you can scroll text into view using the mouse (click and drag) or by using the arrow keys.

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.

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

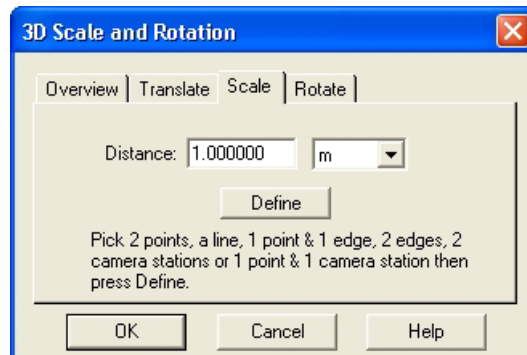
To add translation you need at least one Photograph, Point Table or 3D Viewer window open. You can open one of these while the 3D Scale Rotation dialog is open.

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.

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.

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. 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.

4. 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.

5. 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.

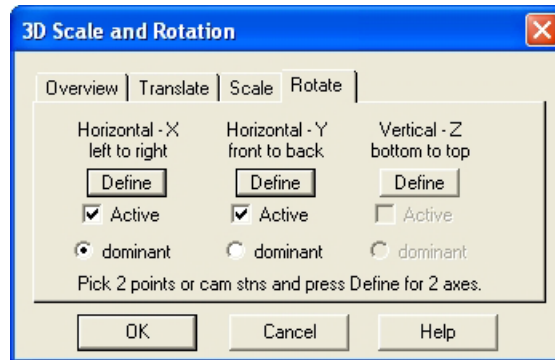
Setting Rotation

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.

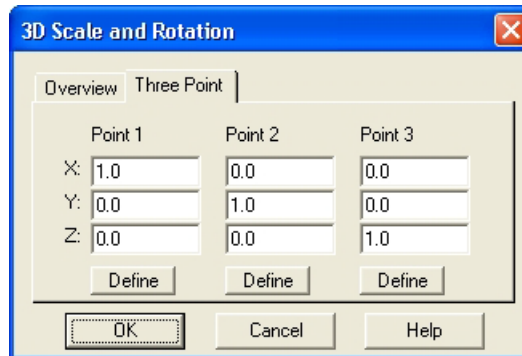
Note: If you have more than three known XYZ points with good spread over the model volume it would be a good idea to consider using Control Point Marking instead of Three Point Rotation. You will get better results if the control points are good quality. See the *Control Point Constraints* section.

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 hold the definition for points to be used in the three point scale and rotation.

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.

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. Select one model point on a photograph, 3D viewer or table.
The point will highlight in red.
5. 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.
6. 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.
7. Repeat steps 4, 5 and 6 to define the other two points.
8. Press OK
The Three Point Scale and Rotation is now defined. It will be used during Measure, 3D Export and Table display and export.


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*.

PhotoModeler allows measurement of point coordinates, line lengths, surface areas, edge end points, and cylinder attributes and other inter object attributes.

To Measure Features

1. Pick up the Measurement tool  from the toolbar or choose "Measure" from the Project menu.

PhotoModeler will open up the Measure Toolbar.

2. Click the mouse on a point, line, curve, edge, surface, cylinder 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 Measure Toolbar.

3. To measure another feature or set of features repeat step 2.

Measure Toolbar

Units: meters Selected: 1 point(s) X, Y, Z: -0.027 -0.006 -0.720 Precision: 0.0 0.0 0.0

The Measure Toolbar displays information and measurements of the user selected set of features.

Measurement Information

The top section displays the following information:

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	sum of line lengths, closest distance between lines, and angle between lines
3+ lines	sum of line lengths
1 curve	curve length
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	closest distance from point to line
1 point & 1 triangle surface	closest distance point to the plane defined by the Surface (note, only works with 3 point 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 and XYZ difference between the two stations' perspective centers
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)

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. 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. 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.

It should be noted that in these closest distance calculations the end points and vertices of the line and Surface are ignored. For example, a line segment from (0, 0, 0) to (1, 0, 0) and a point at (20, 0.1, 0) have a closest distance of 0.1 because it is the perpendicular distance to the line and not the line segment that is shown.

Note. This measurement works with three point surfaces only. A multi-point (four points or more (or curves or edges)) surface, if selected for closest-distance measurement, will display nothing.

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 Tabs* 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).

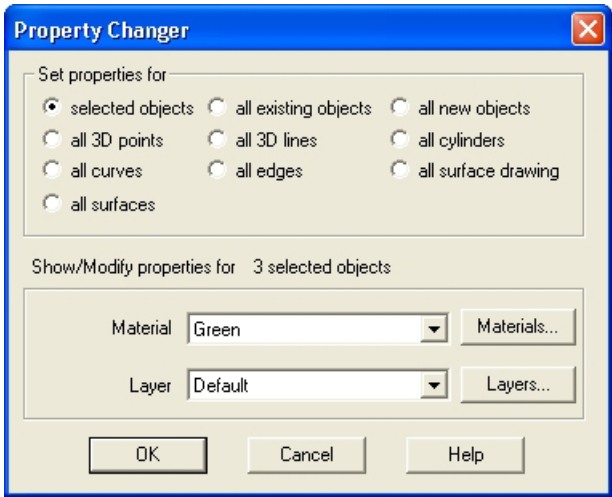
For further discussion of the meaning of precision refer to *Accuracy* and *Precision* in the Glossary.

Object Properties

All 3D Points, Edges, Lines, Curves, Surfaces, Surface Drawings and Cylinders 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 and for smoothing surfaces.

These Object Properties are not to be confused with the specific properties each object type has as described in the *The Objects That Make Up A Model* section.

Property Changer Dialog



The Property Changer Dialog is used to assign the Material or Layer of objects in the model.

The dialog is access through the Property Changer menu item of the Edit Menu.

The Property Changer Dialog has three sections. The top section controls what object or objects are to have the properties studied or modified. The second section in the middle informs you of how many objects are under study and their type. The third section is used to set the Material or Layer for the objects selected in the top section of the dialog. See also *Current Layer Tool* and *Current Material Tool*.

Object Selection

The top section of the Property Changer Dialog provides controls for selecting different sets of objects so their properties can all be changed at once. The options are:

selected object(s):	This is the set of objects that are current selected on all photographs.
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all objects:	This is all points, lines, cylinders, Surfaces, and surface drawings in the project.
all new objects:	This option does not affect any existing objects but sets the project default so that any newly created objects will get these attributes.
all 3D points:	All existing 3D points in project.
all edges:	All existing edges in project.
all lines:	All existing lines in project.
all curves:	All existing curves in project.
all cylinders:	All existing cylinders in project.
all surfaces:	All existing Surfaces in project.
all surface drawing:	All existing surface drawings in project.

When any of these selection options are chosen the bottom part of the dialog will show the Material and Layer for the set of objects if all objects in the set share the same. If the objects in the current selected set do not share the same attributes (i.e. some have Material A and some Material B) then the attribute will display as blank (i.e. Material drop down list will be blank).

Note: when the material is set to “White” (the project default) and the object selection is “all new objects” then any newly created Surfaces will be assigned to “SurfaceDefault” instead of “White” if SurfaceDefault exists.

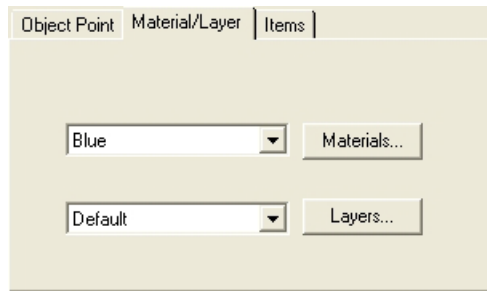
Setting Properties

When you want to change the Material or Layer for the set of selected objects you select the desired attribute from the appropriate drop- down list. If the attribute does not yet exist (i.e. you want a red Material that has not yet been defined and so is not yet in the drop down list) you press on the Materials button to define or modify materials or press on the Names button to define or modify Layers. The Materials button brings up the *Materials Dialog* and the Names button brings up the *Layer Dialog*.

When returning from the Materials Dialog or Layer Dialog, where you might have created a new attribute, you will need to pick the new attribute from the drop-down list if you want it assigned to the set of selected objects.

Note: Like most things in PhotoModeler, these properties are dynamically linked with other aspects of the projects. For example, if you change all cylinders to a red Material, then any open 3D Viewers currently showing cylinders will automatically update to show the new red material on the cylinders.

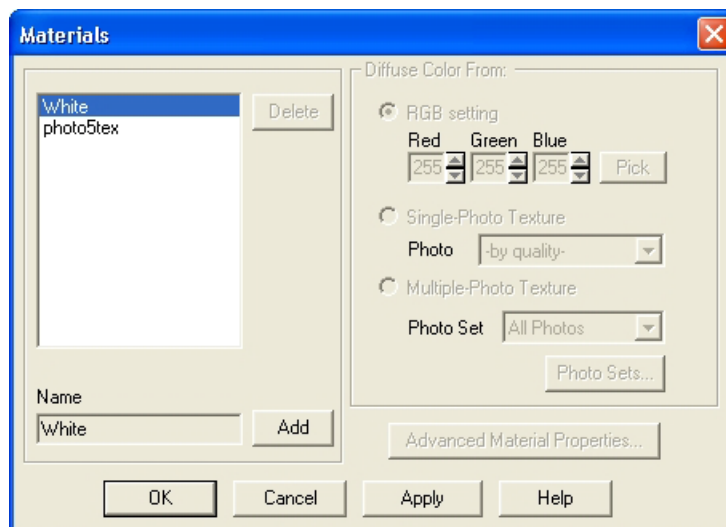
Material/Layer Properties



When one of the *Property Sheets* is opened there will usually be a Material/Layer tab. This tab shows the name of the Material and the name of the Layer for the 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 lists. Alternately the Materials or Layer button can be pressed to add new Materials and Layers. These buttons bring up the *Materials Dialog* and the *Layer Dialog* respectively.

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, the *Property Changer Dialog*, via the "Materials..." menu item in the Edit menu, or from the "Materials" button on any of the *Property Sheets*. 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% greylevel (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 *Photograph Properties Dialog*) 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.

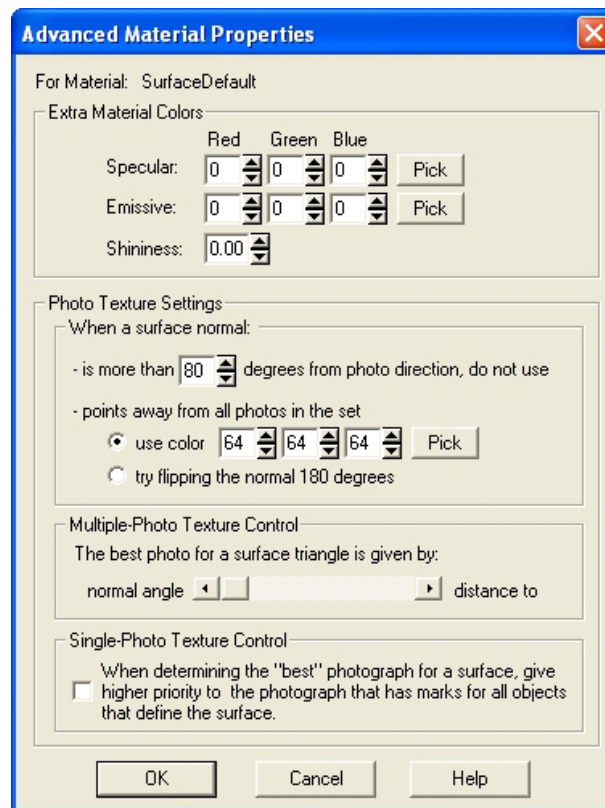
In some cases you will want to specify a specific photograph for a particular Surface or set of Surfaces. This is accomplished by defining a photo-texture Material with the Photo list set to the number of the desired photograph. Using this manual override gives you the flexibility when the "by quality" 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 Extra Materials Colors section adds three more properties to the Diffuse Color property found on the Materials Dialog.

The Photo Texture Settings section controls how photo-texturing is applied to surfaces.

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 the *Material Attributes* section for more information.

Surface Normal Settings

These settings define that is considered an inappropriate photo choice and what to do in that case. These settings apply to the Single-Photo Texture and Multiple-Photo Texture cases.

The setting “When a surface normal is more than N degrees from photo direction, do not use” defines the angle which is considered too shallow for appropriate texturing. For example, if N is 80 degrees, and a Surface or part of a Surface has a normal vector that points at an angle of 88 degrees from the direction of a particular photograph's view vector, then that photograph will not be chosen to texture that Surface or part Surface. As that angle between the surface normal and the view direction of the photograph's camera station gets large, less and less of the photographic data covers the surface and if it were used to texture it would be distorted and low quality. When the angle is greater than 90 degrees the surface faces away from the photograph.

The setting “When a surface normal points away from all photos in the set:” 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. There are two choices: a) use color, and b) try flipping the normal 180 degrees. The first choice will set up a fake textured material made of a solid color given by the r,g,b setting. The second choice rotates the normal of the surface 180 degrees and searches for a photograph again (to meet the angle constraint given above). This will not result in true textures for that surface but it might be suitable or good enough for your model. If a photograph still cannot be found after flipping the normal then the r,g,b setting given just above is used for the material for that part of the surface.

Multiple-Photo Texture Control

The Multiple-Photo Texture Control is a slider that controls how the multiple-photo texturing algorithm chooses which is the best photograph for a particular triangular face of the Surface.

When the slider is to the left, then only the angle of the surface normal relative to the photograph's view direction vector will be used. That is, that the photograph that points most toward the surface will be used over all other photos. In other words the surface is facing the photographing and not slanted away from it.

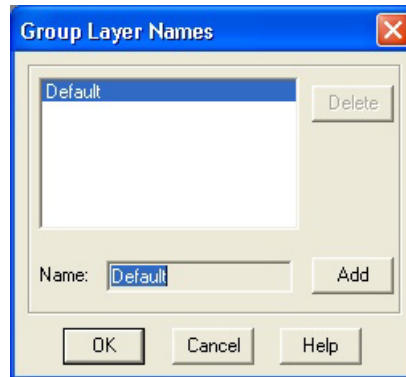
When the slider is to the right, then only the distance of the middle of the surface triangle to the photograph's camera station's perspective center is used to determine with photograph to choose. The photograph that is taken closest to the surface will be chosen.

If all the photographs are taken at similar distances from the object, then leaving the control to the left (to use normal angle) would give best result. If there are some photographs taken at much larger distance and you don't want them to be used, the slide the control a bit more to the right.

Single-Photo Texture Control

This property controls if a single-photo, 'by quality' texture ranks images that have marks for all objects defining the surface ahead of other images. This tends to pick better photographs for single photo textures.

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 through the *Property Changer Dialog*, from the "Layer" button on any of the *Property Sheets*, and from the Layer toolbar. 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.

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 Configuration Dialog* takes care of that.

Photo Projections

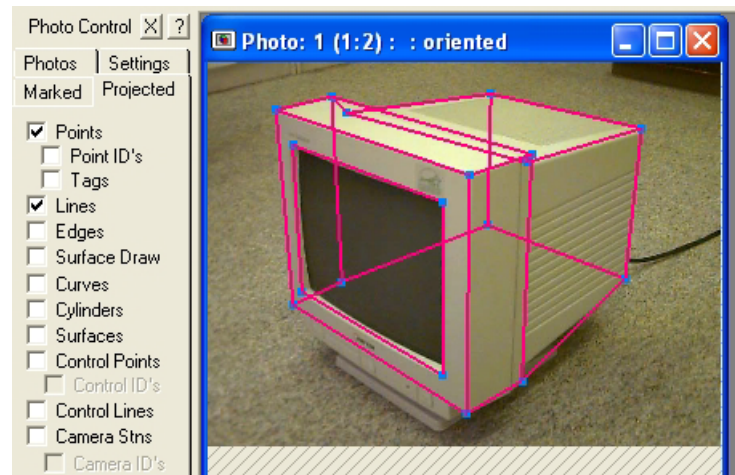
A projection is 2D view of the current 3D model data such that the viewpoint and view parameters exactly match the camera station and camera of the photograph they are being displayed on.

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 are controlled by the *Projected Visibility Tab*.

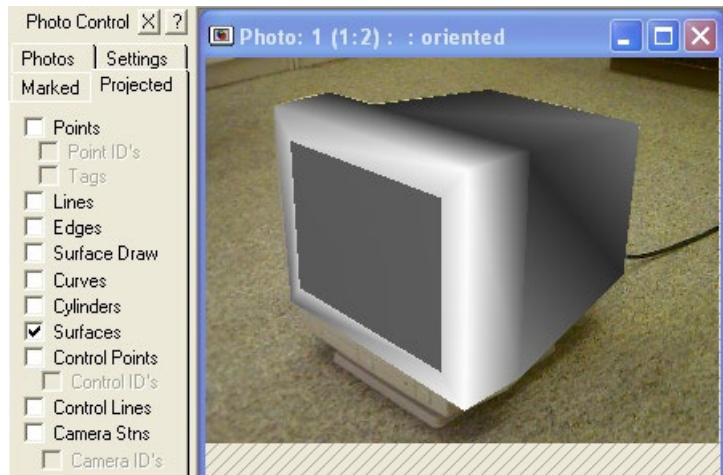
The following shows the visibility set so all normal marks are off and the Points and Lines Projection visibility is on. You can see the whole wire frame model of the CRT monitor including those lines behind. This view quickly tells us that the 3D and camera station solution for this photograph are reasonable 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 the *Preferences* dialog. 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 Photo Control Side Bar Settings Tab.	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.

Once a project has been processed and the Camera Stations have valid positions, PhotoModeler will keep a 3D Point's location up-to-date on the fly. In other words, any change to the project which effects the position of a 3D point is immediately reflected in that point's 3D location. This can be seen in the 3D Viewer. For example, bring up the 3D Viewer and a photograph and tile side by side. Grab a point on the photograph that is referenced and appears in the 3D Model Viewer. As you drag the Marked Point you can see what effect this has on the 3D position of the underlying 3D Point.

To open a 3D Viewer:

1. Ensure the project has been processed at least once.
2. Select the "Open a 3D Viewer" menu item from the Project menu.
A 3D Viewer window will appear.
3. To close the 3D Viewer when done, use the X close button in the upper right of the window.

Multiple 3D Viewer windows can be opened at once. Each of the open 3D Viewers can be showing different contents and different view points. Once the 3D Viewer options have been chosen and that dialog closed, the view appears. The view direction can be manipulated with a number of controls described below.

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 *Model Centering* section below.

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 Mode* tool is also available for the 3D Viewer.

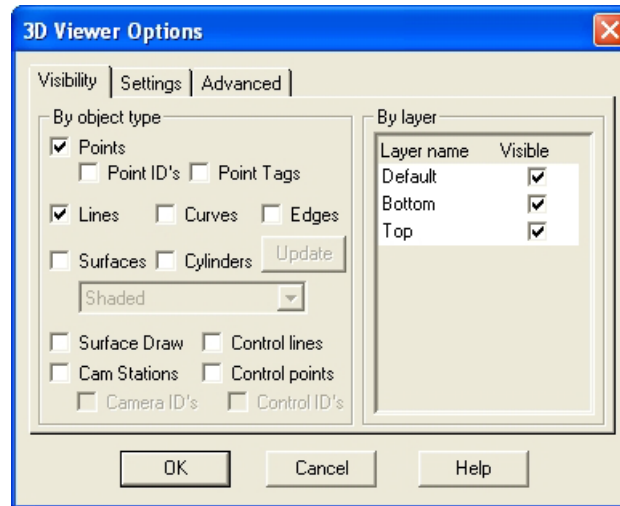
3D Viewer Options Dialog

The 3D Viewer Options Dialog controls the display of one 3D Viewer window. This dialog appears when a 3D Viewer window is first opened so initial settings can be made and when the "Options" button in the bottom right corner of the 3D Viewer is pressed.

This dialog is divided into three tabs. The *3D Viewer Visibility Tab* controls what objects will be shown in the associated 3D Viewer window. The *3D Viewer Settings Tab* controls various settings that affect how these objects will be displayed. The *3D Viewer Advanced Tab* controls some less used settings such as backface culling, stereo, and texture size.

When the OK button is pressed, all the new options from both tabs will take effect on the associated 3D Viewer window. If Cancel button is pressed instead no changes will be made.

3D Viewer Visibility Tab



The Object Types check boxes in the 3D Viewer Options Dialog visibility tab control whether a particular type of object will appear in the 3D Viewer window if any of that type of object exist in the project and have had their 3D position calculated.

Points	When this box is checked, all 3D Points in the project that have solved xyz positions and appear on 2 or more "in-use" photos will be drawn as small squares using the diffuse color of their assigned material.
Point IDs and Tags	When these boxes are checked, all 3D Points in the project are displayed with their ID number (perhaps user name too) or a 'T' for tag respectively. 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 'Points' 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..
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.

Surfaces & Photo Texture	<p>When this box is checked, all Surfaces that have solved 3D positions will be drawn using the display style selected in the drop down.</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>
Cylinders & as Centerlines	<p>When this box is checked all Cylinders that are solved will appear. If "as centerlines" is checked on the Settings Tab then they will be drawn as lines down their centerline otherwise as full cylinders. Cylinder can be textured also so the Photo Texture comments above apply. When the "as centerline" setting is on, this takes precedence over textures.</p>
SurfaceDraw	<p>When this box is checked all Surface Drawings (lines and curves) that appear on 3D Surfaces will appear as vector lines in their assigned diffuse material.</p>
Curves	<p>When this box is checked all Curves that have complete 3D solutions will be displayed as vector tessellated line segments. How fine this tessellation is can be controlled on the <i>Preferences</i> Dialog.</p>
Control Points	<p>When this box is checked all Control Points that have been imported are displayed in their 3D position. These are not the points generated by control point marking but the real world 3D co-ordinates as indicated in the control point dialog.</p>

Control IDs	When this box is checked all Control Points that have been imported will be shown with their imported or assigned name. Available only when 'Control Points' is checked.
Control Lines	When this box is checked all Control Lines that have been imported are displayed drawn between their two Control Point end positions. These are not the lines generated by line marking but the real world 3D lines as indicated in the control point dialog.
Camera Stations	When this box is checked all solved camera station locations (the position of a camera when it took one of the photographs in the project) will appear as small camera symbols showing the true relative position and orientation relative to the model.
Camera IDs	When this box is checked the ID of Camera Stations is displayed in text next to the Camera Station symbol. This option is only enabled when Camera Stations are visible. If you notice that the text ID offset location from the camera symbol needs to be increased or decreased, you can edit the "CSIDOffset" setting in the "ProjectViewer(3D_Viewer)" section of the ini file. Note that if the setting is not present, you will have to add it to the ini file in this section.

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.

The Layer Visibility section of the dialog allows you to turn on/off all objects contained within a specific layer. Objects will only be displayed if both their object type check box and the layer they are part of are set to be visible.

Note: all objects will be rendered in the 3D Viewer in a color defined by their Material. The default Material for all objects is white.

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 smooths that transition so it is not as obvious.

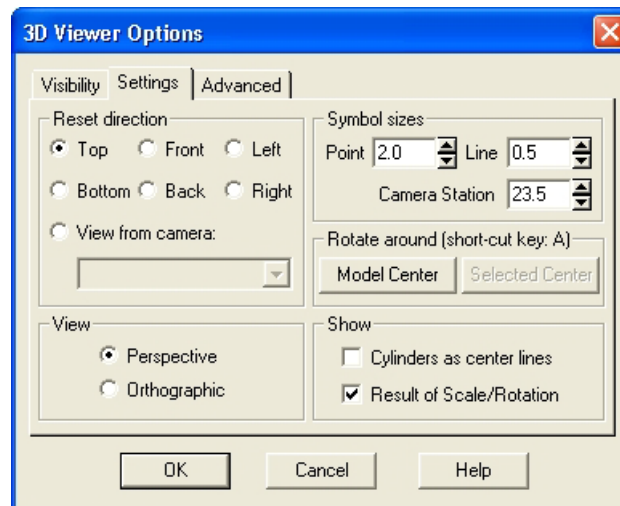
Next to the Surfaces check-box in the 3D Viewer Options dialog is an "Update" button. This button becomes available when Quality Textures are turned on. Pressing Update will cause the textures to be recomputed.

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 does not recompute the textures on all changes in the model. When the textured model becomes in whole or in part untextured (while surfaces) you can enter the Options dialog and press the Update button to have the textures recomputed again.

Note that when quality texture mode is turned off, no update is needed because all changes happen on the fly.

There are settings in the Preferences dialog that control the processes that are carried out during quality texture creation. See *Preferences - Export / Textures*. For example, feathering for quality textures in the 3D Viewer may be turned off by default.

3D Viewer Settings Tab



This tab controls various settings that affect how the 3D viewer operates and displays objects.

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

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.

Symbol Sizes

PhotoModeler uses some heuristics to display the real-world size of the point symbols, lines, edges, curves and camera symbols. These heuristics 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.

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.

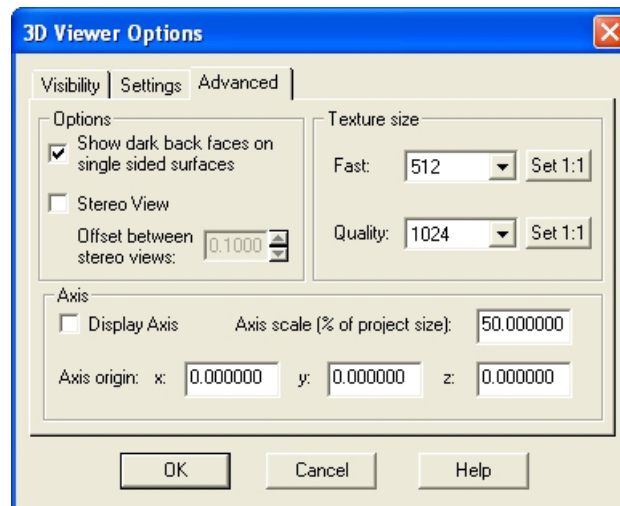
Show

The settings in the show section control how objects are displayed.

If “Cylinders as center lines” is checked when Cylinders are selected as an object type then Cylinders will be drawn as lines down their centerline otherwise they are displayed as full cylinders.

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).

3D Viewer Advanced Tab



The Advanced Tab of the 3D Viewer Options Dialog controls four lesser used features.

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 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. The “Set 1:1” buttons calculate what texture map size would give you one texture pixel to one photograph source pixel. This would be close to the optimal size for quality.

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 downsampled by the video driver. This will degrade the quality and increase the setup time. Contact your video card manufacturer to determine the maximum size.

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).

The Axis section controls whether the X, Y, Z axes are displayed in the 3D Viewer window. Check the Axis box to turn on the display. 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.

Video Export

When the PMV Module is installed and a PMV project is loaded the 3D Viewer Options Dialog shows another tab called ‘Video Export’. See *PMV 3D Viewer Animation Export* for more information.

Tables

Tables are similar to spread sheets with rows and columns of data. The tables in PhotoModeler are:

- the Photo Table,
- the Point Table,
- the Edge Table,
- the Curve Table,
- the Surface Table,

- the Silhouette Table, and
- the Cylinder Table.

The *Photo Table* is used to view and manipulate photograph, camera and camera station data and is described in another section in the manual.

The *Point Table* is used to view the properties of Object Points and is described below.

The *Surface Table* is used to view the properties of Surfaces and is described below.

The *Silhouette Table* is used to view the properties of Surfaces and is described below.

The Edge, Curve and Cylinder Tables are all similar and are described in the *Other Object Tables* section below.

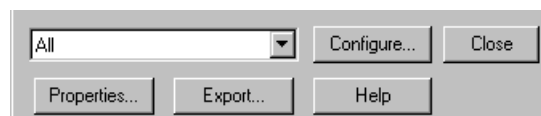
Every table in PhotoModeler looks similar and can be configured similarly. All tables have a common set of controls at the top. They are described in the next section called *Table Top Dialog*.

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.

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 Configuration Dialog.

When a vertical or horizontal scrollbar is visible, you can split your table into separate 'scroll regions' which enable you to keep portions of the table visible at all times. At the top of the vertical scrollbar or the left of the horizontal scrollbar is a small rectangular graphical element. As you move your mouse over the area between this small rectangle and the top or left scroll button with the arrow, your mouse cursor will change and indicate that you can click and drag a new scroll region into place. While your cursor is in this state, hold your mouse button down and drag it to create a new scroll region and split your table. This is a very useful tool if you want to keep portions of your table (such as the ID column or a certain row) visible while you scroll other portions of the table.

Table Top Dialog



All Tables in PhotoModeler have a common set of controls at the top. These controls are laid out the same way and have similar function in all Tables. Those controls are shown above.

The first control is the drop down list box of all current Table Configurations. A Table Configuration stores the type and order of the columns of data in the table. These can be fully configured by the user. Each table type (photo, point, edge, curve, and cylinder) has its own independent set of configurations. To switch the current view of the open Table to a particular configuration, pick it from this list.

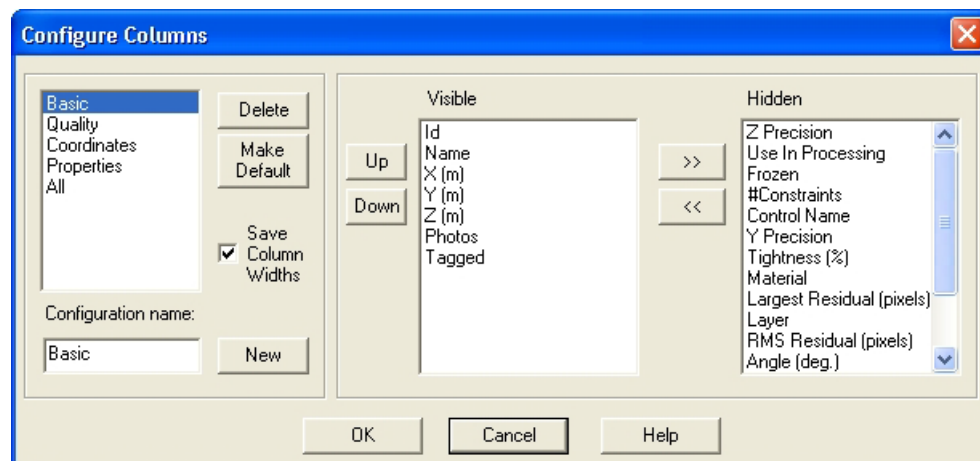
To add, remove or change configurations for this table, press the "Configure..." button. This will bring up the *Table Configuration Dialog* which is described below.

The "Properties..." button will be active when one or more items are selected in the table's data section. When pressed, this will bring up the property sheet showing the properties of the currently selected item(s).

The "Export..." button brings up the *Table Export Dialog*.

The "Help" button brings up the help file and the "Close" button has the same operation as the "X" button in the upper right - it closes the table.

Table Configuration Dialog



The Table Configuration Dialog is opened by pressing the "Configure..." button on any of the Tables (Photo, Point, Edge, Curve, and Cylinder).

This dialog provides the capability to configure which types of data are displayed on the particular table. The types of data are organized by columns and a column can be included (or not) and can be placed in a particular order.

Sets of columns and their order can be saved as a named configuration which is quickly accessible from the drop down list at the top of each table.

The dialog is split into two sections. The section on the left is used to add and remove named configurations and the section on the right is used to add and remove columns from the selected configuration.

To add a new configuration:

1. Press the "New" button.
A default configuration with name "New Layout" will be added.
2. In the Configuration Name edit box type in a new name.
3. In the right section modify which columns you wish to appear and in which order. See "To modify an existing configuration" below.
4. Press the OK button.
The dialog will close and you will be returned to the Table. You can then select the configuration from the drop down list if you want to see the results.

To delete a configuration:

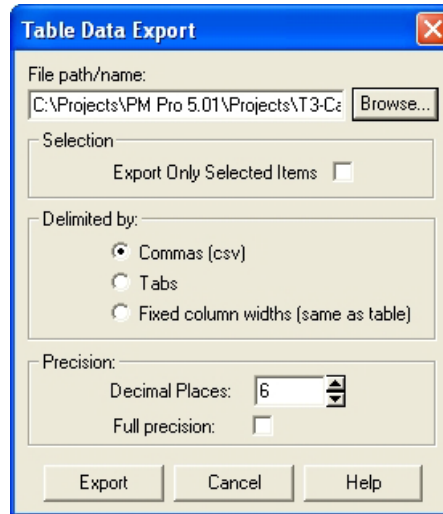
1. Select the name of the configuration you wish to delete from the top left list box.
2. Press the Delete button.
3. Press the OK button.

To modify an existing configuration:

1. Select the name of the configuration you wish to delete from the top left list box.
The current settings for this configuration will be displayed on the dialog.
2. There are a number of modifications you can now make.
3. To make this the default configuration (which means it will be the configuration to appear whenever this table is first opened), press the "Make Default" button.
The configuration name will jump to the top of the list. The configuration shown at the top of the list is always the default one.
4. To change whether this configuration saves its column widths (which means that any change you make to the width of a column while viewing, is saved for the next time this configuration is displayed) check or uncheck the "Save columns width" box.
5. To add to the columns of data that are displayed select one or more column names in the Hidden list and press the "<<" button. You can select multiple items by using either the shift or the ctrl key modifiers.
The list of hidden and visible columns will update to show the new settings.
6. To remove columns of data that are displayed select one or more column names in the Visible list and press the ">>" button.
The list of hidden and visible columns will update to show the new settings.
7. To change the order of the columns displayed select one or more column names in the Visible list and press either the "Up" or "Down" buttons. The order of the items in the Visible list is the order they will appear on the table (top most in the Visible list show as left most on the table).
The list of hidden and visible columns will update to show the new settings each time the "Up" or "Down" button is pressed.
8. Press the OK button.

The configurations for Photo, Point, Edge, Curve and Cylinder are all stored separately and do not affect each other. These configurations are stored in the ini file.

Table Export Dialog



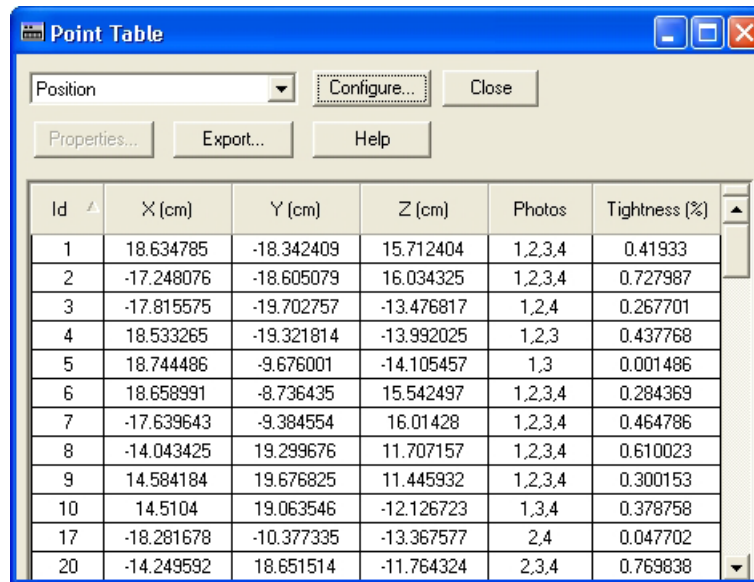
Export will write the contents of the currently visible Table data contents to an ASCII text file. You can set various export options in the Table Export Dialog, such as how the table's values will be separated in the text file (either by commas, tabs or the approximate column widths as visible in the table), the number of decimal places up to 13. The table export will use the same column order that is visible in the currently selected configuration in PhotoModeler.

Select or create a file to export to (click Browse... to change the directory or file name), set the other export options and click Export. A message box will appear when the export has completed and will remind you of the location of the exported file.


If you only want to export selected items, check the "Export only selected Items" checkbox, otherwise all items will be exported in the specified format. If nothing is selected in the table this checkbox is disabled.

These files are suitable for import into other software packages (such as a spread sheet program like Excel (r)).

Point Table



Id	X (cm)	Y (cm)	Z (cm)	Photos	Tightness (%)
1	18.634785	-18.342409	15.712404	1,2,3,4	0.41933
2	-17.248076	-18.605079	16.034325	1,2,3,4	0.727987
3	-17.815575	-19.702757	-13.476817	1,2,4	0.267701
4	18.533265	-19.321814	-13.992025	1,2,3	0.437768
5	18.744486	-9.676001	-14.105457	1,3	0.001486
6	18.658991	-8.736435	15.542497	1,2,3,4	0.284369
7	-17.639643	-9.384554	16.01428	1,2,3,4	0.464786
8	-14.043425	19.299676	11.707157	1,2,3,4	0.610023
9	14.584184	19.676825	11.445932	1,2,3,4	0.300153
10	14.5104	19.063546	-12.126723	1,3,4	0.378758
17	-18.281678	-10.377335	-13.367577	2,4	0.047702
20	-14.249592	18.651514	-11.764324	2,3,4	0.769838

The Point Table displays information about Object Points in the currently open Project. The Point Table is opened from the Project Menu / "Open a Point Table" item, or from the Table toolbar button  and its sub-menu.

See the [Tables](#) and [Table Top Dialog](#) sections above for background information and details on the top part of the table.

There are many different properties of Object Points that can be displayed in this table and all can be exported to a Text file using the Export button.

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 keep 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) 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, trouble shooting and for export.

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.

Surface Table

The Surface Table displays information about all surfaces in the currently open Project. The Surface Table is opened from the Project Menu / Tables sub menu/"Surface Table" item, or from the Tables toolbar button and its sub-menu.

See the Tables and Table Top Dialog sections for background information and details on the top part of the table.

There are many different properties of Surfaces that can be displayed in this table and all can be exported to a Text file using the Export button. The Surface table lists each surface's ID, whether it has a 3D position, the Surface Type, the number of Defining Objects, 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 Properties button) or view the corresponding projections using the "Expand Selections to all Windows" ("W" key) command.

Silhouette Table

The Silhouette Table displays information about all silhouettes in the currently open Project. The Silhouette Table is opened from the Project Menu / Tables sub menu/"Silhouette Table" item, or from the Tables toolbar button and its sub-menu.


See the Tables and Table Top Dialog sections for background information and details on the top part of the table.

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 the Properties button) 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.

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. These tables are opened from the Project Menu / "Open a ____ Table" item, or from the Table toolbar button  and its sub-menu.

See the *Tables* and *Table Top Dialog* sections above for background information and details on the top part of the table.

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.

All these items can be exported to a Text file using the Export button.

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) or view the corresponding marks using the "Expand Selections to all Windows" ("W" key) command.

These tables are a key capability in PhotoModeler for review, trouble shooting and for 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

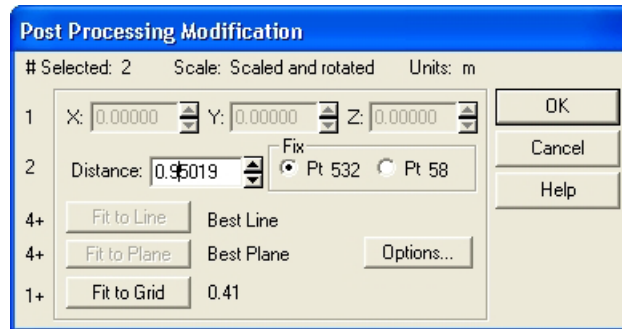
If the 3D model you have created in PhotoModeler has low accuracy or poor shape, you can improve it by doing one or some combination of the following:

- 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*, *Taking Photographs* and *Marking Points*),

- Add more photographs to the project with the aim of improving photograph overlap (See *Audit* and *Taking Photographs*),
- 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 Pro 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.

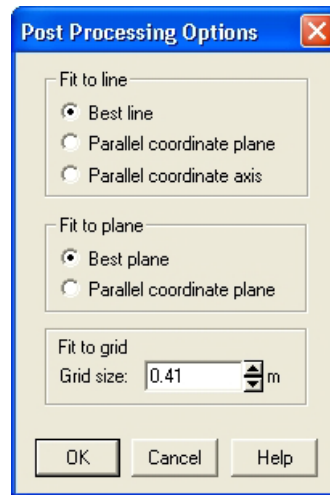
Fit to Plane

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 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

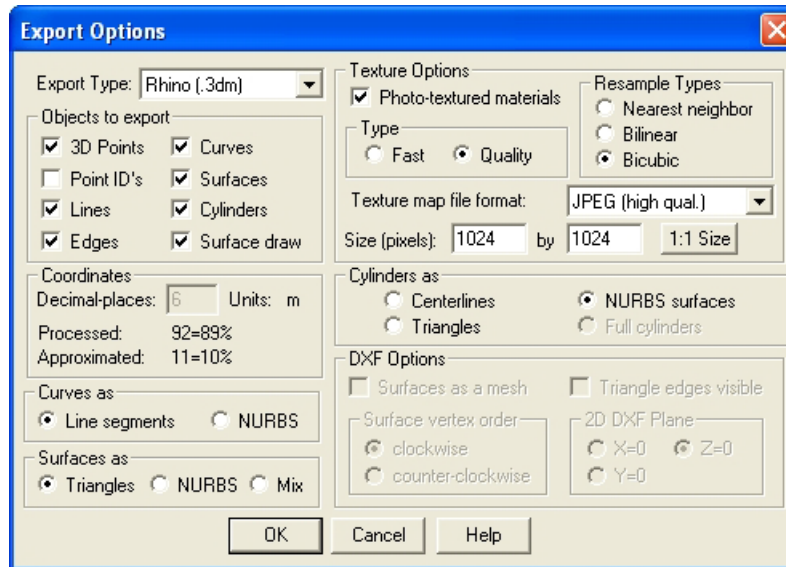
PhotoModeler exports data in the following 3D file formats: DXF, 3DS (3D Studio), OBJ (Wavefront), X (Microsoft DirectX), VRML 1 and 2 (Virtual Reality Modeling Language for the Web), IGES, and RAW (raw coordinate data). PhotoModeler can also export the 3D data in a model projected onto a plane in 2D. 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 and Maya Script format.

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 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. Other data types (surfaces, curves, etc.) can be exported to Maya using one of the other formats.

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.

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), and Maya (.ma) .

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.

	DXF	3DS	VRML	OBJ
3D Points	yes			yes
Point IDs	as text			
Lines	yes		yes	yes
Edges	as lines		as lines	as lines
Curves	yes ⁴		yes ⁴	yes ⁵
Surfaces	yes ¹	yes ¹	yes ¹	yes ²
Cylinders	yes ⁶	yes ⁶	yes ⁶	yes ⁶
Surface Draw	yes		yes	yes
Photo-Textures		yes	yes	yes ³

	IGES	STL	3DM	RAW	Maya
Points	yes		yes	yes	Yes ¹⁰
Point IDs			yes ⁹		
Lines	yes		yes	xyz's	
Edges	as lines		as lines	xyz's	
Curves	yes ⁸		yes ⁵		
Surfaces	yes ⁷	yes ¹	yes ²	xyz's	
Cylinders	yes ⁷	yes ¹	yes ⁶		
Surface Draw	yes		yes	xyz's	
Photo-Textures			yes ³		

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 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

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 Object Properties (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 (eg. 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.

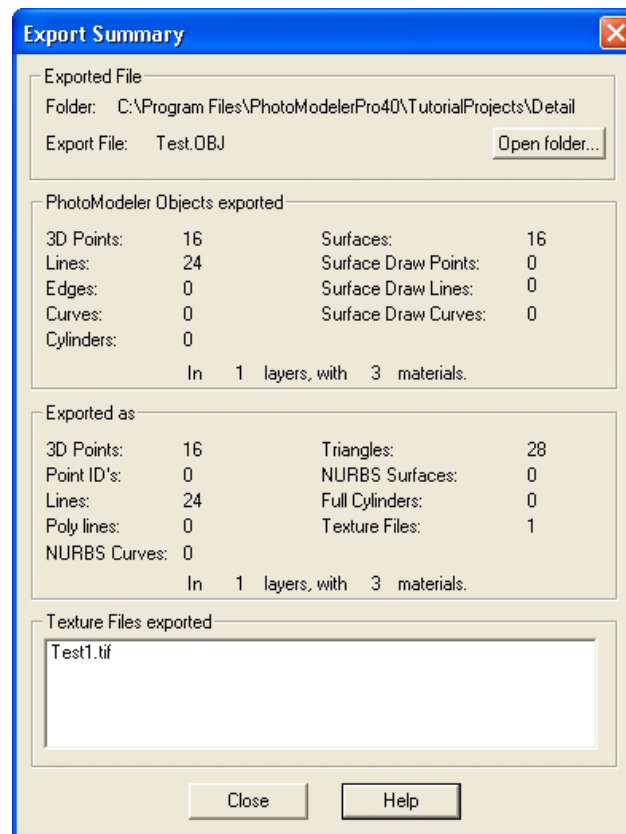
"Triangle edges visible" is used to specify if the "visible" flag is to be set when exporting the edges of the 3D triangular faces. Without this setting some packages will import the PhotoModeler created DXF file with faces but none of the faces will appear (they will be there, just not visible).

"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.

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. An "Open folder" button brings up a File Explorer pointed to that folder/directory so you can access the files just created.

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.

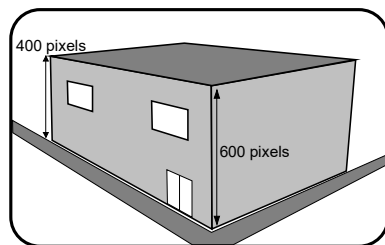


Photo Texture of wall will have variable resolution

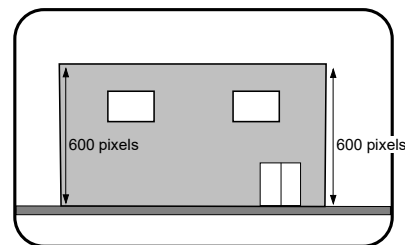


Photo Texture of wall will have constant resolution

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 contrasty 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.

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 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.

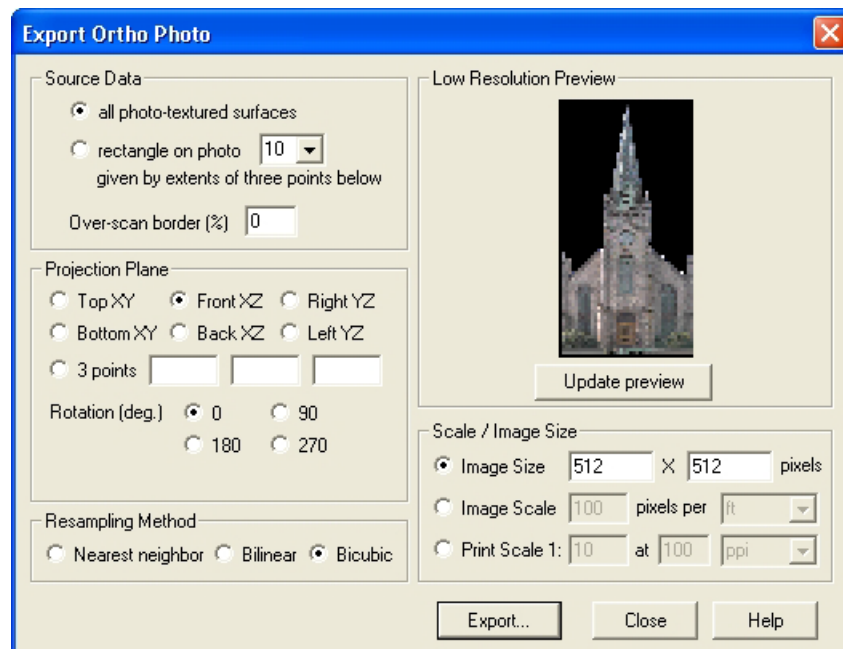
See the *3D Model Export* section for a method for extracting textures tied directly to the 3D model.

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 *Object Properties* and *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	<ul style="list-style-type: none"> - Requires the project have surfaces and that they have photo-textured materials with appropriate parameters. 	<ul style="list-style-type: none"> - 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 $\text{initial image width} * \text{overscan} / 100$. 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 Tabs* 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.

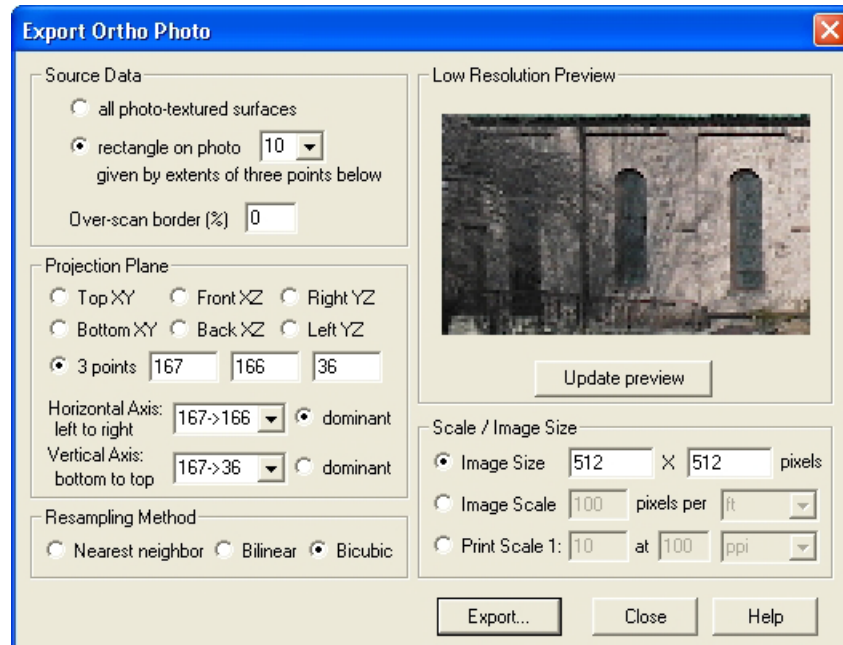
When an edge is chosen the point displayed will have an 'a' or a 'b' appended. So 14a means the first point of edge with ID 14. Object Points and Edge Points can be mixed. So the three edit boxes might contain: 12, 14a, 14b which means that the projection plane is defined by Object Point 12 and both 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 modelling 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:



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 have been chosen.

Ortho Photo Preview and Adjustment

The third step to create an ortho-photo is the review of 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.

PhotoModeler ASCII Export Format

The File menu / Export Text file item produces a file with much of the project data in an ASCII format. This format is not generally used and is being phased out of the product. It remains for existing PhotoModeler customers. Most information it contains is available in Tables or the Status Report. The only information it contains that is not currently exported elsewhere are the Marked Point x,y locations. If you need further detail please contact Eos Systems or your reseller.

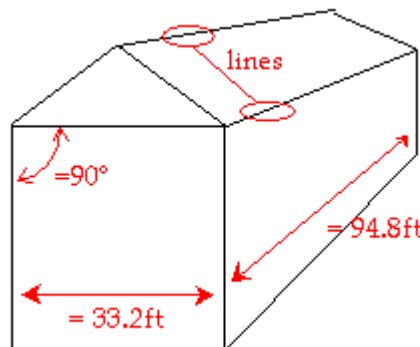
Working with Constraints

A "Constraint" is a piece of additional information the user knows (or is willing to assume) that is provided to PhotoModeler to help solve certain problems.

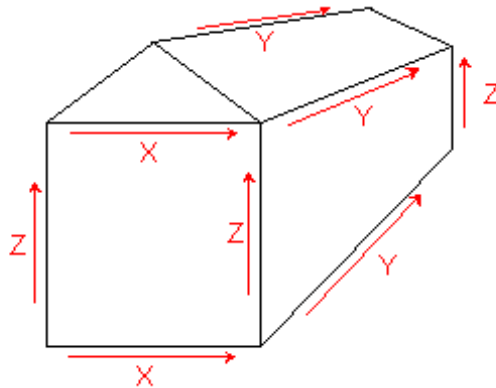
There are three main categories of Constraints in PhotoModeler. They are: Multi-photo Constraints, Axes Constraints, and Control Point Constraints.

Control Points have existed in PhotoModeler since the beginning but they were not called "constraints". We now reclassify them to provide some consistency. A Control Point is a piece of knowledge the user has about the X,Y,Z coordinate values of a point in the scene or on the object.

The Multi-photo Constraints are pieces of knowledge on various things like distances, length, parallelism, intersections, and angles. These constraints do not work in or 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 next section, *How to use Constraints in PhotoModeler*, describes how you add, remove, and edit Constraints.

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 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.

How to use Constraints in PhotoModeler

This section discusses how to use the various dialogs, toolbars, windows and cursors to add, remove and modify constraints in PhotoModeler.

The Control Point sub-section goes into quite a bit more detail about Control Points and how to use them, because they are treated differently by the PhotoModeler User Interface.

Non-Control Point Constraints

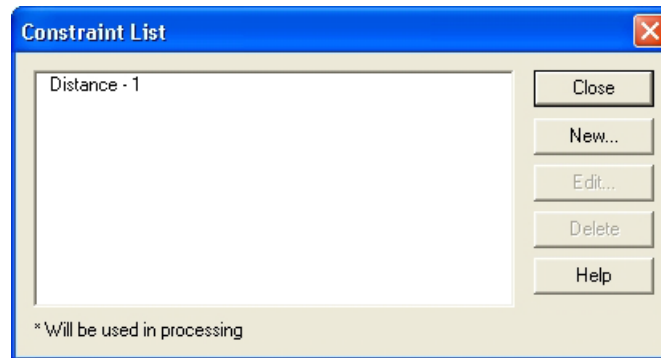
Manipulating Constraints


All Constraints that are not Control Points, have a unified method for being added, removed, and modified.

Constraints can be added two ways. The first is through the *Constraint List 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 *Constraint Edit Dialog*. See the sections below for details.

Constraint List Dialog



This dialog can be accessed through either the Constraint menu item on the Project Menu or through the Constraint List  button on the *Constraint Tool Bar*.

This dialog shows all the Constraints (non-Control Points) 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.

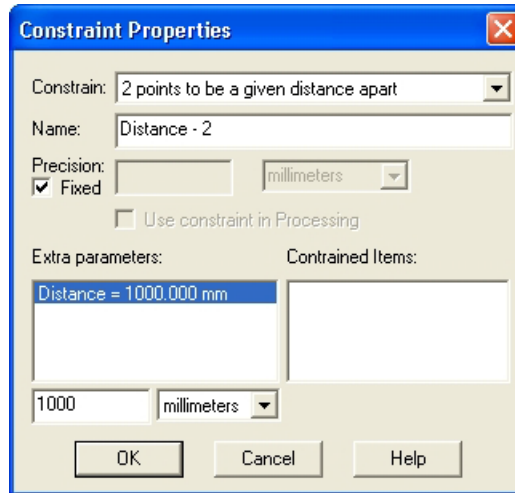
The New button brings up the *Constraint Edit Dialog* so that a new Constraint can be added. Constraints added this way will have no constrained objects (points, lines, etc.) but they can be added later. Note that Constraints can be added directly from the Constraint Toolbar with all objects that are selected already included.

The Edit button is available when a Constraint is selected in the list. It also brings up the *Constraint Edit Dialog* but with the specific settings for that selected Constraint.

The Delete button is available when a Constraint is selected. This immediately deletes the selected Constraint (warns first but there is no undo so be sure you want to do this). Note that you can also disable a Constraint temporarily - see the next section.

The Close button closes the dialog.

Constraint Edit Dialog



This dialog is opened by one of:

- the *Constraint List Dialog* New button,
- the *Constraint List Dialog* Edit button, or
- the *Constraint Tool Bar* New button.

This dialog provides facilities for modifying and setting:

- a user name for the Constraint,
- the precision,
- whether it will be processed, 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.

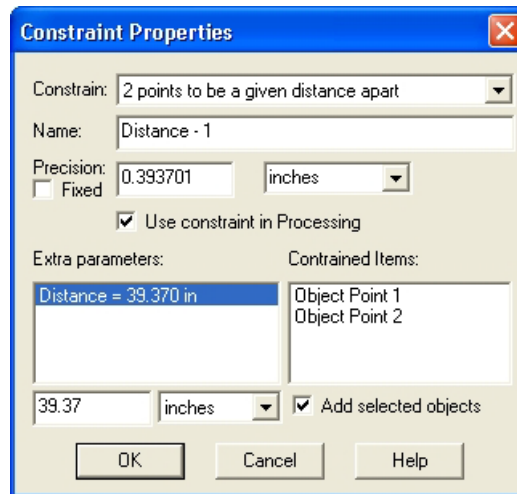
The precision can be "fixed", which means PhotoModeler tries its best to meet the constraint exactly (this may not always be possible). The precision can also be a non-fixed value. Example, a parallel constraint might be fixed (which means PhotoModeler tries its best to make the two edges or lines perfectly 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.

Some Constraints have extra parameters, and some display error amounts after processing. The next section discusses these.

Changing Constraint Parameters



The following constraints have extra parameters the user needs to set:

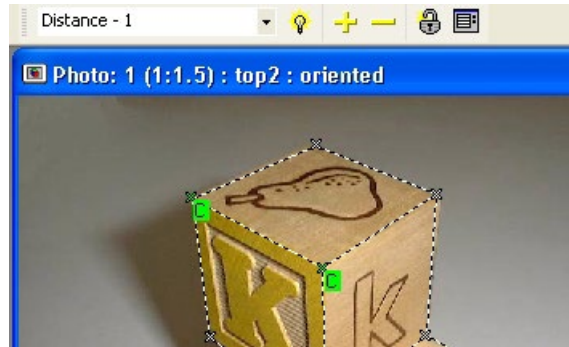
- 2 points to be a given distance apart [user specifies distance]
- 2 lines to be a given angle [user specifies angle]
- 2 edges to be a given angle [user specifies angle]

See the section, *Constraint Types*, for additional information.

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 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.

Constraint Tool Bar



The Constraint Tool Bar is a toolbar that appears when you enter Constraint Mode. This tool bar is used to add and remove objects from Constraints.

This tool bar contains six controls:

- the current constraint drop down list,
- the active constraint light bulb,
- the add (+) and remove (-) objects buttons,
- the new Constraint button, and
- the Constraint List button.

The current constraint drop down list

All Constraints, whether active or in-active, that are part of the current project (but not Control Points) 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 "Front Distance" has been selected above. This drop down list also contains an entry called "All Constraints" which highlights all constrained objects on open views.

The active constraint light bulb

Once a Constraint has been selected in the drop-down, the light bulb will appear in one of three states. If the light bulb is lit up with a yellow surround that means the selected Constraint is valid and "active". If it has a crossed red circle around the light bulb, that means the Constraint does not have sufficient objects to be valid and is "inactive". If the light bulb looks unlit, that means the Constraint has sufficient objects but the user has turned the Constraint off.

The add and 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 or 3D), and press the yellow "+" 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 yellow "-" button. The objects that were removed will immediately redraw with the Constraint highlight removed.

The New Constraint button

The New Constraint button provides a method for creating a Constraint and adding objects in fewer steps. While in the Constraint mode, you select the object you wish to be part of a new constraint (using Shift-Select), press the New Constraint button, pick the type of Constraint on the *Constraint Edit Dialog*, and press OK.

The Constraint List button

The Constraint List button is a short cut for the Project Menu, Constraints menu item. It brings up the *Constraint List Dialog*.

Processing Constraints

Constraints are processed by different parts of PhotoModeler depending on their type.

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.

Multi-photo Constraints are processed only during Global Optimization.

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 Constraint Edit 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.

Control Point Constraints

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.

In photogrammetry a differentiation is typically made between a Control Station, which is the known position on the ground or on the object in the real world and Control Point, which is the mark on the photograph corresponding to the image of a Control Station. In PhotoModeler we typically call both of these Control Points and when we need to identify just the mark on the photograph we call it a Control Mark.

Control Points in PhotoModeler can come from four different sources: 3D DXF files, ASCII CTL files, cube shapes, and user created points.

When using a 3D DXF as a Control Point source, you can create a DXF file (perhaps with AutoCAD or with PhotoModeler model output) that contains 3D points, 3D lines and Text entities. The Text entities in the DXF file are used to label the closest 3D point with a Control Point ID (described in the *Marking Control Points* section).

When to use Control Points

Control Points seem like an interesting concept but when do you use them?

There are six circumstances when Control Points are used in PhotoModeler:

1. for Inverse Camera (recreating parameters for unknown Cameras),
2. for single photograph projects,
3. for Perspective Matching of photographs to a 3D wireframe,
4. for tying together and improving the accuracy of projects with large numbers of photographs spread out over a large or long area,
5. when Camera Station geometry is quite weak (i.e. low angles), and
6. when the source of Control Points is of much higher accuracy than PhotoModeler and accuracy is a prime concern in the project.

Note that 1), 2), and 3) can also be met with *Axes Constraints* described below.

For Inverse Camera

Control Points can be very useful when trying to recreate a description of a Camera from photographs of unknown source. See the chapter *Working with Unknown Cameras and Photographs* for more detail.

For Single Photo Projects

When you are extracting information such as Surface Drawings, photo-textures and ortho-photos from a single photograph, Control Points are required to set up the planar geometry and to solve for the Camera Station location.

For Perspective Matching

Control Points from a 3D wireframe model (imported as a DXF control in PhotoModeler) can be used to generate an accurate description of the position, angle and perspective of a photograph to match the wire frame model. See later on in this chapter for more detail and review the *Working with Unknown Cameras and Photographs* chapter as many of the techniques for Perspective Matching are similar.

For Large Photo Spreads

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.

For Weak Camera Station Geometry

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.

For High Accuracy Surveys

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 a medium resolution 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.

When not to use Control

For normal everyday PhotoModeler use, Control Points are not required.

There are two related circumstances under which you should not use Control Points in your project:

1. Do not use Control Points if you are doing a standard PhotoModeler project and your Control Points are of the same order accuracy as expected from PhotoModeler. In other words, if you expect about 1 in 1000 accuracy from PhotoModeler and your Control Points are accurate to around 1 in 1,000 do not use them. PhotoModeler uses an advanced free-network adjustment algorithm that produces the highest possible accuracy for a photographic survey. Adding Control Points to your project will turn free-network adjustment off and may degrade the accuracy of the result. (Note you may still use such control to ensure

a certain coordinate frame for a model - similar to using *Three Point Rotation* but with more than three points).

2. Do not use Control Points if you are unsure of them or you are guessing at the shape of the object. For example, do not use a cube shape to match an automotive van because the van is not exactly cubic. Telling PhotoModeler that something is a cube, when it is not will really mess up your results.

What makes good Control

Good Control Points:

- are accurate and match reality,
- are spread out over the scene or object being measured, and preferably do not all lie on a plane,
- are sufficient in number (for example with InverseCamera every photo must have at least four control points (if solving for focal length only)),
- have depth and fill a volume,
- are covered well by the photographs, and
- cover a large percentage of the photograph.

Using Control Points in PhotoModeler

Control Points can be used in a number of ways in PhotoModeler but the initial setup is always the same. To use Control Points:

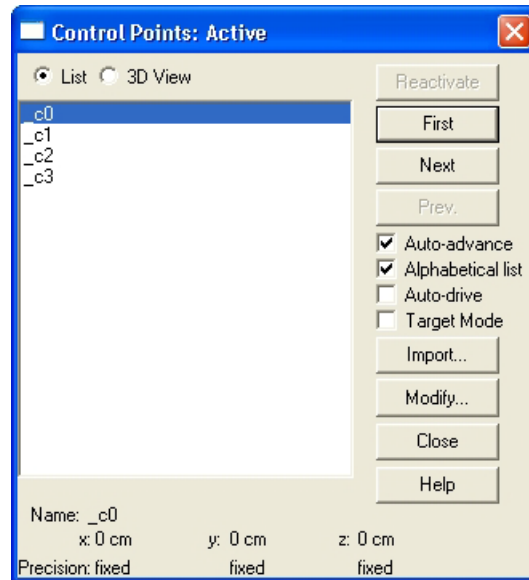
1. Decide on your source of Control Points (a wireframe from DXF, a set of points with Text Tags from DXF, a CTL file, a Cube, or a set of points that you will add manually),
2. Mark the Control Points on the photographs they appear on,
3. Complete any other marking and referencing as necessary, and
4. Process the project.

Marking Control Points

Control Points need to be marked on Photographs so PhotoModeler can use them. Marking Control Points is done in Control Point Marking Mode. This mode is entered by using the "Mark Control Points" item in the Marking menu or by pressing the Control Point Mode toolbar button.

When PhotoModeler is in Control Point Marking Mode the Control Points Dialog will be on the screen. The next section discusses this dialog.

Control Points Dialog



The Control Points Dialog is used to mark Control Points on photographs. The dialog acts as a source of the 3D coordinates needed when defining control.

Points that appear highlighted in this dialog can be marked on the currently active photograph. This dialog can be used only when a photograph window is active.

To read control points into your project press the Import... button and the *Control Import Dialog* will appear.

To edit a control point click the Modify.. button which opens the *Control Point Edit Dialog*.

The Control Marking Dialog has two methods of displaying control points: 1) as a list of identifying strings or 2) as a 3D View.

List View

The List View (shown above) shows a list of control point identifier strings. These strings are either automatically created (for Cube shapes, pre Pro 3.0 Measurement Shapes, and DXF files that have no Text ID's accompanying the points) or are read from the import file. Control points can be selected in the List View by either selecting the control point name with the mouse or by using the First, Next and Prev. buttons on the right.

3D View

The 3D View depicts the control points and any connected lines in a mini 3D Viewer window embedded in the Control Marking Dialog. This 3D View is similar to the

PhotoModeler 3D Viewer window except that it has no Options button, and it displays the current highlighted point in red.

Control points can be selected in the 3D View by using the First, Next and Prev. buttons on the right of the dialog.

Display

When a control point has been selected (either in List View or 3D View) its information appears at the bottom. The point's name, x,y,z coordinates and its precision are displayed. If a control point is fixed (i.e. cannot be adjusted by 3D Processing by setting its precision to 0 or a negative number) the precision will say "fixed" at the bottom of the dialog.

When a control point is currently selected the program will be in Control Point marking mode and that control point can be marked on any open photograph.

The Control Marking Dialog is resizable. Move the mouse to one of the edges of the dialog and you will see the Windows resizing cursor. Click and drag the dialog to the new size. You can make the dialog as big as your screen but it will shrink only so small (to keep buttons all visible).

Unlike some other modes in PhotoModeler, the Control Point Dialog remains on the screen when you switch out of Control Point marking mode. When you do drop out of Control Point mode, the dialog remains on the screen but goes into a inactivate state. In this state it will not supply 3D Control Points for marking. To go back into Control Point marking, click on the "Reactivate" button. When the Control Point dialog is active and the application is in Control Point marking mode, the "Reactivate" button will be disabled.

Choosing and Marking a Control Point

The "First" button returns the dialog to the start of the Control Point list. The "Next" button moves the dialog to the next point and the "Prev." moves the dialog back to the previous point. The "Next" button will be disabled if the current point is the last one in the list and the "Prev." button will be disabled if the current point is the first one on the list.

The "Auto advance" check box controls how the Control Points are presented during marking. If "Auto advance" is checked, the current Control Point will advance to the next unmarked Control Point on the current photograph after the current point has been marked. Turning auto-advance off is a good way to check which Control Points have been marked on a photograph because as each point is highlighted on the Control Point Dialog, it will also be highlighted in yellow in the currently active photograph if it has been marked there.

When auto-advance is on and you are marking control points on a photograph, clicking on the right mouse button will show a menu where you can pick to skip that

control point and advance the selection in the Control Dialog. The right-click menu also mirrors the first, next and previous point buttons on the dialog.

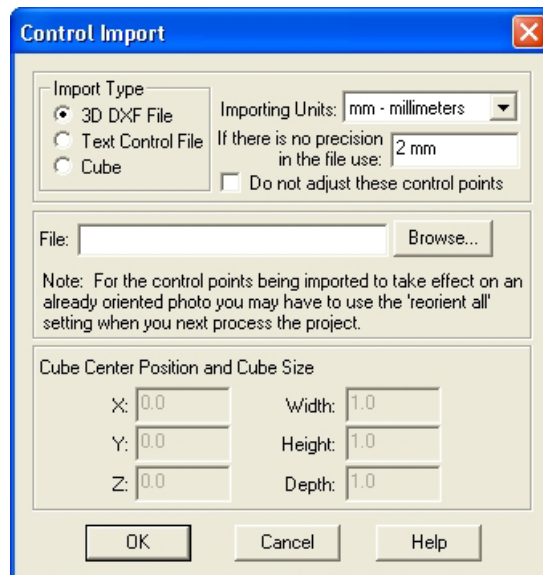
The "Alphabetical List" check box controls the sort order. If it is checked then the points are listed in alphabetical order in the List View (and are chosen in that order with Next/Prev. buttons). When it is not checked the list is in the order of import (i.e., the order the points were read from the DXF or CTL file). Note, if you alphabetically sort numbers the ordering is not numeric (i.e., the ID's: 1, 2, 3, 4, 5, 10, 11, 21, 22, 41, 42, 43 is sorted alphabetically as: 1, 10, 11, 2, 21, 22, 3, 4, 41, 42, 43, 5).

The "Auto-drive" check box controls whether the cursor will automatically jump to the expected location on an oriented photograph. If the photograph the control points are being marked on is well oriented this setting can greatly speed up the marking process. You can be zoomed in and as each control is marked, the photo center and cursor will automatically jump the location of the next point (unless it is off the photo in which case you should hear a "beep").

When the desired control point is highlighted in the list or 3D View you move the cursor over the photograph and if you get the Control Point Marking cursor you can click down to mark the correct location. You can later drag the point if you wish. If the cursor goes to the no-action cursor when over the active photograph then the highlighted control point must be already marked on this photo. You can mark it on another open photograph or try the next control point.

If the "Target Mode" check-box is checked you will be marking a sub-pixel target. This involves clicking in the center of the target and dragging out the boundary. See the *Sub-pixel Target Marking* section for more detail.

Control Import Dialog



The Control Import Dialog provides for the import and definition of Control Points in PhotoModeler. Imported *Control Points* can come from three different sources: 3D DXF files, ASCII CTL files, and cube shapes. You can also manually create your own control points (see *Control Point Edit Dialog* section below).

3D DXF Control Files

Any DXF file that contains 3D Points and optionally 3D Lines and Text strings can be used as a source of control points in PhotoModeler. The DXF file can come from a CAD package or as an export from PhotoModeler (another project or the same project even). To identify the points in a DXF file with "identifier strings" that will appear in the List View, the DXF file needs to have TEXT strings defined that have identical coordinate values to the POINTs in the file. When a text string is placed with x,y,z coordinate values matching a POINT or LINE endpoint x,y,z coordinate it will become the identifier string for that point.

To make sure that DXF imported control points do not get duplicated, whenever a DXF import is completed each point will be renamed uniquely. For example, there are four control points in a project that were originally imported from a DXF file and were named _dxf1, _dxf2, _dxf3, _dxf4. Now, four dxf control points with the same positions as the existing points are imported. The four new points will overwrite the existing points so that the new set of control points will be named _dxf5, _dxf6, _dxf7, _dxf8. The four new points will still be located at the same positions as the previous ones, only their names will have changed. DXF imported control points will only overwrite (and rename) existing control points that have the same position.

Normal DXF files have no notion of measurement units so one must know what units are used (inches and feet are common) and set the Importing Units appropriately. See *Importing Units and Precision* for more information.

To load a DXF file for control, choose the DXF option under Import Type, and type in or Browse to get a file name for a DXF file. If you use the Browse button the *Open Control or DXF File Dialog* will appear.

A precision value will also need to be assigned to the control points being imported. See *Importing Units and Precision*.

When the Import Type, Importing Units, Precision and File name have been set, press the OK button to import the file. If any errors occur during import you will be informed, otherwise the new control points will be added to the project. See the section, *Control Import Rules*, for more information on how old and new control points are combined during import.

ASCII Text CTL Control Files

The text control file is a simple ASCII text file used to define x,y,z control points. You import it much like the DXF file described above. The only differences are that the file format is different and the precision can be set on a point by point basis. Review the *3D DXF Control Files* section for the procedure.

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
e1a     10.0   256.0  41.0   0.5
e1b     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.

Cube Shape Control

Often rectangular shapes appear in your photographs and can be made useful sources of control points. For this reason, you can define a rectangular cuboid shape of any size and centered at any location to be a source of eight control points. Enter in the size of the cuboid and optionally a center in the measurement units shown in Importing Units and when you click OK, eight control points will be imported into the project. These points will be on the corners of the cuboid defined by the sides: $X1=Xc-Width/2$, $X2=Xc+Width/2$, $Y1=Yc-Depth/2$, $Y2=Yc+Depth/2$, $Z1=Zc-Height/2$, and $Z2=Zc+Height/2$.

Importing Units and Precision

The control points defined by the DXF file, CTL file, or cube are all imported into the project in the units set in the Importing Units drop-down list. The importing units do not need to match the units currently used by the project. The numbers will be converted as needed.

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 CTL file (if present) will override the precision in the dialog.

If the "do not adjust these control" check box is set 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 Control Points dialog and the *Measure Toolbar*.

Note: The precision edit box and the "Do not adjust.." check box affect only the cube import, DXF import, and CTL import for control without defined precision. In other words, if a control point has precision defined in the CTL file these two controls will have no effect on it.

Control Import Rules

When a project already has existing control points and new control points are imported, what happens? The following outlines the control import rules:

If a project has some control points (either marked or unmarked), then existing control points will be affected in this way:

1. if an existing control point has exactly the same name as a control point being imported (either CTL file or a cube), then its x,y,z value is replaced by the imported point (unless the existing point's name begins with an underscore (" _"), see 'C' below).
2. if an existing control point does not have the same name as any imported point (either CTL file or a cube) then the imported point is added to the project as a new Control Point (unless the existing point name begins with an underscore (" _"), see 'C' below).
3. if an existing control point's name begins with an underscore (" _"), and if the imported point is from a DXF file (with unnamed points), then the existing point is checked to see if it is within a very small distance of one of the imported

points (approx. 0.1 microns). If it is this close, the existing point is replaced by the imported point.

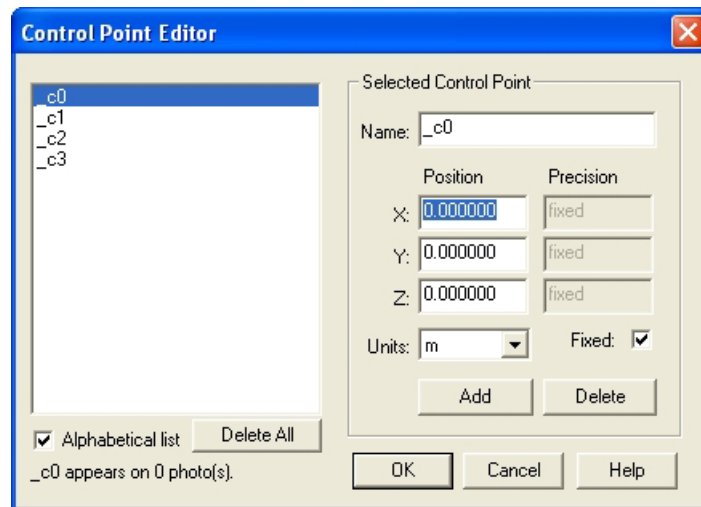
In other words, if you import a CTL file with named control points or a DXF file with named points (a control point is named in a DXF file if a text string is found to have the same coordinates as a 3D point) and that control points already exist in the project with the same names as those being imported, then the x,y,z values of these same named points will be replaced by the importing values. Note that cube points are always named the same way so when you import a new cube all existing marked cube control points will be replaced with the newly imported values.

Names starting with "_" are used in PhotoModeler to name unnamed DXF points and pre-PhotoModeler Pro 3.0 Control Points. Imported control points will replace existing control points if the imported point has a very close x,y,z position to an existing control point with a name beginning with an underscore ("_").

Open Control or DXF File Dialog

When the Browse button is pressed in the *Control Import Dialog* when either the DXF or CTL options are chosen, an Open File Dialog will appear. Depending on which option was chosen it will either ask for a CTL, TXT or a DXF file. When an existing DXF or CTL file has been chosen, the Open button can be pressed to return the file name to the file name edit box in the Control Import Dialog.

Control Point Edit Dialog



The Control Point Edit Dialog provides for the addition, deletion and edit of Control Points in PhotoModeler. The list box contains the list of control points from the project (the default control points, control points that you imported using the *Control Import Dialog*, or manually added control points) and will be sorted in the same way as the

Control Points Dialog. You also have the option of sorting the list alphabetically in this dialog by checking 'Alphabetical list'.

When you select a control 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 control point was marked. This is significant because you will not be able to delete a control point if it has been marked on any photos.

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 (which you set during project set-up).

Your project will start with a default set of four control points (the X,Y,Z axes). If you import a set of control points, they will be appended to the project's control points. You can manually edit or delete any of these control points or add new ones.

Editing a Control Point

To modify a Control Point, select one from the list and then edit the values in the edit boxes at right. You can edit a point's name or any of the point's x,y,z positions or precisions.

By choosing to 'fix' the point's precision (by checking the 'fix' checkbox) the precision edit boxes are disabled and display 'fixed' in the precision fields. Unchecking the 'fix' checkbox restores the precisions to a default value (which is proportional to the 'Default Control Point Import Precision' value and can be set in Preferences under the General Tab). When a precision is 'Fixed', it will not be adjusted during *Global Optimization*. In other words it is considered to be infinitely precise. If you fix a control point that has a poor value you may cause processing to fail.

You will be notified if any of your entries are invalid and you must fix them before you proceed. Invalid entries are in these four categories:

- **Names Format:** A name cannot contain spaces and cannot begin with an underscore ("_"). Although it is legal for imported control points from a .dxf file or default axis control points to have an underscore, once you begin editing the control point's name, you cannot use an underscore as the first character. This prevents any .dxf import from creating duplicate named control points.
- **Duplicate Names:** Each control point's name must be unique. You cannot edit the name of any control point so that it matches any other control point's name.
- **Duplicate Positions:** Each control point with a name that begins with an underscore ("_") must have a unique x,y,z position. This prevents any .dxf import from creating duplicate positioned control points. Note that it is acceptable for uniquely named control points that do not begin with the underscore to share the same x,y,z position.

- Any numeric values (in x,y,z positions or precisions) cannot contain alphabet characters or spaces. The exception is if you are entering an exponent value (e.g. 4.1E-3), in which case an 'e' or 'E' is allowed in all but the first or last position.

None of your edits will be applied to your project until you click OK. If you press Cancel at any time, you will return to the previous dialog and none of your changes will have been applied.

Deleting a Control Point

To delete a control point from your project, select it from the list and click Delete. You can continue to add, delete, or edit remaining control points in the list until the list is emptied or you click OK. Deleted control points will not be deleted permanently from the project until you click OK. If you click Cancel, the deleted control point will be restored in the project.

You will not be able to delete a control point if it has already been marked one or more photos. The status line at bottom left of the dialog displays the number of photos that the selected control point appears on. To delete a marked control point, first exit this dialog, select the desired control point on the photo (make sure you are in 'Select' mode) and 'uncontrol' it by choosing 'Uncontrol selected point(s)' under the Marking menu. After 'uncontrolling' the point, it will still be visible in Control Points dialog. You can now mark the point again, or return to the Control Point Edit dialog to delete it from the list or modify it.

You can delete all listed control points by pressing the Delete All button.

Adding a Control Point

To add a control point click the Add button. A new point is created and automatically given a unique name and default position and precision values. You can edit the new point's name, position, and/or precision at any time by modifying the values in the text boxes.

You can continue to add, delete, or edit remaining control points in the list. New control points will not be added to the project until you click OK. If you click Cancel, the newly added control points will be not be included in the project and any edits you made while in the dialog will be lost.

Constraint Types

This section lists all the Constraints provided by PhotoModeler Pro. 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	One constraint for every pair of known angle

allowed:	
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.

Control Points

Control Points are not handled the same way as the Constraints listed above due mostly to the nature and volume of data supplied. Since they are a form of constraint we can still describe them in the same way:

Description:	Constrain one Object Point to a known X,Y,Z location.
Objects:	Exactly one 3D Object Point
Extra Parameter:	The XYZ position
Number allowed:	One constraint for every known XYZ coordinate
Use:	To help with InverseCamera, to improve weak camera geometry, to improve shape, and sometimes to improve accuracy. Used in single photo projects by Orientation and in multi-photo projects by Global Optimization.

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. This information is called a Constraint. InverseCamera can use known 3D points or Axes Constraints. See the *Axes 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 *Photograph Properties Dialog*.

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 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.

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 *Photograph Properties Dialog*).

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 the *Photograph Properties Dialog*.

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 the *Photograph Properties Dialog* for 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 crush 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 reimport 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 *Photograph Properties Dialog*). 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 Pro 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 circular 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.

The targets will usually be one of three types:

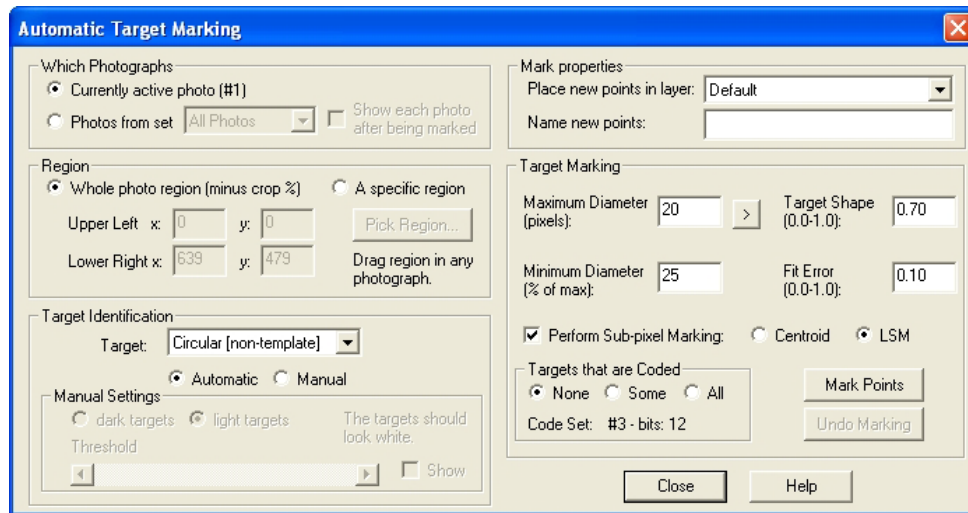
- stick-on natural-light targets,
- stick-on retroreflective targets, or
- projected targets.

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.

In addition to plain circular dots for targets, PhotoModeler Pro, 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 identification method,
- Choosing the name and layer in which to place new points,
- Setting up the target identification parameters, and
- 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).

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 how targets are identified

First, there are different types of targets - the default being circular 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.

Second, there are two methods used by the program to identify and separate targets from the background. The automated method is what you will normally use. The manual method can be used if the automated method is not working in some circumstance or is too slow. To use the manual method:

1. Choose the 'Manual' option.

2. Pick whether the targets are light circles on a dark background (typical of projected targets and retroreflective targets) or dark circles on a light background (typical of laser printed naturally lit targets).
3. Check the Show Targets box.
The whole photograph will change to a black and white image where the white parts are considered to be targets and the black, the background. If the image is a 24 bit color image, there will be a small delay as the image is converted to grayscale.
4. Adjust the Threshold slider.
Grab and drag the middle button in the threshold slider while watching the photograph window. When the targets stand out by themselves with little noise and no attached regions then you can continue. If you cannot find one threshold that works for the whole region you can execute this process starting above and by picking a smaller regions.
5. Then proceed onto the next steps.

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.

Setting up the parameters

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 what nature of target to find.

Enter in the diameter (in pixels) of the largest target in the region or areas to be marked. This number does not need to be exact. If you do not know the size you can measure it using the > button which operates much like the Pick Region mode. In this case you zoom in on the largest target and you draw a box around it that just encompasses it. It should be larger than your largest target. Targets smaller than this value will not be marked.

The minimum diameter is a percentage of the maximum and the default is acceptable in most cases.

Decide if you wish the marker to find elongated targets (circles become elongated ellipses as the angle increases). Circle Shape values between 0.4 and 0.9 will generally be suitable. Try the default value first. This is available only if the Circular Target type is selected above.

If a Template Target is chosen in the 'Target' drop down box then the 'Max RMS Residual' appears in the place of the 'Circle Shape' parameter. This controls how similar the template must be to the underlying image for the target to be accepted. If the LSM RMS residual (root-mean-square difference in gray levels between image target and template target pixels) is bigger than this number after the best match is computed then the target point is not marked. This is useful to throw out spurious matches. A MaxRMS of 0.0 means the template has to exactly match the image target (all pixels exactly same), and a value of 1.0 means the template will match pretty much any source image (although the LSM marker fails and will not mark before the 1.0 value can be reached) - so the smaller this value the better the match needs to be. By selecting existing template marked points you can see the current LSM RMS residual on the status bar. A MaxRMS of 0.09 to 0.2 is usually a suitable range depending on type of target and amount of perspective distortion.

If you are using Circular Targets you can control whether a target is marked or not by adjusting the "Fit Error" value. 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. This setting is similar to the Max RMS Residual described above for template target marking.

Decide if sub-pixel target marking will be done. If "Perform Sub-pixel marking" is not checked, the marking will be the fastest but the least accurate.

The Coded Targets section will be available if the Coded Targets module is installed. See the Automatic Marking of Coded Targets section below.

Typical Scenarios

A typical usage for a single photograph would be to: a) open the photograph, b) open the Automatic Marking Dialog, c) leave most of the default values alone, d) choose the 'Currently active photo' option, e) pick a target size (maximum target diameter), and f) press the 'Mark Points' button.

A typical usage for marking all photos would be to: a) open the Automatic Marking Dialog, b) leave most of the default values alone, c) choose the 'Photos from set' option (with set All Photos), e) enter a target size (maximum 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.

Automatic Marking of Coded Targets

If you have *Coded Targets* in your photographs and you have the Coded Targets Add-on Module installed, you can use the last section of the Automatic Target Marking Dialog. There are three choices for 'Targets that are Coded': 'None', 'Some', and 'All'.

‘None’ is the default and this means that no Coded Targets will be searched for during the automatic marking.

‘Some’ means that there are a mixture of uncoded (plain circular dots) and coded targets in the photograph. Every circular dot is checked to see if it has a code ring. If it does not have a code ring or the code is invalid then the dot target is marked as a normal target. Targets with valid code rings are identified by their code.

‘All’ means that all targets to be marked must have valid code rings. Targets and dots found without valid code rings are not marked. This is the best approach when there are many other conflicting circular shaped objects in the scene.

Note that you cannot choose ‘Some’ or ‘All’ unless the LSM Sub-pixel marking method is chosen. Properly detecting coded targets depends on the LSM sub-pixel method.

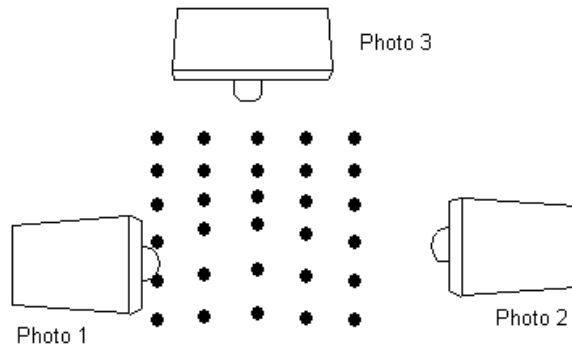
The type of Coded Target recognized is fixed for the project and was setup in the Project Wizard. The set displayed here must match the set printed and used in this project. If the targets being used do not match these settings (in terms of number of bits and radial parameters) then the automatic coded target matching will not work properly. The *Project Information Dialog* can be used to change the project’s default code set if no coded targets have been marked yet. Further details are provided in the *Coded Targets* section.

Note: there may be some coded targets that cannot be found (either too small, too sharp an angle, not enough of a gap between target and code ring or the code ring and background are too similar in color/intensity). So it is a matter of making sure there are enough good coded targets in each image to do what you want taking into account some of the targets might be missed. This also means that when the ‘Some’ option above is used, when a coded target is missed you might end up with small code bits being marked as targets.

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 *Photography for Curves, Edges, Cylinders and Automatic Referencing*. 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 main sections:

- 1. Which Objects ?**: Contains four radio button options:
 - ☒ All points in project
 - ☐ All points in layer: Default
 - ☐ All silhouettes in project
 - ☐ All silhouettes in layer: Default
- 2. Parameters**: Contains:
 - Project Scale Status: Not scaled
 - Search Distance: 0.0004108 m
 - ☒ Perform search distance doubling iterations
 - Minimum number of photos: 3
- 3. With automatically referenced points**: Contains:
 - Name them: ar
 - ☐ Set them to "do not process"
- 4. Referencing**: Contains a table showing the number of oriented photographs and the resulting number of points:

Number of oriented photographs:	Result
On one (1) photograph:	6
On two (2) photographs:	2
On three (3) photographs:	0
On four or more (4+) photographs:	21

 Below the table is an 'Execute Referencing' button.
- 5. Undo Automatic Referencing**: Contains:
 - Number of saved referenced marks: 0
 - An 'Unreference previous references' button.

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 unmatching. 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:

Automatic Referencing for Two Photographs

1. Which Points ?

☒ All points in project

☐ All points in layer: Default

2. Parameters

Project Scale Status: Scaled and rotated

Search distance: 0.008597 in

Two photo referencing works with near planar surfaces.

Plane defined by all points in layer: Default

Allowable distance off plane for a match: 0.01719 in

3. With automatically referenced points

Name them: ar

☐ Set them to "do not process"

4. Referencing

On one (1) photograph: 0

On two (2) photographs: 9

Execute Referencing

5. Undo Automatic Referencing

Number of saved referenced marks: 0

Unreference previous references

Close Help

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.

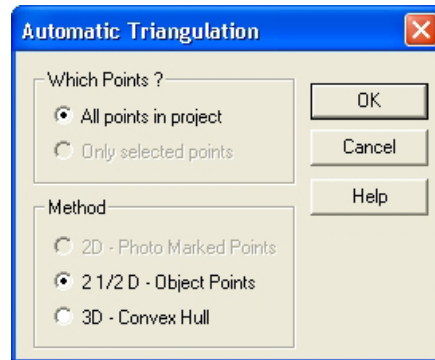
Another approach is to pick a very small off-plane distance threshold and then execute the referencing. Only points that are very close to the defining plane will be referenced. Then pick a bigger threshold and repeat until you get to the biggest threshold as described above. In this way, at each stage, 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 Marking menu.

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.
Since no points are selected the defaults will be "All points" and "2.5D".
2. Press the OK button.
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.

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* 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 tab 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.

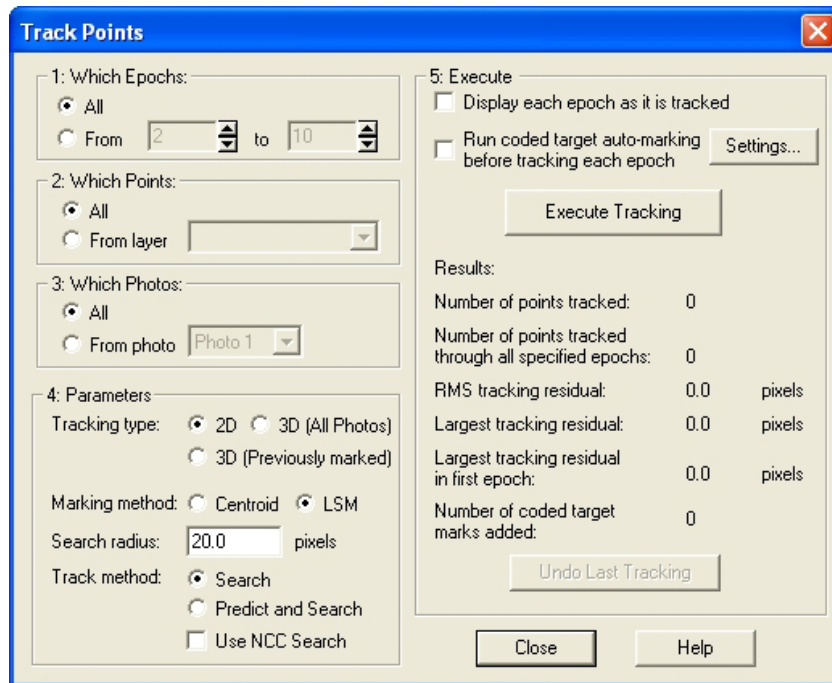
If you do not want any of your changes to propagate you can turn off propagation by pressing the Propagate button on the PMV toolbar or by choosing the Propagate item on the PMV menu.

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 access 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.

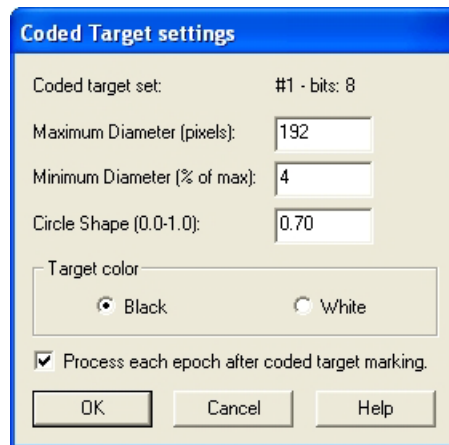
PMV Type 2 projects must use 3D tracking because there is no relationship between photos between epochs in type 2 projects.

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.

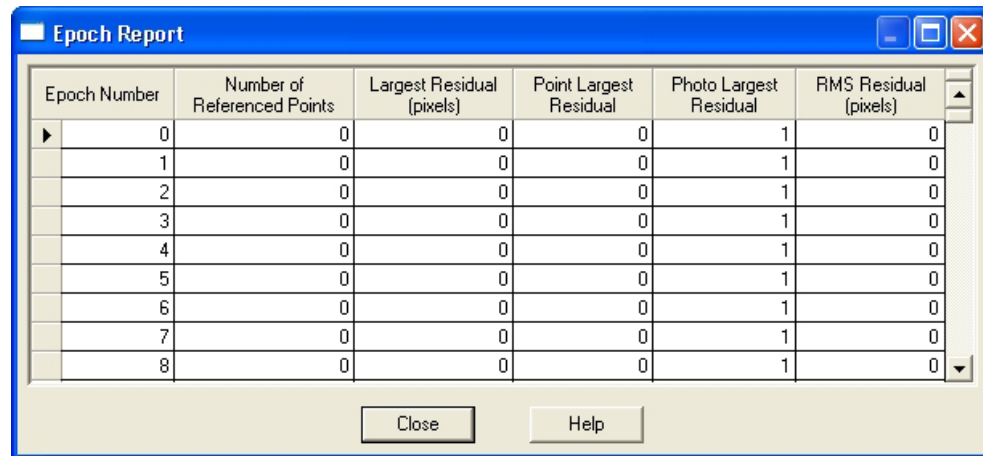
When there are Coded Targets in a PMV project it is a good idea to use the standard coded target automatic marking instead of standard tracking (because otherwise the code ring bits can get confused as targets to track). The advantage of using coded targets in a PMV project is that as long as they are 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 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 Epoch Report Dialog



The Epoch Report dialog box displays a table with the following data:

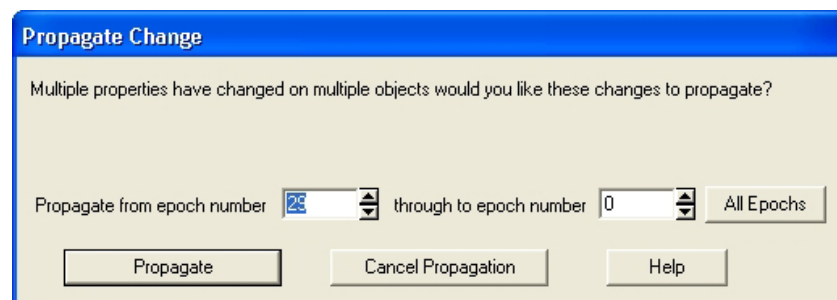
Epoch Number	Number of Referenced Points	Largest Residual (pixels)	Point Largest Residual	Photo Largest Residual	RMS Residual (pixels)
0	0	0	0	1	0
1	0	0	0	1	0
2	0	0	0	1	0
3	0	0	0	1	0
4	0	0	0	1	0
5	0	0	0	1	0
6	0	0	0	1	0
7	0	0	0	1	0
8	0	0	0	1	0

Buttons: Close, Help

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)).

PMV Propagate Dialog



Propagate Change

Multiple properties have changed on multiple objects would you like these changes to propagate?

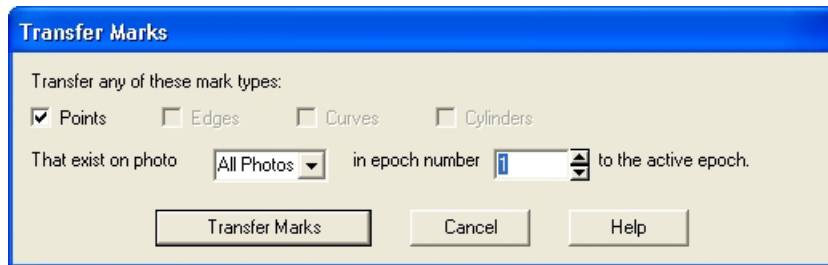
Propagate from epoch number through to epoch number

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



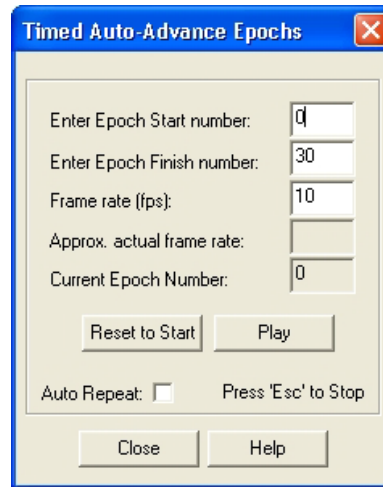
The Transfer Marks dialog comes up when the Transfer Marks tool, or the "Transfer Marks" item on the PMV menu is selected. The marks of the selected type(s) that appear on the selected (or all) photos in the epoch number chosen will be moved to the currently active epoch. If the marks already exist in 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.

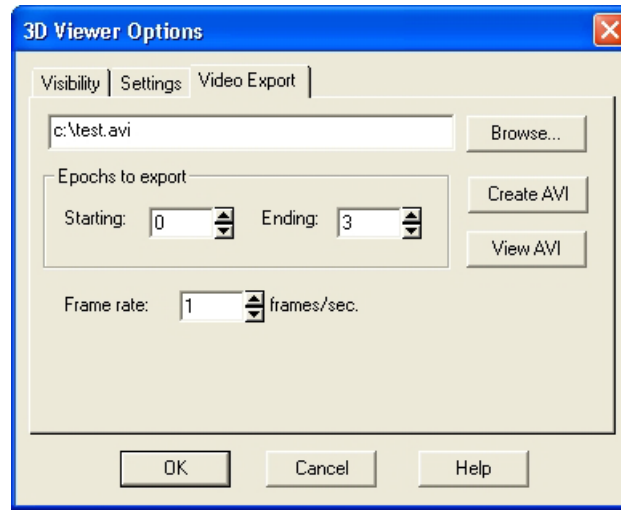
Auto-repeat: Select this checkbox if you want your animation to loop back to the starting epoch automatically, after the last epoch has been displayed.

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 tab called Video Export.



This tab 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 tab you produce an AVI animation video that shows this particular view for each epoch chosen.

The edit field at the top of the tab 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 tab.

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 tab.

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).

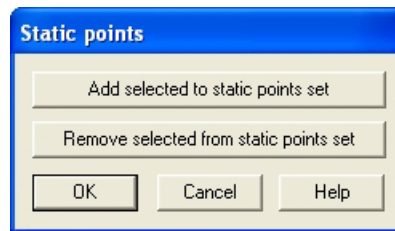
Differences between PMV Type 1 and Type 2 projects

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

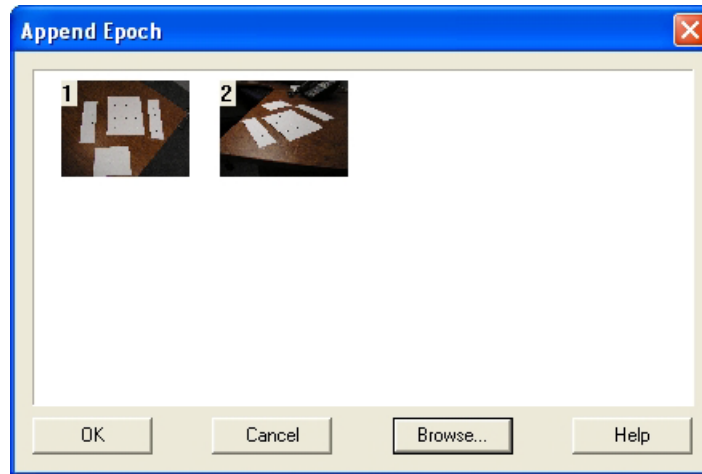


PMV Type 2 projects require designated static points to maintain a common coordinate system between epochs. The Static Points Dialog is used to add and remove points from the static set.

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 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).

Coded Targets is an add-on module. For information on installing the Coded Target module see the *Modules* section.



One of the 8 bit coded targets

The three main reasons that you may be interested in Coded Targets are: a) to increase the speed at which projects can be completed, b) to improve the speed and robustness of the crucial orientation stage which all projects must go through at the start, and c) to improve robustness and reduce the chances of misreferenced points.

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). This will determine which set of targets you will

use (pick the lowest number of bits that fills your need for enough unique codes).

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.
5. Photograph your scene so that each target appears in at least two photographs from good angles.
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.
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.

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 subpixel 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

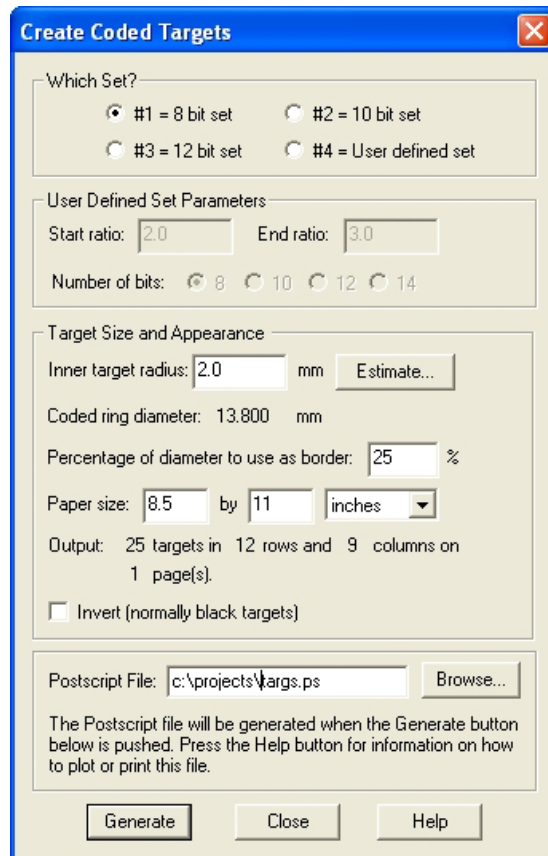
Coded Target points are displayed and represented a bit differently so that you can distinguish them. The following table describes how to identify a coded target in various parts of the program's user interface.

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"
Status Bar	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



The Create Coded Targets Dialog is used to generate a Postscript file to be used in the printing or manufacture of *coded targets*. It has three main sections.

The first section is used to define which set of targets are needed. The choices are: 1) the fixed 8bit set, 2) the fixed 10bit set, 3) the fixed 12bit set, and 4) the user defined set. The first three have been internally defined and produce reasonable results in most situations.

The 8 bit set has 8 ring bits of 45 degrees each. There are 25 unique codes in this set.

The 10 bit set has 10 ring bits of 36 degrees each. There are 45 unique codes in this set.

The 12 bit set has 12 ring bits of 30 degrees each. There are 161 unique codes in this set.

The user set can have 8, 10, 12 or 14 bits (note 14 bits generate 561 unique codes).

The code set you use should be entered in the *Preferences - Coded Targets* Tab so that when *Automatic Target Marking* is run it will default to the correct set.

When the user set is chosen, extra information needs to be entered. See *User Set Parameters*.

The second section of the dialog controls the size of the targets and the number of targets per page. See *Target Size and Appearance*.

With appropriate settings you can fit many targets on one page or just one target per page.

The last section is where the name of the Postscript file is entered.

When the Generate button is pressed, the Postscript file is 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).

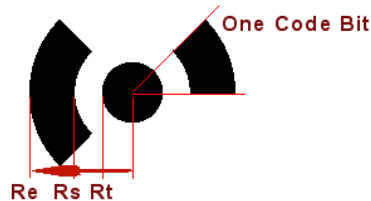
Note: If you do not have the font 'Helvetica' (a standard post script font) installed with some post script interpreters (such as Distiller) you may see a warning about the font being replaced. This warning can safely be ignored.

User Set Parameters

When Set #4 of the 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 Rt 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.

Target Size and Appearance

The values in the “Target Size and Appearance” section of the Create Coded Target Dialog control the size of the coded targets and the number of targets placed on each page.

The 'Inner target radius' 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 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 coded target depends on the outer diameter of the code ring and this is controlled by the end radius ratio. The start and end ratios are fixed for code sets 1,2 and 3 and can be user defined with code set 4 as described in the previous section. This overall size is displayed in millimeters as the 'Coded ring diameter'.

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*.

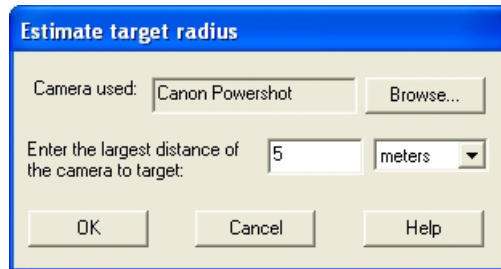
The 'Percentage of diameter to use as border' defines how much space will be left around each target. If the coded targets will not contrast with the object they are being applied to you should be sure to leave a reasonable border so the edges of the target can be detected. It is important to leave enough 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.

The 'Invert' 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). Also 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.

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 10 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 = $5 * w / pw$

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 = $5 \text{ pixels} * 360 \text{ in} / 2048 \text{ pixels} = 0.88 \text{ in (or 22mm)}$.

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.

Minimum target radius = $(5 * fw * D) / (f * pw)$

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:

Minimum target radius = $(5 \text{ pixels} * 6\text{mm} * 8000\text{mm}) / (6.2\text{mm} * 2048 \text{ pixels}) = 18.9\text{mm}.$

Automated Coded Targets Project

There is a potential of fully automating a project when Coded Targets are used.

When the Coded Target module is installed there is an option on the New Project Wizard Welcome pane for Automatic Projects. When this option is chosen, the Wizard asks for all the settings needed to execute the project without operator intervention.

The program can automatically carry out target marking (coded and non-coded targets), 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 *Project Wizard: Welcome (Automated Coded Targets Project)* for information on the Wizard.

We strongly recommend you get used to successfully processing coded target projects with the more manual process (standard project, running automatic marking, running processing, setting up scale/rotate, etc.) before embarking on fully automating the work.

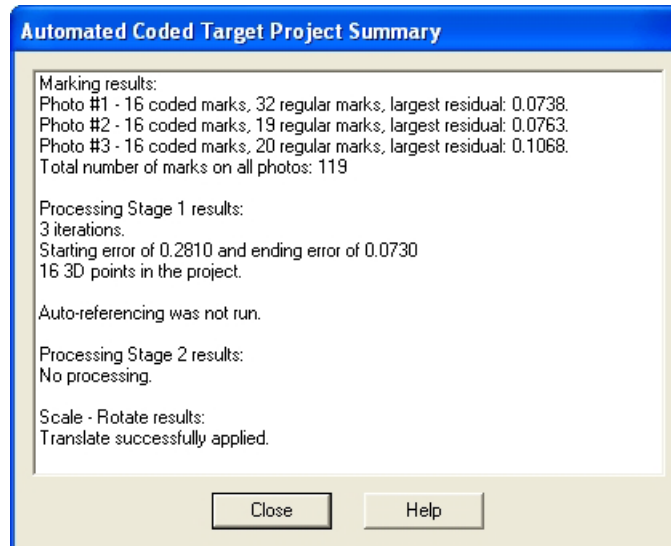
While this system could be used for projects without coded targets it is not that useful because only automatic marking can be carried out. The power comes when sufficient coded targets are used.

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.

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.

The *Automated Coded Target Project Summary* dialog appears at the start of automatic processing to provide feedback.

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 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 second 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 third section shows the results of the optional automatic referencing (used if the project has non-coded targets as well and if the project was successfully processed in the previous stage).

The fourth section shows the results of the optional second processing which is useful if automatic referencing has added new points to the project.

The fifth and 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 commandParm2 ...". 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 Pro.
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 Pro 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

Camera/Photo:

AddPhoto

GetCamera

AddCamera

GetPhotoCamera

SetPhotoStation

GetPhotoStation

SetPhotoProcessing

GetPhotoList

SetPhotoSet

RemovePhotoSet

Object Information:

GetMarkedPoint

GetMarkedPointByIndex

GetNextPoint

GetNextPointID

GetNum3DPoints

GetNumMarkedPoints

GetPoint

GetUnits

GetNextCylinder

BoundingBox

ResetLists

Scale Rotate:

Scale

Translate

RotateAxes

RotateXYZ

Exporting:

Export

Export3DDXF

ExportTable

Automated Tools:

AutoMark

AutoReference

AutoReferenceByLayer

TwoPhotoAutoReference

Modeling:

MP

DeleteMarkedPoint

DeleteMarkedPointByIndex

MFP

Process

SetIterationType

Show3Dviewer

CreatePointCloud

DefineControlPoint

ImportSilhouettes

Following is a full list of commands, sorted alphabetically:

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"

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 MinPercent CircleShape MarkType(1=Non-sub,2=Centroid,3=LSM) [Coded(1=No CT,2=Some CT,3=All CT)] [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 the targets in pixels, MinPercent is the percentage of the max size the smallest target will be, CircleShape is a value between 0.1 - 1.0 that determines how circular the target must be, N is the type of marking to do: 0=No sub-pixel,1=Centroid, 2=LSM. The last parameters are optional and are only valid if the Coded Target module is installed. Coded indicates the nature of the target's coding: 1=No coded targets, 2=Some targets are coded, 3=All targets are coded. 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 2 0.7 1 3 3 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 name x y z px py pz" where: "name" 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 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"</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),</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>
Return:	<p>"1" if export is successful 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 - an invalid parameter - the export file could not be created
Example:	<p>"Export 5 c:\temp\TestExport.obj 1 0 1 1 1 1 1 1 512 512 0 2 1 0 0 1 0 0 0 0 0 0 0"</p> <p>return "1"</p>

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" 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.
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 6 1 1 1" return "1"

ExportTable

Description:	Export the indicated table in the format specified to a text file.
Syntax:	"ExportTable tableType formatType fileName onlySelected" where: "tableType" is 1 for Point Table, 2 for Surface Table, 3 for Curve Table, 4 for Edge Table, and 5 for Cylinder Table, "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:	"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
Example:	"GetCamera kodak1" returned "1 35.2 36.2 23.8 18.2 12.1 0.000023 0.000004"

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 "
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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"

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:	<p>"1 n p c x y z"</p> <p>where:</p> <p>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.</p> <p>Failure returns</p> <ul style="list-style-type: none"> - incorrect number of parameters - no project is open - 'n' does not correspond to an existing point - the point has no 3D position.
Example:	<p>"GetPoint 5"</p> <p>return "1 5 1 0 34.2 534.3 244.2"</p>

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.</p>
Return:	<p>"1 x y z w p k" or</p> <p>"1 x y z r11 r12 r13 r21 r22 r23 r31 r32 r33" or</p> <p>"1 x y z x2 y2 z2 roll"</p> <p>if successful or "0" if not</p> <p>where:</p> <p>"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.</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 - photo is not oriented

Example:	"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"
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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 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 'ctlName' is optional and is the name of a control point to assign to this point.
Return:	"1" if the point was marked successfully. "0" if it was not successful. Failure returns <ul style="list-style-type: none"> - 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 c1" return "1"
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MFP

Description:	Mark a fiducial point on a photograph.
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"
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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).
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"</p> <p>where:</p> <p>"flag" is the sum of:</p> <ul style="list-style-type: none"> - 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 <p>('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>Optional:</p> <p>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)</p> <p>rca = 0,1,2 where 0 = do not run, 1 = unreference, 2 = set to do not use, 3 = rename</p> <p>name = name points to rename if rca= 3</p>
Return:	<p>"1 iter i.e. fe" if successful or "0" if not</p> <p>where:</p> <p>"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:	<pre>"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"</pre>
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RemoveLayer

Description:	Remove a layer by passing in the name of layer to be removed.
Syntax:	<pre>"RemoveLayer layerName" where: layerName is a string for the name</pre>
Return:	<pre>"1" if successful, or "0" if not successful. Failure returns - name of layer not removed</pre>
Example:	<pre>"SetLayerByName NewLayer 2 PointName" return 25</pre>

RemovePhotoSet

Description:	Remove a photo set by passing in the name of set to be removed
Syntax:	<pre>"RemovePhotoSet psName" where: psName is a string for the name</pre>
Return:	<pre>"1" if successful, "0" if not successful. Failure returns - Name of set not removed</pre>
Example:	<pre>"SetPhotoSet pset 2 4 8" return "1"</pre>

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:	<pre>"ResetLists"</pre>

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.
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 camear station 3</p>

RotateXYZ

Description:	Set the rotate part of the project affine transform based on an origin and two axes points.
Syntax:	" 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.
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"
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Scale

Description:	Set the scale part of the project affine transform.
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:	"1" if successful, "0" if not successful. Failure returns - incorrect number of parameters - no project is open - 'n' not in valid range
Example:	"SetIteratorionType 1" return: "1"

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>

Show3DViewer

Description:	Show a 3D Viewer with requested options visible, optional to maximize
Syntax:	"Show3DViewer optBtn optDlg doRotate pts lines surfs cyls cyllines textures sd edges curves camstns perspective maximize" where: booleans are (1 for true, 0 for false): optBtn - show Options button optDlg - show Options dialog before 3D Viewer displays doRotate - apply Scale rotate to model pts - show points lines - show lines surfs - show surfaces cyls - show cylinders cyllines - show cylinders as centre lines textures - show photo textures sd - show surface draw edges - show edges curves - show curves camstns - show camera stations perspective - show perspective corrected textures (ie quality textures) maximize - maximize the window
Return:	"1" if successful or "0" if this command failed.
Example:	"Show3DViewer 0 0 1 1 0 1 0 0 0 0 0 0 0 1" return "1"

Translate

Description:	Set the translate part of the project affine transform based on a location defined by a point or camera stations.
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 strn 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.. for Word and Excel).

```
Sub RunFullDDETest()  
    '  
    ' Test new DDE Commands in PhotoModeler Pro  
    ' 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 cp1 0.0 2.95 2.9",  
ret) Then GoTo Failure
```

```

        If Not DDECommand(c, "DefineControlPoint cp2 0.0 0.0 2.9",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint cp3 0.0 0.0 0.0",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint cp8 0.0 2.95 0.0",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint cp18 2.8 2.95
2.9", ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint cp19 2.8 0.0 2.9",
ret) Then GoTo Failure
        If Not DDECommand(c, "DefineControlPoint 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 cp1", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 2 283.728 161.240 cp2", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 3 286.280 297.752 cp3", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 4 178.720 225.768 cp8", ret)
Then GoTo Failure
        If Not DDECommand(c, "MP 1 5 278.0 46.0 cp18", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 6 390.0 92.0 cp19", ret) Then
GoTo Failure
        If Not DDECommand(c, "MP 1 7 380.0 224.0 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 bar 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 bar.

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 section *Photography for Curves, Edges, Cylinders and Automatic Referencing* 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 *Photography for Curves, Edges, Cylinders and Automatic Referencing* section.

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.

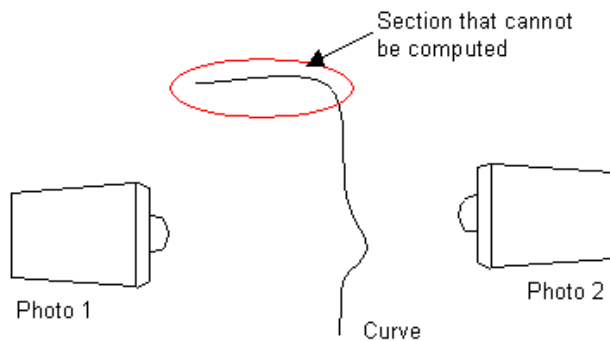
Another consideration with closed curves is that PhotoModeler assumes all marks "view" the curve from the same side. Imagine a horizontal metal ring that you will be modeling using a closed NURBS curve. If you photograph the ring from only one side (call it the upper side) then you will not encounter 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

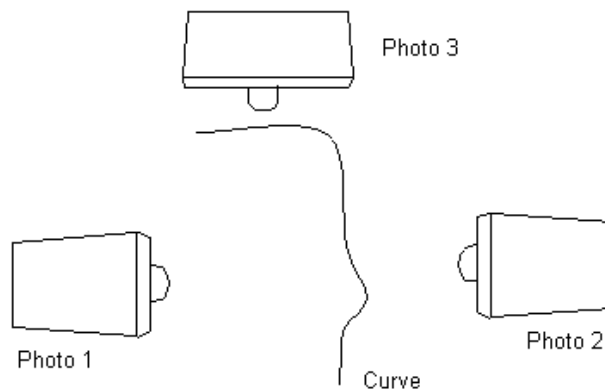
If the Curve is shown as "3D" in its status bar, does appear in the 3D Viewer and does export but is not complete then it is not possible for PhotoModeler to compute part of the curve.

You should first consider what photographs these marks appear on and whether they are suitable for that Curve. See the section *Photography for Curves, Edges, Cylinders and Automatic Referencing* 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 *Trouble-Shooting Procedure* below to figure out how to fix the problems.

Trouble-Shooting 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 the *Photograph Properties Dialog* 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 *Control Points Dialog* 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 Information 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 *Control Points Dialog* 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 *Photograph Properties Dialog* 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 Information 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 Information Dialog).
6. To get correct format size you can use a quick calibration method in the Camera Setup Wizard , see Determining Digital and Video Camera Format Size or use full Camera Calibration (see Camera Calibration).
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 manual on placing cameras called *Taking Photographs*. Study the trouble-shooting 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:

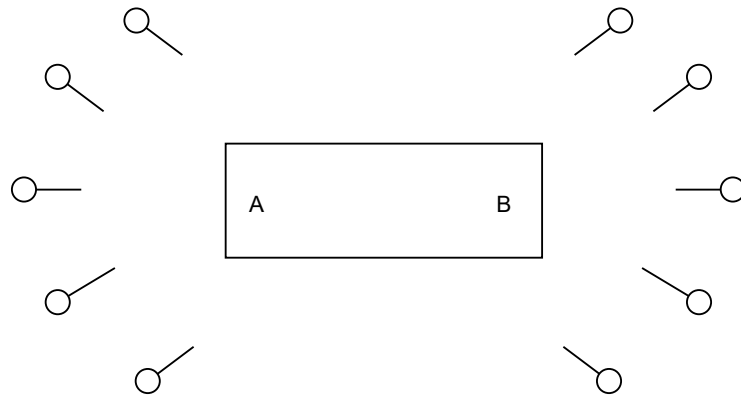
1. The point has one more incorrect references.
2. The point has been marked inaccurately in one or more photographs.
3. The point has been marked on only two photographs.
4. The point has a poor angle maximum (lower than 10 degrees).
5. There are too many points which are imaged on just two or three 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 be 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 subpixel 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.

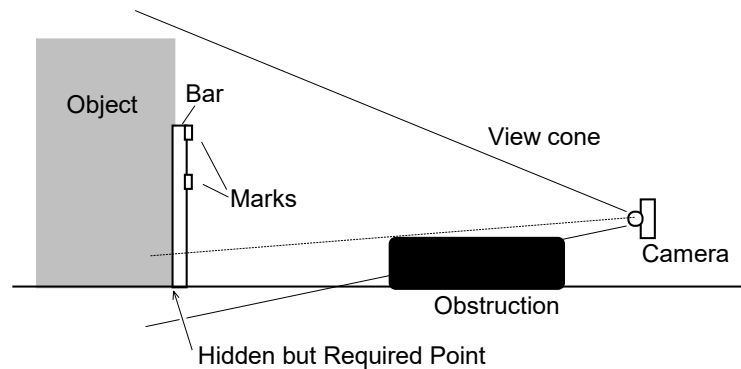
On the other hand, there are many objects, both large and small, that you can take clear photographs of and in which you can identify each point precisely and uniquely. There are also many work-arounds for the problems listed above.

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:



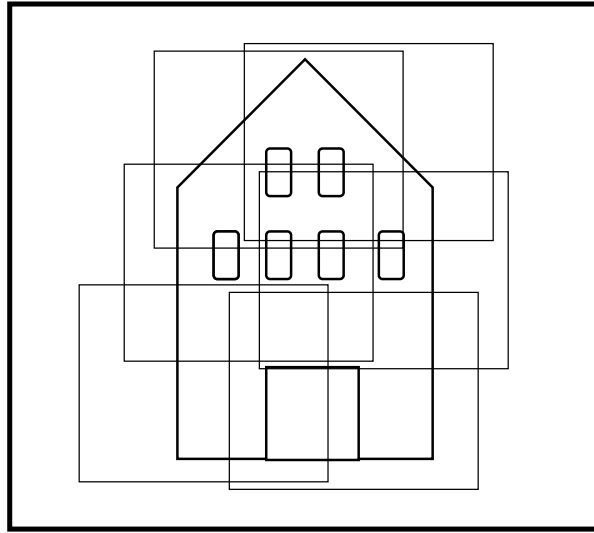
The two upper marks can be seen and measured. The third mark can be projected from the positions of the other two and a known distance. This is quite easy to do in most CAD programs. You would not want to do this for very many points but when you are stuck it can be helpful.

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 undetailed model 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 undetailed 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.

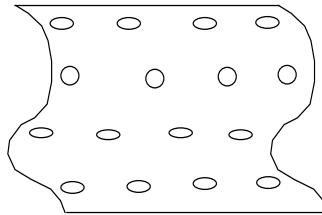


Using photograph overlap to capture a large structure

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:



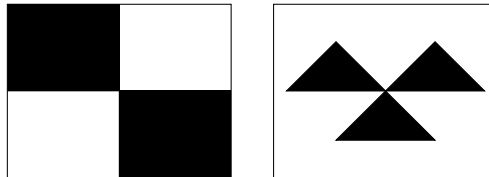
Any type of surface, from a car fender to a ship hull can be targeted in this fashion but some care has to be taken in deciding on the color and size of the targets. You can purchase various size dots in different colors from stationary stores. A calculation for the appropriate size for a dot target 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 at least 3-5 pixels across the sub-pixel marker will work.

Manually Marked Targets

The other form of target could look like one of the following:

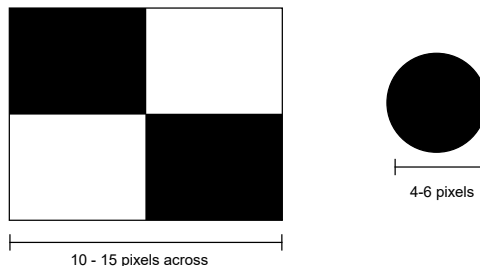


This type of target type (that uses straight lines as opposed to using a circular dot) can be manually marked or in some cases be marked by the Template Target sub-pixel marker. See *Template Target Marking* for more detail. These cannot be marked by the Circular Target Subpixel marker.

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.

Target size

The critical factor when using targets is to create or buy them at the appropriate size. The size of the target is based on the pixel resolution of the camera being used. Circle patterns should be at least 4 pixels across and manual targets about 10 to 15 pixels across in the final image (manual targets cannot be marked with PhotoModeler's subpixel marker):



The method to calculate the actual size depends on the resolution of the camera, the focal length of the lens and the distance of the object from the camera. A much easier way to calculate the size is based on the coverage of the object by the pixels of the image.

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.

Given that the number of pixels in the image is W_I across, that the object being measured is about W_O wide and that the whole object fills the image (i.e. you fill as much of the ViewFinder with the object as possible, which is a common method of taking photographs for PhotoModeler), then the target size should be approximately:

$$\text{Dot target diameter} = W_O / (W_I / 6)$$

$$\text{Manual target width} = W_O / (W_I / 15)$$

For example, measuring a 40 foot wide building using an Olympus 5050 digital camera with a resolution of 2560 by 1920:

$$\text{Dot target diameter} = 40 / (2560 / 6) = 0.09 \text{ feet} = 1.1''$$

$$\text{Manual target width} = 40 / (2560 / 15) = 0.23 \text{ feet} = 3''$$

Let us look at a poor case: Using a video camera with capture board and a resolution of 640 by 480 to measure the curved surface of a large ship that is 300 feet long. The required target sizes are:

$$\text{Dot target diameter} = 300 / (640 / 6) = 2.8 \text{ feet} = 34'' !$$

$$\text{Manual target width} = 300 / (640 / 15) = 7 \text{ feet!}$$

Obviously you would not want to climb over the ship pasting up 7 by 7 foot targets! This demonstrates the importance of a high resolution camera.

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.

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.

New Project...

Create a new PhotoModeler project. A new project is created and PhotoModeler opens the *Project Setup Wizard* to allow the user to create a project and camera. See also *Creating a New Project*.

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 Control Side Bar* 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.

Photo Overview...

Brings up the *Photo Overview Dialog* which shows all photographs in the project.

This tool is available only when a project containing photographs 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*.

This tool is available when a photograph is active.

Export Text File...

Save a project in *PhotoModeler ASCII Export Format*.

This tool is available when a Project 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 Dialog*).

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 Tab (see *Preferences - General*).

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 Mode

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.

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.

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.

Properties of Selected...

This tool will open *Property Sheets* for the objects currently selected.

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.

Property Changer

Change the properties (such as Materials and Layers) for groups of objects in the project. This tool opens the *Property Changer Dialog*.

This tool is available when a project is open.

Image Enhance...

Opens the *Image Enhance Dialog*. 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 photograph is open and active.

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 Tabs*).

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.

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.

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 Control Points

Pick up the Control Point Marking tool and open the Control Points Dialog. See *Marking Control Points*.

This tool is only available when a photograph is active.

Mark Fiducials

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 shown when the camera that is being used requires fiducial marks, and then it is only enabled when a photograph is open.

Define Targets

Opens the Define Targets Dialog so that Template Targets can be modified and imported into the project. See the *Define Targets* section for more detail.

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.

Uncontrol 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.

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.

Select Unreferenced Items

Selects all unreferenced items in the active photo. Useful when used in Referencing Mode to quickly identify items that need to be referenced.

This tool is available, while in Referencing mode when the Source Photo is active. In other modes, the tool is available when any photo is active.

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.

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.

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*.

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).

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.

Processing 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.

Cameras...

Open the *Project Cameras 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.

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.

Constraints List...

Displays the *Constraint List 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.

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.

Measure Mode

Pick up the measure tool. With this tool you can determine the location of a point, the length of a line or the area of a Surface. Projects must be successfully processed and have a defined scale before this tool is available.

See also *Measure Toolbar*, *Processing* and *3D Scale and Rotation Dialog*.

This tool is available when a project has been processed and given a scale.

Post Processing Modification...

Open the *Post Processing Modification Dialog*.

This tool is available when a project is open.

Open a 3D Viewer

This tool shows a list of currently open 3D Viewer Windows if any are open. If you click the tool before the sub-menu of open viewers expands, a new 3D Viewer Window will be opened. See *Viewing the 3D model*.

This tool is available when a project is open.

Tables

This opens a sub menu showing a list of available tables that can be opened.

Open a Photo Table

Open a *Photo Table*.

This tool is available when a project is open.

Open a Point Table

Open a *Point Table* to display XYZ coordinate spread-sheet and other Object Point properties.

This tool is available when a project is open.

Open a Surface Table

Open an Surface Table to display the properties of all Surfaces in the project. See *Surface Table*.

This tool is available when a project is open.

Open a Curve Table

Open an Edge Table to display the properties of all Edges in the project. See *Other Object Tables*.

This tool is available when a project is open.

Open an Edge Table

Open an Edge Table to display the properties of all Edges in the project. See *Other Object Tables*.

This tool is available when a project is open.

Open a Cylinder Table

Open an Edge Table to display the properties of all Edges in the project. See *Other Object Tables*.

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

Position and size all open windows so that they do not overlap.

This tool is available when a document window is open.

Cascade

Position and size all open windows so that their titles are visible and they "cascade" from the top left to the bottom right corners of the application window.

This tool is available when a document window is open.

Minimize All

Convert all open windows to icons.

This tool is available when a document window is open.

Close All

Close all open windows.

This tool is available when a document window is open.

Arrange Icons

Arrange all document icons in neat rows.

This tool is available when a document window is open.

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 document window is open.

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 one or more document windows are open.

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 document window is open.

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 document window is open.

Zoom To Area Mode

Pick up the zoom-area tool. See also *Changing the Magnification of a Photograph*.

This tool is available when a photograph window 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 photograph window is open.

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 photograph window is open.

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 photograph window is open.

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.

Modules...

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 *Modules Dialog* and view currently installed modules.

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.

Tutorial Script

Opens the Tutorial Script Help file. This file contains the script of the tutorial voice-overs as well as a feature map for the videos.

This tool is always available.

PhotoModeler on the Web...

Shows a sub menu of three 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; and

3) A link to the section of the PhotoModeler website that shows a list of modules available for purchase from Eos Systems.

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 the Standard Toolbar.

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* and *Object Properties*.

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* and *Object Properties*.

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 *Shortcut Key Customization* for more information.

File Menu	
New Project	Ctrl+N
Open Project	Ctrl+O
Save Project	Ctrl+S
Save As Project	Shift+Ctrl+S

Edit Menu	
Undo	Ctrl+Z
Delete Selected Items	Del
Enter Select Mode	1
Enter Region Select Mode	D
Select All in Active View	Ctrl+A
Expand Selection to all Windows	W

Marking Menu	
Enter Mark Point Mode	2
Enter Mark Edge Mode	3
Enter Mark / Create Line Mode	4
Enter Path Surface Mode	5
Enter Surface Draw Mode	6
Enter Mark Curve Mode	7
Enter Mark Cylinder Mode	8
Enter Mark Fiducial Mode	9

Enter Mark Control Points Mode	0
Enter Sub-pixel target sub-mode	S
Automatic Triangulation	N
Flip Surface	L

Referencing Menu	
Enter Reference mode	R
Quick Reference	Shift+Q
Unreference selected items	Ctrl+U
Point Audit Selected	Q

Project Menu	
Process	F5
Audit	Shift+F5
Constraint Definition mode	C
Measure mode	M
Open a Photo Table	F6
Open a 3D Viewer	F7
Open a Point Table	F8
Open an Edge Table	F9
Open a Curve Table	F10
Open a Cylinder Table	F11

Display Menu	
Tag Selected Items	T
Clear Selected Tags	Shift+T

Window Menu	
Tile Windows	F12
Close All Windows	F4
Zoom to Fit	F
Zoom to Fit all Photos	Shift+F
Enter Zoom In mode	I

Enter Zoom Out mode	O
Enter Zoom Area mode	U
Zoom Previous	Y
Enter Pan mode	P

Help Menu	
Open Help File	F1

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
Switch between windows	Ctrl+Tab

In key order:

Numbers	
1	Enter Select Mode
2	Enter Mark Point Mode
3	Enter Mark Edge Mode
4	Enter Mark / Create Line Mode
5	Enter Create Surface Mode
6	Enter Surface Draw Mode
7	Enter Mark Curve Mode
8	Enter Mark Cylinder Mode
9	Enter Mark Fiducial Mode

0	Enter Mark Control Points Mode
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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
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
F2	Open Training mode
F3	Resize Training mode windows

F4	Close All Windows
F5	Process
Shift+F5	Audit
F6	Open a Photo Table
F7	Open a 3D Viewer
F8	Open a Point Table
F9	Open an Edge Table
F10	Open a Curve Table
F11	Open a Cylinder Table
F12	Tile Windows

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
Ctrl+Tab	Switch between windows (photos, tables, 3D Viewer, etc.)

Glossary

Terms

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.

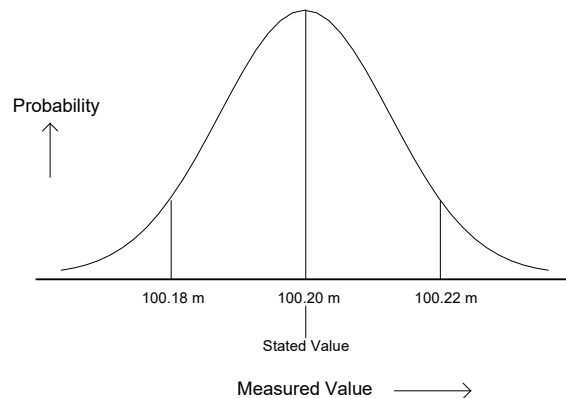
Precision pertains to the closeness to one another of a set of repeated observations of a random variable. Thus, if such observations are closely clustered together, then these

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.

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.

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.

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 the Preferences dialog on the Colors tab.

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.

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 on the *Marked Visibility Tab*. The residuals can be seen in numeric form and summarized on the *Point Table*.

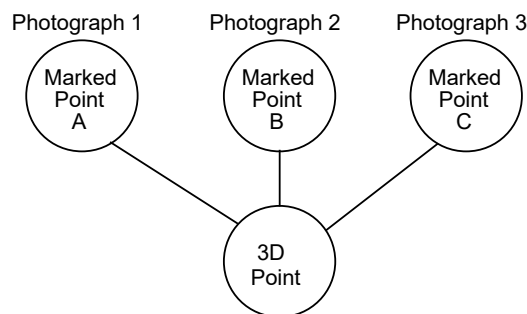
Marking residuals are one of the best indicators of project quality and should always be checked after processing. All projects should have the largest point marking residual of under 10 pixels. For projects with known and calibrated cameras the largest residual should be less than 3 pixels and for projects 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*.

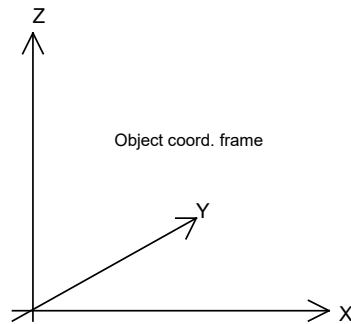
Object Point

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.



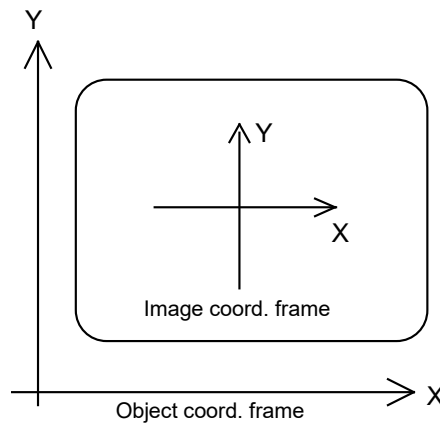
Euler Angles: Omega, Phi, Kappa

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.

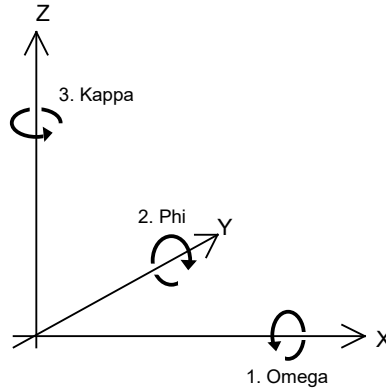
In the following figure, you are looking through the back of the camera towards the object coordinate frame when the camera is in its default position (that is omega, phi and kappa all equal zero) :



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.

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.

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 Chips Tab*, the *Photo Table*, the *Add/Remove Photographs Dialog* and the *Photo Overview 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.

Point

Refer to definitions of *3D Point*, *Marked Point* and *Referenced Point*.

Point Cloud Surface

A *Surface* fit through a number of 3D points approximating a 2.5D surface.

Point ID

A unique number identifying each 3D model point in the project. This number stays the same for the life a point. Point IDs are displayed on the status bar 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

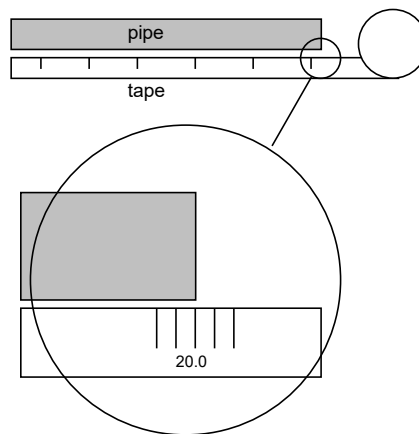
Target has a unique code (that number printed on the coded target by the *Create Coded Targets Dialog*) and there is a direct relationship between the target code and the point ID. If you recognize a point as coded (in a photograph the coded target has a different symbol, in a 3D viewer the id is surrounded 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.

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 *Measure Toolbar*, *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.

Principal Point

The location in a camera where the optical axis of the lens intersects the imaging plane.

Project

See *Measurement Project*.

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

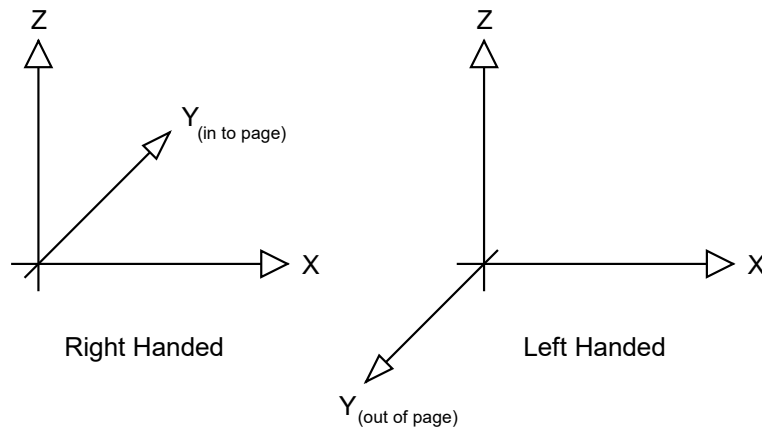
A type of *Target* made from retro-reflective material. Retro-reflective material is a type of sheet that reflects light back in the direction of the light source (unlike a diffuse material that reflects light in all directions (white paper is diffuse) and unlike a mirror that reflects light at opposite 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.



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 *Point Cloud 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

A value used to indicate the accuracy of an Object Point's photo markings in conjunction with the accuracy of the camera station orientations. 'Tightness' is displayed in a number of areas of which the most commonly used is the *Point Table*.

The 3D position of an Object Point is computed by intersecting light rays from photographs. Due to measurement error those light rays never intersect at a perfect point in 3D space.

If we call the closest distance between any two light rays k and j used in the computation of point i as CD_{ikj} , define the largest CD_{ikj} value for any point i as LE_i , and we call the approximate project size (as entered in the Project Information dialog) as PS . Then the tightness value is a percentage computed as:

$LE_i = \text{maximum } (CD_{ikj} \text{ for all } k \text{ and } j)$

$\text{Tightness of point } i = LE_i / PS * 100$

Example of a point number 10 appearing on three photos:

$CD_{10,1,2} = 0.1\text{cm}$

$CD_{10,1,3} = 0.2\text{cm}$

$CD_{10,2,3} = 1.0\text{cm}$

Therefore $LE_{10} = 1.0\text{cm}$

$PS = 20 \text{ meters}$

Therefore tightness for point 10 = $0.01\text{m} / 20\text{m} * 100 = 0.05 \%$

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).

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.

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