

PhotoModeler Pro

User Manual

Version 4.0

Eos Systems Inc.

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PhotoModeler Pro 4.0

The following lines link to the main sections of the PhotoModeler Pro Help file. Click on these links to visit each section, click on the "Help Topics" button above to see the Table of Contents, or click on the ">>" button above to browse the file topic by topic.

Introduction

Welcome to PhotoModeler

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 by letting 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 photographs and locates the marked features in three dimensions. The marks become accurately measured points, lines, curves, cylinders or polygons 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 [Producing a 3D Model](#).

New for 4.0

This section provides a quick overview of the major new features in PhotoModeler Pro 4.0 since the Pro 3.1b release. See the file "changes.txt" in the install directory for a detailed list of all changes to PhotoModeler.

New Modeling Features

- **NURBS Curves:** Create full 2d or 3d NURBS (Non-Uniform Rational Bezier Spline) Curves (open, closed or circles) by marking curved objects in one or more photos with the new Curve Tool.
- **Edges:** Ever wanted to mark the edge of an object but you did not have matching end points in at least two photos? Edges are line-like objects where the end points do not need to match across photos.
- **Constraints:** Give additional information to PhotoModeler regarding distances, lengths, angles, parallelism so as to improve the shape and accuracy of the project. Also use the new Axes constraints to carry out powerful single photo projects.
- **New Surfacing Functions:** In addition to the current 3 point surface tool, you can now create 4 point surfaces, multi-point surfaces, and surfaces attached to Curves and Edges. An automated surfacing tool also creates triangle-based meshes quickly from many 2d, or 3d points.

Accuracy Improving Features

- **Camera Field-Calibration:** For the highest accuracy a camera needs to be calibrated at the distance and focus setting used in your projects. While self-calibration in Pro 3.1 assisted with this, the new field calibration mode allows more thorough calibrations for the best possible accuracy.
- **Constraints:** Give additional information to PhotoModeler regarding distances, lengths, angles, and parallelism so as to improve the shape and accuracy of the project.

Improved Project Support

- **New Single Photo Capabilities:** A larger variety of single photograph projects can now be carried out, all without control points. Using the new axes constraints and a new algorithm, PhotoModeler can solve many interesting archive and forensic photo situations.
- **Project Merge:** Large projects can be split into smaller more manageable PhotoModeler projects and then merged back into one.
- **New Image Formats and Image Engine:** A new imaging engine, means PhotoModeler handles more image formats, and handles them faster and more accurately. Due to licensing restrictions, we do lose the ability to load LZW compressed TIFF files though.

New Capabilities and Efficiency Improvements

- **Photo Rotation:** For easier handling of portrait photographs.
- **Object Property Dialogs:** A consistent set of dialogs for selected objects so their properties can be changed one at a time or as a set.

- Projections: Shows where computed 3D points, edges, lines, surfaces, and curves project onto any photograph (even if you have not marked it on that photograph). Great for checking accuracy of fit, photograph completeness and for marking control point positions you cannot see.
- Referencing Improvements: Referencing is such an important activity in PhotoModeler so a number of improvements have been made to improve efficiency. They are: Auto-Drive (drives the destination photo cursor to the expected point), Photo Drop Down Lists and Auto-Tile (makes the two photo referencing mode easier to handle), Auto-Advance Photo (makes stepping through multiple photos to complete a referencing easier), and Single Point Mark and Reference (allows for single point marking in source photo with immediate referencing).
- Automatic Target Marking: picks out sparse or dense high contrast circular targets from a region or whole image and automatically marks them to sub-pixel precision.
- Automatic Referencing: for certain projects (or parts of projects) that are 2.5D shape, are well oriented, and well marked it can automatically form the references for points across multiple photographs.
- Automatic Surfacing: creates triangulated meshes on 2D, 2.5D and 3D convex surfaces.
- Control Point Editor: (4.0c) user editing (adding, deleting, modifying) of individual control points.

User Interface Improvements

- Configurable Tables: Control which columns of data are visible in each type of Table and their order.
- Resizable and Dockable Project Photos Dialog: The project's photos are now always available down the left side of the application window (optionally).
- Right Click Menus: many modes now have pop-up menus when you press the mouse's right button. This brings PhotoModeler to modern UI standards and improves efficiency.
- Real-time Image Enhance: See the image brightness, contrast, and gamma change in real time as you move the enhancement sliders.
- Alt-Zoom window: in any mode hit the ALT key and you get an immediate zoom in view of the photo where the cursor is located. You can carry out most operations (select, mark, move, draw, reference etc.) in this temporary zoom window.
- Temporary Zoom Mode: Now you can zoom and pan your photograph no matter what mode you are in.
- New Toolbar Look & Dynamic Toolbars: The toolbar has been redesigned to have a more modern look and new sub-toolbars enhance the usability without increasing complexity.
- User Preferences: All the preferences (for colors, process settings, etc.) which were accessible only in the ini file are now front and center on the new tabbed Preferences dialog.

Technical Support

When you are having trouble with PhotoModeler we suggest you try the following before contacting Technical Support:

1. Try to repeat the problem and narrow down the circumstances under which it occurs.
2. Review the troubleshooting sections of this manual and refer to the index for other pointers.

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 number (from Help-About or inside cover of manual),
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.

For 90 days after your purchase you get:

- telephone, fax and e-mail support with response time of 24 business hours or less,
- support for both PhotoModeler problems and project problems, and
- free minor release upgrades.

After the 90 days free support Eos will set up a paid support contract best suited to the customer or the particular project. Please contact Eos Systems Support for more information.

Support Contacts:

Internet E-Mail:	support@photomodeler.com
Web:	http://www.photomodeler.com

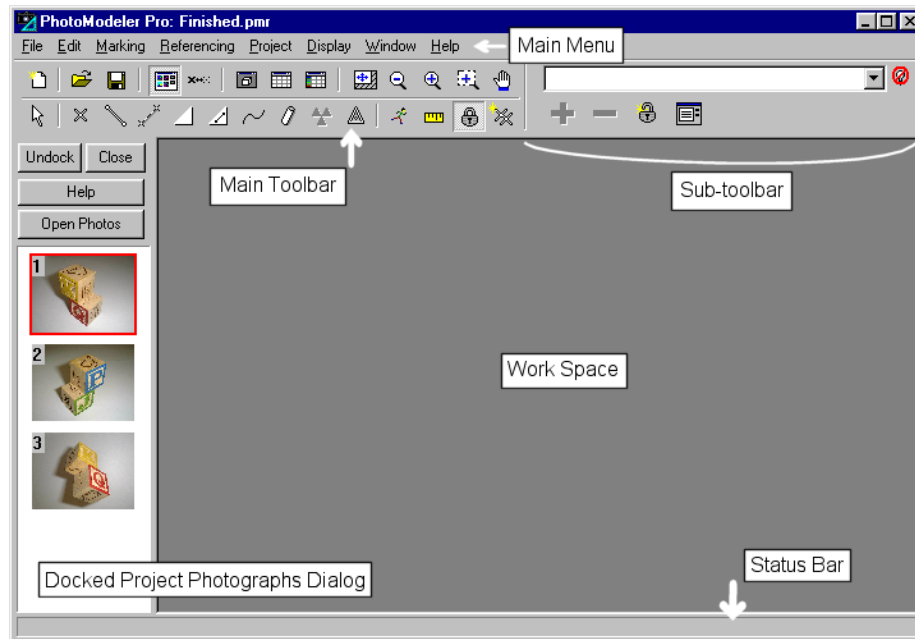
PhotoModeler

User Interface

PhotoModeler is a program that runs under Microsoft Windows (95, 98, NT 4.0(sp3+), 2000) . 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, a main toolbar, a work space, and a status bar (see references below). Optionally there can be the Docked Project Photographs Dialog and a Sub Toolbar.



PhotoModeler screen

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 about on 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 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 Photographs 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 removes the gray color and allows you to select them.

Main Toolbar

Immediately under the menu bar is the toolbar as two rows of buttons. These graphical buttons initiate commonly used PhotoModeler tasks. The first three buttons are used to create, open and save Measurement Projects. Some of the buttons are tools (put PhotoModeler into a mode) and some are immediate actions (such as zoom-to-fit).

Sub Toolbars

Beside the Main Toolbar is a blank area. This blank area is filled with different toolbars based on the current mode. Not all modes have Sub Toolbars.

Tools

A tool is used to accomplish a task. Tools are represented by graphical buttons on the Toolbar. When a tool has been selected PhotoModeler will change the cursor to a symbol representing the tool.

Tools operate only on active windows in PhotoModeler. 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 Preferences dialog.

See also Toolbar Reference for more detail on the types of tools available and what each tool does.

Docked Project Photographs Dialog

In the default configuration, PhotoModeler Pro, displays all photographs that are part of the project, as little images down the left side in a "docked" dialog. This dialog can

be "undocked" to give more work space area or to provide display for fewer or more images.

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

The status bars for selected items are:

Marked Point Status Bar

Photo Mark: x:<x>, y:<y> pixels, residual:(<x-resid>,<y-resid>) pixels

- <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 below) for the Object Point associated with the selected Marked Point

3D Object Point Status Bar

Object Point: id :<id>, tightness:<tightness>%, appears on <photos>, appears on <unused photos>.

- <id> is the id number 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: 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>, num. surface elements:<num1>, num surface draw points:<num2>, material:<mat-name>, group/layer:<group-name>

- <id> is the identification number of this surface (a unique number among all surfaces)
- <num1> 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 a multi-point surface it will be 0 (Surface shape cannot be computed) or N (where N is the number of triangles used to compose the overall surface)
- <num2> is the number of surface draw points drawn on or associated with that Surface. This is useful to know before you delete that Surface.
- <mat-name> is the name of the material assigned to this surface
- <group-name> is the name of the group this surface is assigned to

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 ids:(<id1>,<id2>), material:<mat-name>, group/layer:<group-name>

- <id1>,<id2> are the ids of the points that make up the line
- <mat-name> is the name of the material assigned to this surface
- <group-name> is the name of the group 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>% <units>, appears on <num> oriented photos.

- <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)
- <num> is the number of oriented photos this cylinder is marked on

Curve - open Status Bar

Curve: id:<id1>, appears on <num> oriented photos, common point: <id2>, is <3d>, <is planar>.

- <id1> is the id number of the Curve object
- <num> is the number of oriented photos this curve is marked on
- <id2> is the id number of the common 3D Object Point (for referenced curves only).
- <3d> is the string "3D" (which means the Curve is 3D is whole or in part) or "not 3D" (which means the Curve cannot be computed in 3D in any part)

- <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".

Curve - closed Status Bar

Closed Curve: id:<id>, appears on <num> oriented photos, is <3d>, <is a circle>.

- <id> is the id number of the Curve object
- <num> is the number of oriented photos this curve is marked on
- <3d> is the string "3D" (which means the Curve is 3D) or "not 3D" (which means the Curve cannot be computed in 3D).
- <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".

Edge Status Bar

Edge: id:<id>, appears on <num> oriented photos, is <3d>, angle: <angle>.

- <id> is the id number of the Edge object
- <num> is the number of oriented photos this edge is marked on
- <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.

Camera Station in 3D Viewer 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

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.

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". zoom.

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 complete list of shortcut keys is given in the section [Keyboard Shortcut Reference](#).

Cursor Keys

Accurate positioning is required when marking points on photographs. Sometimes it is easier to move the cursor by small precise amounts using the cursor keys instead of using the mouse. PhotoModeler supports the use of cursor keys for this purpose. Cursor keys are sometimes referred to as "arrow keys".

In a document window you can use the up, down, right and left arrows to move the mouse cursor to its desired location. If you hold down the shift key and press a cursor key on top of a selectable item such as a Marked Point, PhotoModeler will simulate the mouse "drag" operation. To terminate the drag operation, release the shift key.

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.

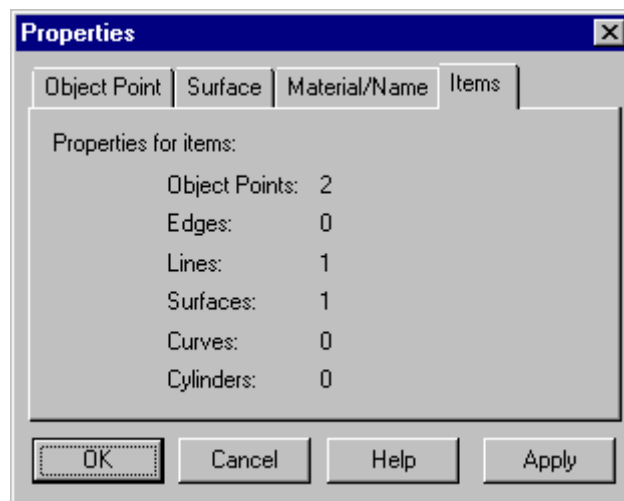
See the section, [Selection and Visibility](#), for more detail.

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 the right mouse menu "Properties of selected..." items 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/Name Properties](#), describes the Material and Object Name sheet, and the following section, [Selected Items Sheet](#), describes the Items sheet.

Selected Items Sheet

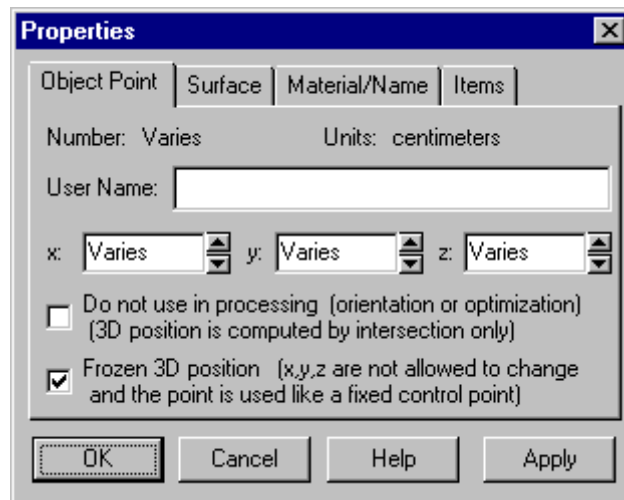


Whenever one of the [Property Sheets](#) is opened, the last tab in the dialog is the "Items" tab. This tab displays what objects types and the number of objects that are being reflected in the display of the other tabs.

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 Object Layer Names. 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/Name", 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.

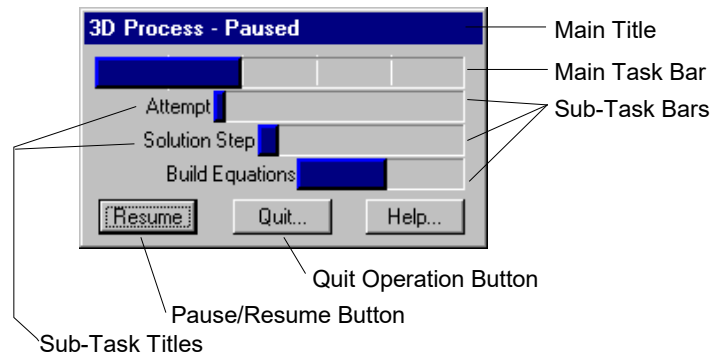
Progress Dialog

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



Progress Dialog

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 means 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 is 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.

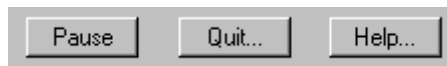
So to complete 3D Process from the state shown in the diagram above would require that the bottom sub-task, "Solve Equations" complete, then the remaining "Solution Steps", then the remaining "Attempts" and then the remaining steps in "3D Process" all complete. At any time, a glance at the Progress Dialog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



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 all program options that are saved from session to session. These settings are saved in the PhotoModeler ini file saved 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 and its solving algorithms. These should only be changed if you understand fully what you are doing. For further information on these you may contact Eos Systems technical support.

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 items on photos.
Referencing	The color used during referencing to denote items to be referenced.
Scale/Rotate/Constraint	The color used to denote the items active for the Scale/rotate or Constraints when those dialogs appear.

Projection Colors

Points	The color of the point symbols when projected onto photos.
Control points	The color of the control point symbols when projected onto photos.
Lines/edges/curves	The color of the lines when projected onto photos.
Surfaces	The color of the surface pattern when projected onto photos.

3D Viewer Colors

Ambient light	The RGB setting for the ambient light for 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.

Preferences - 3D Viewer

The 3D Viewer tab controls those options to do with the viewing of the model in the 3D Viewer.

Field	Description
Try to use Direct3D software driver	If checked the 3D Viewer attempts to bypass any 3d hardware acceleration (which may be causing troubles). If you have DirectX 5.0 or later installed use the Microsoft dxdiag utility instead.
Use ambient light only when textured	If checked the headlight is turned off when the model is textured.
Point symbol smoothed	If checked the point symbol cube is smooth-shaded.
Navigate 3D Viewer with lower texture quality	If checked the 3D Viewer uses a faster but lower quality texture rendering during model rotation, pan and zoom.
Texture quality (0-5)	Controls which form of texture rendering the 3D Viewer uses from Direct3D. The higher the number the better the rendering but slower.
Maximum photo texture size (KB)	Controls how big the texture image files can be in the 3D Viewer. Larger means higher quality but textured models take longer to display and are slower to navigate.
Control Point Viewer Scale	Controls the scale of point and line symbols in the mini-3D Viewer used in the Control Point Dialog.
Cylinder quality (3-100) Line quality (3-100)	Control the number of faces used to view cylinders and lines as tessellated solids in the 3D Viewer.
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.

Preferences - 3D Export

The 3D Export tab controls the export of 3D models.

Field	Description
Tessellation's Cylinder quality (3-100) Line tube quality (3-100)	Control the number of faces used when cylinders, lines, edges and curves are exported at tessellated solids.
Shininess Conversion Factor	These values control how the PhotoModeler Material Shininess value converts to each formats value for shininess which is usually non-linearly defined.
Texture capture border (pixels)	Controls how many extra pixels are added to the border of captured texture areas (which allows for some slop and round off in renderers texture mapping).

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).

Preferences - General

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

Field	Description
Show Tool Tips	If checked the tool-tip text boxes appear on the toolbar.
Open Photos Dialog when Project is opened	If checked the Project Photographs dialog (docked or not) opens automatically when a project is opened.
Surfaces default to double sided	If checked all new Surfaces have their "double sided" property turned on.

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.
Show Only Open Photos in Referencing Lists	If checked only open photos will be shown in the referencing source and destination photo drop down lists. If not checked, all photos in the project (regardless if they are open or not) will be shown in the expanded lists.
Use the PhotoModeler 3.1 accelerator/shortcut keys	If checked the shortcut keys used in PhotoModeler Pro 3.1 will work instead of the new set in Pro 4.0.
Right-click works like PhotoModeler 3.1 in Line draw, Curve draw, Control Point marking, and Referencing	If checked the right-click will not bring up a menu in these modes but instead work like it did in Pro 3.1.
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.

Field	Description
Subpixel method threshold size (pixels)	Controls which type of sub-pixel target detector is used. If target is smaller than this number LSM is used, otherwise the Centroid method.
Weld search distance (pixels)	Controls what distance is considered to be a valid matching point on a photo for weld.

Maximum backup versions (_verN)	Controls the number of backup version pmr files kept.
Default Control point import precision (% of project size)	Controls what is the default value used for Control Import precision.
Ortho-photo preview size (pixels)	Controls the size of the preview image in the Ortho-photo Extract dialog.
Number of recent projects to display	Controls how many projects are listed in the "Open Recent Project" menu item.
Delay before auto driving (milliseconds, 10 - 1500)	Controls how long a delay there is before referencing auto-drive takes place.
Use accurate (but slow) lens distortion correction for 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 involves a 3D point to 2D photo-point projection will use the slower but more accurate method. This affects things like the calculation of marking residuals, the accuracy of the curve algorithm, unreference point weld, automated referencing, etc. This should normally be on by default.
Use accurate (but slow) lens distortion correction for texture mapping	The creation of ortho-photos and perspective corrected textures requires a 3D to 2D projection. When these boxes are checked these operations will use the slower but more accurate method of lens distortion correction. Generally one will not see much difference between the two methods for texture extraction so leaving this unchecked is usually appropriate.
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.

Preferences - Image

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

Field	Description
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Image resolution check thresholds (%)	 Controls the amount 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.
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Photo display

Point IDs font size	Controls the font size in 'points' of the ids that display on photos.
Surface pattern density (0,1,2,3,4)	Controls the density of the pattern used by Surfaces on photo. 0 is solid, 4 is least dense.
Width of lines when set to 'thick' (screen pixels, 1 - 7)	Controls the width of lines drawn on photos when the "thick" setting in checked in the Visibility dialog.
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.

Alt-Zoom Window


Size	Controls the size of the Zoom-Window brought up by the ALT key. eg. 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 if 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).

Image Zoom Levels	Controls the zoom levels used by zoom tools in photo display.
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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.
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.
Guarantee contrast of guide/ghost lines	If checked all ghost/guide lines (line, curve, edge draw etc.) are drawn to guarantee contrast no matter the image contents although the contrast may be lower in some cases.

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 (62% probability level) that a Marked Point is within its true location. This value is key if you wish to get meaningful precision numbers for Object Points after processing.
Sub-pixel target points	 Controls the one-standard-deviation (62% probability level) that a sub-pixel Target Marked Point is within its true location. This value is key if you wish to get meaningful precision numbers for Object Points after processing.

Camera Calibration

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

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 unweighted solution which may produce more consistent results but is far less stable (esp. if principal point is being solved for).
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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

Write the post processing deviation and correlation report	If checked a post-processing report on parameter deviations and correlations will be written to disk after a successful global optimize.
Only report parameter correlations over this %	Controls which correlation values are printed in the report.



Preferences - Orientation

The Orientation tab controls the Orientation stage of Processing

Field	Description
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Number of points to include in relative orientation	 Controls the number of points chosen from all photo points to be used during relative orientation stage. A low number speeds up orientation but there is a greater chance of failure or incorrect orientation.
Number of points to include in orientation check	 Controls the number of points studied to allow relative orientation pick from multiple conflicting solutions. See Valid orientation checks below.

Valid orientation checks






If roll angle is greater than ___ use this weighting factor against the solution: ___	 These two values control how PhotoModeler picks from multiple conflicting solutions to orientation. This weights against cameras that are rolled upside down because this is uncommon.
If a projected point is closer to camera than ___ use this weighting factor against the solution: ___	 These two values control how PhotoModeler picks from multiple conflicting solutions to orientation. This weights against cameras that placed extremely close to the model data because this is uncommon.

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 InverseCamera 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.

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.

In additional to the main help file there are Training Cards. These Training Cards appear in a special help window that appears at the top of the screen tiled with PhotoModeler. This mode can be turned off and on using the Training Mode item in the Help menu (or the F2 key). The Training Cards give suggestions for what to do next for most modes of the program.

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. Both types of camera descriptions can be created by the Camera Calibrator program. PhotoModeler can create just Approximate Cameras. 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 having the Camera Calibrator process them.

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 background on creating Approximate Cameras.

Plan the Measurement Project

In multiple photo projects each point or feature 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 and lines on the photographs to denote the features that are important to you.

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, X, IGES 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 in Pro 4.0?"

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 in PhotoModeler Pro 4.0 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 and constraints are not required but may be used if needed to improve accuracy
- 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 in the PhotoModeler Pro 4.0 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 Constraints (optional) if there are known relationships of features (e.g. parallel lines)
5. Add surfaces and use Surface Draw if necessary
6. Do point, distance and area measurements of the scene using the Measure tool

What features of PhotoModeler will I need to use?

- Camera Calibrator
- Constraints and/or Control Points
- Inverse Camera
- 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 4.0'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 Calibrator
- 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 4.0'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 Calibrator

- 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 using Object Properties dialog
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 4.0'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 using in the Object Properties dialog
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 Calibrator
- 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 Calibrator
- 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 4.0'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 4.0'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 Calibrator
- 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 Calibrator
- 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

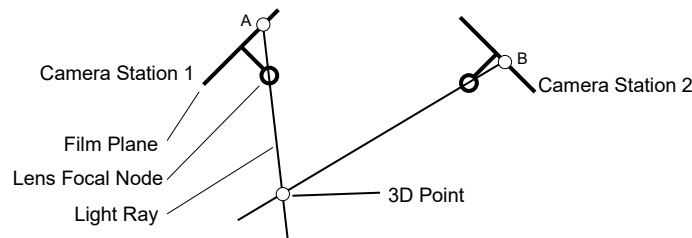
For best results some guidelines should be followed when positioning the camera during photography. The following is a summary of some guidelines for how photographs should be taken. These guidelines are each discussed in detail in this chapter.

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

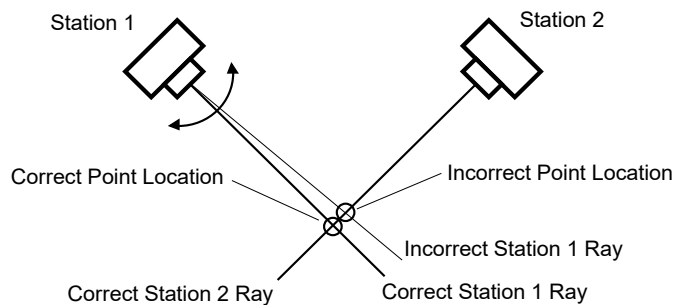
Representations of two Camera Stations are shown in this figure. Each of these show the position of the film or the CCD and the focal node of the lens at the moment the picture was taken. These representations are simple two dimensional drawings but are sufficient to describe the method.

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

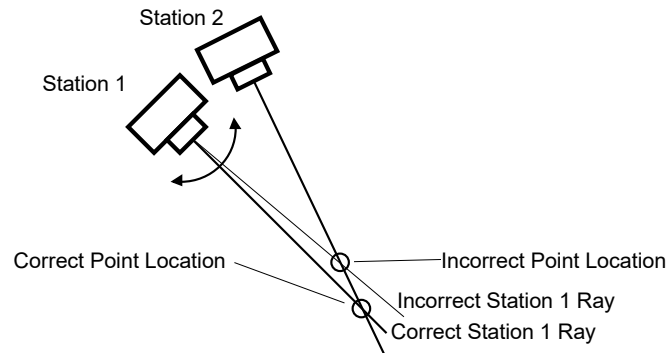
The process of measurement is never perfect. Measurement is instead the process of reducing and minimizing errors so as to maximize accuracy. If PhotoModeler has incorrect camera positions or orientations, it will generate an incorrect position for the 3D point. The figure below shows such a case. It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



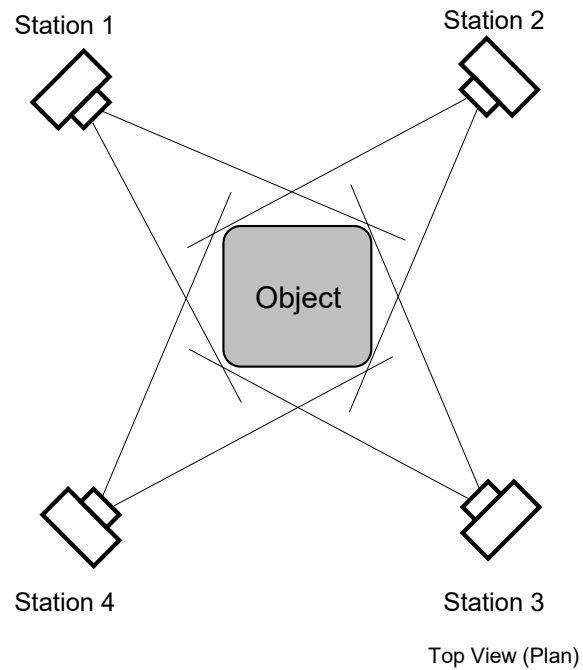
Point Location Error with Bad Camera Positions

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

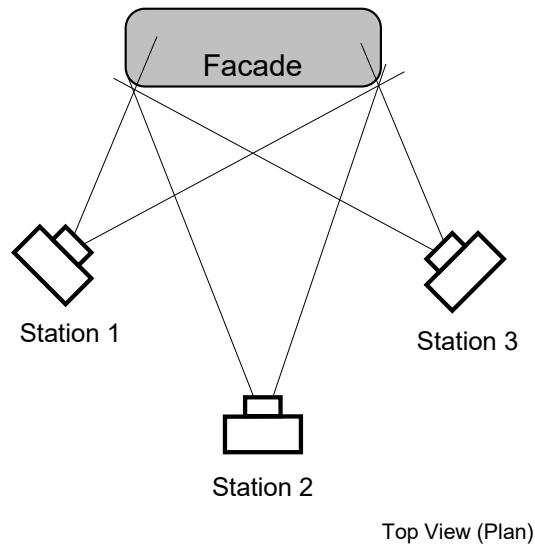
If you are measuring a box shaped object and you are using four photographs, take the photographs off the four corners of the object. All the photographs can be taken at the same level but one or two sides of the box will not be photographed. Often missing a side is not important. The figure below shows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

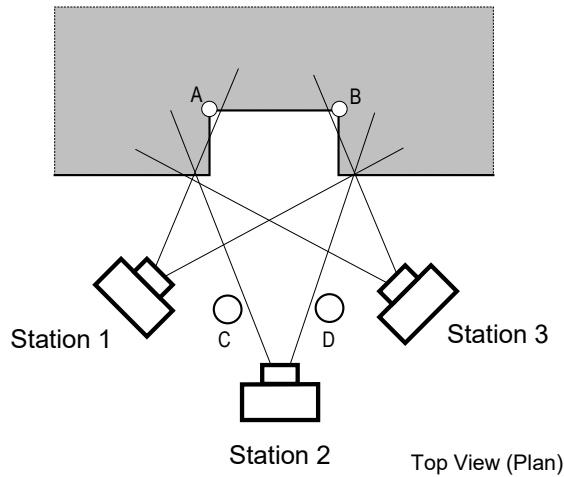
Guideline 2: Take at Least Three Photographs

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.

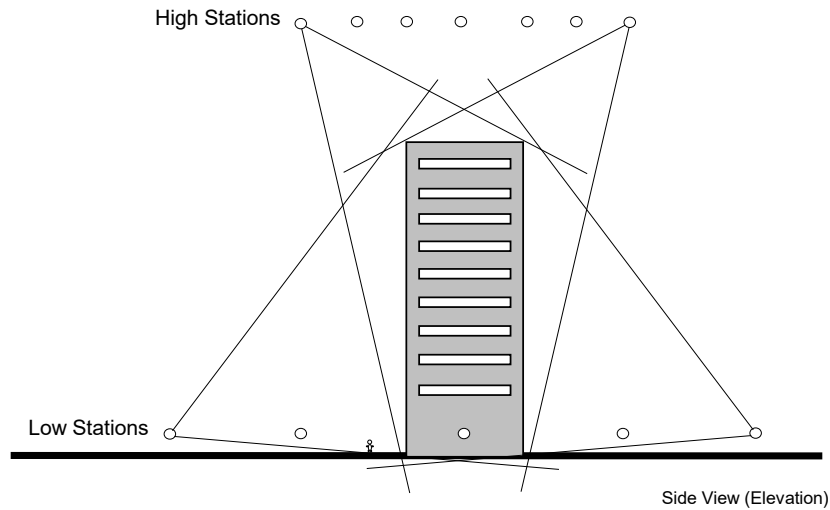


Camera Station Positions for an Alcove

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

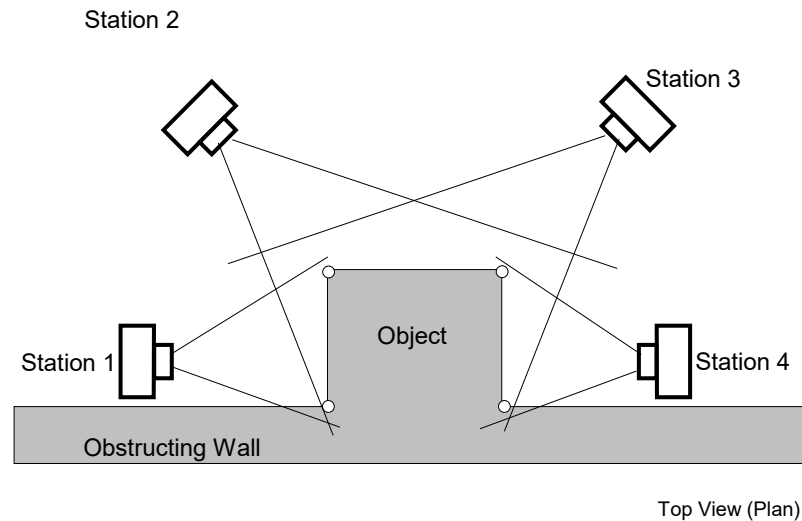
Guideline 3: Try to take photographs with good vertical and horizontal separation. Try to surround the object of interest and try to get above and below it.

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.

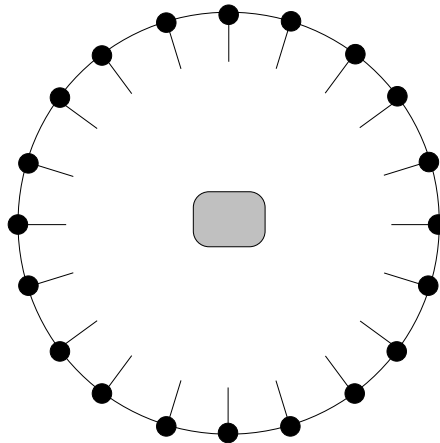
You do not need to follow these guidelines strictly, but you should be aware of them. The closer you come to meeting these guidelines, the easier the measurement process will be and the more accurate the measurements.

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.

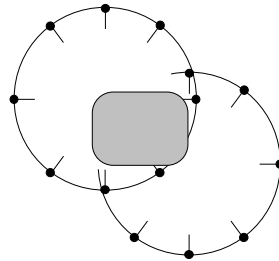
Photographing an object using "rings" is quite easy:

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:

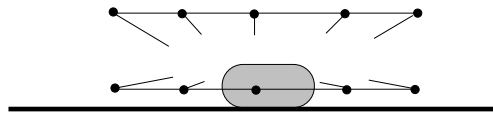


Top View of Camera Positions in a Ring around Object

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:

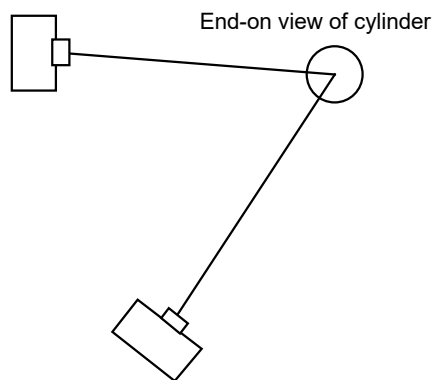
- the photographs be clear and in focus,
- the constrained items (edges, lines, control points) be clearly visible and spread out over the photograph, and
- if trying to recover all the camera parameters in an Inverse Camera procedure, the photograph should be in three point perspective (i.e. have three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

Photography for Curves, Edges, Cylinders and Automatic Referencing

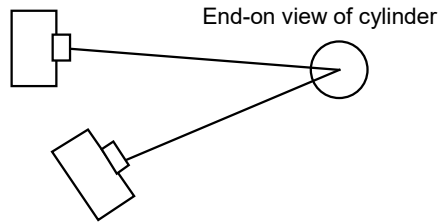
There are some slightly different requirements when taking photographs when you know you will be modeling with curves, edges and or cylinders. These requirements are similar when you wish to use the Automatic Referencing feature.

PhotoModeler's edge, curve and cylinder algorithms depends 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.

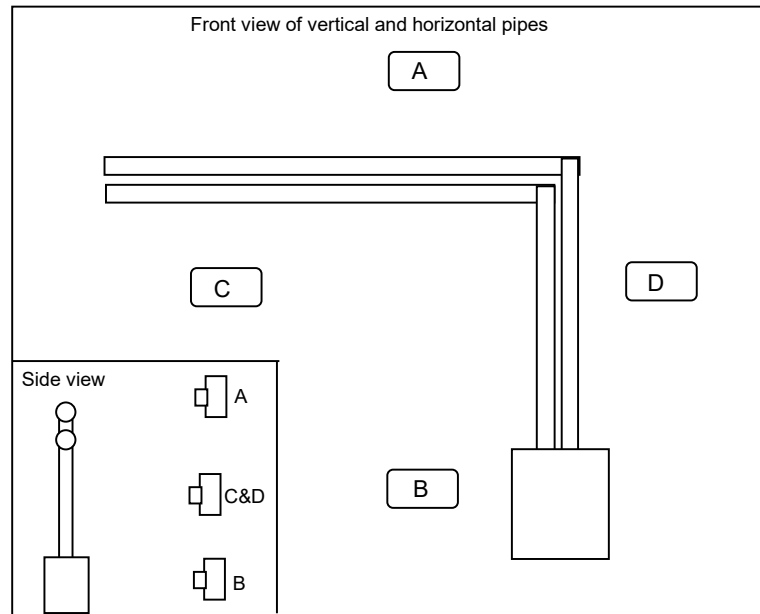
A Curve has similar requirements but the issues are more complex because a curve can be both horizontal and vertical within the same curve. This means you need both vertically separated photos and horizontally separated ones and the curve has to be marked and referenced on all of them.

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.

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: Welcome

The Project Wizard welcome screen lists the steps required to complete a 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: Units and size

This wizard screen prompts for the units of measure you would like for display and for a rough object 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](#).

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 cameras 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 camera 2. The camera manual/specification sheet 3. A piece of paper 4. Tape (or something to stick the piece of paper to a wall with) 5. A ruler or tape measure 6. 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: 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: Stock Cameras

If your camera is listed in the list box select it, as PhotoModeler has been pre-configured to work with your camera. If your camera type is not listed click the "My camera is not in the list" check box below the list of cameras.

When you have selected your camera type from the list or checked the "My camera is not in the list" box 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: 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 a border 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 camera PhotoModeler needs to determine the actual physical size of the imaging area of the CCD chip. You need to carry out some simple steps:

1. Take a picture of a piece of paper stuck to a wall.
2. Enter the distance the camera was from the piece of paper when the photo was taken.
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

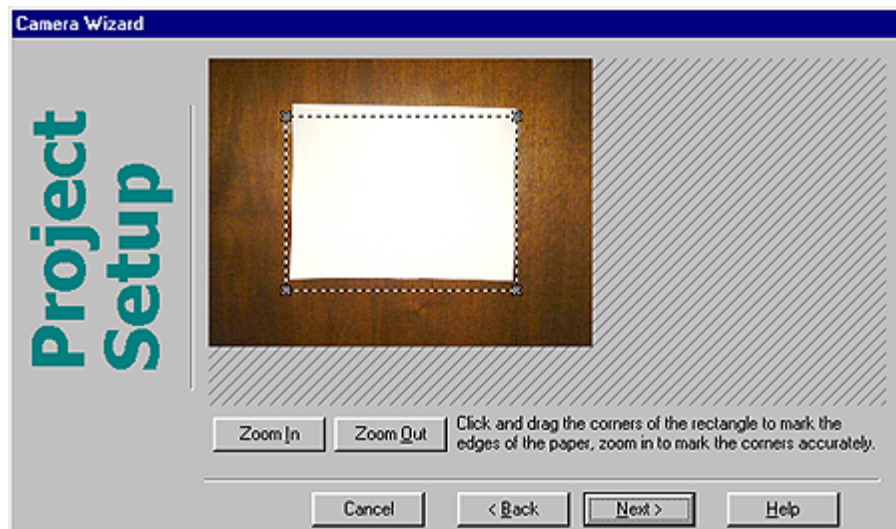
This screen prompts you for three pieces of information.

1. The file name of the image of the piece of paper on the wall.
2. The size of the piece of paper.
3. The distance your camera was from the piece of paper. Measure the distance from the paper to the location of the imaging chip, usually just behind the back of the lens.

Note: the more accurately you enter the information for 2 and 3 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



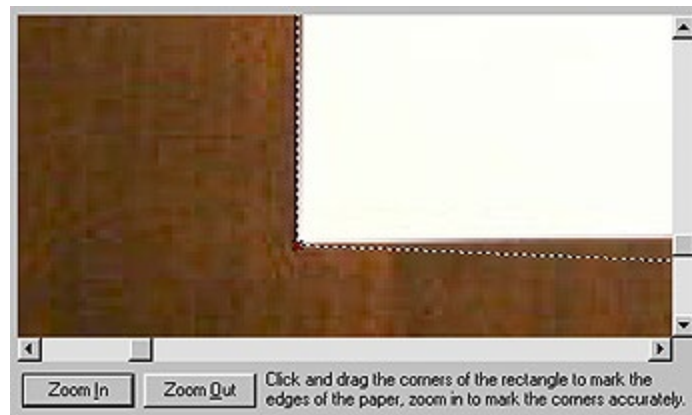
This screen displays the image you selected on the previous wizard screen, with a rectangle outline drawn on top.

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 effects 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

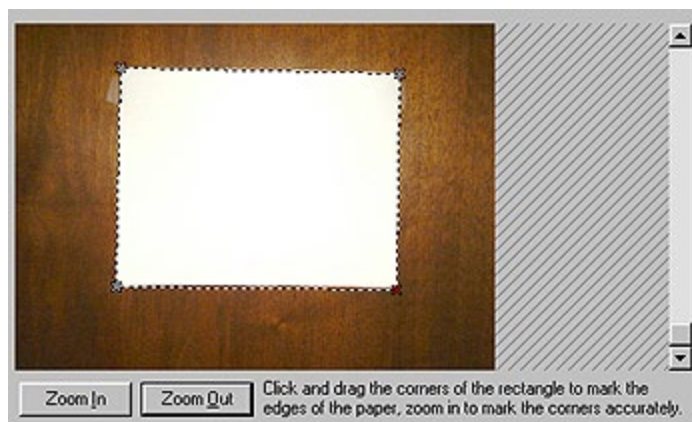
left corner. Once you have zoomed you can use the scrollers to move the image around.

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 hit Next>).



Camera Wizard: Paper rotation error

This screen indicates that the picture you took of the paper has too much rotation. For PhotoModeler to properly determine the format size and pixel squareness the paper has to have little or no rotation relative to the camera.

Please retake the paper picture and reimport it.

You should hit the <Back on this screen. 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 the .PMR file. Click the Browse... button to select the file or enter the name and path of the file in the edit box provided and then click the Next> button to load the camera.

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 (ie. 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 hit 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 Calibrator.

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 (ie. 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 (ie. 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.

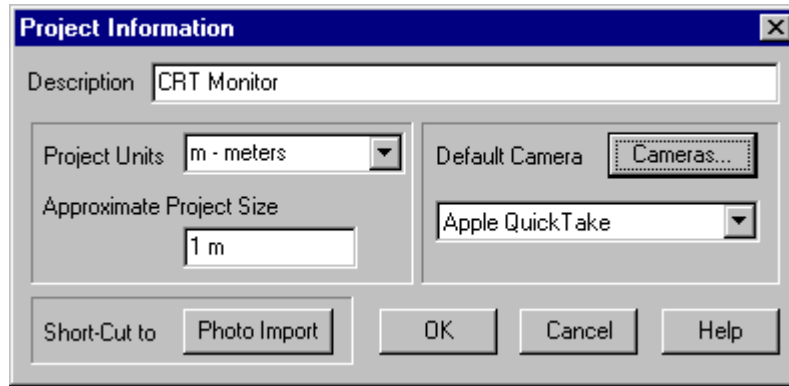
Photo Import Wizard: Finished

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.

Project Information Dialog

The information created by the Wizards is also accessible directly through various dialogs. The project information is accessible through the Project Information Dialog.



The Project Information Dialog is accessed by the Project Information menu item from the Project menu. It contains information first collected by the Project Setup Wizard.

This dialog shows properties that affect the whole project. The first is the project description. This is a text string 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 project 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 Dialog. 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 as often as you want without affecting PhotoModeler internal coordinate data.

The third property is the approximate size of the object or scene in this project. 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. Again 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 default camera. All new photographs, as they are imported into a project, are assigned a camera. The camera assigned is the one shown in this dialog. The camera can be changed on a per photo basis using the Photograph Properties Dialog. The default camera is most useful when a project is done with only one camera (which is quite common) and so each individual photo does not need to be told what camera took it. New projects will not have any cameras imported or created. To create a new camera or load one from disk you press the Cameras button to bring up the Camera Information Dialog.

All of these project properties are normally set up when a project is first created and then not modified but they can be changed at any time. For instance, you can change the default reporting and measurement units for a project part way through your project work. You might have started the project in inches but decide to go metric and switch to centimeters.

The buttons along the bottom of the dialog are used to accept the project property changes, to not make the changes, or get help on the dialog. The Photo-Import short cut button is not used much anymore due to the introduction of the Project Wizard. It remains here for user interface compatibility. It jumps to the [Add/Remove Photographs Dialog](#).

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.

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](#) and [Saving a Project](#).

Merging Projects

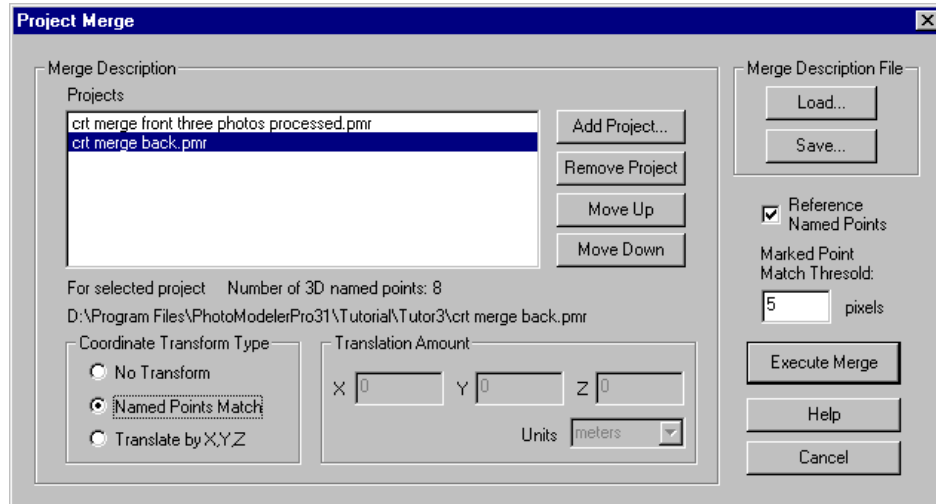
There are some circumstances where a larger project will be broken down into smaller projects. When the smaller projects are complete you may want to combine the projects together to complete the model, view the completed model, reprocess etc.

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.

An example 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 non, 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 Points", is checked then any user-named object points with the same name are referenced together (note this is independent of the named-point match 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:

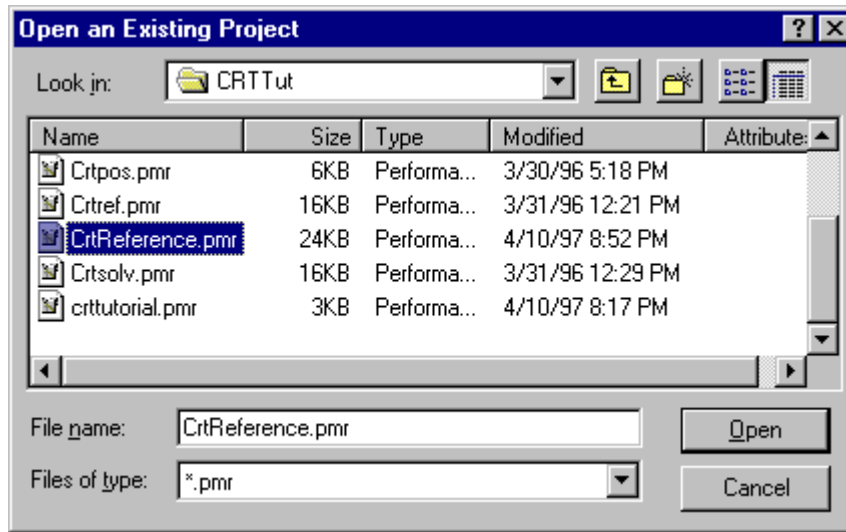
crttut.pmr	- file you would work with as it is most recent
crttut_ver7.pmr	- the next most recent version
crttut_ver6.pmr	
crttut_ver5.pmr	
crttut_ver4.pmr	
crttut_ver3.pmr	- the oldest version

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 under Windows 95,98,2000 or NT 4.0 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.

Working with Cameras

Deciding on a Camera and Scanner

Deciding on the camera and scanner to use with PhotoModeler will probably be the most important and the most difficult decision 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.

Effect on Results

The camera/scanner combination you use will affect the results you get with PhotoModeler. Generally, the higher the image quality of 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.

Film and the Film Plane Insert

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.

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.

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 PhotoModeler Calibrator and verify with field use and calibrations. Use high contrast circular targets and the sub-pixel target marker.

I want the best accuracy PhotoModeler can give me and I am not too worried about a few of days turn around.

Use a medium format film camera with very-high quality non-zoom lens. Use a reseau grid or full frame scanning. Perform a full calibration using the Camera Calibrator. Scan the negatives with Kodak's Pro PhotoCD or use a high-quality negative scanner that does not move the film but the scan head instead.

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 up to 640x480. You will probably need to calibrate the camera and digitizer using the Camera

Calibrator program. 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 Film Plane Insert you will need a full frame scanner such as the Nikon LS-3510, Microtek 35t and 45t or the Leaf 35. For best results you will need to calibrate the camera using the Camera Calibrator program. 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 photographs 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 InverseCamera feature if you know nothing about the camera that took the photographs and you still need reasonable accuracy.

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.

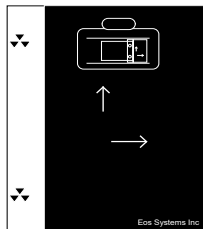
Using a scanner (such as PhotoCD) is best done with a fiducial insert. If the scanner is very consistent (the PhotoCD auto-gate scanner is sometimes this way) you can forego fiducials and use the PhotoCD with no fiducial camera type.

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

Included in the PhotoModeler package is a small piece of plastic film that looks like this:

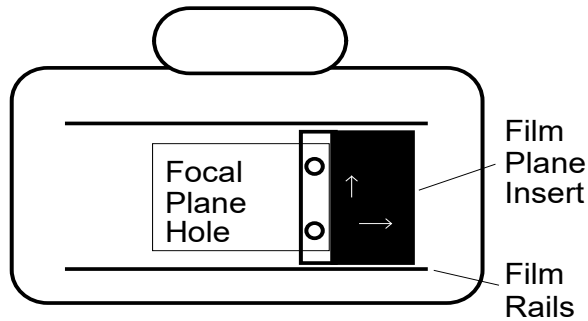


This is the Eos Systems Film Plane Insert. To use this insert glue it into the camera between the film rails projecting out into the imaging area.

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.

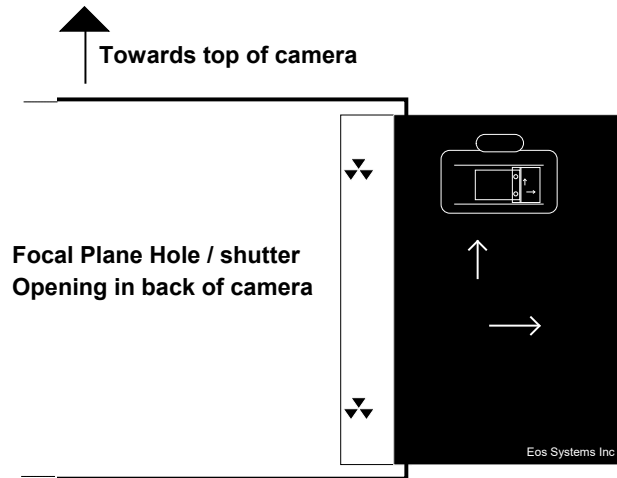
To modify the camera, follow these steps:

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 the [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

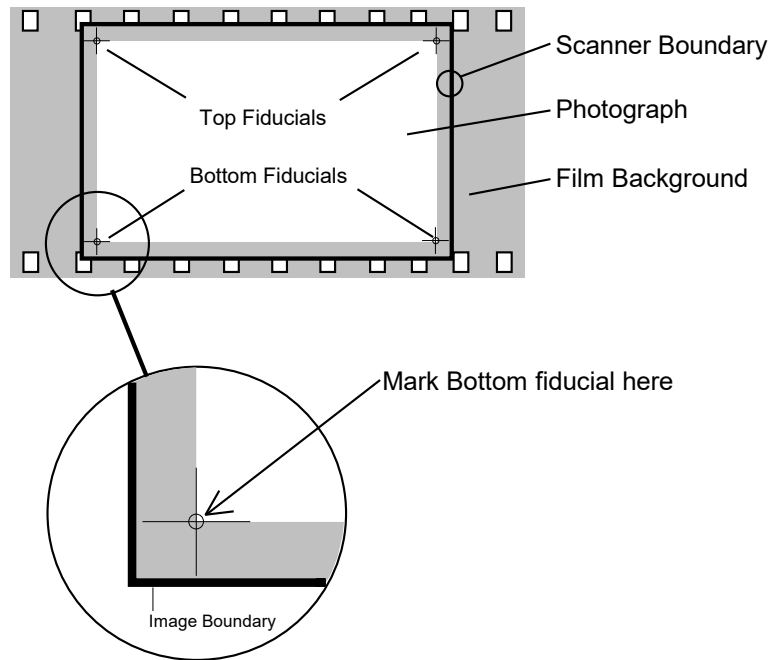
You may have a number of photographs of an object taken before you obtained PhotoModeler, before you inserted the Film Plane Insert in your camera or you may not wish to use the insert. Can you use these with PhotoModeler? The answer is "yes", but a few conditions must first be met if you want *high*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

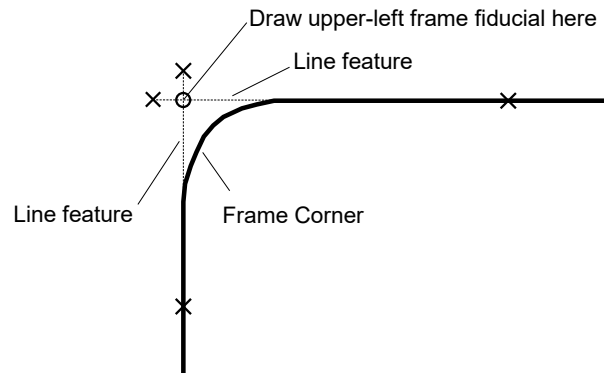
If these conditions are not met you can still get reasonable results by using the appropriate non-fiducial camera type or by using the [Inverse Camera](#) procedure.

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.

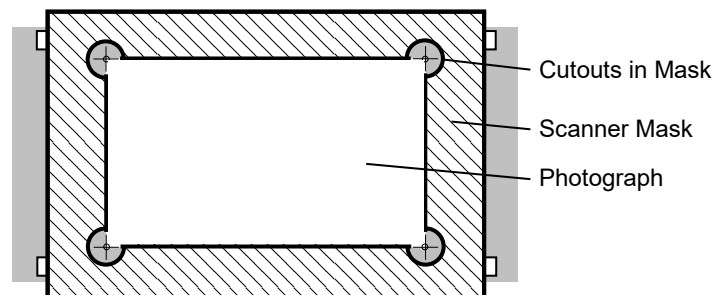
A good way to mark the frame corners in PhotoModeler (especially when they are rounded) is to use some dummy line features as construction lines. Line them up along the frame edge and then use the line intersections to mark the fiducial.



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 and scanner 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 and scanner. 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 Calibrator, 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 either PhotoModeler or by the Camera Calibrator program. If you are not using the Wizard to create a camera you need to enter in some parameters that describe the camera. You may not know these numbers exactly so provide the best numbers you can. To enter these parameters you will fill in the Camera Information Dialog (shown below). This dialog is the same in both PhotoModeler and the Camera Calibrator. 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.

To create an Approximate Camera using the Camera Dialog:

1. Start PhotoModeler.
2. Select the "Load/Save Cameras" menu item from the File Menu.
The Project Cameras Dialog will appear.
3. Click on the "New..." button to create a new Camera.
4. Fill out the Camera Information Dialog as discussed in the tables below.
5. Click on "OK".
6. 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: Eos Fuji MX700 in macro

Focal Length: 7.6000 mm

Format Size W: 7.1451 H: 5.2908 mm

Principal Point X: 3.5725 Y: 2.6454 mm

Lens Distortion K1: 0 K2: 0

P1: 0 P2: 0

Image Size: 640 x 480 Set from file

Fiducial type: No Fiducials

Fiducials: mm

Modify...

Calibrated: no ☐ 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 " <u>Determining Digital and Video Camera Format Size</u> " for a quick way of determining format size. |

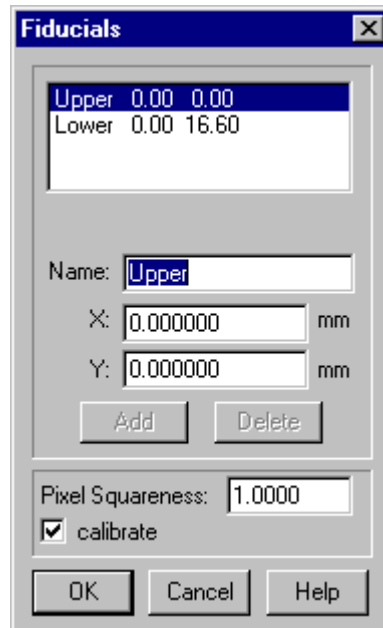
Principal Point:	The reference point in the image to which all marks and lens distortion parameters are related. In a fiducial camera the principal point is in the same coordinate system as the fiducials; in a CCD camera the principal point is relative to the upper-left corner of the image. Set this 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 Lens Distortion Formulation .
Image Size:	The resolution of the images created by this camera.
Fiducial type:	If this is a film camera with fiducials 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.
Inverse Camera:	If checked, this camera is used for Inverse Camera processing (in other words, the camera parameters are not that well known). A camera with this set will be copied for each photo it is assigned to.

Note 1: The calibration part of the Camera Calibrator program is suited best to fine tuning camera parameters - not for trying to find camera parameters when they are completely unknown. If the first approximations of the camera parameters are close to the true values, the calibrator will tune them well. If the approximations are very far off, the calibrator may not solve and if it does solve the result may not be very accurate. Try your best to start the calibration with good first approximations for the parameters. See [Camera Calibration](#).

Note 2: 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 close focus 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.

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.

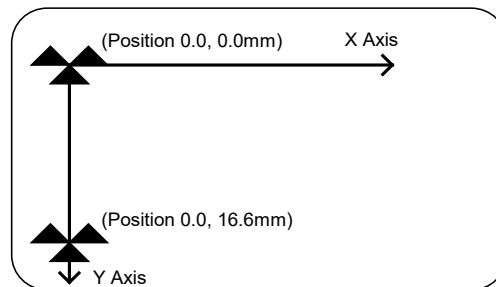
Fiducials cannot be removed from the Camera types, "35mm film w/ Eos Insert" or "35mm film w/ frame edge fiducials". Fiducials also cannot be removed if they have been marked on any Photograph in the project. If you wish to remove a fiducial that is marked, track it down on all Photographs and delete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

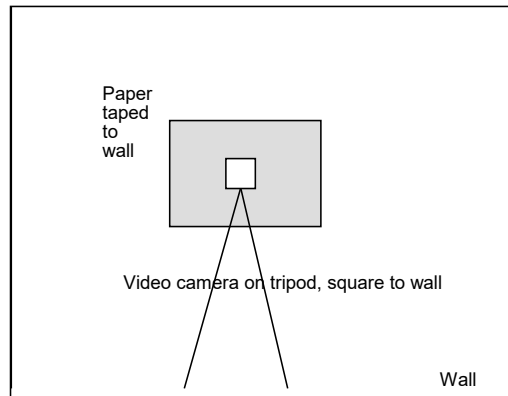
The best way to set up digital and video cameras is to use the [Camera Setup Wizard](#). If you want to do the format size calculations yourself or check the wizard's results you can follow the method below.

You will need

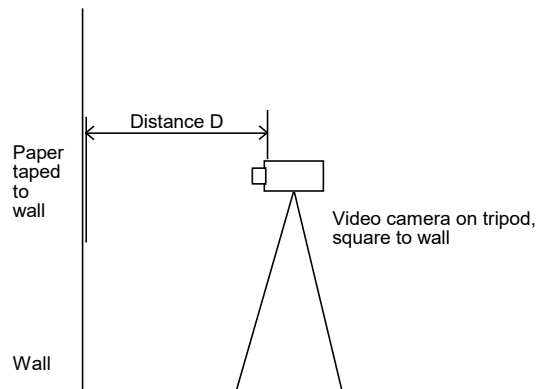
- the video or digital camera
- a tripod (or camera support of some form)
- a sheet of 8.5"x11" paper (or A4 sheet)
- a measuring tape
- a small portion of a flat wall
- a good estimate of the focal length of the camera (the focal length you are going to use)

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.

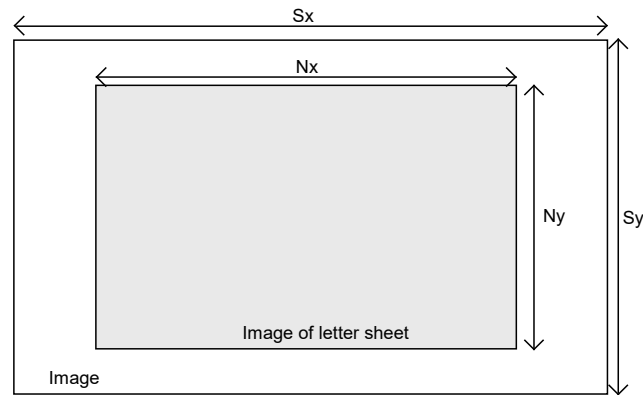


Back view of camera setup



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 Nx and Ny.
You can find pixel positions in PhotoModeler by loading an image and marking points. When a points is selected its pixel position appears in the status bar. Nx and Ny 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 Sx and Sy.
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:

$$h = Py / D * f / Ny * Sy$$

where Py 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 = 8.3mm.

The measurement made were D = 27.5", Nx=361 pixels, Ny=272 pixels, Px=11", Py=8.5", Sx=496, Sy=360.

Therefore w = 11" / 27.5" * 8.3mm / 361 * 496 = 4.56mm
and h = 8.5" / 27.5" * 8.3mm / 272 * 360 = 3.39mm

Notice that we measure the distance D and the size of the paper Px,Py 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, Px, Py 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:

$$xc = x + drx + dpx$$

$$yc = y + dry + dpy$$

where xc,yc 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:

$$xc = x * (1 + drb / r)$$
$$yc = y * (1 + drb / r)$$

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

$$dr = drb / r$$
$$xc = x * (1 + dr)$$
$$yc = y * (1 + dr)$$

The formula used by PhotoModeler for dr is given by:

$$dr = K1 * r^2 + K2 * r^4$$

where $r^2 = x^2 + y^2$ (r^2 means r to the power of 2)

where K1 and K2 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:

$$dr = A0 + A1 * r^2 + A2 * r^4$$

To convert this balanced form to PhotoModeler's unbalanced form you use:

$$s = (1 - A0)$$
$$f = f2 / s$$
$$K1 = A1 / s$$
$$K2 = A2 / s$$

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 and K2 with a different sign than PhotoModeler. If you are not getting good results with the above try changing the sign of K1 and K2. 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).

$$A0 = - (K1 * r0^2 + K2 * r0^4)$$

$$s = (1 - A0)$$

$$f2 = f * s$$

$$A1 = K1 * s$$

$$A2 = K2 * s$$

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 calib40.ini file found in the Windows directory:

```
[Process]
```

```
...
```

```
P1Dev=-0.001
```

```
P2Dev=-0.001
```

When these are set to negative numbers the Camera Calibrator 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 calib40.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.

Building a Calibrated Camera

To get the highest accuracy you will want to calibrate your cameras and lenses. The Calibration process is described in detail later so it is not covered here.

One of the steps in building a calibrated camera involves setting initial camera parameters. The tables shown above in the Approximate Camera section should help you do that. Refer to the User Manual for the remaining steps.

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 brand 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.

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 done hit 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 hit 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.

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 hit 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.

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 (in PhotoModeler and the Calibrator) 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 the PhotoModeler Camera Calibrator, 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.

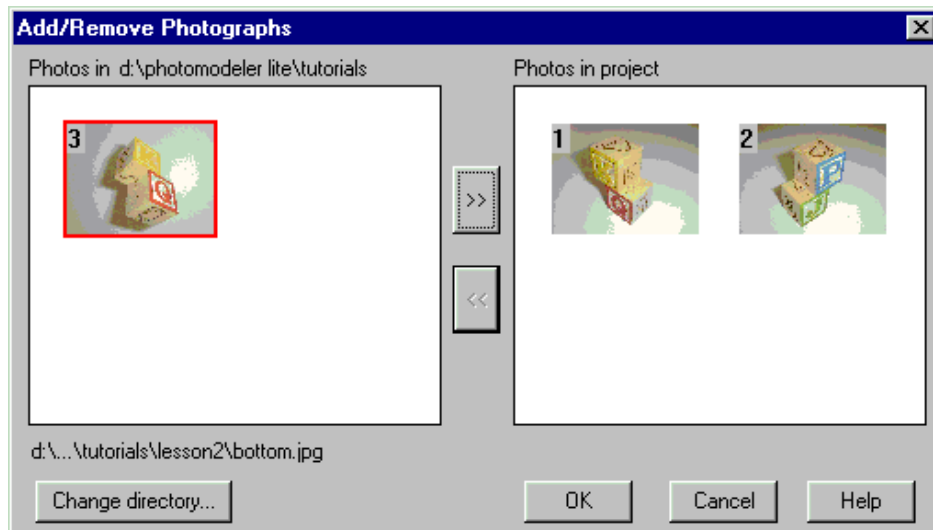
Adding Photographs to Your Measurement Project

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](#).

Add/Remove Photographs Dialog



The Add/Remove Photographs Dialog is used to import Photographs into and to remove Photographs from the current Project.

The dialog is composed of two large regions that show image chips of photographs 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 image 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 (in PhotoModeler and the Calibrator) 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 image chips for all recognized image formats will be loaded and displayed in the Directory Photographs area.

Select an image 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.

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.

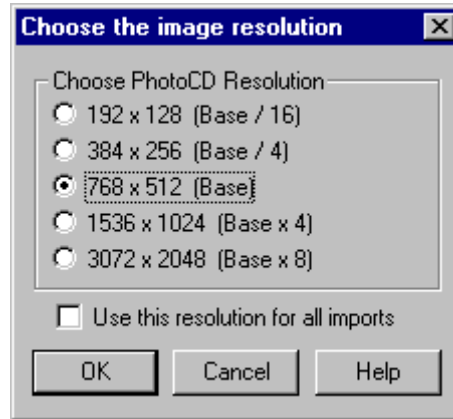
Any photograph additions to the Project can be canceled by hitting the "Cancel" button on this dialog.

Removing Photographs from a Project

To remove a Photograph from a Project first select the image chip of the required Photograph (its file name will appear at the bottom of the dialog), then hit 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).

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.

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 press the Open Photographs toolbar button or select "Open Photographs..." from the File menu. This selection will bring up the [Project Photographs Dialog](#). This dialog shows photograph chips of every photograph you have imported. You may open one or more photographs by choosing its photograph chip and pressing the "Open Photos" button.

If you would like to open all your photographs at once, you may choose "[Open All Photos](#)" from the File menu.

Caution: When using "Open All Photos" with large photographs, PhotoModeler may reduce their resolution in order to fit them all into memory at the same time. These reduced photographs are suitable for some tasks, but when marking the features of your 3D model you should use full resolution photographs.

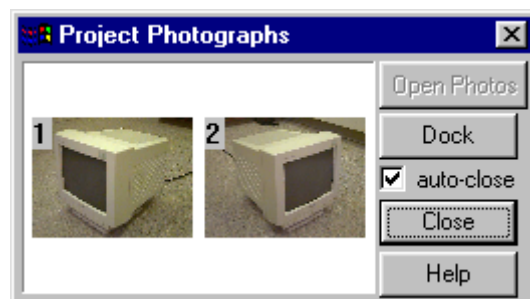
Project Photographs Dialog

The Project Photographs Dialog is the central control in PhotoModeler for opening photographs and accessing their properties. This dialog can be opened from the toolbar or from the File/Open Photographs menu item.

This dialog has two forms, a docked and an undocked form. Both forms are shown below.



Docked Project Photographs



Undocked Project Photographs

The docked Project Photographs dialog will open by default whenever a Project is opened. This behavior can be changed in the [Preferences](#) Dialog.

If you press the Undock button, the dialog will switch the floating non-modal form above called the "Undocked Project Photographs Dialog". When in this mode, the dialog can be closed, moved around the screen but more importantly resized to show any number of photograph chips.

To open a Photograph (i.e. so marking can be done) select one of the photo-chips with the mouse (it will highlight with a red border (or current select color)) and press the Open Photos button. Multiple photographs can be opened at once by selecting multiple chips (using shift or control keys and left mouse button) and pressing Open Photos. If you are opening just one photograph, the chip can be double-clicked as a short cut. If a Photograph is already open then opening it again from this dialog will bring it to the front.

If the photograph you wish to open is not in this list see [Adding Photographs to Your Measurement Project](#).

This undocked dialog can be closed using the "X" button in upper right or the Close button. If the "auto-close" check box is checked then whenever one or more photographs are opened this undocked dialog will close right away.

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 Photos dialog.

Note: PhotoModeler has an automated mechanism for creating smaller versions of each image. These smaller versions are used in the Project Photographs Dialog, Add/Remove Photographs and the Open All Photos menu item. 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.

Photograph Properties Dialog

Photo Properties

Photo #: 1

Camera: Apple QT100

Processing Action

☐ Do not use

☒ Use and adjust

☐ Use but no adjustment

Texture and Auto-Color

Photo Quality: 0

Inverse Camera Processing

Solve for: ☐ focal length ☐ principal point ☐ format aspect

Photo Rotation

☒ None ☐ 90 Deg. ☐ -90 Deg. ☐ 180 Deg.

Description:

Image Filename: d:\...\tutorial\tutor3\crt1.jpg

Camera Station

Position (cm)		Angles	
X:	68.3476	Q:	54.8903
Y:	-67.7295	P:	40.0395
Z:	41.1586	K:	23.2739

Oriented: yes

OK Cancel Help Apply

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.

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 (ie 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 and Auto-Color

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, 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 Dialog](#).

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.

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

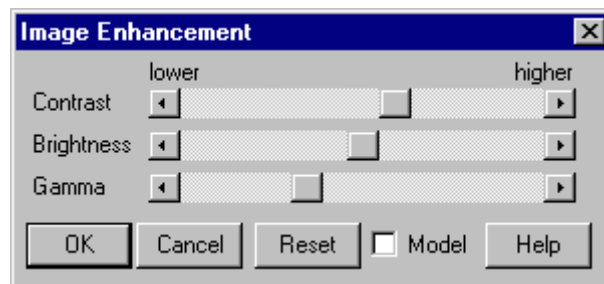
Right click menu	to access zoom 1:1
Alt key	to access zoom window to get quick magnify
Zoom area toolbar	to get precise area to view
Ctrl left mouse button	to get precise area to view while in any mode

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 Marking Menu. Modify the values in the Brightness and Contrast Dialog.

Image Enhance Dialog



This dialog is opened with the Marking 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.

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, hit 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.

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 hit 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.

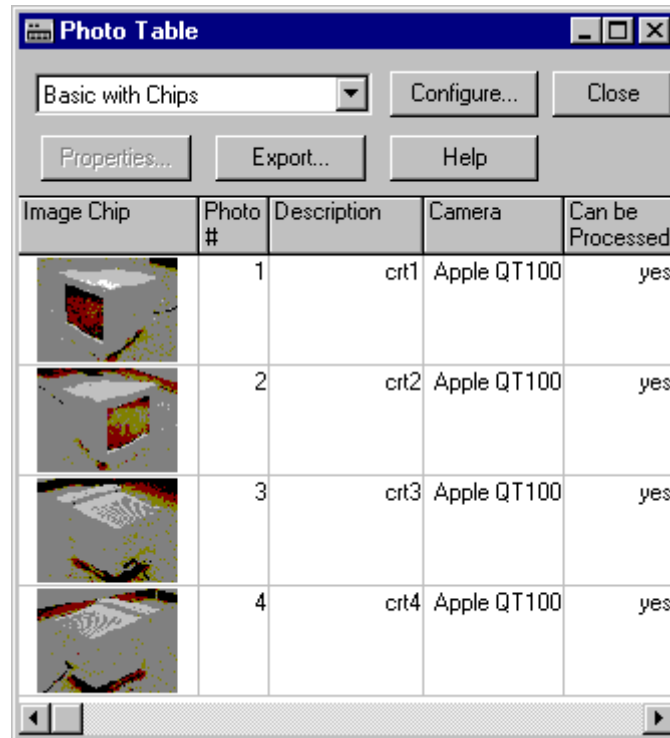
You want to switch a project from TIFF to JPEG images

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
Photo #	number	Unique identifier number
Description	text	User define photo name

Camera Station Property	Type	Description
Center X	# units	The Camera Station position in the current coordinate system.
Center Y	# units	
Center Z	# units	
Omega	# degrees	The Camera Station angles.
Phi	# degrees	
Kappa	# degrees	
Target X	# units	A point at arbitrary distance that the camera is looking at.
Target Y	# units	
Target Z	# units	
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 numbers of pixels.
Image Width	# 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 Marking Residual on this photo.
RMS Residual	# pixels	The RMS (root mean squared) Marking Residual on this photo.
Inverse Focal Length	boolean	"yes" if InverseCamera solution for focal length is requested.
Inverse Format Aspect	boolean	"yes" if InverseCamera solution for format size is requested.
Inverse Principal Point	boolean	"yes" if InverseCamera solution for principal point is requested.

Camera Property	Type	Description
Camera	string	Name of the camera used by this photo.
Focal Length	# mm	The focal length of that camera.
Format Height	# mm	The size of the imaging format of that camera.
Format Width	# mm	
Prin. Point X	# mm	The principal point of that camera.
Prin. Point Y	# mm	
K1, K2	#	Lens distortion parameters for that camera.
P1, P2	#	
35mm f	# mm	The 35mm camera equivalent focal length for digital cameras.
FOV H	# degrees	The field of view of that camera.
FOV W	# degrees	

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 (ie. 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, 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,
- Edges,
- Curves,
- Cylinders,
- Lines, 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.

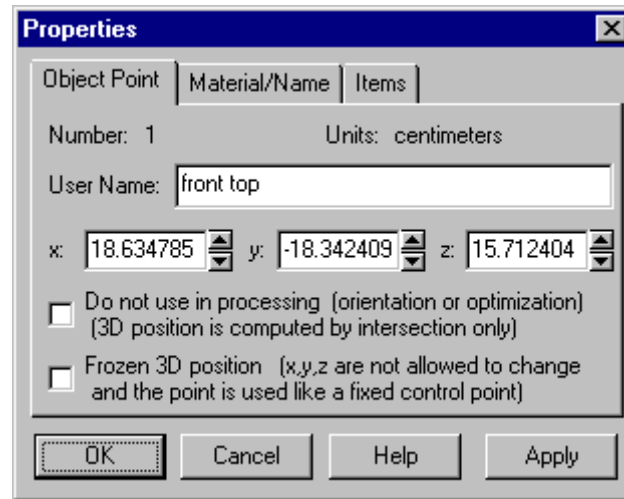
Object Points are created by placing Marked Points on Photographs. These Marked Points are then referenced together (in a multi-photo project) to define the 3D location of the Object Point.

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.

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,
- 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/Group

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 (ie. they define a plane that is not necessarily one of the coordinate planes (ie 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,
- a 3D position defined by two X,Y,Z end points,
- a Material, and
- a Layer/Group.

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

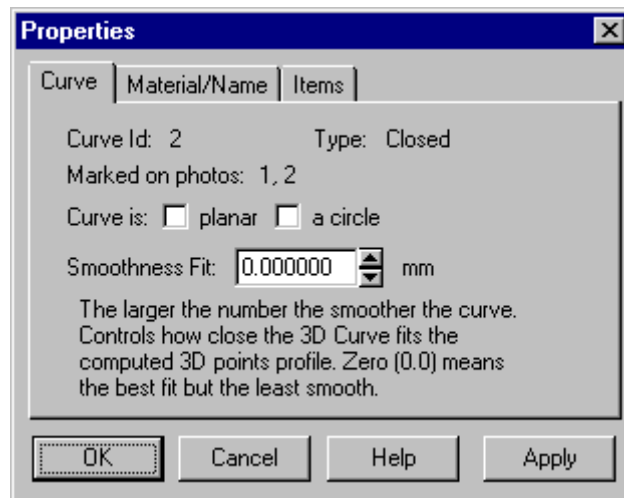
- fires when an edge point is moved
- fires when one of the photos its mark appears on is oriented, reoriented or forced unoriented
- fires when the user changes camera parameters or camera station parameters for that photo
- from constraints computation when the edge is used in one of the [Axes Constraints](#)

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,
- 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 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/Group.

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,
- a 3D position defined by two X,Y,Z end points of the center line and a radius,
- a Material, and
- a Layer/Group.

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.

Cylinder:: id:2, dia:4.15 ft, len: 24.97, ct[0.00,-0.00, 1.00], angle:53.2, error: 0.1% Good, appears on 2 oriented photos.

Cylinder Status Bar

When a cylinder is selected on a photograph, the status bar at the bottom of the application shows all its relevant data. Reading from left to right that is:

- the cylinder identification number assigned by PhotoModeler (e.g. 2)
- the diameter in the project units (e.g. 4.15 feet)
- the length of the modeled section of the cylinder (e.g. 24.97 feet)
- the center-line unit direction vector (e.g. z axis = 0,0,1)
- the angle between photos imaging this cylinder (e.g. 53.2 degrees)
- the fitting error as a percent of cylinder diameter (e.g. 0.1% of 24.97feet = 0.3 inches)
- an indication of whether this is a good cylinder calculation (e.g. Good)
- the number of oriented photographs that this cylinder is referenced on (e.g. 2)

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/Group.

How Lines become 3D

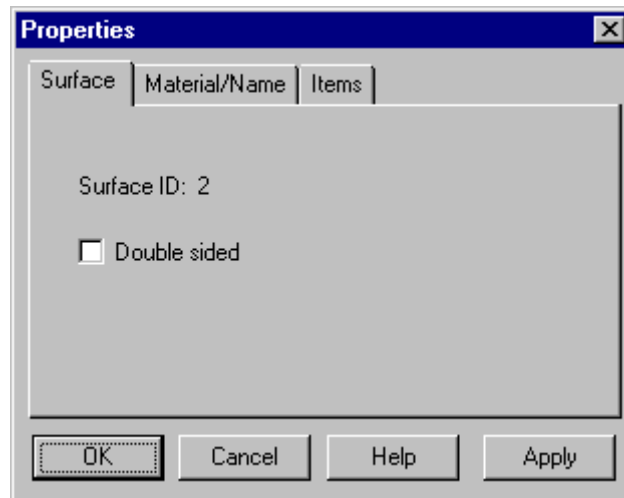
Lines get their 3D position solely from the 3D positions of their end Object Points.

Surfaces

A Surface is a an object that helps make the 3D model look "solid". Surfaces are applied Materials such a colors and photo-textures to make the model look more realistic. Surfaces are the only object in PhotoModeler that can be photo-textured.

Surfaces are created by picking Object Points, Edges and Curves as the boundary of the region to become the surface. At minimum a Surface must have three points (Object Points or end points of Edges), or a Curve. A Surface can be composed of any number of boundary Points, Edges and Curves.

Surface Properties



The Surface Properties Dialog can be accessed by selecting a Surface (in a Photograph or 3D Viewer) and using 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.

A Surface has these properties:

- a unique identifier number called an ID,
- a "double-sided" flag - when set the Surface will be visible from both sides in the 3D Viewer (and in some export formats),
- a Material, and
- a Layer/Group.

How Surfaces become 3D

Surfaces get their 3D position solely from the 3D positions of their constituent objects. So if one of the objects (a point, curve or edge) is not 3D, the Surface will not be 3D either (ie. will not appear in exports or the 3D Viewer).

Marking

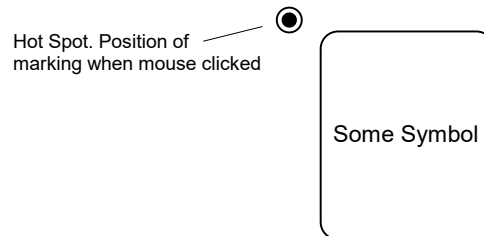
Marking is the process of creating and positioning an object on a photograph. Points, edges, curves, cylinders and fiducials are items marked on photographs.

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 Project Photographs Dialog.
2. Pick up the desired tool (point, edge, curve, etc.) from the toolbar or select the appropriate mode from the Marking menu.
In some modes a sub-toolbar will appear.
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.
For specifics on marking edges, cylinders and curves see the sections below.


4. 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.
The Fiducial Sub-Toolbar will appear.
2. Choose the name of the Fiducial you wish to mark on the Photograph from the drop list on the Fiducial sub-toolbar.
3. 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.

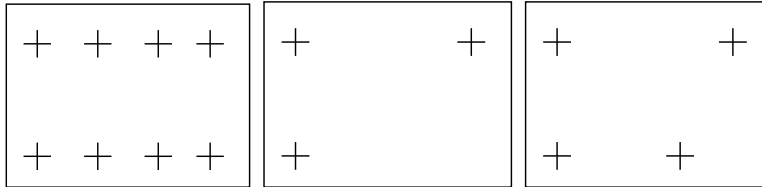
Fiducial points can be moved and deleted the same way that Marked points can. You cannot, however, use them as end points in lines or surfaces, or reference them to other points.

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.

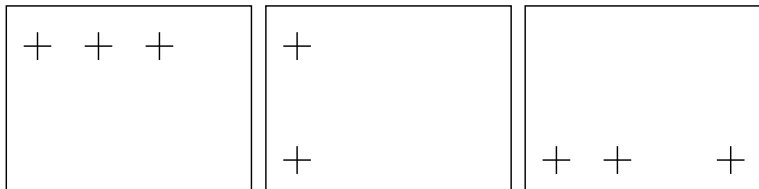
The requirement for sufficient fiducials depends on the type of camera. If the Camera being used has only two fiducials (i.e. Eos Film Plane Insert) then both fiducials have to be marked on every photograph. If the Camera being used has three or more fiducials then a minimum of three fiducials must be 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:

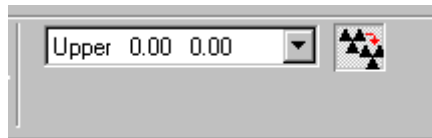


but these are not:



Fiducial Sub-Toolbar

When Fiducial Marking mode is entered, the Fiducial Sub-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.

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 Sub-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, 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, 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 Dialog](#).

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 and the Cylinder Mark. An Object is something that exists globally to all photographs. The Objects in PhotoModeler are Object Point, Edge, Curve, Cylinder, Line, 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 and Cylinder Mark and these Objects: Line and Surface. All of these can be selected.

3D Viewer windows display these Objects: Object Point, Edge, Curve, Cylinder, Line 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 Object Points on all open photos and the Object Points in the 3D Viewer and Point 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.

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 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 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 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 Object Table	Select in a 3D Viewer
Point Mark	yes		
Object Point		yes	yes
Edge Mark	yes		
Edge		yes	yes
Curve Mark	yes		
Curve		yes	yes
Cylinder Mark	yes		
Cylinder		yes	yes
Line	yes		yes
Surface	yes		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.

To select Objects in a Table:

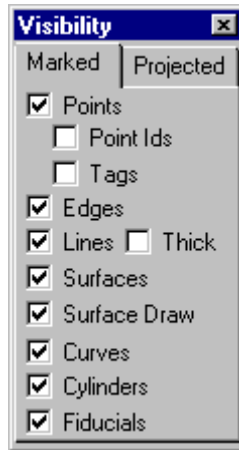
1. Pick up the Select tool from the toolbar  or choose "Select Items" from the Edit Menu.
PhotoModeler will change the cursor to the selection cursor.
2. Select the first object by clicking on it with the mouse.
The object will highlight with a black border around the row in the table.
3. Holding down 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. First the photo update starts to get slower, second certain objects get harder to select, and third it gets harder to see the photographic data under all the markings.

All the photographic marks can be turned on and off. This is done with the Visibility Dialog.

Visibility Dialog



The Visibility Dialog controls what types of object are displayed on the currently open photographs. This dialog is accessed through the Display Menu or via the Toolbar

button . The dialog is non-modal (it can stay on the screen while any other operation is going on) to make it easy to turn on and off items when required. The dialog is closed by pressing the Windows X button in upper right.

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.

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" 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](#).

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.

For information on the Projection tab of this dialog see [Projections Visibility Dialog](#).

Referencing

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

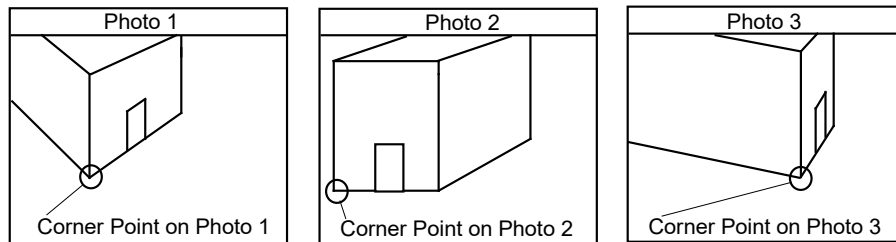
The user must reference each object (point, edge, curve, cylinder) in every photograph it is marked on, to every other instance of the same object, in all of the photographs it appears on.

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. a) Mark points and lines on each photograph. b) Then reference points between photographs.
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, 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 and **Cylinders** must be marked in both the Source and Destination photographs before they can be referenced so only option 1 is available.

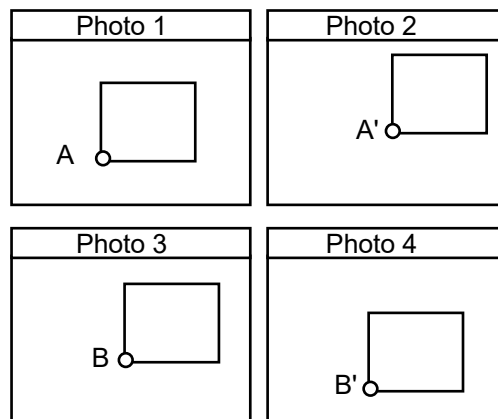
Referencing is Additive

- 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 and Curve Marks.

Reference Sub-Toolbar



When Reference mode is entered by selecting "Reference Mode" in the Referencing menu, or by pressing the Reference Toolbar button , the Referencing Sub-Toolbar will appear.

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

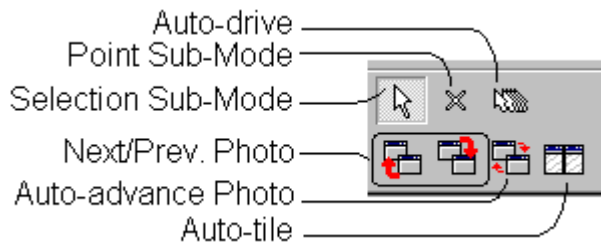
While objects are usually referenced across multiple photographs, all referencing actions take place between two photographs. These two photographs are called the "Source Photo" and the "Destination Photo".

In the Source Photo you select marks (Marked Points, Edge Marks, Curve Marks, or Cylinder 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 Sub-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-tile: 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: Auto-drive, Auto-advance, and Auto-tile can be set to be off by default by settings on the General tab of the Preferences Dialog.

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 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.

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 Sub-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).
- 6a. 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.
- 6b. 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.
7. Continue step 6, until all the marks that are highlighted on the Source Photograph and are visible on the Destination Photograph, have been referenced.
8. Repeat steps 3 through 7 for different Destination Photographs. You may use the Destination Photo advance buttons on the Reference Sub-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 and Surfaces

- When two Marked Points are referenced they represent two different views of the same Object Point in space.
- Lines and Surfaces 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.

The same thing will happen for Surfaces marked on the Source Photograph. When all three vertices are referenced to points on the Destination Photograph, the Surface will appear on the Destination Photograph.

In addition, Lines and Surfaces 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 performed on all the points in your project at once or on a group of selected points.

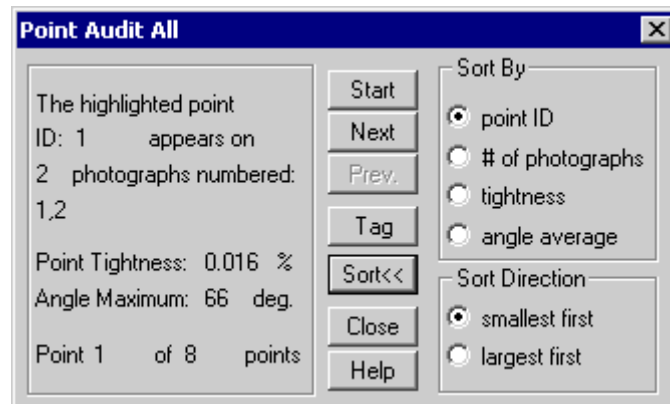
To Point Audit all of your points:

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.
You can use single point select, multiple select or rectangular selection. See [Selection and Visibility](#).
3. Select "Point Audit Selected..." from the Reference menu.
4. Study each point as shown by the yellow highlights and the Point Audit Dialog.

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. In other words they are not directly accessible (except for in the Object Properties Dialog).

Marking Points

To mark a point, first open or activate the desired photograph.

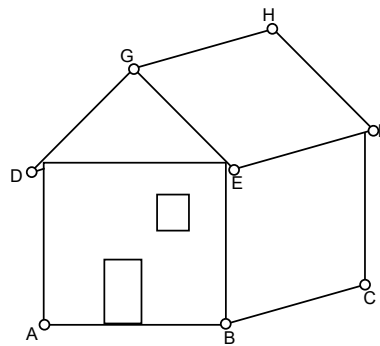
To mark a point:

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 activate 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

Background

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.

Target Shape

The Sub-pixel Target Marker is designed primarily to mark circular targets. There are two methods of sub-pixel marker in PhotoModeler: the centroid method and the Least-Squares Matching (LSM) method. The centroid method works with any blob shape that is similar to a filled circle whereas the LSM method works with filled circles only (that may look elliptical due to perspective).

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 targets with a drawing program and a laser printer or for an object with constant color you can use the removable sticky dots available at stationary stores.

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 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:

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

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 ten to twenty times improvement in accuracy. So for a mega-pixel digital camera you could expect about 1 in 8,000 to 1 in 16,000 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

The Sub-pixel Target Mode affects only Point Marking and Control Point marking.

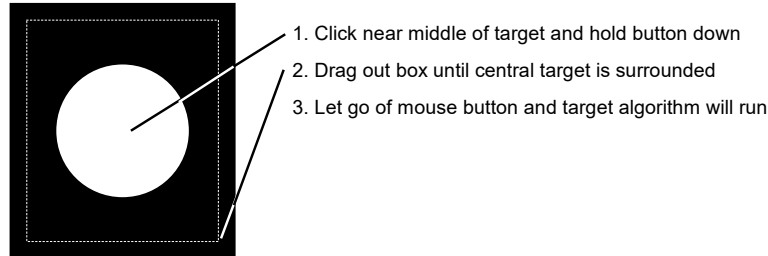
To turn on sub-pixel target mode go to the Marking menu and turn-on (check) the Sub-pixel Target Mode entry. Once in this mode, any marking done with the Marked Point tool or the Control Point tool will be done differently. You can turn the Sub-pixel Target mode on and off whenever you want.

The Sub-pixel Target Mode can also be turned on and off with the button on the Marked Point Sub-toolbar.

When this mode is on, the Marked Point tool cursor and the Control Point tool cursor will look a bit 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. 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 an X with a circle around it and the sub-pixel Control Point looks like a bloated triangle.

If you select and move a sub-pixel point, it will lose its "sub-pixel" characteristic and turn back into a normal point.

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.


LSM uses an iterative template matching process that is more robust, handled 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.

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 - [Curve or an Edge does not appear 3D](#) or in the Taking Photographs chapter - [Photography for Curves, Edges, Cylinders and Automatic Referencing](#).

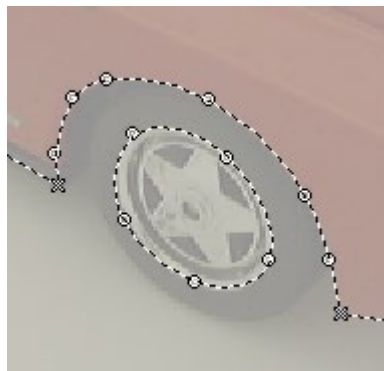
Curves

Curves are created, deleted and modified by manipulating Curve Marks. In other words they are not directly accessible.

Marking Curves

To mark a curve on a photograph:

1. Pick the Curve mode tool from the toolbar: 
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.
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.
4. 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.
5. 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.
6. 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".
- 3a. If you choose "Extend..." the existing curve will be added to as if you were continuing to draw the existing curve.
- 3b. 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.
4. 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

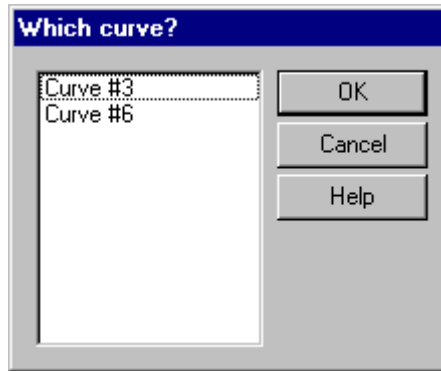
1. Go into Select mode (arrow cursor).
2. Place the tip of the arrow cursor over a Curve Point and click the left mouse button to select the point.
The curve point will highlight.
3. Press the Delete key on the keyboard or use the "Delete Selected Items" menu under the main Edit menu.
The curve point 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 ids 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 Weak Area Display

One tool that helps with determining curve accuracy and indicates potential problems is the "Weak Area Display". To active this tool, you go into Curve mode, move the cursor over a curve, right click to bring up the Curve menu and choose the "Show weak curve areas" item. This display only works if the Curve is already 3D.

When turned on, this display shows a varying-thickness black line along the curve projection. The thicker this line, the less accurate that section of the curve is.

Conversely, the thinner the line, the more accurately PhotoModeler has been able to compute that curve section. Ideally you want the black line to be a single pixel thickness all along the curve.

To improve areas of the curve where the "weak area display" shows a thick line, you will need to reference this curve on another photograph that is a rotation about the tangent to this section. For example if you have an arch and the left and right legs show thin weak areas (ie. they are not weak) but the top of the arch is a thick weak area (ie. it is weak and inaccurate) you probably have the curve marked on two photographs taken left and right of the arch. If you mark and reference this curve arch on one or more photographs that are at a different elevation to the two current photographs then you will have a better rotation about the top part and its weak area line should become thinner.

Cylinders

Cylinders are created, deleted and modified by manipulating Cylinder Marks. In other words they are not directly accessible.

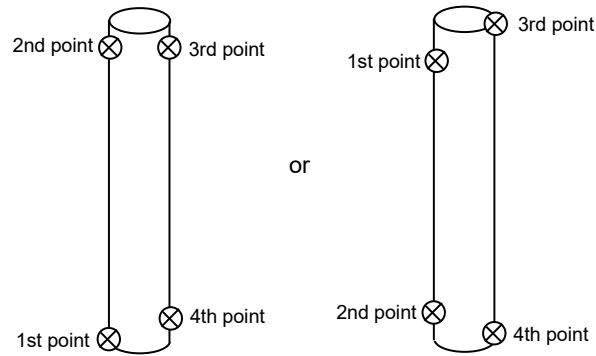
Marking Cylinders

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.
The temporary line will follow the movement of the mouse.
4. 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.

5. Repeat steps 3 and 4.
PhotoModeler will continue to create connected lines and new Marked Points.
6. Click the right mouse button to bring up the menu and choose "End Draw", or hit 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, hit 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 Dialog to turn off all items but lines. This makes selection and deleting easier.

Surfaces

Creating Surfaces


A surface is described by connecting multiple points, edges and curves. In this sense they are not "marked" but instead "created" from existing objects.




Surfaces are required for texture extraction, ortho-photo production, surface drawing and for export to external rendering and animation packages that expect 3D faces or meshes.


Surfaces can be created with four different tools in PhotoModeler:

- the three point triangle tool,
- the four point tool, and
- the multi-point and object tool.

To create a three point Surface:

1. Switch into the Surface Creation mode by pressing the Surface Tool  on the main toolbar or by selecting "Create Surfaces" from the Marking menu.

The Surface Sub-tool bar will appear.   

2. Select the three point sub-tool:  (if not already down).
The cursor will change to the three point surface cursor.



3. Select three points (marked points, object points or edge points) you wish to create a surface with, (either by selecting three points, by selecting one point and a line, or by selecting two connected lines). Note the point selection can be done in photographs, 3d Viewers or the Point Table. In photographs you can select the points in any order.

When three points have been selected, PhotoModeler will create the surface defined by these points. PhotoModeler will clear the selection highlight on these three Marked Points.



4. Repeat step 3 to create additional surfaces.

Note: Point selection behaves differently during surface creation. Three points at a time can be selected without using the shift key to extend your selection. Selection highlights are cleared after each surface is created.

To create a four point Surface:

1. Switch into the Surface Creation mode by pressing the Surface Tool  on the main toolbar or by selecting "Create Surfaces" from the Marking menu.
The Surface Sub-tool bar will appear.
2. Select the four point sub-tool:  (if not already down).
The cursor will change to the four point surface cursor.
3. Select the four points (marked points, object points or edge points) of the surface in order. On a photograph you can select them either clockwise or counter-clockwise. Be careful not to select the points in such an order that you create a "bow-tie" effect.
As you select the points the path defining the surface boundary will be shown. When the four point has been selected, the path will erase and the Surface will appear.
4. Repeat step 3 for additional four point Surfaces.

To create a multi-point / object Surface:

1. Switch into the Surface Creation mode by pressing the Surface Tool  on the main toolbar or by selecting "Create Surfaces" from the Marking menu.
The Surface Sub-tool bar will appear.
2. Select the multi-point sub-tool:  (if not already down).
The cursor will change to the multi-point surface cursor.
3. Determine what order you will select the points and objects (marked points, object points, edge points, or curves). You will need to make sure the path you define does not cross over itself and will close properly.
4. Select the first point of the path.
The selected point will highlight.

5. Select the second point or a curve.
The second point or curve will highlight and a path will be drawn on the photograph to show what part of the surface boundary you have created so far.
6. Continue with selecting points and/or curves to complete the path.
7. When you are finished you can either click back on the first point in the path, or you can use the right-click menu and the "Close " item.
The path will erase and the surface will appear on the photograph (if it is legal and does not cross itself).

Note 1: The multi-point Surface tool is the only way to create surfaces that are attached to NURBS curves. Both open and closed curves can be surfaced but closed curves can belong to a surface that contains only it.

Note 2: The order an open curve is added to a surface can be ambiguous at times. To ensure the order of the curve is correct be sure to select the end point of the curve in the correct order. Either select the end ObjectPoint first and then the curve, or if you wish the curve to be added in the other order, select the curve and then the end ObjectPoint.

Creating Surfaces using the 3D Viewer or Point Table

As with lines, surface can be created by selecting points in 3D Viewer and Point Table windows. You can select the three points for a surface from one window or three different windows if you wish.

At this time only the three point Surface tool can be used to create surfaces in the 3D Viewer and Point Table.

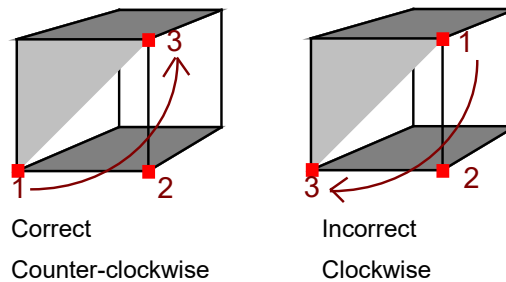
The main issue to deal with when creating surfaces in a viewer is point ordering. The surfaces in PhotoModeler are one sided (that is they appear from only one side in the 3D Viewer and when exported to some programs). Which way the surface faces depends on the order of the surface's three vertices. When the surface is marked on a photograph one does not need to worry about order because PhotoModeler always makes sure the surface faces the camera for a photo. On the other hand when creating using a 3D Viewer or Point Table the pick order of the points defines the surface's normal direction.

Note: Surfaces do have a "double sided" property that alleviates this problem somewhat. See [Surface Properties](#).

The rule is: if you are outside the model looking in toward it, then a surface that is facing you will have its three points sorted in a counter-clockwise fashion.

This means that when you create a surface using one of the Viewers (and this means use the Viewer to select all three points or to select just the 3rd point) you must be careful of the order you select the points.

When creating surfaces in the 3D Viewer always select your points in a counter-clockwise fashion. If you do not, it will look like the surface was not created. It will be created, it will just be facing backward.



Deleting Surfaces

To delete a surface, you should open the photograph containing the surface you wish to delete. Make this photograph the active photograph.

To delete a surface 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 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. 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 surface or surfaces from all photographs.
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.

Surfaces can also be deleted by selecting them in the 3D Viewer and pressing the delete key.

Note: if you have many surfaces to delete and you do not want to delete any other points or features you can use the Visibility Dialog to turn off all items but Surfaces. This makes selection and deleting easier.

Surface Drawing



Surface drawing gives you the ability to draw in only one photograph and on a plane defined by Surface to produce 3D data. 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 appear on a photograph with a solved Camera Station and the 3D coordinates of the Surfaces points must be known (i.e. have been solved already or are Control Points).

You can mark Surface Drawings at any time (before the project is processed) and they will update automatically when anything changes (such as the orientation of the photo/camera station or the positions of the 3D Points used in the underlying Surfaces).

To draw on a surface:

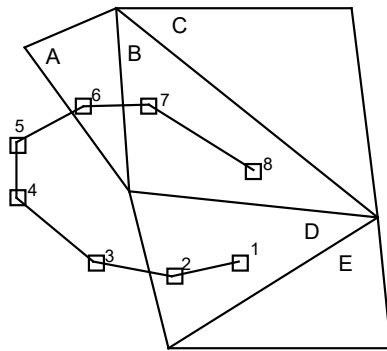
1. Make sure you have one or more Surfaces marked in the photograph (they do not need to be visible to be used).
2. Pick up the Surface Draw tool .
3. Decide if you will be drawing straight lines or curves. If curves pick the curve option from the sub-toolbar .
4. Click the first point inside a Surface.
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.

If the Surface is moved or the Surface Draw points are moved then the assignment between them may change automatically. The rules are:

1. If a Surface Draw point appears inside the triangular area of a Surface on a photograph then that point is assigned to that Surface.
2. If the Surface Draw point is outside of a Surface then it is assigned to the Surface of the point closest to it in the Surface Draw line (based on the order the points were first drawn).

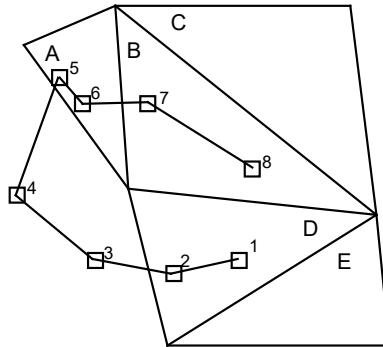


Surface Draw Assignment to Surface Elements

In the figure above there are five Surfaces labeled A through E. A Surface Drawing has been done starting at point 1 and going to point 8. These points will be projected onto different planes based on the Surface assignments:

- Points 1 through 5 will be assigned to Surface D.
- Point 6 will be assigned to Surface A.
- Points 7 and 8 will be assigned to Surface B.

If you were to select Surface Draw point 5 and drag it onto Surface A, the point would get automatically assigned to this new Surface and its 3D position would be recomputed based on A's plane not D's. This new 3D position would be updated automatically in any open 3D Viewer or Point Table when the point is dropped.



Reassignment of Surface Draw Points

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),
- cannot be surfaced, 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 one of more of the three points used to define the assigned Surface may not have a 3D position (i.e. they are not control or they do not appear on two or more oriented photographs). Click on the Surfaces defining points to see if all three have valid positions.

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.

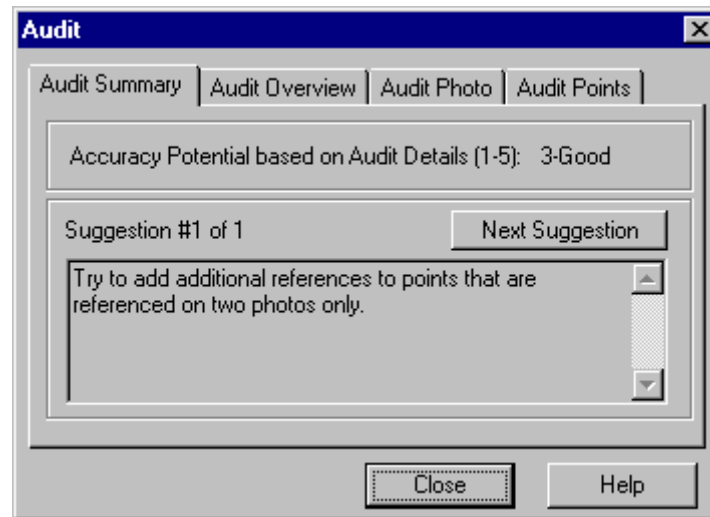
Audit

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.

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. Project 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.

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.

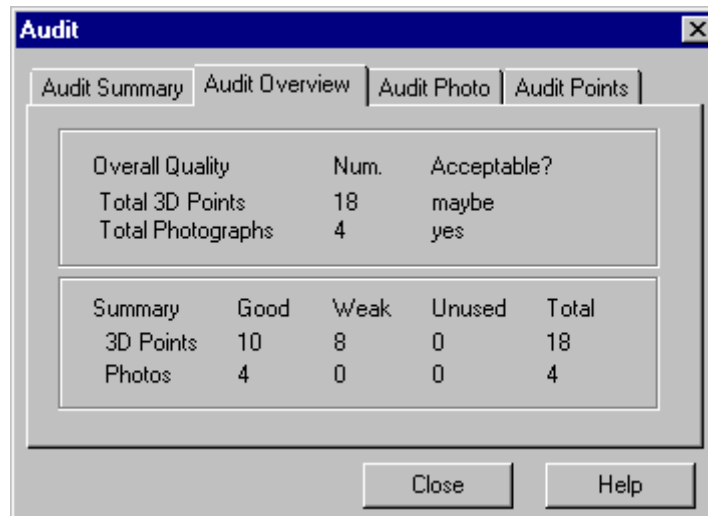
If processing does not succeed or the resulting 3D model is poor, the user should take steps to change the "no" entries to "maybe" or "yes" and to change the "maybe" entries to "yes". The section below, called Fixing Audit Problems, describes how that can be done.

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



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 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 some small number of Weak Points and Unused Points. 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

	Min.	Max.	Avg.	Acceptable?
Points Per Photo	12	14	13	maybe
Photo Coverage (%area)	55	67	61	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.

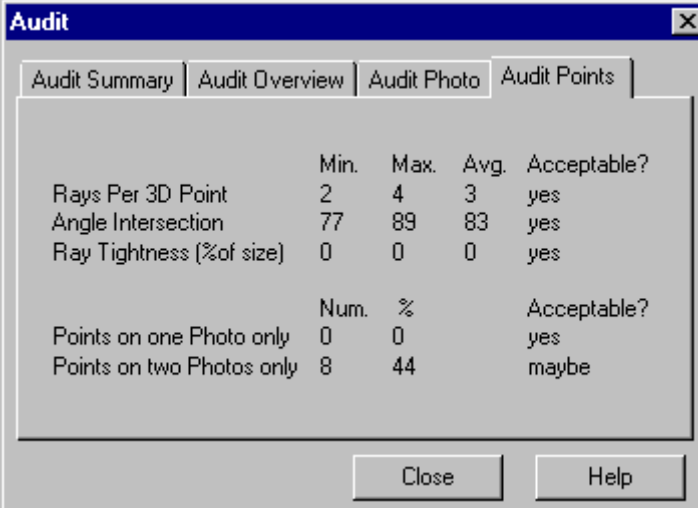
Every photograph must have at least six Marked Points or three Control Points marked on it before it can be used properly.

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



	Min.	Max.	Avg.	Acceptable?
Rays Per 3D Point	2	4	3	yes
Angle Intersection	77	89	83	yes
Ray Tightness (% of size)	0	0	0	yes

	Num.	%	Acceptable?
Points on one Photo only	0	0	yes
Points on two Photos only	8	44	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 Taking Photographs 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 Marking Fiducials .
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 Point Audit Dialog for a means to identify single unreferenced points.
Points on two Photos only	Decrease the number of points marked on only two photographs. See Point Audit Dialog 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. See Project Photographs Dialog .
Points - Unused	See above for improving Rays Per Point, Angle Intersection, Ray Tightness.

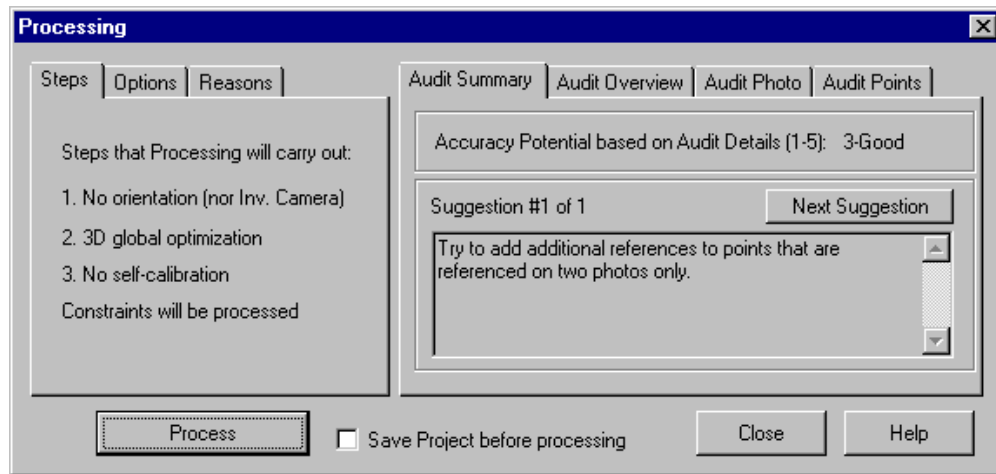
Adjustment and Processing

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 stated 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 contain 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 three main stages of 3D Processing (Orientation, Global Optimization, and Self-Calibration).

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 Global Optimization 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 Self-Calibration and Field Calibration sections below.

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

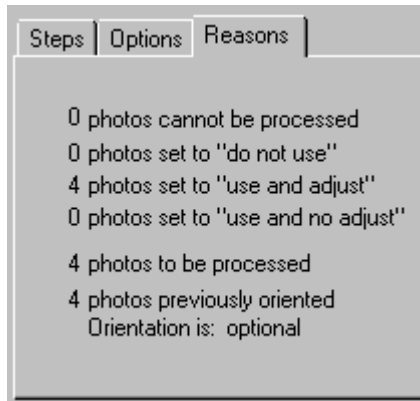
when you may want to do an Orientation only, a Global Optimization only, or ask for Self-Calibration or Field-Calibration.

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.

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 hit 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 (ie. 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
- each processed photograph's points must cover a reasonable area of the photograph (ie. 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 Calibrator in that it is trying to solve the parameters of one camera. Field calibration can be a replacement for the Camera Calibrator in some circumstances.

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.

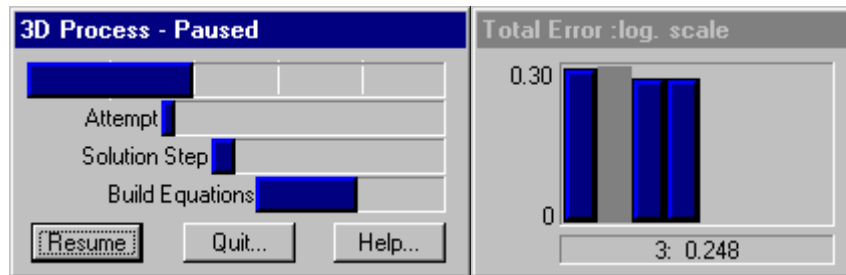
When should Field Calibration be used?

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 PhotoModeler's Camera Calibrator program. 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 hit 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 (ie it does not appear when orientation-only processing is done). 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).

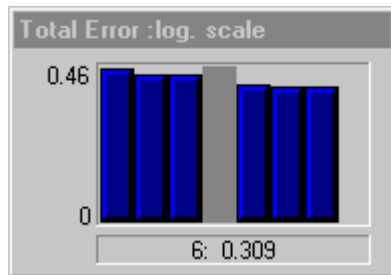
The error values shown in this dialog are technically referred to as the *standard error of unit weight*. These values are unitless and combine information from image residuals, camera parameter residuals, edge residuals, constraint residuals and control point residuals. If there are no control points, 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 hit the "Quit..." button on the [3D Process Dialog](#) to stop the processing early if you wish.

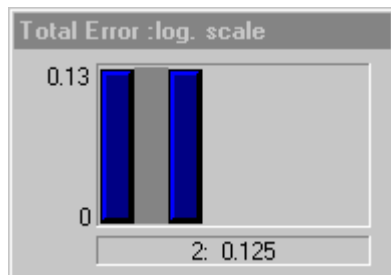
The Total Error Dialog will usually show two sets of bars separated by a gray area. The first set corresponds to the first Optimization phase and the second set of bars to the second Optimization and Self-Calibration phase. Sometimes the first vertical bar in the second set will be larger than the last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

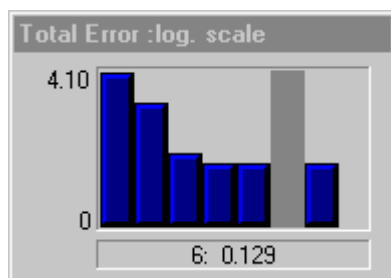
You can think of the Total Error Dialog as the pulse of your project. While the most important thing is that the bars gets smaller as processing proceeds, one can get useful information by studying the shape of the error chart. The following examples show Total Error Dialog results for various types of projects along with hints of what is right or wrong:



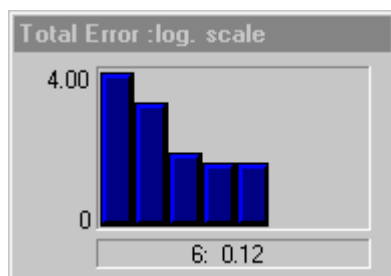
Successful two stage processing. Most projects that are set up well will have error dialogs that look like this. After the initial orientation only small optimizations are needed.



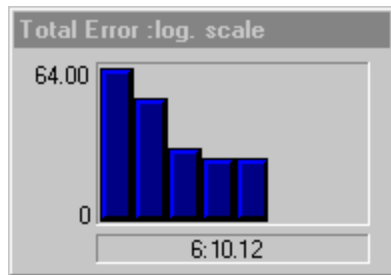
Successful two stage processing of a strong project that has probably been processed before (there is not much room for improvement).



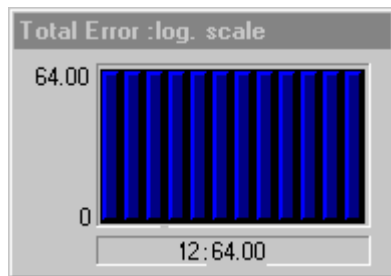
Successful two stage processing where the initial orientation was ok but not perfect. The optimizer was able to produce a good solution in the first stage and the second stage was used as a check.



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.



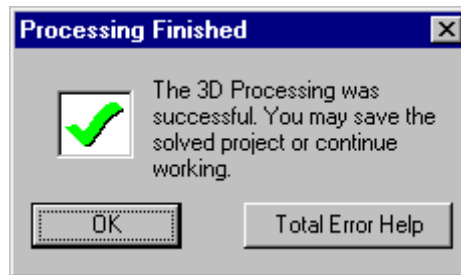
Somewhat successful one stage processing where the initial orientation was weak. While the processing might have succeeded the final error is quite high (10.2, when good values are under 1.0). A model might have resulted from the processing but it is suspect. Look for referencing errors or camera parameters problems.



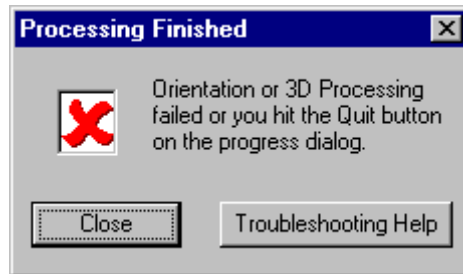
Most processing failures will look something like this. You might see small decreases in the error bars or they may be all similar height. The error values will also be high (over 5.0). This implies some inconsistency in the project (perhaps a misreferenced point or camera parameters that are not quite correct).

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.



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.

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 hit "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 hit 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

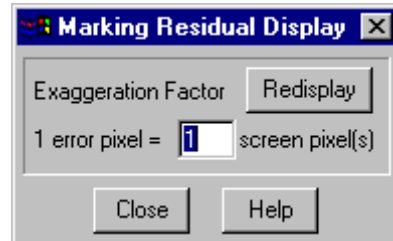
After a 3D Processing has completed successfully there are a few quick checks you can make to verify the quality of the processing. These are:

1. 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.
2. Open up the 3D Viewer and study the shape of the resulting model. Does it look OK? Is the shape what you expect?
3. 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.
4. 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 Unreferenced Point Weld.

Marking Residual Display Dialog



The Marking Residual Display Dialog is used to control the display of Marking Residuals on Photographs.

When this dialog is open each currently displayed Marked Point on a 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 Control Point locations, referenced points, Camera Station orientations and Camera information.

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 Marking Residual Display Dialog provides an 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 scaled by the factor. For example, if the exaggeration factor is 10 then the black bars are all drawn 10 times longer than reality but they still point in the same direction.

Whenever the exaggeration factor is changed, the "Redisplay" button must be pressed to get the Photograph display to update.

The Residual Marking Display can be very useful in tracking down certain types of marking and referencing errors.

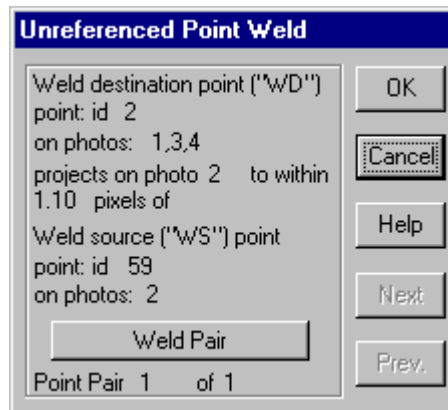
- a) Marking errors: if you have a point that has 5 references (appears on 5 photographs) but has been incorrectly placed on one of those photos then the Marking Residual error for the point will be large and will point in the direction on the photograph where it should be marked. This display will not 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 exaggeration 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.

Note: The Projection display is very similar to Marking Residuals. If you turn on Point Projections in the Projections Visibility Dialog, and then bring up Marking Residual display with an exaggeration factor 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 PhotoModeler has processed the 3D model, its proportions will be correct. In other words, if the width of a door is 1/2 its height, PhotoModeler will calculate a value for the model door width that is 1/2 of its calculated height. The absolute value PhotoModeler assigns 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 the distance between two points in your model.

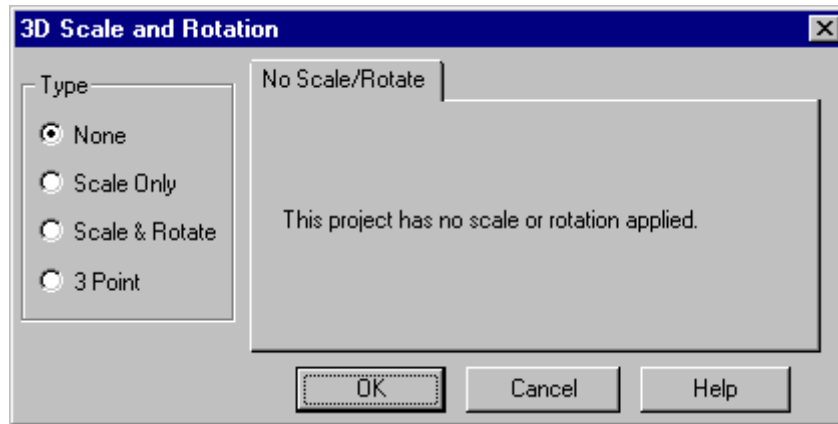
Similarly the rotation of the model will seem rather arbitrary after processing. This is because PhotoModeler does not yet know which way the model is to be oriented (unless you have used control points or axes constraints). To correct this you need to tell PhotoModeler how to rotate the model for 3D Viewer display and for 3D Model Export.

A project can be in the following states with regards to scale and rotation:

1. no scale or rotation,
2. scale and rotation set by control points,
3. no scale but rotation set by [Axes Constraints](#),
4. scale defined by the following dialog but no rotation,
5. scale defined by the following dialog and rotation set by Axes Constraints, and
6. scale and rotation defined by the following dialogs.

States 2, 5 or 6 are one of the states you will usually want to get the project into.

3D Scale and Rotation Dialog



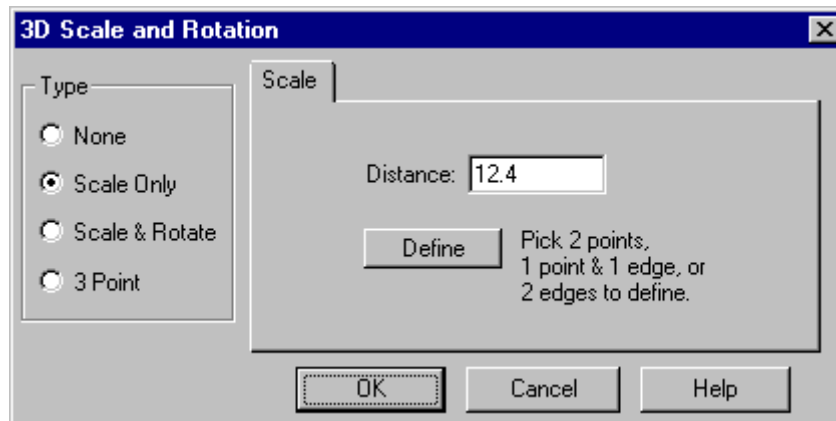
The 3D Scale and Rotation Dialog is used to control the scale and rotation of the project. This scale and rotation is applied post processing.

The dialog is brought up using the Project menu, "Scale/Rotate ..." item. The dialog has four different forms. The default is the "No Scale/Rotate" form which is shown above. All projects will be in this form when they are first created.

The other forms of the dialog are for:

- Setting Scale,
- Axes Rotation, and
- Three Point Scale/Rotation.

Setting Scale



The Scale tab appears when the type is set to "Scale Only" or "Scale & Rotate".

The "Define" button is pressed when you have selected two points, one point and one edge, or two edges to use as your scale. Whenever this dialog is on the screen PhotoModeler will highlight all visible scale points and will show them tagged with an "S" on photograph windows.

The Distance text box is used to enter the known distance between the two points you have selected.

After you have defined a scale, pressing "OK" will confirm your choices.

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 "Scale Only" button from the Type group.
3. Enter the distance you recorded, when taking photographs, in the Distance text box.
This number by default is in project units but you can specify any other type of units by adding the unit specifier (m,cm,mi,in,ft etc.).
4. Using the Select tool, select the two points, one point and one edge or two edges on the photograph (or other window) between which you know the distance.
To select both these points 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 as the scale points.
PhotoModeler will highlight these scale points in green and draw with a "S" tag in any open photos.
6. Press "OK" to confirm this choice of scale.

Rotating and Positioning the Coordinate System

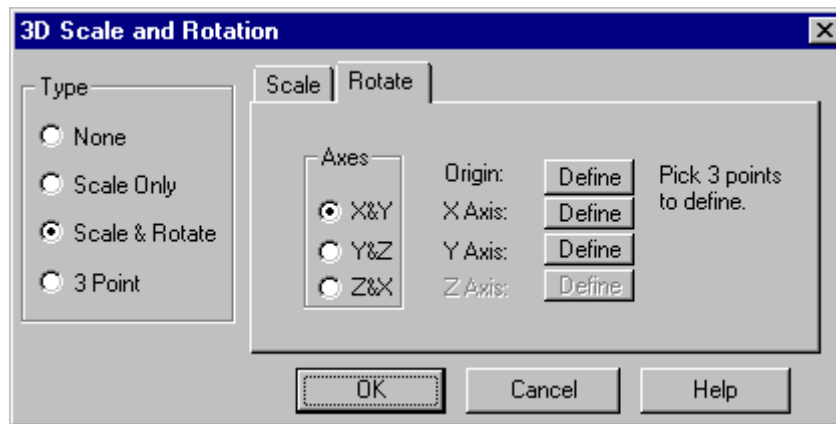
The 3D points in your solved model are described in a Cartesian coordinate system by X,Y and Z values. The directions of the X, Y and Z axes and the origin are arbitrary in PhotoModeler unless you specify them.

There are four ways to fully specify the coordinate system:

- use Control Points,
- use Axes Constraints,
- use the Axes Rotation part of the 3D Scale & Rotation Dialog, or
- use the Three Point part of the 3D Scale & Rotation Dialog.

The Axes Rotation involves selecting an origin and the direction of two of the axes. You may specify any of the three axes combinations, X and Y, Y and Z or X and Z. The Three Point involves picking three model points and entering in the coordinates for them in your desired coordinate system. The following two sections deal with these two methods.

Axes Rotation



On the Rotate Tab of the 3D Scale and Rotation Dialog there are buttons to define the origin, X axis, Y axis and Z axis points. In addition the radio buttons, "X&Y", "Y&Z" and "Z&X" allow you to choose which two axes you will define. You only need to specify two axes. PhotoModeler uses a right handed coordinate system. The steps to define a coordinate system are described in Rotating and Positioning the Coordinate System.

Each of the origin, X axis, Y axis or Z axis is defined by picking one point and pressing the "Define" button for that value. Any open photograph, or 3D viewer windows automatically display the chosen points highlighted and tagged in photos. The Origin is shown tagged with an "O", the x axis point with an "X", the y axis point with a "Y", and the z axis point with a "Z" in any open photograph.

When you have defined the coordinate system, press "OK" to confirm your choices.

You will need to decide which 3D point will be the origin (0,0,0) of the coordinate system and then decide on your primary axis (based on which pair, "X&Y", "Y&Z" or "X&Z" you use). The second axis point should be close to right angles with the primary axis but it does not need to be exactly 90 degrees. In fact PhotoModeler will handle a secondary axis definition point between 20 and 160 degrees from the primary axis. When the coordinate system is computed, PhotoModeler calculates the exact secondary axis at 90 degrees to the primary axis based on the plane defined by the three points (origin and two axes points).

Note: Remember that PhotoModeler uses a right-handed coordinate system. So for example if you are defining X and Y, you would first define the origin and X axis points, then if you lined up your right hand's thumb with this axis (and hold your hand like a toy gun), and line up the index finger with the Y axis point, the third finger (held at 90 degrees to the first two) will point to the positive Z axis.

To set the origin of the coordinate system:

1. Select "Scale/Rotate..." from the Project menu.
PhotoModeler will bring up the 3D Scale & Rotation Dialog.
2. Select the "Scale & Rotate" button in the Type group.
PhotoModeler will show the Scale and Rotate tabs.
3. Activate the Rotation tab.
4. In a window (e.g. photograph) select one point for your origin.
PhotoModeler will highlight this point.
5. Press the "Define" button across from Origin.
The origin will be highlighted in green and on photos will be tagged with an "O". You may change the origin at any time by selecting a new point and pressing "Define" again.

To set the direction of a coordinate system you must first define its origin.

To set the direction of the coordinate system:

1. Select "Scale/Rotate..." from the Project menu.
PhotoModeler will bring up the 3D Scale & Rotation Dialog.
2. Select the "Scale & Rotate" button in the Type group.
PhotoModeler will show the Scale and Rotate tabs.

3. Activate the Rotation tab.
4. Choose the axes you would like to define, by pressing one of the radio buttons "X&Y", "Y&Z" or "X&Z".
5. Select the point on an open window towards which this axis will point from the origin.
6. Press the "Define" button across from this axis.
The axis point 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.
7. Repeat steps 5 and 6 to define the one other axis.

When you measure points, or create an export file, PhotoModeler will use the scale and coordinate system you have defined.

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 or a map or can be made up if you have a good idea of the effect you are after.

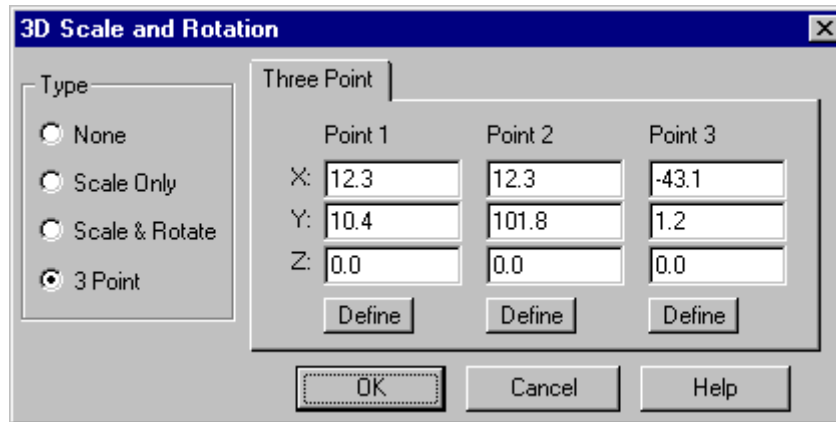
Note: If you have more than three known control points with good spread over the model volume it would be a good idea to consider using Control Point Marking instead of Three Point Rotation. You will get better results if the control points are good quality. See the [Control Point Constraints](#) section.

It is important to understand how the scale and rotation are done in the three point case so you can achieve best results. We will call the three points in the PhotoModeler model M1, M2 and M3 and the three entered coordinates 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](#).

Three Point Scale/Rotation



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 "Scale & Rotate" button in the Type group.
PhotoModeler will show the Scale and Rotate tabs.
3. Activate the Three Point tab.
4. Select one model point on a photograph (or other window).
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.

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

Measure Toolbar

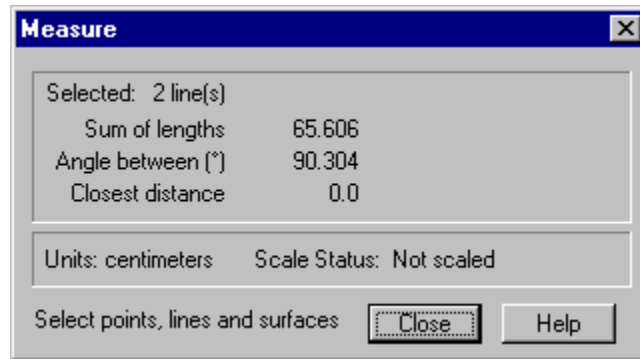


	Sum of lengths	65.034
	Angle between (°)	179.402
Units: cm	Closest distance	3.769

The Measure Toolbar displays information and measurements of the user selected set of features. It is a compact form of the [Measure Dialog](#).

Measure Dialog

The Measure Dialog displays information and measurements of the user selected set of features. To see these values, select points, lines, Surfaces, cylinders or combinations of them while the Measure Dialog is on the screen and the contents of this dialog will update interactively.



Measure Dialog

This dialog is opened by pressing the dialog button  on the Measure Sub-toolbar.

The Measure Dialog is split into two sections: Measurement Information and Units and Project Scale Status.

Measurement Information

The top section displays the following information:

Items Selected	Information Displayed
1 point	x,y,z and x,y,z <u>precision</u>
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 surface	surface area, volume above xy plane
2+ surfaces	sum of areas, sum of volumes above xy plane
1 cylinder	diameter of cylinder, length of cylinder, 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 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 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 cuves 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 dialog and select all the Surfaces (made easier by using the [Visibility Dialog](#) to turn off all features but Surfaces).

The end result would be a volume measurement of the sand pile in project units cubed.

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 two standard deviations based on the post-processing covariance matrix of the 3D object points. If we assume that the starting standard deviations (as defined in the ini file) accurately reflect reality then these precision values give a 95% confidence interval for that point (i.e. a 95% 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.

Units and Project Scale Status

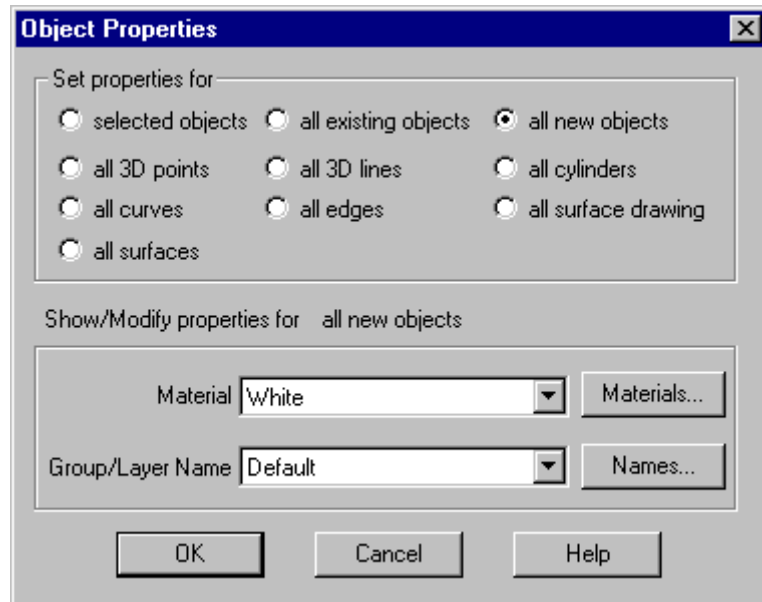
The bottom section shows the units of the measurement and the Project Scale Status. This status refers to how the project has been scaled or rotated in a coordinate system. This status provides an indication of what to expect from the measurement values displayed. This status can be one of: "Not scaled" which means that no scale or rotation has been applied and the measurements shown in the dialog are based on an ad-hoc scale and coordinate system set up by PhotoModeler; "Scaled" which means that only a scale has been applied to the project and the values in this dialog reflect that; "Scaled and Rotated" which means that the project has had a scale and rotation applied and the values in this dialog reflect that; "Control based" which means that the project was solved with control points and so the values shown in this dialog are based in the coordinate system of the control points.

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 Group/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.

Object Properties Dialog



The Object Properties Dialog is used to assign the Material or Group/Layer Name of objects in the model.

The dialog is access through the Object Properties menu item of the Edit Menu.

The Object Properties 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 Group/Layer Name for the objects selected in the top section of the dialog.

Object Selection

The top section of the Object Properties 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.
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 Group/Layer Name 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).

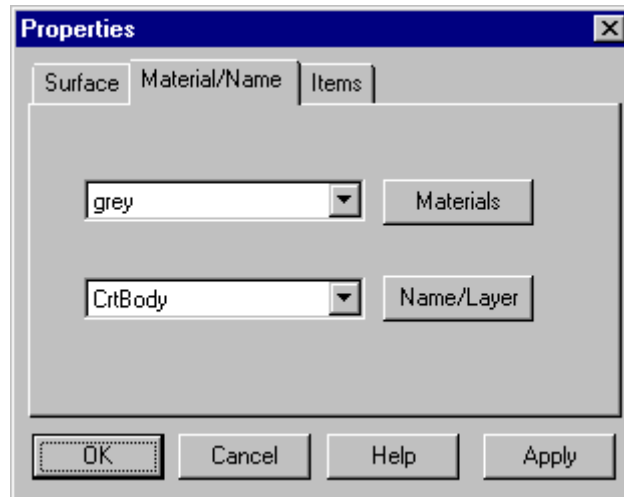
Setting Properties

When you want to change the Material or Group/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 Group/Layer Names. The Materials button brings up the Materials Dialog and the Names button brings up the Group/Layer Name Dialog.

When returning from the Materials Dialog or Group/Layer Name 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.

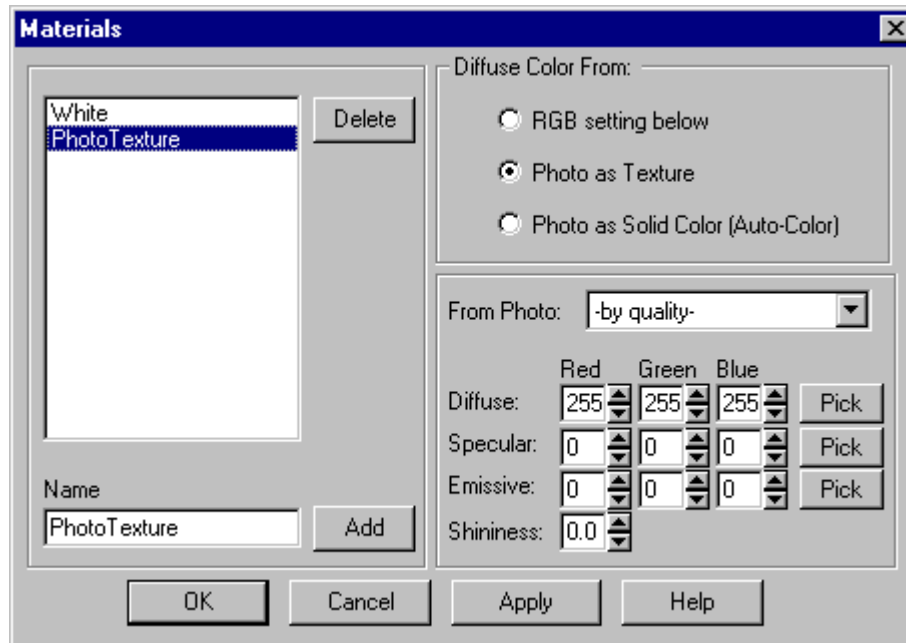
Material/Name Properties



When one of the Property Sheets is opened there will usually be a Material/Name tab. This tab shows the name of the Material and the name of the Group Name/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 Group/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 Name/Layer button can be pressed to add new Materials and Layers. These buttons bring up the Materials Dialog and the Group/Layer Name 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 Object Properties Dialog, via the "Materials..." menu item in the Edit menu, or from the "Materials" button on any of the Property Sheets.

All projects have a material called "White" which cannot be modified or deleted. It is a non-textured diffuse white material.

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. Texts 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.

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 areas with very shiny materials and large weak highlight areas (or no highlights at all) with dull materials.

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 at the bottom right. If set to "Photo as 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 section below on the "From photo" control for a description on how photo materials are derived. If "Diffuse Color from" is set to "Photo as Solid Color" then the RGB diffuse color of the surface will be set to be the

average RGB value of all the pixels under the corresponding Surface. This setting like "Photo as Texture" can be set of Surface features only.

From photo drop-down list

The "From photo" 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 "From 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.

One interesting feature of using a manual override for the photograph is that you can specify a photograph material for a Surface for which the Surface does not appear on that photograph. For example, if you selected a couple of Surfaces on photo 4 that do not appear on photo 2 (because the corresponding Marked Points are not visible) you can create a new Material with Diffuse color from photo 2 and assign it to these two Surfaces. When PhotoModeler creates the photo-textured material for these Surfaces it projects the 3D points onto photo 2 to determine what area of the photograph to use for photo-texturing.

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.

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.

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.

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.

Group/Layer Name Dialog



The Group/Layer Name Dialog is used to create, delete and modify Group/Layer Names. A Group/Layer Name 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 group names for a house project). These Names are most 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 Object Properties Dialog, or from the "Name/Layer" button on any of the Property Sheets.

All projects have a Group/Layer Names called "Default" which cannot be modified or deleted. Unless otherwise set all objects get placed in the Default group.

To add a new Group/Layer Name, press the Add button. A new Group/Layer Name with a default name will be added. You can change this name by typing in the Name edit box.

To delete a Group/Layer Name, select it in the project Names list and press the Delete button. Note when you delete a Group/Layer Name, and only if dialog is exited with

OK, any objects that are assigned to this Group/Layer Name will be placed back in the Default Group/Layer Name.

To modify a Group/Layer Name, select it in the list of project Names, and its name will appear in the Name edit box. There are only two things you can change with a Group/Layer Name and the first is its string and the second is its smoothing attribute.

When a Group/Layer Name has the "Smooth shaded" check box set, all Surfaces that are in its set will be smooth shaded in the 3D Viewer or will be exported with the appropriate normals or smoothing groups to ensure it will be smooth shaded by an external package.

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

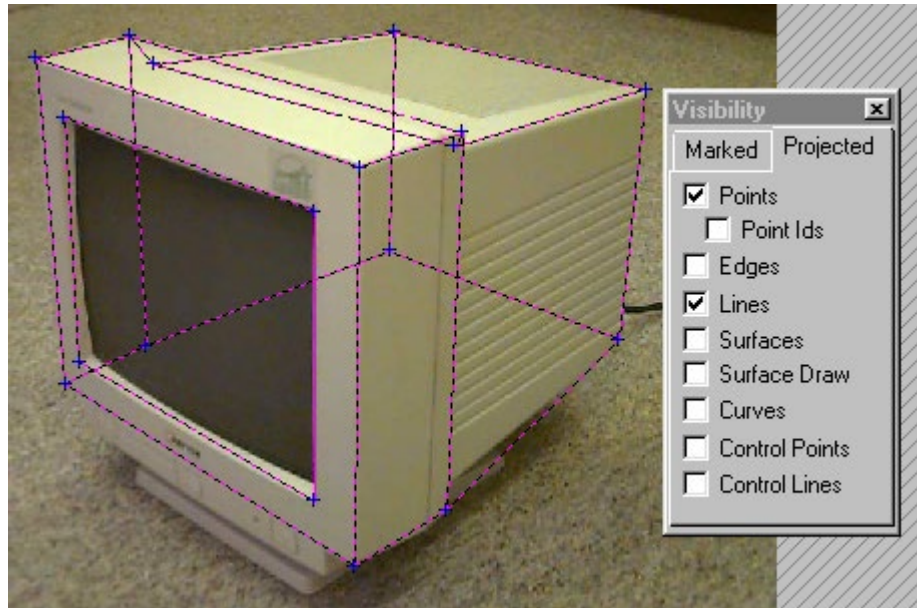
A projection is 2D view of the current 3D model data such that the viewpoint and view parameters exactly match the camera station and camera of the photograph they are being displayed on.

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.

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

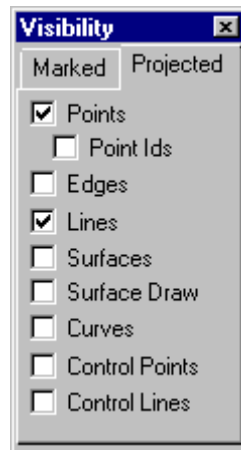
monitor including those lines behind. This view quickly tells us that the 3D and camera station solution for this photograph are reasonable good.



Project Display Example

Note that projections display on photographs that are oriented only.

Projections Visibility Dialog



The Projections Visibility Dialog is the second tab of the Visibility Dialog.

This dialog controls what types of objects will be projected onto and displayed on all open Photographs.

Note: projections will only display on oriented photographs.

Note: the colors used by projections can be changed in the Color tab of the Preferences dialog.

Control Projections

The bottom two check boxes on the Projections Visibility Dialog 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 Projections Visibility Dialog, 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.

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.

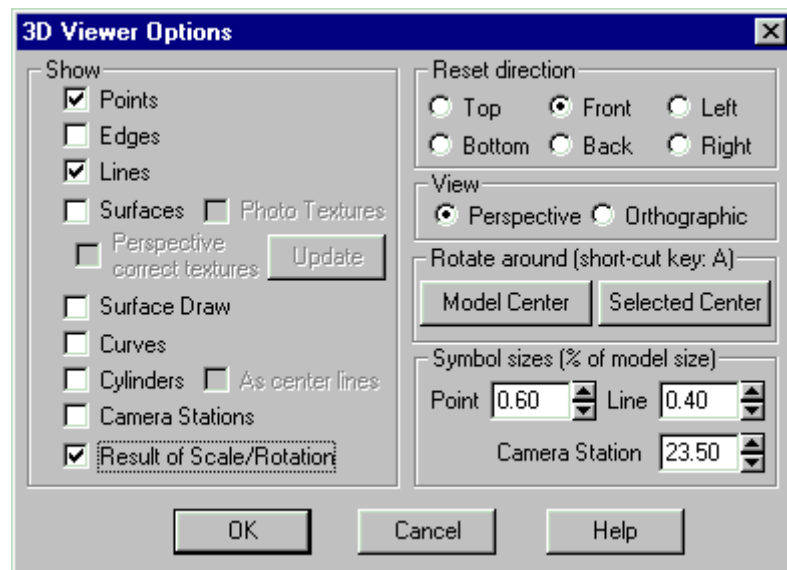
Once a project has been processed and the Camera Stations have valid positions, PhotoModeler will keep a 3D Point's location up-to-date on the fly. In other words, any change to the project which effects the position of a 3D point is immediately reflected in that point's 3D location. This can be seen 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. Some video boards with Direct3D acceleration can display only a limited number of 3D Viewers at once. When you hit that limit you will get a Direct3D error message.

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 five sections. On the left the top section controls what types of objects are currently shown in the associated 3D Viewer window. The bottom left and top right of the dialog control the type and orientation of the view. The middle right section controls the view center and the bottom right of the dialog has three controls for the displayed size of the symbols used.

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

Object Types

The Object Types check boxes in the 3D Viewer Options Dialog 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.

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 cubes.
Edges	When this box is checked, all Edges that have a solved 3D position will be drawn as narrow cylinders.
Lines	When this box is checked, all Lines that connect solved 3D positions will be drawn as narrow cylinders.
Surfaces & Photo Texture	When this box is checked, all Surfaces that have solved 3D positions will be drawn either with their diffuse color or with a photo-derived texture if they have a photo-textured Material and the Photo-texture box is checked. The photo-textures will be corrected for perspective if the "Perspective correct textures" box is checked (note: this can be time consuming). Also see Perspective Correction of Textures .
Cylinders & as Centerlines	When this box is checked all Cylinders that are solved will appear. If as Centerlines is checked then they will be drawn as lines down their centerline otherwise as full cylinders.
SurfaceDraw	When this box is checked all Surface Drawings (lines and curves) that appear on Surfaces between solved 3D points will appear as narrow cylinders.

Curves	When this box is checked all Curves that have complete 3D solutions will be displayed as a narrow curved cylindrical path.
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.

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. 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.

Perspective Correction of Textures

The 3D Viewer can display photo-textures with perspective distortion removed. This distortion will be most noticeable on faces 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 horrible without it.

Perspective correction of textures is available for exported models also when using PhotoModeler Pro.

Beside the "Perspective correct textures" check-box in the 3D Viewer Options dialog is an "Update" button. This button becomes available when perspective correction is turned on. Pressing Update will cause the textures to be recomputed.

The algorithm for perspective correction is very advanced and exact and so can be slow with big photographs. For this reason, PhotoModeler does not recompute the textures on all changes in the model. Three actions that do cause the textures to recompute are: processing, changing a photo-textured material in Materials or Object Properties dialogs, and pressing the "Update All 3D Viewers" button beside the quality setting in Project Photos dialog.

Other changes (such as adding new Surfaces, dragging a point, changing camera parameters, marking control, etc.) do update the 3D geometry on the fly but the textures will no longer match. The most obvious case is when a new Surface is drawn on a photo with a photo-textured material, the surface will appear in the 3D Viewer but the texture will be wrong. Pressing the Update button in the 3D Viewer Options dialog will fix the textures.

Note that when perspective correction is turned off, no update is needed because all changes happen on the fly.

View Orientation

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.

The first dialog control of the view is 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.

The second control is the Scale/Rotation check box. When this 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).

To check your orientation, set the Scale/Rotation check box and pick a Reset direction such as "Front". 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). 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

Model Centering

Normally, when the rotate control is used in the 3D Viewer, the view rotates about the center 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 use the arbitrary center method.

If you select a point in the 3D Viewer window and then press the A key, the view will then rotate about that point 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 NURBS Curve circle selected and pressed A, the rotation center would become the center of the circle.

Symbol Sizes

PhotoModeler uses some heuristics to display the real-world size of the point symbols, line cylinders, edge cylinders, curve cylindrical shapes 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 three spin controls in the bottom right of the 3D Viewer Options Dialog control the relative sizes of these symbols. The numbers shown are roughly a percent of the objects total size. For example, if you are displaying a house model that is approximately 10 meters wide, and you have Camera Stations displayed with a symbol size of 100% then the camera station symbols will be approximately 10 meters also and will appear as big as the house.

The size of the point symbol refers to one dimension of the cube symbol, the size of the line symbol refers to the diameter of the cylinder for lines, edges and curves, and the size of the camera stations refers to its largest dimension. So if you had all the spin controls set to 1.0% you would find that the point symbol cubes would be the same size as the line diameter (the points would just be visible at the ends of lines) and the camera stations would be about the same size as the points. Reasonable starting values are 0.5% for points and lines, and 10% for camera stations. You can adjust from there to suit your needs.

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, 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 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.

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.

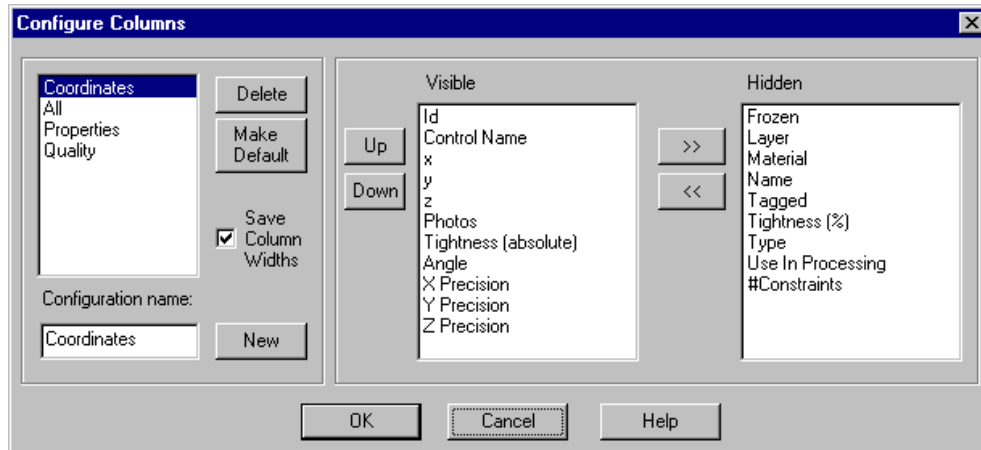
To add, remove or change configurations for this table, press the "Configure..." button. This will bring up the Table Configuration Dialog which is described below.

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 will write the contents of the currently visible Table data contents to an ASCII text file with constant spaced columns. These files are suitable for import into other software packages (such as a spread sheet program like Excel (r)). The exported file is set up just as the columns are currently displayed so you can set up a column configuration that has just the columns of data you want and the column sizes for export.

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.
 - 2a. 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.
 - 2b. 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.
 - 2c. 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.
 - 2d. 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.
 - 2e. 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.
3. 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.

Point Table

Id	x (cm)	y (cm)	z (cm)	Photos	Tightness (cm)
1	18.598366	-18.39071	15.706125	1,2,3,4	0.264667
2	-17.376782	-18.75517	16.132331	2,3,4,1	0.459397
3	-17.798409	-19.68740	-13.471222	2,4,1	0.168976
4	18.550037	-19.42407	-13.849849	2,3,1	0.276512
5	18.744208	-9.675794	-14.105459	3,1	0.001081
6	18.788870	-8.553101	15.566590	2,3,4,1	0.179564
7	-17.589762	-9.334823	15.980236	2,3,4,1	0.293543
8	-14.045540	19.362587	11.780923	2,4,3,1	0.385081
9	14.595620	19.679185	11.459323	2,4,3,1	0.189425
10	14.547167	19.082920	-12.084095	3,4,1	0.239156
17	-18.281021	-10.37725	-13.366788	2,4	0.030012
20	-14.385589	18.712842	-11.630998	2,4,3	0.485962
47	-13.587675	-18.95975	12.072923	2,1	0.027530
48	14.807178	-18.67015	11.823054	2,1	0.479387
49	15.348187	-20.02472	-9.654735	2,1	0.291418
50	-14.195141	-20.04318	-9.662695	2,1	0.164443
55	17.114938	-7.760851	13.977667	4,3	0.052209
56	-15.519683	-8.548225	13.896351	4,3	0.043768

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.

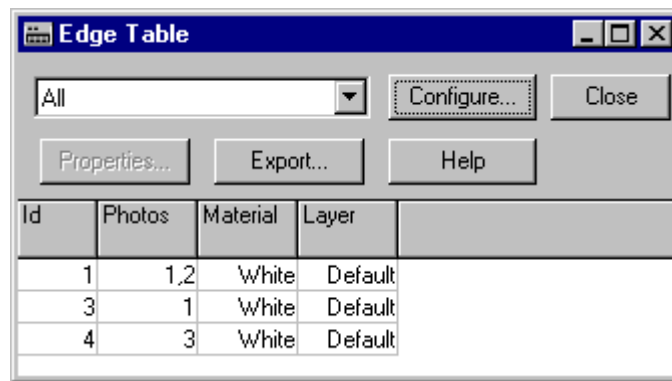
Multiple Point Table windows can be opened simultaneously. The contents of the Point Table keep in sync dynamically with the remainder of the project. For example, if you drag a Marked Point around on a photograph its 3D position in the Point Table

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.

Other Object Tables



Id	Photos	Material	Layer	
1	1,2	White	Default	
3	1	White	Default	
4	3	White	Default	

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.

At this time these tables show only basic information. There are data columns for the object id number, a list of photographs its Marks appear on, and its Material and Layer. 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, Surfaces, 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.

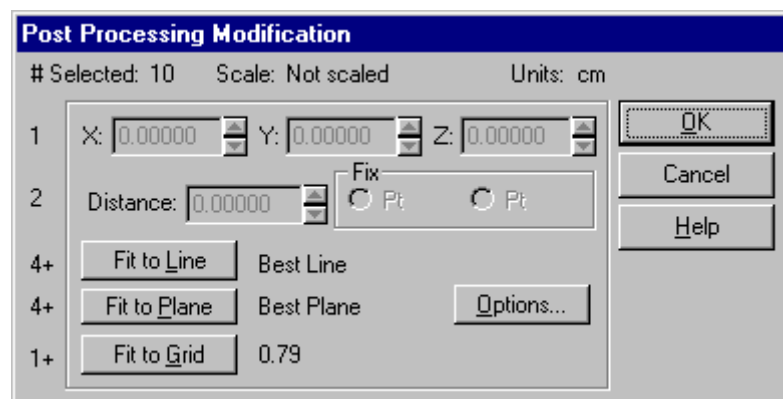
Improve Accuracy

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.

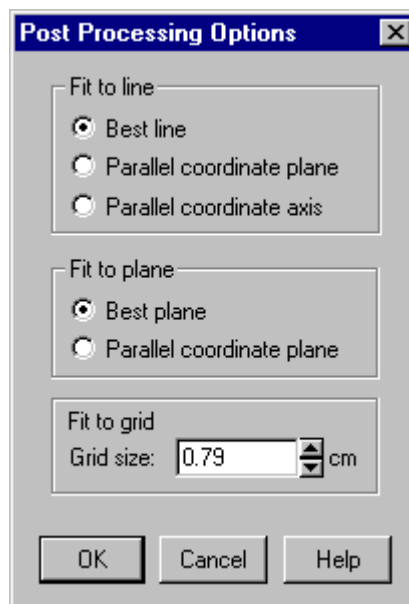
Fit to Plane

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 has 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

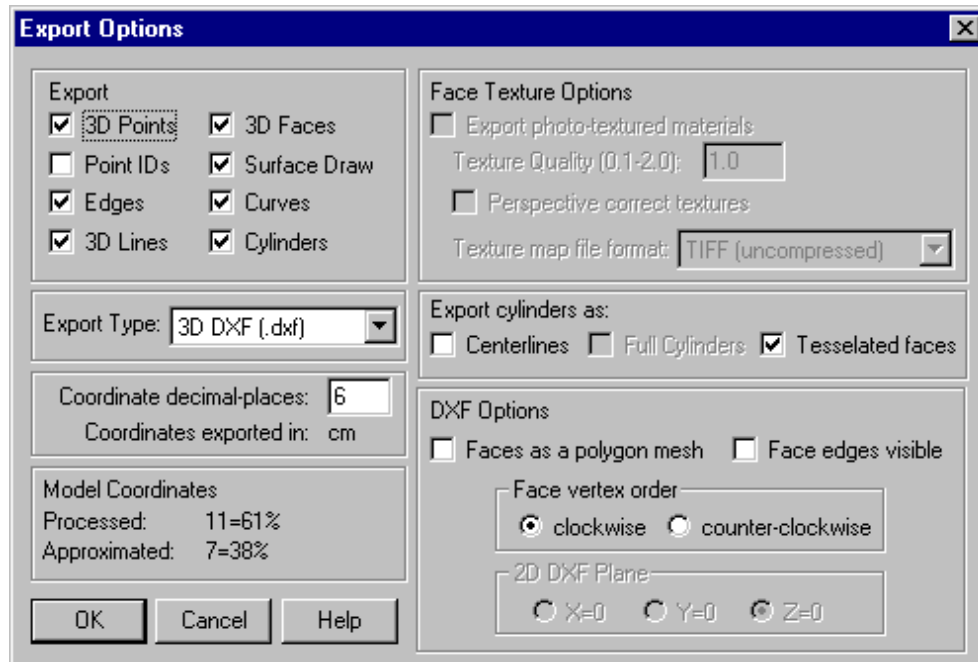
PhotoModeler exports data in the following 3D file formats: DXF, 3DS (3D Studio), OBJ (Wavefront), X (Microsoft DirectX), VRML 1 and 2 (Virtual Reality Modeling Language for the Web), IGES, and RAW (raw coordinate data). PhotoModeler can also export the 3D data in a model projected onto a plane in 2D.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

PhotoModeler can export the following types of data from the project: 3D Points, Point IDs, Edges, Lines, Faces, 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 that in PhotoModeler Surfaces are equivalent to 3D Faces in the export.

Note: It is important to remember that the Object Properties (Materials and Group/Layer Names) affect how these objects are exported. See the [Materials Dialog](#) and [Group/Layer Name Dialog](#) for more details.

Export Type

The Export Type drop down list specifies which type file format to export. Currently supported types are: Autodesk DXF (2D and 3D), Microsoft DirectX, 3D Studio, Wavefront OBJ, VRML (1&2), IGES, and RAW.

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.

The DirectX, 3D Studio, OBJ and VRML 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 and Wavefront OBJ are the only formats that currently support NURBS curves 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.

Note: If exporting smoothed models to 3ds format with photo-texture maps you should note that 3ds has a limitation. It is not possible to described 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.

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 (ie. 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 (eg. Points are exported as small cubes in Direct X).

	DXF	3DS	OBJ	X
--	-----	-----	-----	---

Points	yes		yes	cubes
Point IDs	text			
Edges	lines		lines	cyl. faces*
Lines	yes		yes	cyl. faces
Faces	yes	yes	yes	yes
Photo-Textures		yes	yes	yes
Surface Draw	yes		yes	cubes
Curves	polylines		yes	cyl. faces
Cylinders	cyl. faces	cyl. faces	cyl. faces	cyl. faces

	VRML	IGES	RAW
Points		yes	yes
Point IDs			
Edges	lines	lines	xyz's
Lines	yes	yes	xyz's
Faces	yes		xyz's
Photo-Textures	yes		
Surface Draw	yes	yes	xyz's
Curves	polylines	yes**	
Cylinders	yes		

*note: "cyl. faces" means the cylinder is exported as a tessellated surface that looks like a cylinder.

**note: NURBS curves are exported in IGES as type 126 form 0.

Note: 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 an ini file setting called "WavefrontRotated" that provides the capability to use the former rotation export method.

Coordinate Places

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 "Coordinates exported in" 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.

Model Coordinates

The Model Coordinates section 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.

Face Texture Options

When 3D Faces (Surfaces) are chosen for export, the Face Texture Options become available.

Note: Textures are only exported for a face if that face is set to have a Material with "Diffuse Color from" equal to "Photo as texture". See the [Materials Dialog](#).

The first control, "Export photo-texture materials", controls whether faces with photo-textures will be exported. When this is turned off even faces with photo-textured Materials will not be exported with texture.

The second control, "Texture quality (0.1-1.0)", sets the quality of the exported texture maps. A quality of 1.0 means that the texture maps will have the same resolution as the input photographs. If it is set to 0.5 the output texture maps will have half the resolution of the input photographs. This control can be useful to tune the size of the output texture maps. Note that all texture maps are cropped to remove all unnecessary image data not mapped to a face.

The third control, "Perspective correct textures", sets whether all perspective distortions should be removed from the texture maps. PhotoModeler has an advance proprietary algorithm to remap each photograph to remove perspective to the sub-pixel level. For the highest quality texture maps you will want to use these feature. For models with many small faces the results between perspective correction and no correction will not look that different. Also note that for big images, the perspective correction algorithm can take some time to process.

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) and when exporting to DirectX only the PPM image format is available.

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), and as tessellated faces. 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 faces are a set of 3D faces 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 or DirectX).

DXF Options

The DXF Options section of the 3D Export Dialog has a few controls for the DXF file format.

"Faces as a polygon mesh" is used to specify that all Surfaces in the project should be exported as one DXF polygon mesh.

"Face edges visible" is used to specify if the "visible" flag is to be set when exporting the edges of the 3D 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).

"Face vertex order" is used to specify whether vertices in the faces in the DXF file should be in clockwise or anti-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 be 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.

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 have 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.

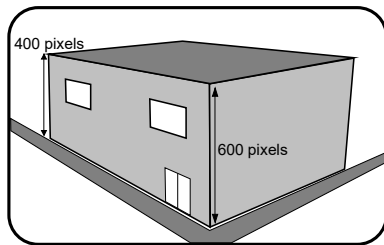


Photo Texture of wall will have variable resolution

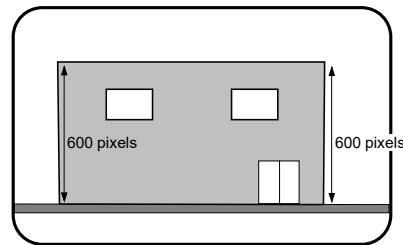


Photo Texture of wall will have constant resolution

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 follow 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 photograph) 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).

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 in that photograph. They need to be processed 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. Single image texture extraction is another name for an Ortho-photo.

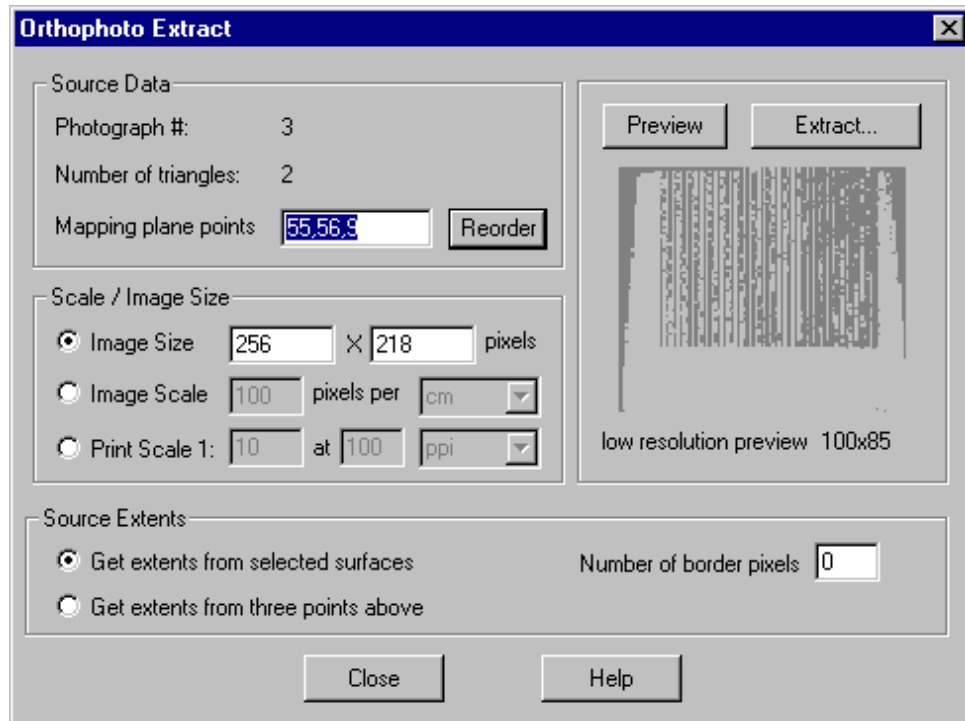
See the [3D Model Export](#) section for a method for extracting textures tied directly to the 3D model.

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 control points to define the plane of the building facade, and then use extended Surface Drawing to extend the Surface to cover the whole building or whole photograph. The resulting Surfaces are selected and an Ortho-photo is created. This Ortho-photo will be equivalent to a single plane rectified photo.

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 (eg. 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. This complete modeling can be quite difficult if all you are using is flat planar sections.

Ortho-photo Dialog



The Ortho-photo Dialog is used to create ortho-photos (i.e., photographs where perspective and shape distortion have been removed). The dialog is accessed from the File Menu / "Export Ortho-photo..." item.

The Ortho-photo Dialog is composed of four areas. The top left area describes the source of the texture image, the middle left describes the output image scaling, the right shows the preview image, and the bottom describes the extents of the image.

Source Data

The Source Data area displays:

- the number of the Photograph that the texture image data is being extracted from.
- the number of Surface triangles that are being used in the extraction (this may differ from the number of selected Surfaces because the Surfaces may contain multiple triangles). If the count of triangles seems low it might be due to some of the Surfaces not being 3D.
- the ids of the points used to define the mapping plane.

The mapping plane is an important part of the process of ortho-photo extraction. Imagine your object is somewhat translucent and has a light bulb behind it (at infinite distance). Now take three points on that object and define a plane going through those points. Then take a piece of flat paper that floats in space and is parallel to that plane.

The light inside the object will project an image onto the paper. This image is similar the texture image PhotoModeler extracts.

By picking different points to define the plane you can get different effects. For a flat surface the obvious choice is three points lying on that surface. That way the mapping plane is parallel to the surface the image is coming from.

The three point IDs shown in the dialog are obtained from the set of selected Surfaces and Marked Points. If you select only Surfaces before starting then the first Surface will be used to define the mapping plane. If you select some Marked Points along with the Surfaces, the first three 3D Points will be used to define the mapping plane.

Edge Points and Surfaces that attach to Edges can be used too. The point ids in this box look different for Edges. An Edge point id will have an "a" or a "b" after it. For example, "5b" is the second point of the Edge with id 5. If the ids box looked like this: "5a,5b,32", the mapping plane would be defined between Edge 5's first and second point and then Object Point 32.

Sometimes it can be difficult to get the correct three points using these methods. Once the dialog is displayed you can edit the IDs of the Mapping Plane Points. This way you can get the mapping plane to sit in the orientation you want. After you have entered three new IDs, hit the Preview button to see what the resulting texture will look like. Remember, you can see Point IDs on the photographs by using the Visibility Dialog.

The order of the points is also important. The first two points define the horizontal axis of the resulting image and the third defines the rotation. With the incorrect order you can get the image inside/out also. You can press the Reorder button until the image in the preview window looks correct. If pressing the Reorder button multiple times does not give the preview in the orientation you wish, you will need to pick three different mapping plane points (or rotate the image later in an image editing program).

Source Extents

The section at the bottom can often be left at its default values. The two radio buttons control how much of the source photograph is used during the remapping process. If you have selected a number of Surfaces before entering the dialog, you will be able to remap all of the source photograph under those surfaces by choosing the top option.

Alternatively you can define the region of the source photo to be extracted to be just the bounding rectangle defined by the three points in the "Mapping plane points" box above. This allows you to do ortho-photo extraction on a single plane without any Surfaces - a fast way of doing rectified photos of building facades.

The "Number of border pixels" box controls how much extra of the source image is remapped outside of the extents defined by one of the two radio buttons.

Preview Area

The Preview area shows the image texture being extracted and has two buttons:

- the "Preview" button is used to see what effect rotation has on the result and
- the "Extract..." button is used to do the final extraction to a file of the desired size.

Scale/Image Size

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.

Ortho-photo Steps

To extract an ortho-photo or planar texture:

1. Select one or more Surfaces or three Points (Marked Points or ends of Marked Edges) in a Photograph.
2. Choose File / Export ortho-photo
3. In the Ortho-photo Dialog pick the correct mapping plane points and the correct order by viewing the preview.
4. Choose the scale of the output image.
5. Press the Extract... button.

A file dialog will appear. Pick the image file type and enter the file name for the output image.

6. Press "Save" on the file dialog.
The remapping will take place (might take some time if the output file is large). The camera position, the surface and points positions, the camera parameters (including lens distortion) are all taken into account while remapping the image.
7. Press "Close" on the Ortho-photo Dialog.
8. Use your exported image in another program, or print it etc.

Using Ortho-photo Extraction for Planar Textures

Instead of using PhotoModeler built in texture extraction process with 3D Model export you may want to have planar texture maps to be applied manually in your 3D rendering program.

To generate good textures you should consider how they will be used and mapped in your rendering program. PhotoModeler generates flat or planar images and so you will probably use a planar mapping in the rendering program also.

You may wonder if using planar mapping limits you to just flat surfaces. It does not. If you select a set of Surfaces that describe a slightly curved surface (i.e. side of a human face) extract that to a planar map with PhotoModeler, you can then use a planar mapping in your rendering program to place the texture back onto the same curved surface and you will get a realistic result. There are some limits. If the surface has a very sharp curve or has many regions that are at a steep angle to the mapping plane then there will be too much distortion during the mapping.

You can also break more complex surfaces into smaller flatter areas and extract separate texture images for each of these areas and then map them in the rendering program separately.

When surfaces are very close to 90 degrees to each other you cannot extract the textures of all surfaces at once successfully. For example, to extract all the images of the sides of a box would require six texture extractions (one for each face).

You may find that the extraction of high resolution images is very slow and you may wonder why. You can think of texture extraction as a reverse raytracing with anti-aliasing. Every pixel in the output image has to be visited in turn and a full 3D mapping that takes into account the output mapping plane orientation, the position of the Surface, and the position of the Camera Station in 3D space has to be computed.

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 but it may be useful for integrating with other 3D and photogrammetric programs.

Note: the text export from the Point Table or Photo Table should be used in place of this file where possible. This capability is in the product for backward compatibility only and may be removed in a future release.

The text file does not fully describe a project. In other words if you were to text export a measurement project and then text import the exported file, you would lose some information. The information lost would be:

- the affine transform information (i.e. the scale and the axis rotation),
- the world object shape, size and chosen front face,
- any Camera Restrictions,
- any Fiducial marks,
- any triangular Surfaces,
- the Project Camera description, and
- the Camera Layout description.

The text file is broken up into sections. The first section describes overall project information. The second section describes the Camera Station information and the associated Camera information. The third section describes the 3D object points. The fourth section describes the marked point locations on the photographs. The fifth and sixth sections describe the feature connections.

File Format

The following table describes what is contained on each line of the file:

Line#	Description of line contents
1	Job title (if its starts with "Bundle Soln" it is assumed this contains adjusted/processed data)
2	Tolerance for solution, maximum number of iterations The tolerance is the difference between the standard error of unit weight between successive iterations, if this tolerance is not achieved during processing then the adjustment stops when the max. number of iteration is hit.
3	Default standard deviation errors: photo-coordinates (mm), control points(m), object points (m), camera positions (x,y,z)(m), camera angles (kappa,phi,omega) (degrees)
4	Calibration camera focal length(mm), principal point (xp,yp) (mm), format size (xs,ys) (mm), lens distortion parameters (K1,K2,P1,P2)
5	Standard deviation errors for above parameters
6	Camera Station number, image file name
7	Camera Station number, position (x,y,z) (m), angles (kappa,phi,omega)(degrees)
8	Camera Station number, standard deviations of position (x,y,z) (m), standard deviations of angular elements (kappa, phi, omega) (degrees)
9	Camera Station number, covariances of camera position (xy,xz,yz)(m) (note: if this record is left blank, no covariances will be considered - right now covariances not used during PhotoModeler processing)
10	Camera Station number, focal length of associated camera(mm), principal point (xp,yp)(mm), format size (xs,ys) (mm), lens distortion (K1,K2,P1,P2)

- 11 Camera Station number, standard deviations for parameters on line 10
(repeat records 6 through 11 for all Camera Stations; end with a blank line)
- (13) Control point number, position (x,y,z) (m), standard deviations (x,y,z) (m)
(repeat record 13 for all control points; end with a blank line)
- (15) Object point number, position (x,y,z) (m), standard deviations (x,y,z) (m)
(repeat 15 for all object points; end with a blank line)
- (17) Photograph number, marked point number, position (x,y)(pixels), standard
deviations (mm) Note: Photograph numbers match Camera Station numbers and
the Marked Point numbers match the Object and Control Point numbers.
(repeat 17 for all marked points on all photos; end with a blank line)
- (19) Feature number., number of object points in feature, point no. 1, point no. 2 etc.
(repeat 19 for all Features, end with a blank line)
- (21) Photograph number, Feature number
(repeat 21 for all photographs and their features, end with a blank line)

Note: The (19) and (21) data lines for Features may be absent.

Note: if any of the standard deviation values are negative, the corresponding parameter is considered to be known and fixed and hence is not varied during the bundle adjustment.

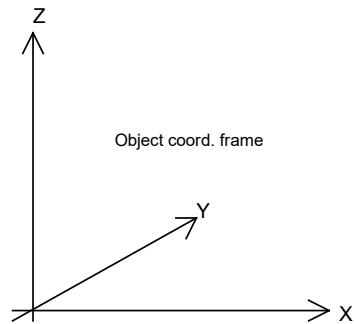
Background

This section describes what some of the terms discussed in the previous section mean. It is assumed that the reader is familiar with PhotoModeler and with probabilistic descriptions of measurement quantities. The section on 3D Measurement in the PhotoModeler User Manual can help with some of the probability background and the section on the Camera Calibrator can help with a description of the camera parameters.

Terms shown in the File Format section are:

Camera Station

A Camera Station is a position of a Camera at the moment of exposure of a Photograph. One measurement project using one camera with eight photographs would have eight Camera Stations. A Camera Station is defined by its position in 3D Cartesian space in a right-handed coordinate system as shown in figure below. A Camera Station also has a rotation relative to the coordinate system. The following section describes the orientation.



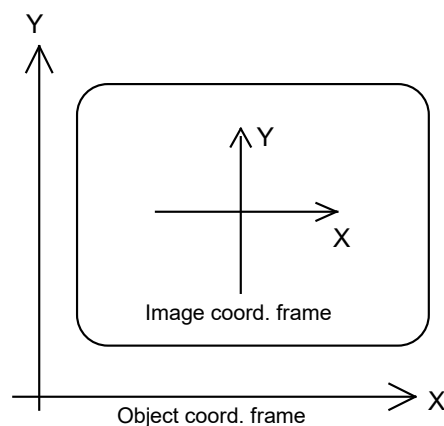
Euler Angles: Omega, Phi, Kappa

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.

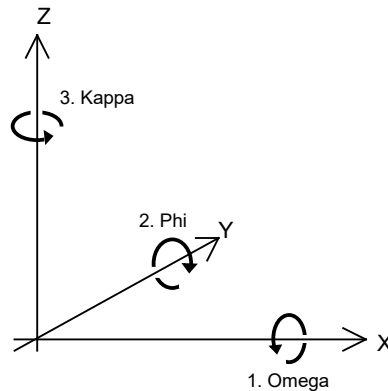
If you line-up the coordinate system of the camera with the coordinate system of the object you have the camera's default position.

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:



Object Point

An object point is a 3D location of a point in the model. These are the essential output of the processing stage of PhotoModeler. All line and Surfaces are connected to these Object Points.

Control Point

A control point is an object point that is at measured and known position. For example, if you measured a large structure and had a survey crew come in a measure a few points on the building and then give you the locations of these points, these points could be used to define the scale and coordinate system of the model. These points are called control points.

Photograph

A photograph is the image captured at the moment of exposure at a Camera Station. Photographs are viewed in PhotoModeler and the user marks points and lines on them.

Marked Point

A marked point is a position on a photograph. Every object point that is imaged on a particular Photograph will have a corresponding marked point on that Photograph. Marked points are positioned on Photographs to sub-pixel precision.

Example file

The following is an example of a simple Measurement Project exported via Text Export from PhotoModeler. This project has one Camera Station / Photograph and one line (two points) marked on the one Photograph. After the file, each line is described.

```
#
1 This is a sample Text Export file from PhotoModeler
2 1.000000 20
3 0.00509 0.00800 0.60000 0.15000 0.15000 0.15000 10.00000 10.00000 10.00000
4 8.283 4.94 3.64 9.15 7.34 0.00248 0.00005 0.00030 -0.00016
5 0.90000 0.20000 0.20000 0.0700 0.0700 0.001000 0.001000 0.001000
6 0 C:\DATA\IMAGES\TUTORIAL\TUT1.TGA
7 0 2.639 2.639 2.639 150.000 35.264 -45.000
8 0 0.1500 0.1500 0.1500 10.0000 10.0000 10.0000
9
10 0 8.283 4.94 3.64 9.15 7.34 0.00248 0.00005 0.00030 -0.00016
11 0 0.90000 0.20000 0.20000 0.0700 0.0700 0.001000 0.001000 0.001000
12
13
14
15 0 1 102.2609 282.7079 0.00509 0.00519
16 0 2 263.6522 350.9478 0.00509 0.00519
17
18 1 2 1 2
19 2 1 1
20 3 1 2
21
22 0 1
23 0 2
24 0 3
```

The following is an explanation of what each line means in this example file:

1 This is a sample Text Export file from PhotoModeler

This line is the title line and matches the Measurement Project description.

2 1.000000 20

This line says that the tolerance for solution is 1.0 and that the maximum number of iterations of Processing is 20 if the tolerance is not met.

3 0.00509 0.00800 0.60000 0.15000 0.15000 0.15000 10.00000 10.00000 10.00000

This line says that the standard deviation errors used as defaults during adjustment are: 0.00509mm for marked points, 0.008m for control points, 0.6m for object points, 0.15m for Camera Station x,y,z position and 10.0degrees for Camera Station angles.

4 8.283 4.94 3.64 9.15 7.34 0.00248 0.00005 0.00030 -0.00016

This line says that the Calibration Camera has a focal length of 8.2383mm, a principal point of (4.94,3.64) mm, a format size of 9.15mm horizontally and 7.34mm vertically, and lens distortion parameters of K1=0.00248, K2=0.0005, P1=0.0003, P2=-0.00016.

5 0.90000 0.20000 0.20000 0.0700 0.0700 0.001000 0.001000 0.001000 0.001000

This line says the standard deviation errors used for the Calibration Camera parameters during adjustment are: 0.9mm for focal length, 0.2 mm for principal point, 0.07mm for format size, 0.001 for lens distortion.

6 0 C:\DATA\IMAGES\TUTORIAL\TUT1.TGA

This line says that Camera Station 0 (would be number 1 in PhotoModeler) has an associated image file called C:\DATA\IMAGES\TUTORIAL\TUT1.TGA.

7 0 2.639 2.639 2.639 150.000 35.264 -45.000

This line says that Camera Station 0 is located at x,y,z of (2.639, 2.639,2.639)m and angles of kappa=150.0, phi=35.264, omega=-45.0 degrees. Note that the order of angles in this file is opposite of the order of application of angles. The angles are applied in the order: omega, phi, kappa.

8 0 0.1500 0.1500 0.1500 10.0000 10.0000 10.0000

This line says that Camera Station 0 has standard deviations of 0.15m for position and 10.0degrees for angles.

9

This line is blank indicating there are no covariance values for Camera Station 0.

10 0 8.283 4.94 3.64 9.15 7.34 0.00248 0.00005 0.00030 -0.00016

This line says that Camera Station 0 has an associated camera with a focal length of 8.283mm, a principal point of (4.94,3.64)mm, format size of (9.15 7.34)mm, and lens distortion parameters of K1=0.00248, K2=0.0005, P1=0.0003, P2=-0.00016.

11 0 0.90000 0.20000 0.20000 0.0700 0.0700 0.001000 0.001000 0.001000 0.001000

This line says that Camera Station 0 has an associated camera with standard deviations of: 0.9mm for focal length, 0.2 mm for principal point, 0.07mm for format size, 0.001 for all lens distortion parameters.

12

This line is blank indicating the end of the Camera Station list.

13

This line is blank indicating the end of the Control Point list. That is, there are no control points in this project.

14

This line is blank indicating the end of the Object Point list. That is, there are no object points in this project. This is the case when 3D processing (bundle adjustment) has not been carried out yet.

15 0 1 102.2609 282.7079 0.00509 0.00519

This line says that on Photograph 0 (corresponds to Camera Station 0) there is a marked point numbered 1 located at x,y pixel of (102.2609,282.7079) with standard deviation of (5.09,5.19) microns. Given the pixel size is about 9 microns this is a standard deviation of about one half a pixel.

16 0 2 263.6522 350.9478 0.00509 0.00519

This line says that on Photograph 0 there is a marked point numbered 2 located at x,y pixel of (263.6522,350.9478) with standard deviation of (5.09,5.19) microns.

17

This blank line indicates that there are no more marked points in the project.

18 1 2 1 2

This line says that there is a Feature numbered 1 with two points. The points that make up this feature are numbered 1 and 2. This is a line feature.

19 2 1 1

This line says that there is a Feature numbered 2 with one point. The point that makes up this feature is numbered 1. This is a point feature.

20 3 1 2

This line says that there is a Feature numbered 3 with one point. The point that makes up this feature is numbered 2. This is a point feature.

21

This blank line indicates the end of the list of Features.

22 0 1

This lines says that on Photograph 0, the Feature numbered 1 appears.

23 0 2

This lines says that on Photograph 0, the Feature numbered 2 appears.

24 0 3

This lines says that on Photograph 0, the Feature numbered 3 appears.

That is the end of the file. When the end of file is reached, there are no more features on photographs.

Working with Constraints

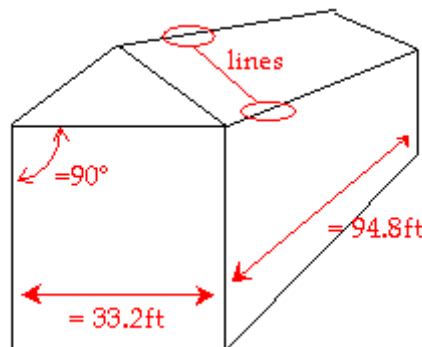
Overview

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.

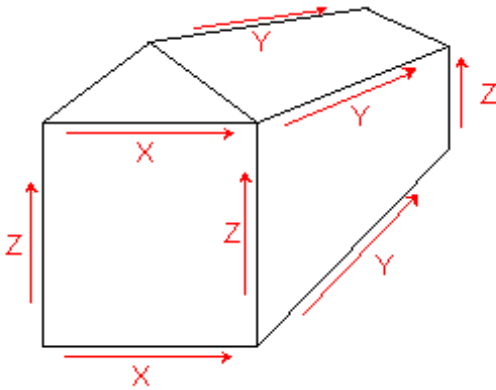
There are three main categories of Constraints in PhotoModeler. They are: Multi-photo Constraints, Axes Constraints, and Control Point Constraints.

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

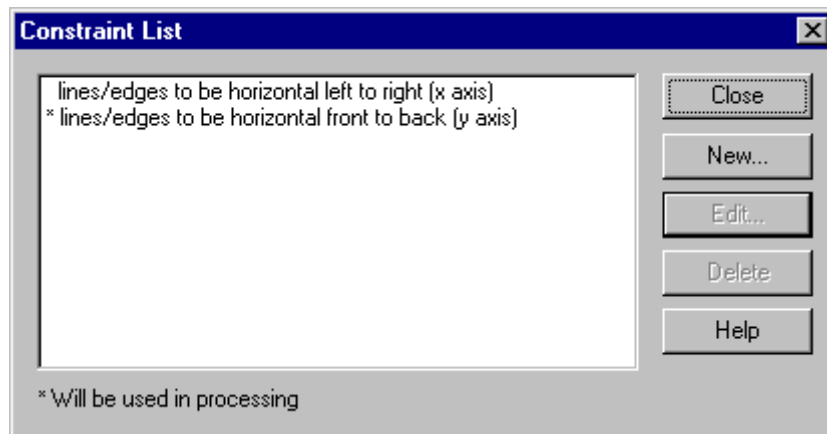
Manipulating Constraints


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.

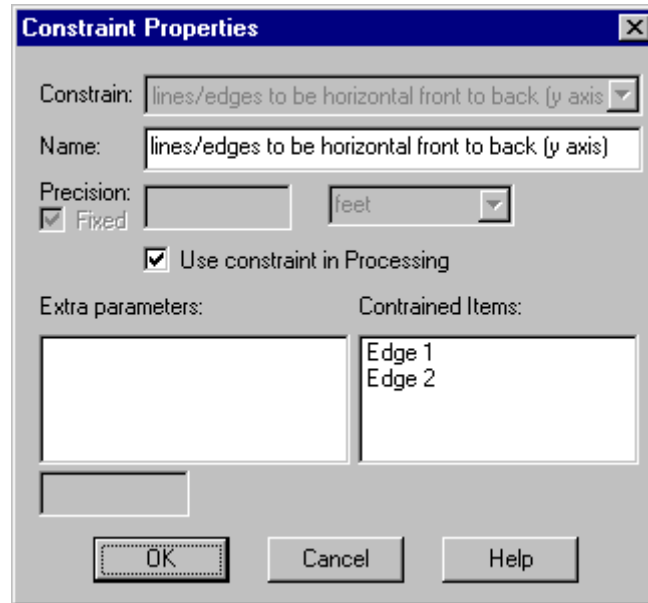
The New button brings up the [Constraint Edit Dialog](#) so that a new Constraint can be added. Constraints added this way will have no constrained objects (points, lines, etc.) but they can be added later. Note that Constraints can be added directly from the Constraint Toolbar with all objects that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

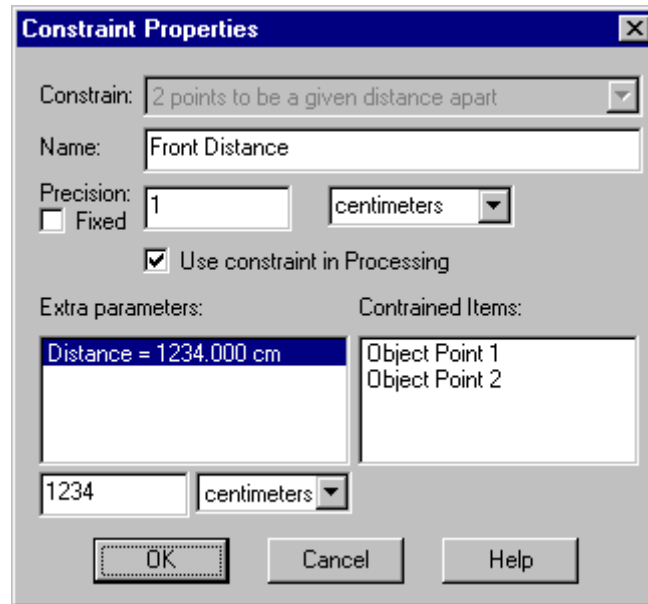
The precision can be "fixed", which means PhotoModeler tries its best to meet the constraint exactly (this may not always be possible). The precision can also be a non-fixed value. Example, a parallel constraint might be fixed (which means PhotoModeler tries its best to make the two edges or lines perfectly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

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:

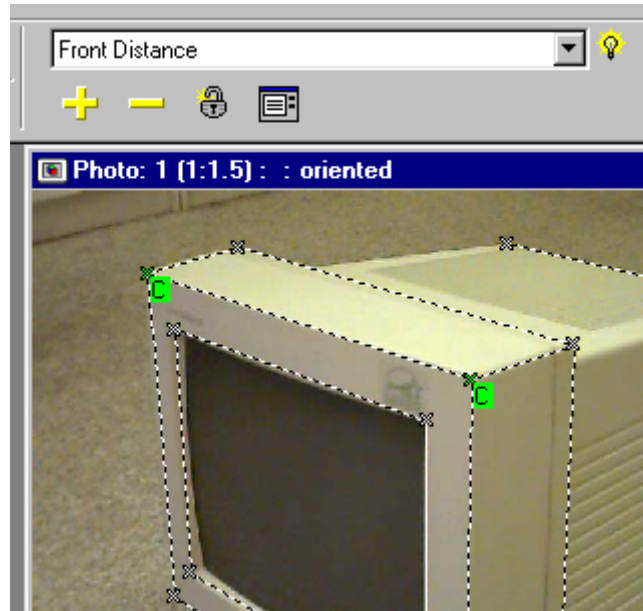
- 2 points to be a given distance apart [user specifies distance]
- 2 lines to be a given angle [user specifies angle]
- 2 edges to be a given angle [user specifies angle]

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 sub-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 Scale/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.

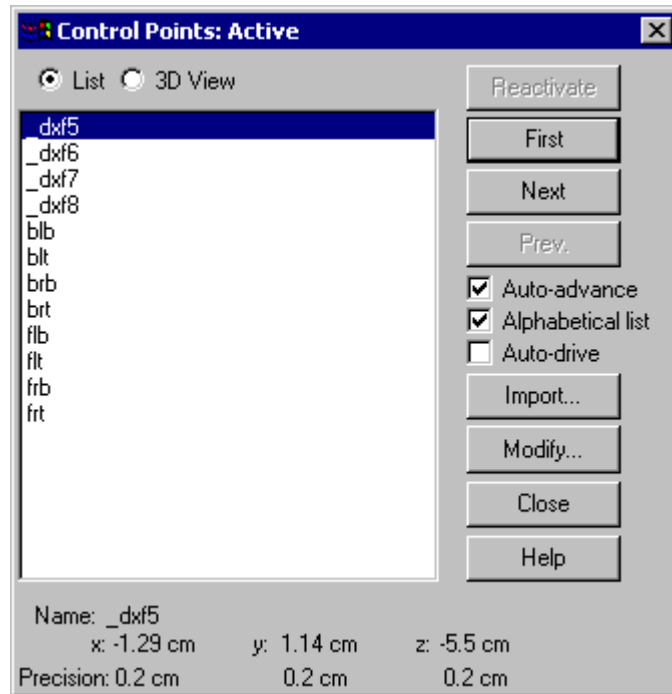
Marking Control Points

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 Point 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 ids 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. The size of the point symbol is controlled by a setting in the phmodel40.ini file.

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 an inactive 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 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.

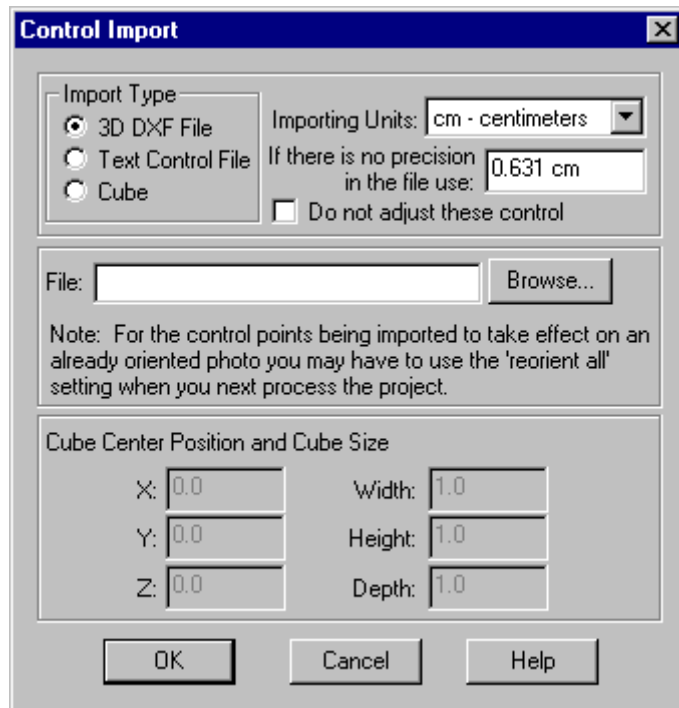
The "Auto advance" check box controls how the Control Points are presented during marking. If "Auto advance" is checked, the current Control Point will advance to the next unmarked Control Point on the current photograph after the current point has been marked. Turning auto-advance off is a good way 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 (ie. the ids: 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").

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 hit 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 be 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 dialog.

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:

- A 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).
- B 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).

- C 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.

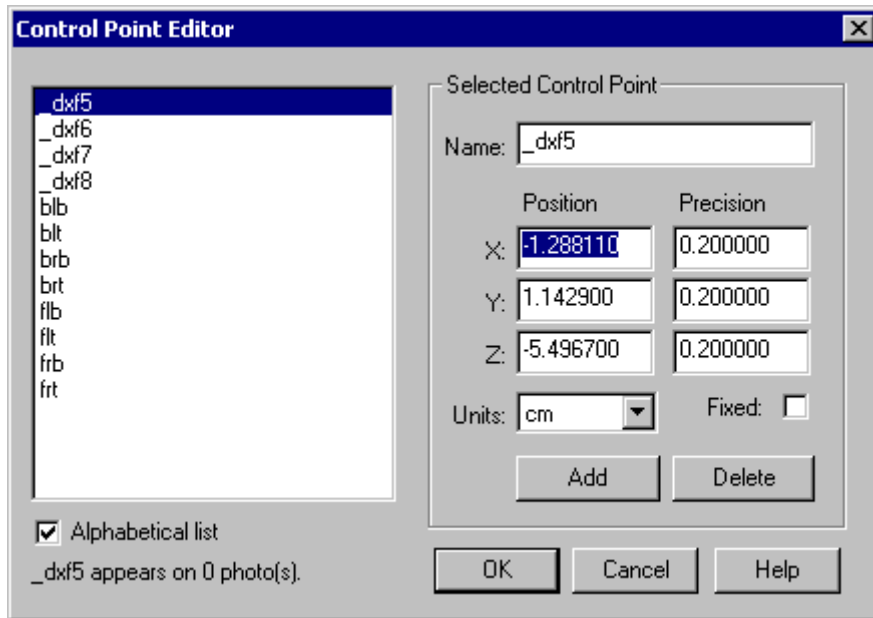
In other words, if you import a CTL file with named control points or a DXF file with named points (a control point is named in a DXF file if a text string is found to have the same coordinates as a 3D point) and that control points already exist in the project with the same names as those being imported, 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.

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 colinear

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 colinear points
Use: To make points lie up and line segments create a straight line. Used only in multi-photo projects and solved in Global Optimization.

4 or more points to be coplanar

Description: Constrain four or more points to line on a plane.
Objects: Four or more 3D Object Points
Extra Parameter: None
Number allowed: One constraint for every known set of coplanar points
Use: To make points lie all in one plane. Note the plane can be at any angle. Used only in multi-photo projects and solved in Global Optimization.

2 lines to be perpendicular

Description: Constrain two lines (their four end points) to be 90 degrees angle apart.
Objects: Exactly two Lines (with 3D Object Points as end points)
Extra Parameter: None
Number allowed: One constraint for every pair of known perpendicular Lines
Use: To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 or more lines to be parallel

Description: Constrain two or more lines (all their end points) to be parallel.
Objects: Two or more Lines (with 3D Object Points as end points)
Extra Parameter: None
Number allowed: One constraint for every set of known parallel Lines
Use: To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 lines to be a given angle

Description: Constrain two lines (their four end points) to be a known angle apart.
Objects: Exactly two Lines (with 3D Object Points as end points)
Extra Parameter: Angle in degrees
Number allowed: One constraint for every pair of known angle
Use: To set a non-zero or non-90 degree angle between lines. Used only in multi-photo projects and solved in Global Optimization.

2 or more lines to be equal length

Description:	Constrain two or more lines (their end points) to be the same length.
Objects:	Two or more Lines (with 3D Object Points as end points)
Extra Parameter:	None
Number allowed:	One constraint for every set of Lines that are the same length
Use:	To improve the shape and squareness of objects and sometimes to improve dimensional accuracy. Used only in multi-photo projects and solved in Global Optimization.

2 edges to intersect

Description:	Constrain two edges to intersect.
Objects:	Exactly two Edges
Extra Parameter:	None
Number allowed:	One constraint for every pair of Edges to intersect.
Use:	To use Edges and produce a more complete wire frame. Processed only in multi-photo projects and solved in Global Optimization but also used to extend the 3D Edges to the common point even if not processed.

1 edge to intersect one point

Description:	Constrain an edge to go through (and stop at) a 3D Object Point.
Objects:	Exactly one Edge and one 3D Object Point
Extra Parameter:	None
Number allowed:	One constraint for every pair of Edge/Point intersections.
Use:	To use Edges and produce a more complete wire frame. Processed only in multi-photo projects and solved in Global Optimization but also used to extend the 3D Edges to the point even if not processed.

2 edges to be a given angle

Description:	Constrain two Edges to be a known angle apart.
Objects:	Exactly two Edges
Extra Parameter:	Angle in degrees
Number allowed:	One constraint for every pair of known angle
Use:	To set a non-zero or non-90 degree angle between Edges. Used only in multi-photo projects and solved in Global Optimization.

2 edges to be perpendicular

Description:	Constrain two Edges to be 90 degrees angle apart.
Objects:	Exactly two Edges
Extra Parameter:	None
Number allowed:	One constraint for every pair of known perpendicular Edges
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

2 or more edges to be parallel

Description:	Constrain two or more Edges to be parallel.
Objects:	Two or more Edges
Extra Parameter:	None
Number allowed:	One constraint for every set of known parallel Edges
Use:	To improve the shape and squareness of objects. Used only in multi-photo projects and solved in Global Optimization.

Axes Constraints

All Axes Constraints are solved during the Orientation stage of Processing. These Constraints are typically used in single photo projects but can be used in multi-photo projects also (they act on a single photo at a time).

Note that during the processing of a multi-photo project, normal global optimize runs without the axes constraints being used at all. When the global optimize is complete, the axes constraints are reviewed to see if any objects need to be forced to lie along certain axes or planes etc. This means you can have some objects (points, lines, edges) appear on only one photo of a multi-photo project and they can have computed 3D positions if they are constrained by one of these constraints.

Note also that the axes constraints allow some limited Inverse Camera solutions (solving for focal length and principal point) on a single photo if the perspective is strong enough. To solve focal length you typically need a strong two point perspective (that means vanishing lines in two directions (x and y axes for example)). To solve focal length and principal point you need strong three point perspective. See the [Working with Unknown Cameras and Photographs](#) section for more detail.

Lines/Edges to be horizontal left to right (x axis)

Description:	Constrain a set of Lines and Edges to be parallel to the x-axis
Objects:	Any number of Lines and Edges
Number allowed:	One constraint per project
Use:	Collecting all Lines and Edges in the project that are parallel to the x-axis (by convention is horizontal left to right). Used mainly in single photo projects.

Lines/Edges to be horizontal front to back (y axis)

Description:	Constrain a set of Lines and Edges to be parallel to the y-axis
Objects:	Any number of Lines and Edges
Number allowed:	One constraint per project
Use:	Collecting all Lines and Edges in the project that are parallel to the y-axis (by convention is horizontal front to back). Used mainly in single photo projects.

Lines/Edges to be vertical (z axis)

Description:	Constrain a set of Lines and Edges to be parallel to the z-axis
Objects:	Any number of Lines and Edges

Number allowed: One constraint per project
Use: Collecting all Lines and Edges in the project that are parallel to the z-axis (by convention is vertical). Used mainly in single photo projects.

Surfaces to be horizontal (xy plane)

Description: Constrain a set of Surfaces to each be parallel to the xy plane
Objects: Any number of Surfaces
Number allowed: One constraint per project
Use: Collecting all Surfaces in the project that are parallel to the xy plane (by convention is horizontal). Used mainly in single photo projects.

Surfaces to be vertical - front (xz plane)

Description: Constrain a set of Surfaces to each be parallel to the xz plane
Objects: Any number of Surfaces
Number allowed: One constraint per project
Use: Collecting all Surfaces in the project that are parallel to the xz plane (by convention is vertical front). Used mainly in single photo projects.

Surfaces to be vertical - side (yz plane)

Description: Constrain a set of Surfaces to each be parallel to the yz plane
Objects: Any number of Surfaces
Number allowed: One constraint per project
Use: Collecting all Surfaces in the project that are parallel to the yz plane (by convention is vertical side). Used mainly in single photo projects.

Surfaces to be planar (any plane)

Description: Constrain one multi-point surface to be a flat plane at any orientation
Objects: One multi-point Surface (must have 4 or more 3D Object Points in Surface)
Number allowed: One constraint per planar Surface
Use: Since any Surface with 4 or more points is not necessarily planar, this constraint lets you specify this. This allows you to propagate 3D information along a surface plane when three of the points of the surface are already computable in 3D. Used mainly in single photo projects. For multi-photo projects and solution during Global Optimization stage see the 4 or more points to be coplanar Constraint.

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

So you have one or more photographs and you are wondering if Inverse Camera will be able to give you a result.

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.

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 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.
10. 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 post-processing report after a successful processing. You can turn this report on in the Preferences Dialog (see [Preferences - Process](#)). The report is automatically written to disk after processing completes. 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 post-processing report looks like this:

```
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 sections 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

- a) How many photos?
- b) What angles between photos?
- c) How much overlap (shared points)?
- d) What is photo quality and sharpness?
- e) The critical dimensions, do they appear on multiple photos or on a known plane in a single photo?

2) Review what is known

- a) 2d or 3d control points available?
- b) Survey data available or a survey can be done?
- c) Can 3d control be made from other knowns?
- d) 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?
- e) Does the control cover the photos well (i.e., not all in small portion of photo)?
- f) If no control points, do you have strong perspective and can use Axes Constraints on parallel edges and lines?
- h) If a crush project, is car make/model/year known?
- i) Is there access to an exemplar vehicle?
- j) 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

- a) Single photo resection with measurement/mapping on plane?
- b) Multiple photo - inverse cameras and normal projects
- c) Is an exemplar needed? Front crush, side crush, using offsets.
- d) Combined crush/exemplar project or separate projects?

- e) 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

- a) 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

- a) Photo with most control visible (with control visible over depth)
- b) Photo that is sharpest
- c) Photo that covers most of the area of interest

7) If using Control Points, Import the Control

- a) Lock control points down with negative precision or check box
- b) 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

- a) With film and scanned prints you can usually determine format size before hand (at least to a good enough approximation).
- b) Start off solving for focal length only (then add principal point if greater precision is needed).

9) Test the single photo solution if possible.

- a) Test using any known dimensions on planes.
- b) Review camera parameters to see if they make sense.
- c) Study the 3D viewer to see if it makes sense.
- d) 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

- a) Using the camera parameters from the first good solution make up new cameras for each photo if you think a zoom lens was involved.
- b) 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

- a) If using multiple photos, just complete the project as any normal PhotoModeler project.
- b) 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 (ie. 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.

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:

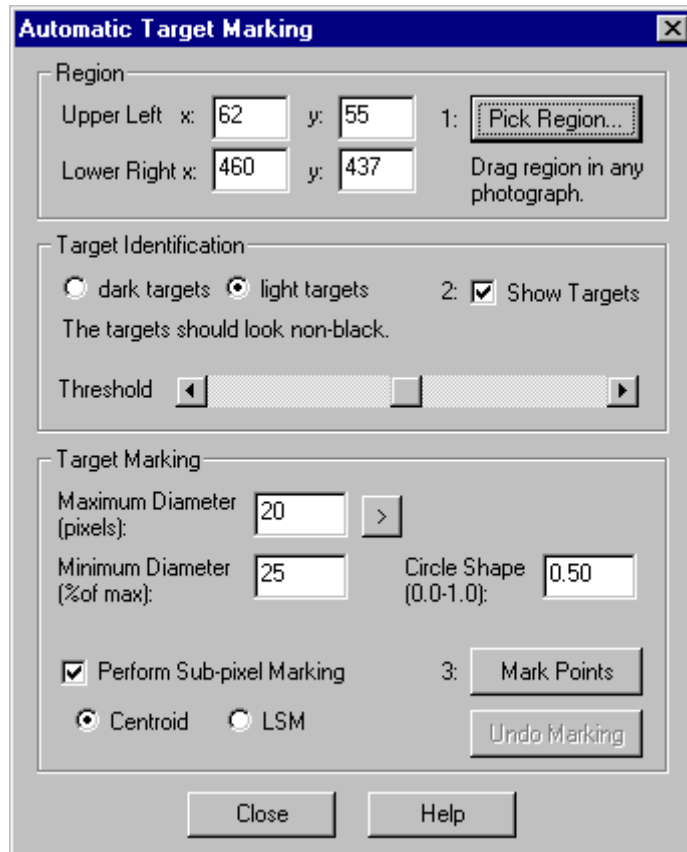
- stick-on natural-light targets,

- 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 (like automatic target marking (in PhotoModeler and the Calibrator) and sub-pixel target marking) only work on 8 bit monochrome (no palette) or 24 bit full RGB images.

Automatic Target Marking Dialog



The dialog box is titled "Automatic Target Marking" and contains three main sections: Region, Target Identification, and Target Marking. The Region section has input fields for Upper Left x (62), y (55), Lower Right x (460), and y (437), along with a "Pick Region..." button and a note to "Drag region in any photograph." The Target Identification section has radio buttons for "dark targets" and "light targets" (selected), a "Show Targets" checkbox (checked), and a "Threshold" slider. The Target Marking section has input fields for "Maximum Diameter (pixels)" (20) and "Minimum Diameter (% of max)" (25), a "Circle Shape (0.0-1.0)" field (0.50), a "Perform Sub-pixel Marking" checkbox (checked), and radio buttons for "Centroid" (selected) and "LSM". At the bottom are "Close" and "Help" buttons. Action buttons "Mark Points" and "Undo Marking" are also present.

Section	Parameter	Value / Option
Region	Upper Left x	62
	Upper Left y	55
	Lower Right x	460
	Lower Right y	437
Target Identification	Target Type	light targets
	Show Targets	checked
	Threshold	Slider
Target Marking	Maximum Diameter (pixels)	20
	Minimum Diameter (% of max)	25
	Circle Shape (0.0-1.0)	0.50
	Perform Sub-pixel Marking	checked
	Marking Method	Centroid
	Marking Action	Mark Points

Automatic Target Marking is a three step process as laid out in the dialog. This dialog is accessed from the Marking Menu / Automatic Target Marking item.

The first step is for the user to define a rectangular region on one photo that contains all or most of the targets. The second step involves verifying the type of targets and their segmenting threshold, and the third step is performing the actual marking.

To perform Automated Target Marking:

1. Open the photograph containing the high-contrast circular targets.
2. Open the Automatic Target Marking Dialog.
3. Press the Pick Region... button.
The dialog will disappear and the selection region cursor will appear when the cursor is over a photograph.

4. Click and hold the left mouse button over the one corner of the region with the targets (it can be any corner).
5. Drag the mouse (while continuing to hold the left button down) to outline the region that contains the targets in the photo.
A marquee box will appear showing you the region being chosen.
6. Release the mouse when the region is defined.
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.
7. 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 (some natural-light targets).
8. 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 optimal red, green or blue channel is chosen (whichever channel has the highest contrast in the region chosen in step 6). The image will then be some primary color on black instead of white on black. This just indicates which channel was chosen.
9. 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 at step 3 picking smaller regions.
10. Enter in the diameter (in pixels) of the largest target in the region.
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.
11. Decide what type of target marking will be done. If "Perform Sub-pixel marking" is not checked, the marking will be the fastest but the least accurate. This might be suitable for a first try as you can easily undo the marking and try again (by pressing the Undo Marking button).
12. Press the Mark Points button.
The black and white region will be replaced with the normal photograph and points will be marked automatically in the white regions.
13. If the markings do not look correct you can press the Undo Marking button and perhaps try again with different parameters.
You may find you need to change the Minimum Diameter and Circle Shape settings to reduce the number of extraneous marks created. The larger the Minimum Diameter (set as a % of the Maximum Diameter) the fewer small white targets will be marked. The larger the Circle Shape setting the more circular the target will have to be to be marked.

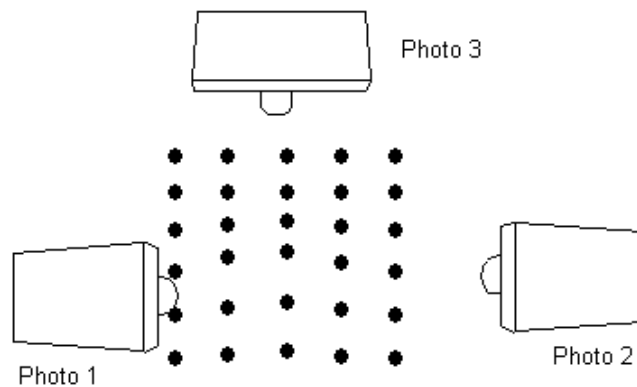
14. Press Close on the dialog to return to normal operation. Note that once OK is hit you will not be able to undo the automatic marking (the points would have to be deleted manually).

Note that you can open and activate different photographs while the dialog is open so many photographs can be automarked without having to close the dialog. Just repeat from step 1 (while skipping step 2).

Automatic Referencing

Automatic Referencing will search through a set of specified unreferenced Marked Points and attempt to optimally reference them together.

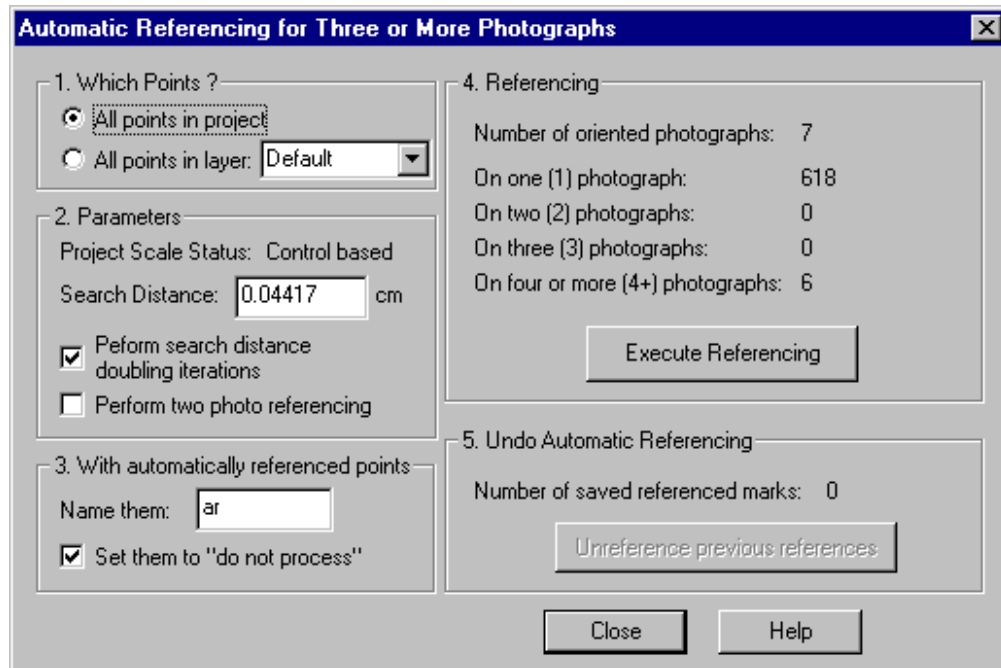
Note that this set of points cannot describe a multi-sided object (for instance points marked on windows and door on both sides of a house) and each point should appear on three or more photographs (four is preferred). Also note that these photographs have to have a geometric relationship similar to that described in Photography for Curves, Edges, Cylinders and Automatic Referencing. One possible configuration is like this:



Starting with version 4.0g of PhotoModeler Pro, automatic referencing can be carried out on near-planar object with only two photographs.

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 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 which Marked Points in the project to reference.
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").
4. Perform the referencing.

Some projects are naturally one sided (example the bowl project in the tutorials) and so all points 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 points, you would place a subset of points in a Group/Layer (see [Group/Layer Name Dialog](#)) and then use the "All points in layer:" option. Note, because some points are not yet referenced, you will have to place all point marks on all photographs, that 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. Group/Layers are saved with the PMR file so you can repeat the segmenting and processing as needed.

The parameters that control how points 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 points to match and in poorly oriented projects with dense point 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. Two photo references are very ambiguous and it is very easy for the algorithm to misreference points 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.

All 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. If the name is blank no changes will be made. You might want to name points to distinguish them from manually marked points. You can also set all successfully referenced points to be set to "do not process". If the automatic referencing is making too many errors you may want to set this so these points will not affect any subsequent processings.

The Referencing section of the dialog provides some information on the current referencing state of the chosen points. 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 points. If you close the project or PhotoModeler the ability to undo the automatic references is lost.

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 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.
The dialog will show the counts of the selected points in terms of how many references they currently have.

4. Choose which points are to be referenced in section 1.
5. Decide which settings you want in section 3 (naming and processing status of referenced points).
6. Press the Execute Referencing button.
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.
7. 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.
8. Press Close on the dialog.
9. 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.).

Note: 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

Search distance: 0.1207 in

Two photo referencing works with near planar surfaces.

Plane defined by all points in layer: planePoints

Allowable distance off plane for a match: 0.4 in

3. With automatically referenced points

Name them: ar

☒ Set them to "do not process"

4. Referencing

On one (1) photograph: 30

On two (2) photographs: 6

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.

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 Group/Layers in the project. See the [Group/Layer Name 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 ids: 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.

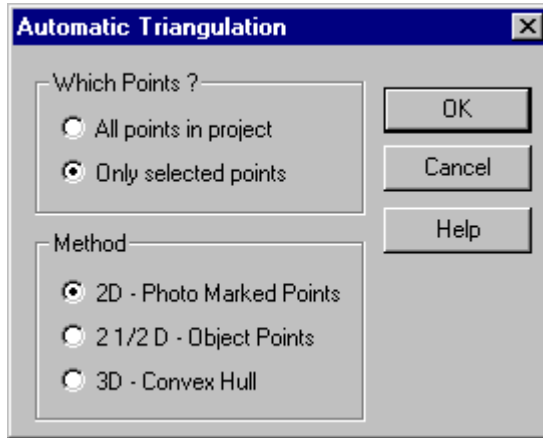
Another approach is to pick a very small off-plane distance threshold and then execute the referencing. Only points that are very close to the defining plane will be referenced. Then pick a bigger threshold and repeat until you get to the biggest threshold as described above. In this way, at each stage, 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).
The surfaces will be created and will appear on the photograph between all the selected points.
5. 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 or the wood bowl in the tutorials):

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.
5. If the shape of the points was not purely convex in 3D you may need to delete some extraneous surface triangles around the edges.

Programming PhotoModeler - DDE Interface

Introduction

PhotoModeler can be controlled and have data fed to it by other Windows applications. PhotoModeler provides a DDE (Dynamic Data Exchange) interface and a set of simple DDE commands for this purpose.

PhotoModeler acts as a DDE server (a server accepts DDE commands and responds to them). To talk to PhotoModeler you will need to use a DDE client (a client initiates a DDE connection to a DDE server and sends commands to it).

DDE clients can be written in many Windows programming languages but one of the easiest is Visual Basic by Microsoft. Other programs like Microsoft Word, Microsoft Excel and Autodesk AutoCAD can act as DDE clients by using Visual Basic for Applications (VBA). Other programming languages like C, C++ and Java may also have DDE command interfaces.

Not every aspect of PhotoModeler can be accessed through DDE. The following subsections outline the DDE commands and provide an example using Microsoft VBA.

Note: DDE is a mechanism built into Microsoft Windows and is not a system developed by Eos Systems. To that extent, PhotoModeler's DDE capability is dependent on DDE functioning correctly on your machine.

Command Structure

PhotoModeler's DDE commands take a very simple form. Most of the complexity of DDE has been left off so we can concentrate on getting real work done. Only the "DDE Initiate", "DDE Request" and "DDE Terminate" messages are used.

All PhotoModeler DDE commands are ASCII text strings and are of the format: "commandName commandParam1 commandParam2 ...". All commands return values and a return code indicating success or failure. PhotoModeler's DDE commands are NOT case sensitive. For example, the commands "GetNextPoint", "getnextpoint" and "GETNEXTPOINT" are all equivalent.

To use the DDE interface of PhotoModeler:

1. Start PhotoModeler 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.

NewProject

Description:	Create a new project (closing any currently open project (without saving it)).
Syntax:	"NewProject units" 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.

Return: "1" if successful or "0" if not.
Failure returns
- insufficient number of parameters
- 'units' is out of range

Example: "NewProject 3"
return: "1"

OpenProject

Description: Open a PhotoModeler project file, closing any projects that are currently open. Note the file name should be in DOS format (ie., 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"

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"

AddCamera

Description: Add a new camera to the project.

Syntax: "AddCamera cName f fw fh pw ph xp yp K1 K2 P1 P2"
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, and "K1 K1 P1 P2" are optional and are the lens distortion parameters.

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 0.002 -0.00005"
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

Example: "AddPhoto 1 kodak1"
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: "SetPhotoStation id x y z 0 w p k"
where id is a unique identifier number for the photograph (≥ 1),
"x y z" is the station perspective center, and "w p k" are the
station's Euler angles (in radians). OR
"SetPhotoStation id x y z 1 r11 r12 r13 r21 r22 r23 r31 r32 r33"
where the r's are the values of the rotation matrix (eg. r21 is the
element in the 2nd row and 1st column). Note, if the command is
successful, it sets the photo to be "oriented".

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
 - 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: "SetPhotoStation 1 23.3 12.1 -1.3 0 0.0 1.4 -2.1" OR
 "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"
 return: "1"

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"

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"

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
- 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"

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"

Process

Description:	Process the project.
Syntax:	"Process flag" where "flag" is the sum of: <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 ('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).
Return:	"1 iter ie fe" if successful or "0" if not where "iter" is the total number of iterations needed for solution, "ie" is error in first iteration of processing and "fe" is the final error. Note if bundle is not run (ie, only orientation) then "iter ie fe" will be "-1 -1 -1". Note this command can take some time to run as it waits to return until processing is complete. Failure returns <ul style="list-style-type: none">- insufficient number of parameters- no project is open- 'flag' is malformed- project fails to process/orient
Example:	"Process 13" return "1 3 12.2 0.1"

Scale

Description:	Set the scale part of the project affine transform.
Syntax:	"Scale pt1Id pt2Id distance" where pt1Id and pt2Id are identifier numbers for the Object Points that scale is defined between. The project is scaled so that the distance between those two points becomes 'distance' (in project's default units). Note that if either of the points is not 3D then the command still succeeds but the project will not be scaled until the points both become 3D.
Return:	"1" if successful or "0" if not. Failure returns <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:	"Scale 12 13 22.34" return: "1"

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"

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"

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"

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"

GetPoint

Description: Return the 3D position of a point with a specified Point ID.

Syntax: "GetPoint n"
where n is the Point ID of the desired point.

Return: "1 n p c x y z"
where n is the Point ID, p is the processed flag (1=point is processed, 0=point is approximated only), c is the control flag (1=point is a control point, 0=not a control), x is the X coordinate (in project units), y is the Y coordinate and z is the Z coordinate of the 3D point. "0" is returned if the command failed.
Failure returns
- incorrect number of parameters
- no project is open
- 'n' does not correspond to an existing point
- the point has no 3D position.

Example: "GetPoint 5"
return "1 5 1 0 34.2 534.3 244.2"

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 affected 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"

GetUnits

Description: Return the measurement units used by the current project.

Syntax: "GetUnits"

Return: "1 xx"
where xx is the unit specifier (one of "km", "m", "cm", "mi", "yd", "ft", or "in"). Returns "0" if the command failed.
Failure returns
- incorrect number of parameters
- no project is open

Example: "GetUnits"
return "1 ft"

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 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 K1 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"

GetPhotoCamera

Description: Get the camera parameters for a particular photo (useful for self-calibration or if all you know is the photo number).

Syntax: "GetPhotoCamera id"
where id is a unique identifier number for the photograph (≥ 1).

Return: "1 !camName! f fw fh xp yp K1 K2 P1 P2" if successful or "0" if not where "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 K1 P1 P2" are the lens distortion parameters.
Failure returns
- incorrect number of parameters
- no project is open
- 'id' does not correspond to an existing photo

Example: "GetPhotoCamera 1"
returned "1 !kodak1! 35.2 36.2 23.8 18.2 12.1 0.000023 0.000004"

GetPhotoStation

Description: Get the computed station orientation for a particular photo.

Syntax: "GetPhotoStation id t"
where 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.

Return: "1 x y z w p k" or
"1 x y z r11 r12 r13 r21 r22 r23 r31 r32 r33" if successful or "0" if not where "x y z" is the station perspective center, "w p k" are the station's Euler angles (in radians), and the r's are the values of the rotation matrix (eg. r21 is the element in the 2nd row and 1st column).
Failure returns
- 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"

ResetLists

Description: Reset the counters for the "Next" commands (e.g. GetNextPoint). This should be called before the "Next" commands are used and any time you wish to start getting the first item again.

Syntax: "ResetLists"

Return: "1" if successful, "0" if not successful.
Failure returns
- incorrect number of parameters
- no project is open

Example: "ResetLists"
return "1"

SetIterationType

Description: Set the type of iteration done by GetNextPoint and GetNextCylinder. This call does an implicit "ResetLists".

Syntax: "SetIterationType n"
where n = 0 to make iteration through all points or cylinders and
n = 1 to make iteration through only those points or cylinders
selected by PhotoModeler user.

Return: "1" if successful, "0" if not successful.
Failure returns
- incorrect number of parameters
- no project is open
- 'n' not in valid range

Example: "SetIterationType 1"
"GetNextPoint"

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"

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"

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 (ie. for Word and Excel).

```
Sub RunFullDDETest()  
    '  
    ' Test new DDE Commands in PhotoModeler Pro 4.0c  
    ' 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 helps 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 photo's are oriented). Also look at the values of the Tightness (unit) column to see if the values seem reasonable for your desired accuracy. Eg. 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 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.
- **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).
- **# 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).
- **Largest Residual** – sort by this column to find single points on photos that may not be marked well.
- **# Referenced** – sort by this column to check to see if minimum requirements are met for multi-photo projects (ie. 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 (ie. 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.

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 (ie. it's 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 under 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

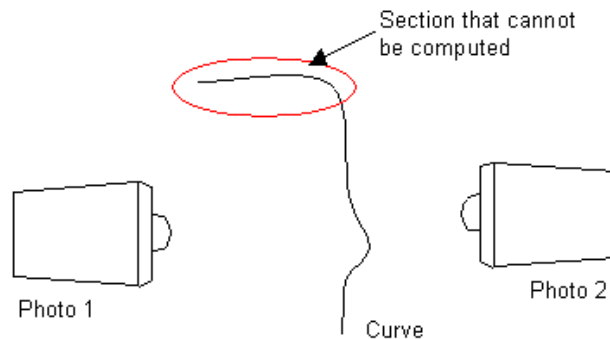
hand, if you photograph the horizontal ring from below also and mark the ring on both the view-from-above and view-from-below photos PhotoModeler will not be able to disambiguate the orientation of the ring. The resulting 3d closed curve will lie in the wrong plane and may have the wrong shape. All closed 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

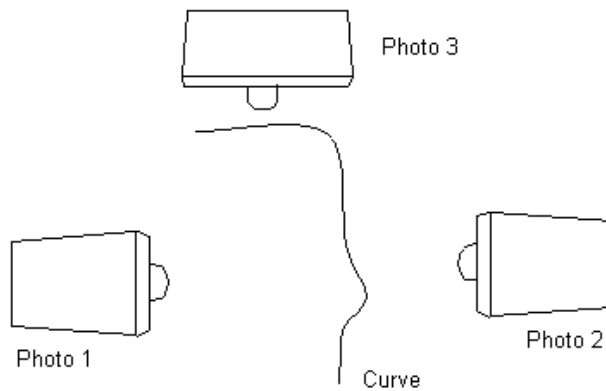
If the Curve is shown as "3D" in its status bar, does appear in the 3D Viewer and does export but is not complete then it is not possible for PhotoModeler to compute part of the curve.

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 (ie 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 (ie. 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 (ie. 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 be 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 (ie. 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 effect 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 (ie. 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).

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.

2. 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.

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.

3. 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](#)).

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](#)).

4. You do not know the parameters of the camera that took the photos so you guessed or used one of the Default Cameras.

If you get bad results your guesses are too far off and perhaps Inverse Camera methods should be used.

5. 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.

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.

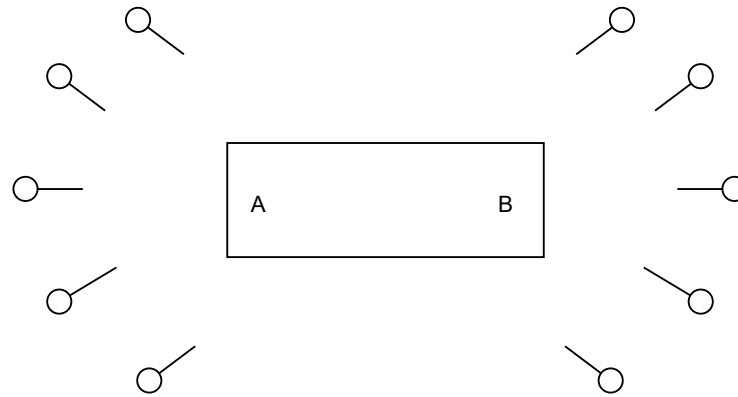
Points that are improperly or inaccurately placed can be the result of:

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 been corrupted or deleted.

If you get a message such as "Unable to write to disk" when Photographs are being loaded or displayed, the problem might be due to the image being on a read-only media. The image cache (.cch) file is being created at this time. To correct, remove the write protect from the disk or copy the images to a read/write hard-disk.

Accuracy and Overcoming Limitations

How Accurate is PhotoModeler?

No measurement technology can be perfect and all measurement involves performing approximations. PhotoModeler is no different.

PhotoModeler has been compared to other techniques of simple measurement such as using a tape measure for linear dimensions and a theodolite for 3D measurements. We have found that the accuracy of a Measurement Project is dependent on a number of factors:

- the quality of the calibration of the camera and digitizer used,

- the resolution of the camera and digitizer used,
- the geometry of the camera positions, and
- the precision with which the user marks object features as they appear in images.

For a project done with the high resolution Kodak DCS and with reasonable user care, PhotoModeler has shown a relative accuracy in linear dimensions of around one part in two thousand (1:2,000) for man made objects (with 95% probability). With higher resolution medium format metric cameras or high quality digital cameras accuracies as high as 1:10,000 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 1:25,000 or higher accuracy in a project that is all or substantially all done with sub-pixel circular target marking.

A relative accuracy of 1:2,000 means that for an object with a 10m largest dimension, PhotoModeler can produce 3D coordinates with 5mm accuracy at 95% (two standard deviations) 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

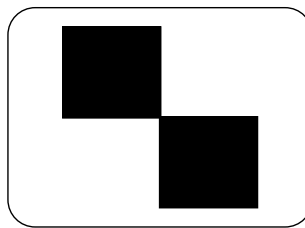
You could then state that your measurement of the skid mark length was likely within 2.0% of its actual value. In other words, the length of the skid is likely within 0.6' of the value derived with PhotoModeler.

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,
- ensure that for points marked on only 3 or 4 photos, these photos are taken with the camera positions 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 special sub-pixel marking algorithms. Users can make targets or they can be purchased at survey stores. The targets often look like this:



and can be any size. A man made target ensures that the same point is precisely located in all images. 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.

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.

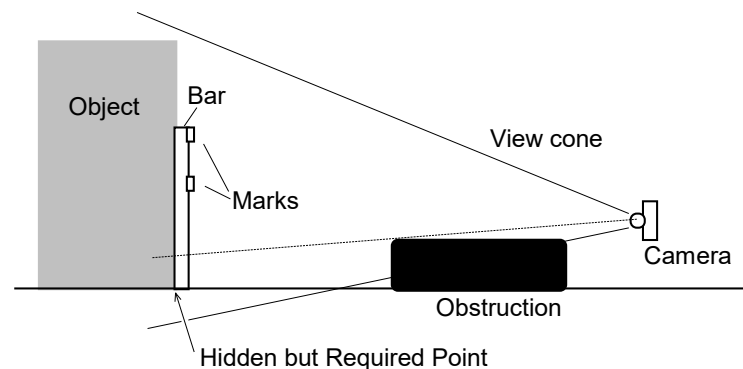
1. The building facade you are modeling has cars parked in front of it and you cannot see where the building meets the sidewalk.
2. The building you are modeling is surrounded by earth berms or uneven terrain and you cannot see the bottom edge of the building.
3. The process plant you are measuring has 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

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.

1. 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.
2. 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.
3. 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:



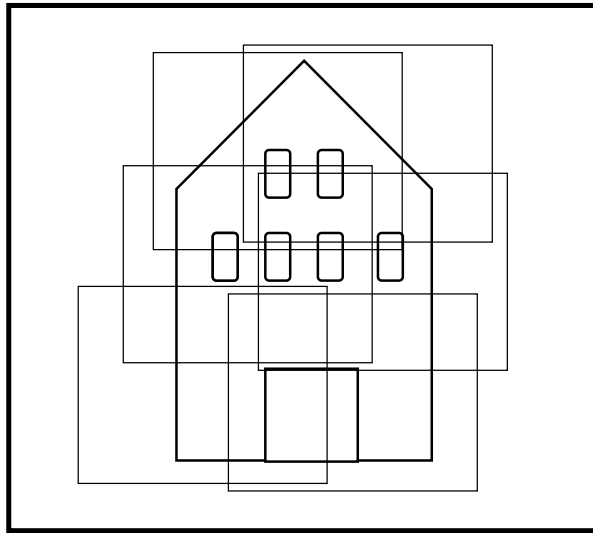
The two upper marks can be seen and measured. The third mark can be projected from the positions of the other two and a known distance. This is quite easy to do in most CAD programs. You would not want to do this for very many points but when you are stuck it can be helpful.

Edges may also assist with this situation.

4. 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.
5. 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 an 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.
6. 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.
7. 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.
8. 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:
 - a) 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.
 - b) 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.

9. 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.

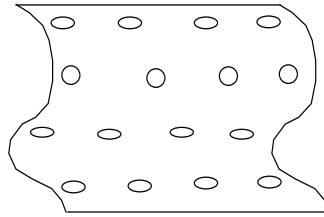


Using photograph overlap to capture a large structure

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.

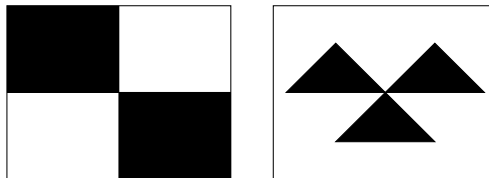
Targets can take two forms: the first is a small circle and is placed on curved surfaces to provide points for marking. For example, the following curved surface has rows of circular dot targets placed on it for marking purposes:



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.

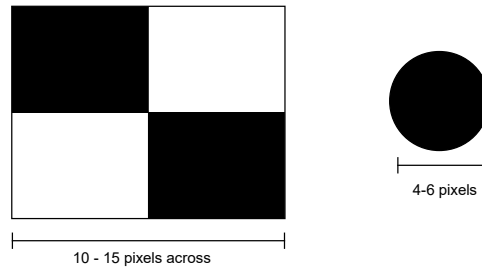
The other form of target could look like one of the following:



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 high precision targets about 10 to 15 pixels across in the final image:



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.

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 at least:

$$\text{Dot target size} = W_O / (W_I / 4)$$

$$\text{High precision target size} = W_O / (W_I / 15)$$

For example, measuring a 40 foot wide building using a 35mm camera with PhotoCD images of 1536 by 1024:

$$\text{Dot target size} = 40 / (1536 / 4) = 0.052 \text{ feet} = 1.2"$$

$$\text{High precision target size} = 40 / (1536 / 15) = 0.39 \text{ feet} = 5"$$

Let us look at a poor case: Using a Logitech Fotoman to measure the curved surface of a large ship that is 300 feet long. The Fotoman Plus has a horizontal resolution of 496 pixels, therefore the required target sizes are:

$$\text{Dot target size} = 300 / (496 / 4) = 1.2 \text{ feet} = 30" !$$

$$\text{High precision target size} = 300 / (496 / 15) = 9 \text{ feet!}$$

Obviously you would not want to climb over the ship pasting up 9 by 9 foot targets!

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.

There are many types of objects and scenes that do not require man-made targets. For curved shapes and objects with few natural sharp features or when high precision is required, targets are the way to go.

Menu and Toolbar Reference

Toolbar Reference

This section describes the tool bar buttons in PhotoModeler.



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 [Creating a New Project](#).



Open an existing project from a disk file. A File Selection dialog is displayed to allow the user to select the project to open, from the list of previously saved files. The user may change directories and open any accessible project. See [Opening an Existing Project](#).



Save the current project as a disk file. The first time this project is saved a File Selection dialog is displayed to allow the user to name this project. After the project has been saved once, subsequent saves will save the project without asking for a name. See [Saving a project](#).



Display the Project Photographs dialog. You may use this dialog to open the photographs in your project.



Open up the [Visibility Dialog](#). The Visibility Dialog provides control over the visibility and selectability of points, lines, etc. on photographs.



Open up a [3D Viewer](#).



Open up one of the Object Tables.



Make the current Photograph zoom so that it fits completely in its window. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-out tool. With this tool you can shrink the contents of a Photograph. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-in tool. With this tool you can magnify a Photograph. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-area tool. With this tool you can zoom into a specific area of a photograph. To use, press the left mouse button over one corner of an area, drag out the desired rectangle and release the mouse. See [Changing the Magnification of a Photograph](#).



Pick up the panning tool. With this tool you can shift a photograph from side to side in a window. See [Changing the Magnification of a Photograph](#).



Pick up the select tool. With this tool you can select items in [Photograph Windows](#).



Pick up the point marking tool. With this tool you can mark points on an open photograph. See [Marking Points](#).



Pick up the edge marking tool. With this tool you can mark edges on an open photograph.



Pick up the line marking tool. With this tool you can mark lines on an open photograph. See [Creating Lines](#).



Pick up the surface creation tool. With this tool you can create surfaces from existing points, edges and curves by selecting them on an open photograph. See [Creating Surfaces](#).



Pick up the Surface Drawing tool. With this tool you can mark points and lines on Surfaces in only one Photograph.



Pick up the Curve Drawing tool. With this tool you can mark curves on open photographs.



Pick up the Cylinder Marking tool. With this tool you can mark the edges of cylinders (pipes).



Pick up the fiducial marking tool. This tool is only available when you are using a film camera with fiducials. With this tool you can mark fiducial points on each photograph.



Pick up the control point marking tool. This tool is only available when a photograph is open and active.



Process the project: 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](#).



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 processed and must have a defined scale before this tool is available. See also [Measure Dialog](#).



Enter the Constraint Definition mode. In this mode you create new Constraints. See [Working with Constraints](#).



Pick up the reference tool. With this tool you identify common points and cylinders imaged on more than one photograph. See also [Referencing](#).

Menu Reference

This section describes the menus in PhotoModeler.

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 selection 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 selection is always available.

Open Recent Project

Provides a sub-menu of all recently opened PhotoModeler projects. By choosing one from the sub-menu, the project is opened right away.

This selection is always available.

Open Merged Project...

Opens the Project Merge Dialog to allow the opening of multiple PhotoModeler projects all merged together.

This selection 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 selection 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 selection 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 selection is available when a project has been created or opened.

Open Photographs...

Brings up the [Project Photographs Dialog](#). The user can open individual photographs from this dialog.

This selection is available when a project containing photographs is open.

Open All Photos

Opens all photographs in a project and displays them tiled in the working area. Depending on your screen resolution, number of photographs and type of photographs, photographs may be opened at less than full resolution. To ensure full resolution select "[Open Photographs...](#)" from the File menu.

This selection is available when a project containing photographs is open.

Cameras...

Open the [Project Cameras Dialog](#) which allows you to create new Cameras, load Cameras from disk and save Project Cameras to disk.

This selection is available when a Project 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 selection 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 selection is available when a photograph is active.

Export Text File...

Save a project in [PhotoModeler ASCII Export Format](#).

This selection is available when a Project is open.

Preferences...

Opens the Preferences Dialog so various settings can be changed.

This selection is always available.

Exit

Leave the program. The program asks you to save any unsaved changes before exiting. See also Saving a Project.

This selection 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 menu is only present when a project is open.

Undo

Reverse the effect of your last change to the project. Once reversed a change can be redone, by selecting Undo the second time.

See also Undoing Changes.

This selection is only available when your last change can be undone.

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 will not allow it to be deleted.

This selection 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 item 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, 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 item is available when a Photograph Window 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 item is only available when in Select Mode or Referencing Mode.

Expand Selection to all Windows

This menu item will search out all Marked Points and Cylinder Marks on open photographs that are currently selected and all Object Points and Cylinders selected in 3D Viewers, and Tables and then add their associated objects to the selection.

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. This function is only needed for Points and Cylinders. See [Universal Selection](#) for more detail.

This item is available when a project is open.

Object Properties

Change the properties (such as Materials and Group/Layer Names) of objects in the project. This menu item opens the [Object Properties Dialog](#).

This item is available when a project is open.

Materials...

Opens the Materials Dialog so the settings for existing Materials can be changed or new Materials created.

This item 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

Pick up the point marking tool. With this tool you can mark points on an open photograph. See also [Marking Points](#).

This selection is only available when a photograph has been opened.

Mark Edges

Pick up the edge marking tool. With this tool you can mark edges on an open photograph.

This selection is only available when a photograph has been opened.

Mark Lines

Pick up the line marking tool. With this tool you can mark or create lines on an open photograph. See also [Creating Lines](#).

This selection is only available when a photograph has been opened.

Create Surfaces

Pick up the surface creation tool. With this tool you can create surfaces from existing points by selecting them on an open photograph. See also [Creating Surfaces](#).

This selection is only available when a photograph is active.

Mark Surface Points

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 selection is only available when a photograph is active.

Mark Curves

Pick up the NURBS Curve drawing tool. With this tool you can draw curves on open photographs.

This selection is only available when a photograph is active.

Mark Cylinders

Pick up the Cylinder marking tool. With this tool you can mark the edges of a cylinder.

This selection 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 selection 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.

This selection is only available when a photograph is open and the camera that is being used requires fiducial marks.

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 selection is only available when a photograph is active.

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 selection is only available when a photograph is open and active.

Marking Residual Display

Open the [Marking Residual Display Dialog](#).

This selection is available when a Project is loaded.

Uncontrol Selected Point(s)

Turn any points in the current selection set that are Control Points back into normal Marked Points.

This selection is available when points have been selected on a Photograph.

Automatic Target Marking...

Opens the [Automatic Target Marking Dialog](#).

This selection is available when a Photograph is open.

Automatic Surfacing/Triangulation...

Opens the [Automatic Triangulation Dialog](#).

This selection is available when a Project 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 selection is available when a project is open.

Auto-drive referencing

Toggle whether PhotoModeler automatically drives to the next point during referencing..

This selection is available in referencing mode only.

Unreference Selected

Break the association between the selected Marked Points, Edges, Cylinders or Curves on the Active Photograph and any objects they have been referenced to on other photographs. See also [Referencing](#).

This selection is only available when one or more Marked Points, Edges, Curves or Cylinders are selected on the active photograph.

Point Audit Selected...

Display a Point Audit dialog and display information about each selected point in turn.

This selection 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 selection is only available when a project is open.

Weld Unreferenced Points...

Open the [Unreferenced Point Weld Dialog](#).

This selection is available when a Project is open.

Automatic Referencing...

Open the [Automatic Referencing](#) Dialog.

This selection 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.

Information...

Displays information about the current Measurement Project. Allows editing of this information, including changing units, camera type, and the project name. See also [Project Information Dialog](#).

This selection is available when a project has been created or opened.

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 selection 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 (ie no error messages) but the result is not correct (ie. 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 selection 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 selection is available when a project has been created or opened.

Constraints List...

Displays the Constraint List Dialog so all defined constraints in the project can be viewed.

This selection is available when a project has been created or opened.

Constraint Definition mode

Enters Constraint Definition mode. See Working with Constraints.

This selection 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 selection is available when a project has been created or opened.

Measure...

Pick up the measure features 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](#), [Measure Dialog](#), [Processing](#) and [3D Scale and Rotation Dialog](#).

This selection is available when a project has been processed and given a scale.

Post Processing Modification...

Open the Post Processing Modification Dialog.

This selection is available when a project is open.

Open a Photo Table

Open a [Photo Table](#).

This selection is available when a project is open.

Open a 3D Viewer

Open a 3D Viewer Window. See [Viewing the 3D model](#).

This selection 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 selection 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 selection 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 selection 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 selection is available when a project is open.

Display Menu**Visible Photo Items...**

Brings up the Visibility Dialog. This dialog allows you to turn items on photographs on and off.

This selection is available when a project is open.

Tag Selected

Tag all points that are currently selected.

This selection is available when points are selected on photographs.

Clear Selected Tags

Clear the Tag off all points that are currently selected.

This selection is available when points are selected on photographs.

Clear All Tags

Clear the Tag off all points in the Project.

This selection 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.

Tile

Position and size all open windows so that they do not overlap.

This selection 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 selection is available when a document window is open.

Arrange Icons

Arrange all document icons in neat rows.

This selection is available when a document window is open.

Iconize All

Convert all open windows to icons.

This selection is available when a document window is open.

Close All

Close all open windows.

This selection 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 selection 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 selection 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 selection 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 selection 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 selection 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 selection 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 selection 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 selection is available when a photograph window is open.

Open Windows

This item brings up a sub-menu listing all open Photograph, 3D Viewer and Point Table Windows. By selecting one of the Windows in the sub-menu, the Window will be activated and brought to the top.

This selection is available when a project is open.

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 selection is always available.

Tutorials

Displays the Table of Contents of the Tutorial Help file.

This selection is always available.

Training Mode

Toggle PhotoModeler Training Mode. When Training Model is on, the application resizes and a special help window appears at the top of the screen. These training cards provide suggestions and direction as you use PhotoModeler.

Resize help windows to fit screen

Resizes the training card window to its default position and size at the top of the screen.

About PhotoModeler...

A summary of information about the PhotoModeler product and its developers.

This selection is always available.

Keyboard Shortcut Reference

The complete list of keyboard shortcuts is given below in two forms: first in menu order and second in key order.

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 Create 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

Referencing Menu

Enter Reference mode	R
Unreference selected items	CTRL+U
Point Audit Selected	Q
Point Audit All	SHIFT+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

Open Visibility Dialog	V
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
Open Training mode	F2
Resize Training mode windows	F3

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 CTRL
zoom-area, pan mode.

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

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
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	Point Audit All
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
V	Open Visibility Dialog
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

Camera Calibration

What is 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 finding values for these camera parameters. Once a camera is calibrated, it will provide accurate measurements.

Note: the Camera Calibrator 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.

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.

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 (e.g. the Canon RC470 has a lens with a 9mm and a 16mm focal setting - you would need two separate calibrations for this camera if you wanted to use both focal settings).
- 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 lens.

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.

Starting Calibration

To start a Calibration you must first create an Approximate Camera using the Calibration Setup Wizard. See the section Working with Cameras for more details.

Steps in Camera Calibration

To carry out a camera calibration for PhotoModeler, the Camera Calibrator program is used. The steps to calibrate a camera are:

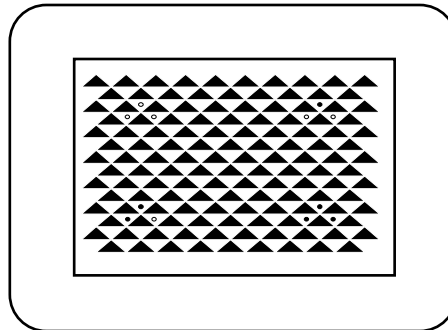
1. Decide on a pattern projection method:
 - a) if using a poster, get the pattern printed or plotted with the orientation shown in The calibration slide section and paste the poster on a flat wall.
 - b) if using a slide projector, project the calibration grid on a flat wall.

- c) if using an overhead projector, get the slide printed on overhead transparency material and project the calibration grid on a flat wall.
2. Set up the calibration shots as discussed in Setting up to take pictures.
3. Take eight photographs of the calibration grid.
4. Measure one distance accurately on the calibration grid.
5. Transfer the eight photographs from the digital camera, scanner or PhotoCD onto your hard disk. Note: The calibrator will use PhotoCD files directly off the CD-ROM but it is slower.
6. Take note of the type of camera you are using and the approximate focal length of the lens used.
7. Start the Camera Calibrator program.
8. Create a new Camera and setup the project using the Calibration Setup Wizard.
9. Open each photograph in turn and mark four control points on all eight photographs. If your camera uses fiducials, mark them as well.
10. Enter the scale distance.
11. Start the Auto-Marking and Calibration process.
12. When the calibration processing is complete, save the project and the camera file.
13. The resulting camera file (*.cam) can now be used by PhotoModeler.

Taking Calibration Photographs

The calibration slide

Included with the PhotoModeler package is a 35mm slide that looks like this:



This is the calibration slide. This slide can be used in a slide projector to project the grid pattern on a wall or it can be used to generate a large poster via photographic means.

If you wish to create a calibration poster to use with calibration instead of projecting the slide you can take the `calib.dxf` or `calib.eps` file (which are installed in the PhotoModeler directory) and plot it on a plotter capable of solid fills (such as an electrostatic plotter). Scale the plot so it is as large as possible. The closer the calibration pattern is in size to the typical objects you measure the better the

calibration will be for your work. When you use the poster, make sure it is as flat as possible before taking the pictures.

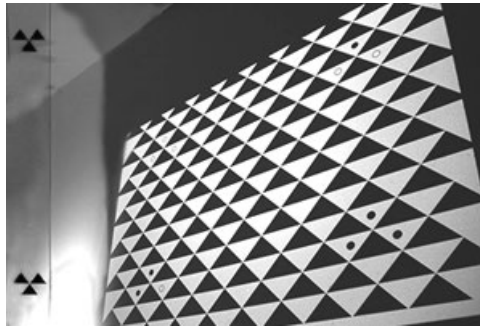
If projecting the grid make sure it is projected the correct way around. That is the three empty circles should appear in the upper left). Calibration processing will fail if the slide is backward.

Setting up to take pictures

A little planning of the calibration photography will make the task much easier. Here are some considerations to take into account as you set up the room and the camera to take the pictures:

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 Note 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 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.

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. 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.



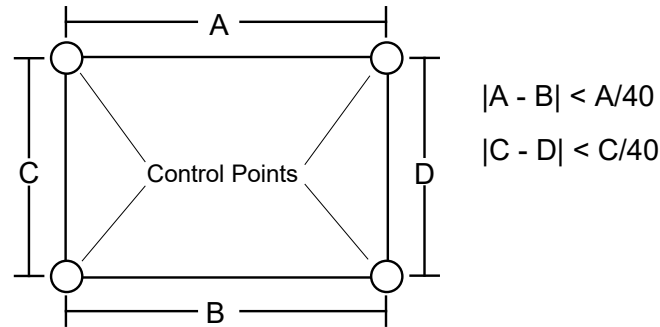
Calibration Slide photo with lit fiducial area

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 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. The calibration pattern should be square. That is, the projected grid must not have a 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 Pythagorus. That is $A^2 + C^2 = \text{diagonal}^2$. Try to get this equality within 1%.

2. All four Control Points must appear on all calibration photographs.
3. The calibration pattern should be flat with no sharp bumps. The flatness of well installed wall board is sufficient.
4. The calibration pattern should fill as much of the camera view finder as possible.
5. The pattern should be clean. No shadows or strong marks should appear in the area of the calibration pattern.
6. The camera positions should be close to 45 degrees from the horizontal and vertical as needed.
7. [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.
8. The photographs should have good focus across the pattern (a small amount of blur due to insufficient depth of field is acceptable).
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. All photographs should be taken with the same focus setting.
11. The camera should be focused at the distance that will be used for most measurement projects.

PhotoModeler does some camera self-calibration, during its 3D processing, when there are sufficient Marked Points on the photographs. A less than ideal calibration will still produce good models when the model has many points in it (over 50 3D points).

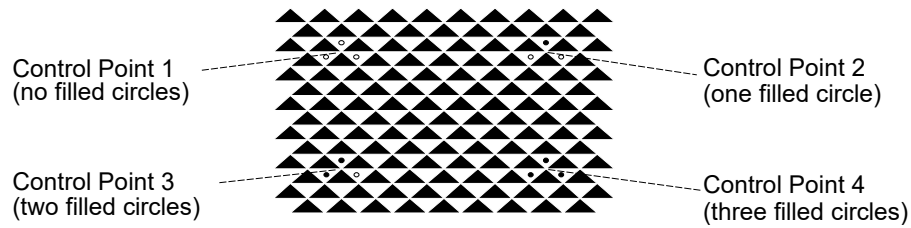
Camera Positioning

To obtain the data needed to calibrate a camera, six or more photographs taken from different angles of a dense point grid is needed. The camera calibration software

works with a specific calibration grid which is discussed in [The calibration slide](#) section. We suggest using eight photographs of the slide taken in the positions described below.

It is very important to note that the grid should fill as much of the photograph as possible. The constraint on size is that the four control point locations must all appear in the photograph and must not be cut off by the edge of the photograph.

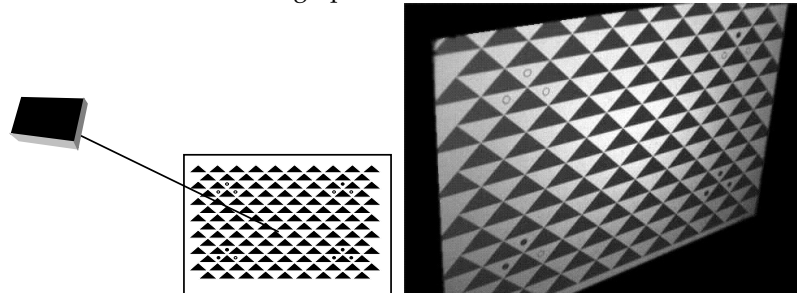
The four control points are shown below:



In the photographs below, note that the control points come close to the edge of the image, but are never cut off. The left column shows a 3D view of the camera position and the projected calibration grid, the right shows an example photograph of the calibration grid from the desired location

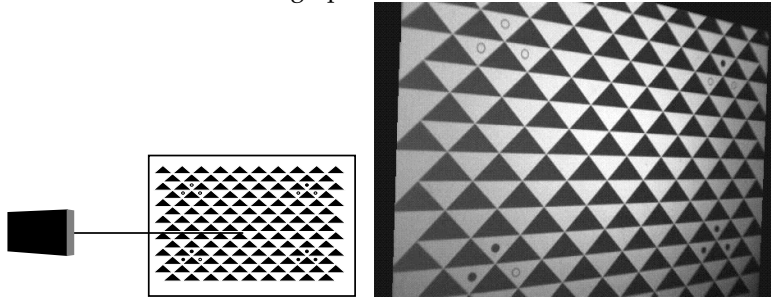
Photograph 1: Upper Left Position

Camera Position & Photograph



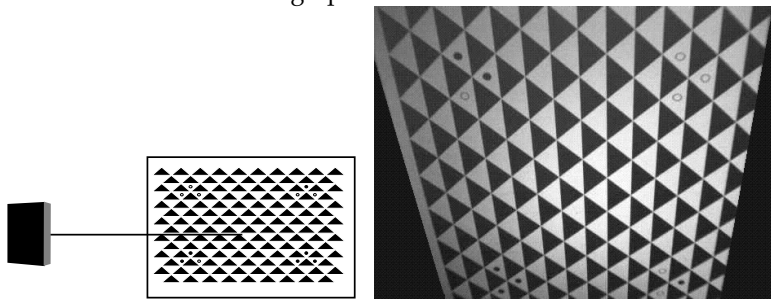
Photograph 2: Middle Left Position

Camera Position & Photograph



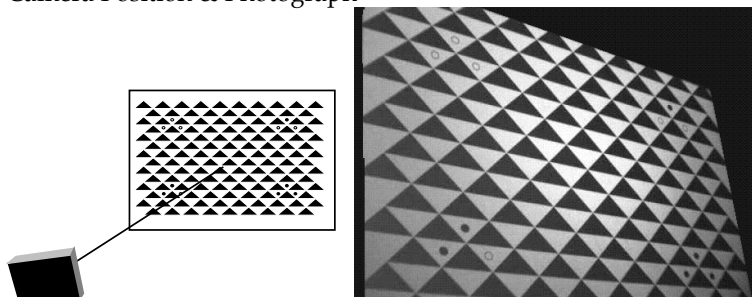
Photograph 3: Middle Left Vertical Position

Camera Position & Photograph



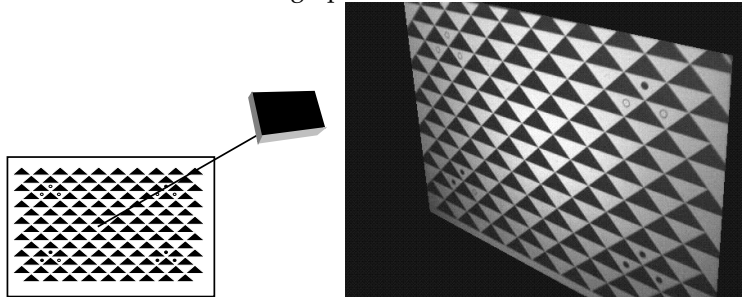
Photograph 4: Bottom Left Position

Camera Position & Photograph



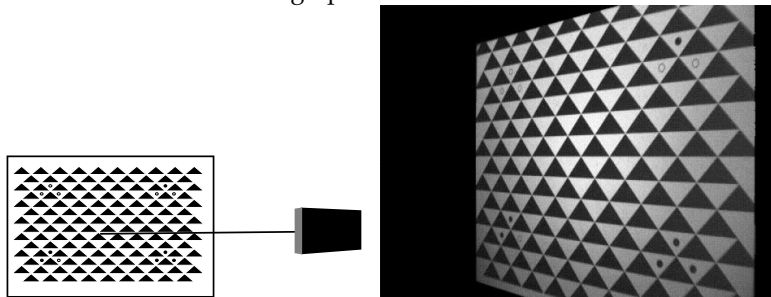
Photograph 5: Top Right Position

Camera Position & Photograph



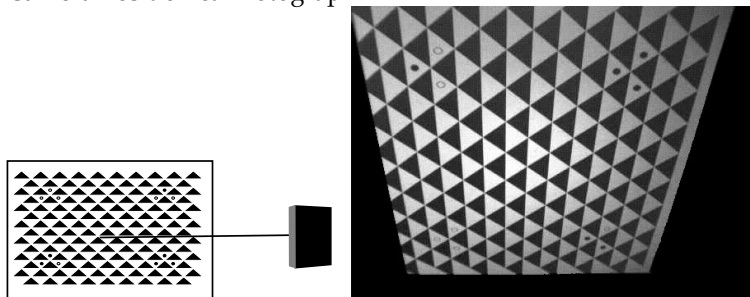
Photograph 6: Middle Right Position

Camera Position & Photograph



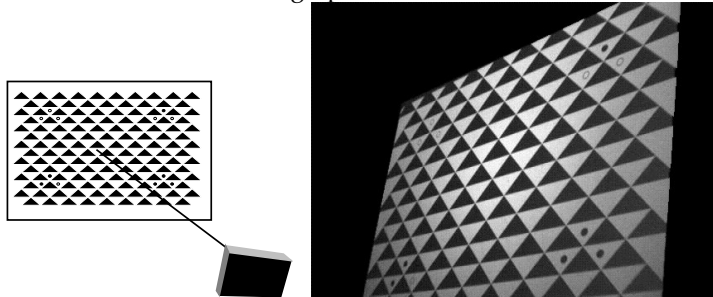
Photograph 7: Middle Right Vertical Position

Camera Position & Photograph



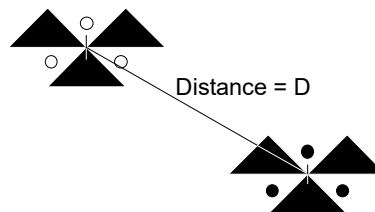
Photograph 8: Bottom Right Position

Camera Position & Photograph

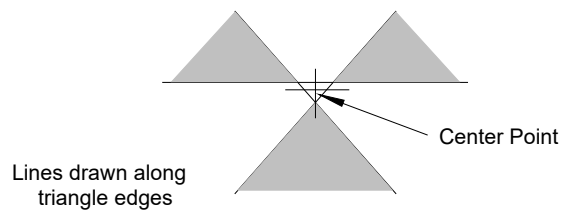


Measuring Scale

The Camera Calibrator needs the distance between control points 1 and 4 on the projected or printed pattern, as shown in the figure below. This distance must be recorded at the time the calibration pictures are taken. Measure this distance with a tape measure as accurately as possible. We suggest that you do the measurement twice: point 1 to point 4 and then point 4 to point 1 to be sure of your result. Record this distance for later use.



If you can mark up your wall or your print, you can get a more precise measurement of the distance. Draw lines along the edge of each triangle and estimate the center of that triangle:



You then measure the distance between the two center points for control 1 and control 4.

Getting Photographs into Your Computer for Calibration

Photographs must be converted to a digital representation that can be stored on a computer's disk system. The Camera Calibrator works with digital photographs in many formats. The accepted formats are: TIF, BMP, PCX, TGA, JPG, PNG, PCT, PSD (PhotoShop), PPM, MAC, CAL, SGI, RGB (SGI) and PCD (Kodak PhotoCD).

For digital cameras, all we need to do is to copy the photographs from the camera to the computer's hard disk. Film cameras require film to be scanned and video cameras require a frame digitizer board.

See the section called "[Getting Photographs into Your Computer](#)" in the PhotoModeler [Importing and Using Photographs](#) chapter for details on how to scan and digitize photographs for use with PhotoModeler and the Camera Calibrator.

Important note 1: 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 like sharpened images because they tend to have additional unwanted noise and extra false edges. Images that are sharpened or "unsharp-masked" usually do not automark well and the calibration will be poor. Either turn off the feature on the camera if you can (pick the "soft focus" or "lowest sharpness" settings) or blur your images in an imaging program like Adobe PhotoShop before using them in the Calibrator.

Important note 2: 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.

Starting a Calibration Project

To calibrate a camera you must create and process a Calibration project using the Camera Calibrator. A Calibration project will be comprised of eight photographs taken of the calibration grid, a scale distance and some starting camera parameters. A Calibration project is similar to a PhotoModeler Measurement Project.

Note: PhotoModeler can read projects created by the Camera Calibrator but you do not need to use PhotoModeler for any calibration tasks.

Calibration Setup Wizard

You start a calibration by choosing "New Calibration Project" from the File menu. When this is selected (or the New Project toolbar button is pressed) the Calibration Setup Wizard will start. This wizard is similar to the Project Setup Wizard used in PhotoModeler.

The differences between the PhotoModeler and Calibrator Wizards are the first and last panes describe different processes and the Camera Wizard path is slightly different.

To get more information on the important steps in the Wizard see the PhotoModeler sections: [Camera Setup Wizard](#) and [Photo Import Wizard](#).

Calibration Setup Wizard: Welcome

The Calibration Setup Wizard welcome screen lists the steps required to complete a Calibration project. The wizard will guide you through the first steps. To advance to the next pane press the Next> button.

The next pane is in the [Camera Setup Wizard](#).

Calibration Setup Wizard: Finished

The finished pane outlines again the steps need to complete a calibration and shows which steps have been completed.

When you pressed Finished you can proceed onto photograph marking as described below.

Using the Calibration Photographs

After you have created a Calibration project you need to mark the photographs. If all the photographs have not yet been added by the Wizard you can do that now using Add/Remove Photos from the File menu.

Opening a Photograph

After photographs have been added to the Calibration Project, they must be opened one by one and marked.

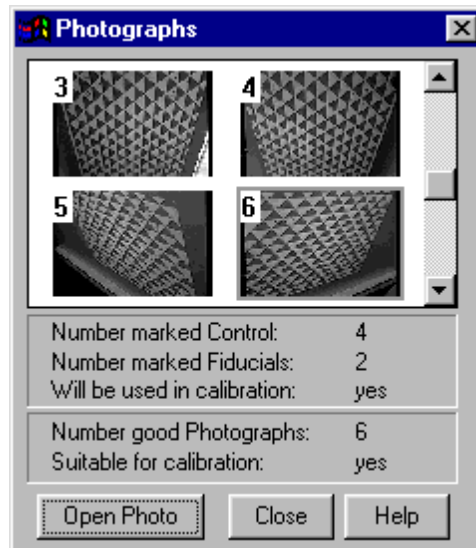
To open a Photograph

1. Press the Open Photograph button on the toolbar or select "Open Photograph..." from the File menu.

The Camera Calibrator will display the Open Photograph dialog. The Open Photograph dialog displays reduced-size versions of each of your calibration photographs.

2. Select one photograph and press "Open Photograph".
The Camera Calibrator will open the photograph you have selected. If any photograph is currently open it will be closed. The Calibrator allows only one photograph to be open at a time.

Open Photograph Dialog



The Open Photograph dialog is used to open photographs one at a time, and to monitor your progress while preparing for calibration. The Open Photograph dialog displays reduced-size versions of the photographs in your project.

To open a photograph, select it and press the "Open Photograph" button or double click on the photograph.

The number of control points and fiducial points marked on a photograph appear beside "**Number of Marked Control**" and "**Number of Marked Fiducials**" in the dialog for the highlighted photograph. When all four control points and sufficient fiducial points (if required) have been marked, the comment beside "**Will be used in Calibration**" will change from "no" to "yes".

As you mark the photographs, the number of photographs that will be included in the calibration is displayed next to "**Number good Photographs**". When six photographs have been marked the comment beside "**Suitable for Calibration**" will change from "no" to "yes". Use all eight photographs even though it says OK after six. A calibration project can be done with six photographs but the results are not as accurate.

Marking Points

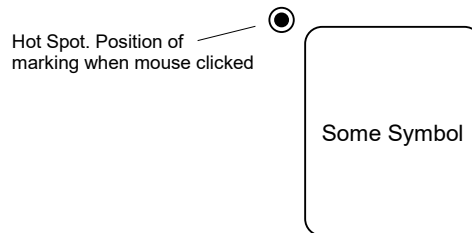
Before the Camera Calibrator can calibrate a camera you must mark four control points and two fiducial points(if using a film camera) on eight photographs taken with that camera.

To streamline your work-flow, the Camera Calibrator will automatically select appropriate marking tools as you mark a photograph. When you open a photograph, the Camera Calibrator will select the Point One tool. When point one has been marked it will select the Point Two tool and will continue to advance the tool until all of the necessary points have been marked.

You can monitor your process by watching the display in the Open Photograph dialog. The Camera Calibrator will keep track of the number of points and photographs marked and will display them in this dialog.

Marking Cursors

The control point and fiducial marking is done with specially designed cursors. These cursors are different shapes to help you remember what mode you are in. They 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.

Marking the Four Control Points

Four control points must be marked on each calibration photograph. See [Camera Positioning](#) for more details.

Control Points are identified on the calibration images by three circles. The control point numbers appear as:

- control #1: three empty circles

- control #2: one filled, two empty circles
- control #3: two filled, one empty circles
- control #4: three filled circles

Hint: The location of these points need only be marked approximately. The Camera Calibrator will reposition these points using image processing algorithms when calibrating. Any fiducials that need to be marked on the other hand, must be marked with the highest precision.

To begin, open one of your calibration photographs. See "[Opening a Photograph](#)".

To mark Point One:

1. Pick up the Point One tool or select "Mark Point 1" from the Marking menu.
The cursor will change to the point one symbol. (The point one symbol is three empty circles.)

Note: When you first open a photograph, the camera calibrator will automatically select the Point One tool for you.

2. Click the mouse on a photograph at the location of Point One on the calibration grid.
The Camera Calibrator will create a point symbol at the location you marked, and the cursor will change to the Point Two tool or No Action cursor. If the Open Photograph dialog is open and this photograph is selected the number of marked control points will increase by one.

Hint: If it is difficult to identify the control point, maximize both the application and the photograph and use the zoom-in tool to magnify the photograph. This will display the photograph with as much clarity as is possible. You can use other zoom tools also such as the +/- keys and the ALT zoom window.

3. Repeat steps 1 and 2 for points two, three, and four.
When you have marked all four control points, the cursor will change to the Select tool or the Fiducial Marking Tool. If your photographs contain fiducials, mark them with this tool.
4. Open the next photograph in your Calibration Project and repeat steps 1 to 4.
Opening a photograph will close the previous one.

You must mark all four control points on each photograph to calibrate your camera.

Note: If you are unhappy with the location of a point you may move it by switching to select mode, selecting it and dragging it with the mouse.

Marking Fiducial Points

If you are using a film camera, you will need to mark the fiducial points on each photograph.

Important: The Camera Calibrator will not reposition Fiducial marks using image analysis techniques as it does with Control Points, so Fiducials must be marked as precisely as possible.

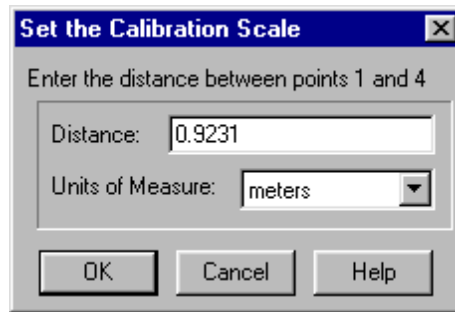
To mark Fiducial Points on a Photograph:

1. Pick up the Zoom-In tool or select "Zoom In" from the Window menu.
The cursor will change to the Zoom-In symbol.
2. Click the Zoom-In tool over the area of the first fiducial point and magnify the photograph until you can see the fiducial mark quite clearly.
The Photograph will become magnified around the region you are clicking the Zoom-In tool on.
3. Pick up the Fiducial Point tool or select "Mark Fiducials" from the Marking menu.
The cursor will change to the fiducial point symbol.
4. Position the Fiducial Point tool accurately over the fiducial point and mark the location. The position marked should be the mid-point between the three triangles. If you cannot see the fiducial because the background is too dark, do not mark it.
The Camera Calibrator will draw a fiducial cross at the location you have marked. If the Open Photograph dialog is open and this photograph is selected, the number of marked fiducial points will increase by one.
5. Pick up the Pan tool and drag the photograph to the location of the second fiducial point.
The photograph will scroll in response to your panning motions.
6. Repeat steps 3 and 4 to mark the second fiducial point.
The Camera Calibrator will draw a fiducial cross at the location you have marked. The cursor will change to the No Action cursor.
7. Repeat steps 1 to 6 for each photograph in your calibration project.

Note: Camera calibration will be most accurate if you mark all fiducials on every photograph. However, if you cannot see all fiducials on every photograph, calibration can still be done if you mark at least two fiducial points or get good coverage if using a multi-fiducial setup.

Entering the Scale Distance

Calibration Scale Dialog



To calibrate a camera correctly the Camera Calibrator requires one accurately measured distance between two points on your calibration grid. The distance required is the distance between control points one and four. You will have recorded this distance while taking the calibration photographs. To enter the scale, select "Set Scale" from the Calibration Menu.

You may enter the scale distance in any of the units shown in the scale dialog units drop down list. See also [Measuring Scale](#).

Processing the Calibration Project

Calibrating

To calibrate your Camera you must first have taken the eight calibration photographs, have marked the four control points on each photograph and have entered the scale distance. For more information on these topics see: [Taking Calibration Photographs](#), [Marking Points](#), and [Entering the Scale Distance](#).

To Calibrate your Camera:

1. Select "Calibrate" from the Calibration menu.
The Camera Calibrator will display the Calibration Stages Dialog. Calibration is a two stage process. The Calibrator will place check marks next to both stages. If this is your first calibration of this camera, both stages must be performed.
2. Press OK to begin calibration.
The Camera Calibrator will begin calibration.

Note: Camera calibration is time consuming. The Camera Calibrator will "yield" so that you may continue to work with other applications, but their performance will be degraded. Calibration is best run on a machine that can be dedicated to this purpose for a period of time.

Calibration Stages Dialog



Camera Calibration is a two stage process. First the calibrator uses image analysis techniques to locate the corners of each triangle on the calibration grid on each photograph. Then these corner locations are used to numerically determine the parameters of your camera. These stages are referred to as "Stage 1: Auto-Mark Points" and "Stage 2: Camera Processing".

The first time you calibrate your camera you will need to run both calibration stages. The Camera Calibrator will save your project file before and after each calibration stage.

Calibration may not be possible in some cases. If Calibration fails, it will most likely fail during Stage 1: Auto-Mark Points. See [Troubleshooting](#) in this chapter for more information.

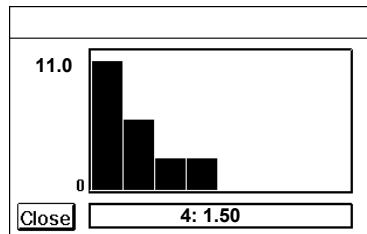
When the calibration is complete you need to study the result to make sure you have a high quality calibration. First you should note the final error bar chart and compare it with the examples shown in [Calibration Error Bar Examples](#). Then take a look at

the final Camera parameters in the Camera Information dialog. Are any of the parameters very different from where they started? If any of them are (esp. focal length) this could point to a poor approximation of another parameter. Make sure the approximations you gave the other parameters are close to being correct. Format size errors can account for large focal length changes.

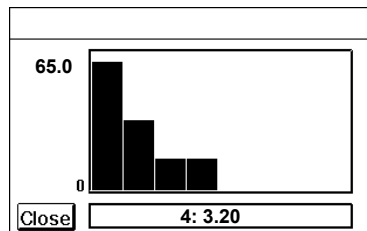
When Calibration is complete, the Camera Information Dialog will display "yes" next to "Calibrated". After you save the camera, you will be able to use the camera with PhotoModeler.

Calibration Error Bar Examples

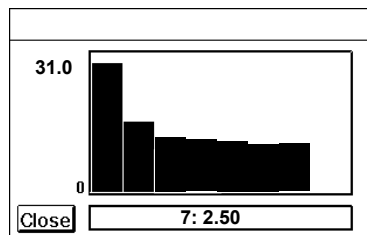
The following shows examples of the Total Error Dialog after processing a calibration project:



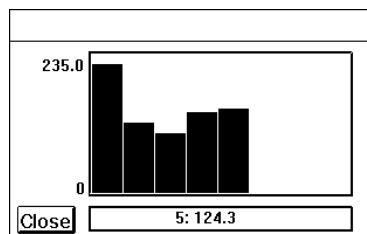
Successful calibration.
A good result.



Successful calibration
but the starting camera
parameters were off a
bit. Usually format size
is incorrect.



Successful calibration
but there was some
problem getting to a
solution. Check your
approximations, and
fiducial positions.



Unsuccessful
calibration. Perhaps the
starting camera
parameters were very
far off.

Other Calibration Checks

Make note of the final error when calibration is complete. A value less than 2.0 is generally a good calibration. A digital camera should have a final error close to 1.0. Very good calibrations can have errors smaller than 1.0.

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 best way to do these checks is to write out the solved calibration PMR file from the Camera Calibrator and read it into PhotoModeler.

In PhotoModeler use the Point Audit tool (under Referencing Menu) and the Marking Residual Display (under Marking Menu) to study the points. In the Marking Residual Display you should be able to get up to an exaggeration of 8 with all eight photos up on the screen and tiled without seeing an error bar. If the error bars are very large and form a pattern then perhaps there was a problem with the calibration. 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.

Note: If you want to improve your calibration you can move and delete markings after Auto-marking and before the Calibration processing. You would do this if the Auto-marker did a poor job on positioning one or more points. Do note that you cannot delete any of the four control points after Auto-mark is complete.

Calibrator Troubleshooting

This section lists some common problems with camera calibration. Each problem is stated and followed by suggestions for correcting it. In most normal calibration projects, few, if any of these problems occur.

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 Marking 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 picking a small region around the fiducial mark and enhancing the contrast or brightness. Do not move the region around the fiducial. You may however modify the intensity and contrast of the region.

Calibration fails during Stage 1: Auto-Marking

If calibration auto-marking fails it tends to do so in the early stages of repositioning the control points. If a control point has particularly bad contrast or focus, the Camera Calibrator may not be able to reposition it accurately. In that case, a warning is put on the screen and if the user wishes, the location marked by the user will be used instead of a computed location. If many of the control points cannot be repositioned by the program, the user should consider retaking the calibration photographs with better contrast.

Auto-marking can fail trying to position a non-control Marked Point in cases where the image resolution is poor, focus is poor or contrast is poor. If the auto-marking fails on only one of the eight calibration photographs then you can try the calibration again with this one photograph removed (delete all the control and marked points on it and it will be ignored). The calibrator will still provide reasonable calibrations with six or seven images.

Auto-marking can also fail if one or more of the control points were marked in the wrong location. If the auto-marker fails or has quite a bit of trouble with the control points, the user should review the positions of the marked control points to ensure that they are all in the correct spot.

Calibration fails during Stage 2: Camera Processing

The second stage may fail if:

- the calibration grid was projected backward,
- the Auto-Mark Points stage missed a lot of points,
- the Auto-Mark Points stage misplaced a lot of points,
- the control points were incorrectly positioned, or
- the camera parameter approximations were far from the true values.

If quite a few points were missed by the auto-marking stage (which you can see if you watch it do the marking on the screen) then the contrast and sharpness of the image is not correct. You will have to try to take the photographs of the calibration slide again.

If quite a few points are not correctly placed by the automarker, it might be due to too much noise or due to automatic sharpening done by a digital camera. See the notes in the section [Getting Photographs into Your Computer for Calibration](#) for more detail.

If the control point positions were marked in the wrong place, usually the first stage fails; in some circumstances it might make it as far as the second stage. To fix this problem, remark the control on the correct spots. See [Marking the Four Control Points](#).

The most common problem with poor camera approximations is an incorrect format size for a non-fiducial camera or improperly defined fiducial positions for a fiducial camera. Review your Camera approximations and check for accurately defined fiducial positions.. Also make sure your project scale (diagonal of calibration grid) is entered correctly. Refer to [Camera Information Dialog](#) for information on how to set the camera parameter approximations correctly.

Menu and Toolbar Reference

Toolbar Reference

This section describes the toolbar buttons in the Camera Calibrator.



Starts the setup wizard for creating a new camera and calibration project.



Opens an existing Calibration Project. The Calibrator will display a file selection dialog, which will be used to select the existing calibration project. When loading a Calibration Project the current Camera (if one is open) is replaced with the current untitled Camera from the project.



Saves the open Calibration Project to disk. If the project has been saved once it is saved under its current name. If the project has not been named, you will be prompted for a name before saving.



Display the Open Photograph dialog. You may use this dialog to open the photographs in your project and watch marking progress. See also [Opening a Photograph](#).



Pick up the select tool. With this tool you can select points to move and delete.



Pick up the control point 1 marking tool. With this tool you can mark the first control point on a photograph.



Pick up the control point 2 marking tool. With this tool you can mark the second control point on a photograph.



Pick up the control point 3 marking tool. With this tool you can mark the third control point on a photograph.



Pick up the control point 4 marking tool. With this tool you can mark the fourth control point on a photograph.



Pick up the [fiducial](#) marking tool. This tool is only available when you are using a film camera with fiducials. With this tool you can mark the two fiducial points on each photograph.



Make the current photograph change zoom level to fit its window. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-in tool. With this tool you can magnify the contents of a window. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-out tool. With this tool you can shrink the contents of a window. See [Changing the Magnification of a Photograph](#).



Pick up the zoom-area tool. With this tool you can zoom into a specific area of a photograph. To use, press the left mouse button over one corner of an area, drag out the desired rectangle and release the mouse. See [Changing the Magnification of a Photograph](#).



Pick up the panning tool. With this tool you can shift a photograph from side to side in a window. See [Changing the Magnification of a Photograph](#).

Menu Reference

This section describes the menus in the Camera Calibrator.

File Menu

The file menu contains operations that create, open and save camera and camera calibration project files, as well as operations for opening photographs.

New Calibration Project...

Starts the setup wizard for creating a new camera and calibration project.

This selection is always available.

Open Calibration Project...

Opens an existing Calibration Project. The Calibrator will display a file selection dialog, which will be used to select the existing calibration project. When loading a Calibration Project the current Camera (if one is open) is replaced with the current untitled Camera from the project.

This selection is always available.

Save Project

Saves the open Calibration Project to disk. If the project has been saved once it is saved under its current name. If the project has not been named, you will be prompted for a name before saving.

This selection is available when a project is open.

Save Project As

Saves the open project to disk after you have selected a name for it.

This selection is available when a project is open.

Save Camera As a .CAM file

Saves the current Camera to disk as a .CAM file after you have selected a name for it.

This selection is available once a project with camera are created.

Open Photograph...

Open a photograph to mark its control points. The Calibrator will display an Open Photograph dialog. This dialog will display reduced-size versions of your calibration photographs.

This selection is available after photographs have been imported.

Add/Remove Photos...

Open the Add/Remove Photographs Dialog to read photograph images into a Calibration Project.

This selection is available after a project has been opened or created.

Exit

Terminate the Camera Calibrator. You will be prompted to save your project if you have changed it since the last time it was saved.

This selection 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.

Undo

Reverse the effect of your last change to the project. Once reversed a change can be redone, by selecting Undo the second time.

This selection is only available when your last change can be undone.

Delete

Remove all points that are currently selected in the active window.

This selection is only available when one or more points are selected on a photograph.

Select All

Select all points in the active photograph.

This item is only available when a photograph is open.

Select Items

Pick up the select tool. With this tool you can move points and select them for other operations.

This item is only available when a photograph is open.

Marking Menu

This menu contains operations used for marking control and fiducial points on photographs. You may choose to mark the four control points or the fiducial points. Image enhancement is also accessed in this menu.

Mark Point 1

Pick up the Point One tool. You may use this tool to approximately locate the first control point.

This selection is available when a photograph is open.

Mark Point 2

Pick up the Point Two tool. You may use this tool to approximately locate the second control point.

This selection is available when a photograph is open.

Mark Point 3

Pick up the Point Three tool. You may use this tool to approximately locate the third control point.

This selection is available when a photograph is open.

Mark Point 4

Pick up the Point Four tool. You may use this tool to approximately locate the fourth control point.

This selection is available when a photograph is open.

Mark Fiducials

Pick up the Fiducial Marking tool. You may use this tool to precisely locate both fiducial points.

This selection is available when a photograph is open and the camera you are calibrating requires fiducials.

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 selection is only available when a photograph is open and active.

Calibration Menu

This menu contains selections that affect your entire Calibration project. You may select choices to change your camera parameters, set the project scale and process your calibration project.

Camera Info

Open up the Camera Information dialog. You may use this dialog to view and modify camera parameters.

This selection is available when a calibration project is open.

Set Scale

Enter the distance between the first and third control points on your calibration grid. This distance is used by the Calibrator to set scale dependent camera parameters accurately.

This selection is available when a calibration project is open.

Calibrate

Process your calibration project. Processing uses the control points, fiducial points, scale distance and camera parameters to correctly calibrate your camera.

This selection is available when a calibration project is open.

Window Menu

This menu provides operations for manipulating photograph windows. Windows can be positioned, sized and zoomed in and out.

Zoom To Fit

Change the zoom of the current photograph so it is all displayed in the window.

This selection is available when a photograph is open.

Zoom Out

Pick up the zoom-out tool. With this tool you can shrink the contents of a window.

This selection is available when a photograph is open.

Zoom In

Pick up the zoom-in tool. With this tool you can magnify the contents of a window.

This selection is available when a photograph is open.

Zoom to Area

Pick the zoom-area tool. This tool allows the user to pick a rectangular area to become as large as the window.

This selection is available when a photograph is open.

Zoom 1:1

Change the zoom of the current photograph so it is displayed such that one screen pixel is equal to one image pixel.

This selection is available when a photograph is open.

Zoom Previous

Change the zoom of the current photograph to the most recent magnification and pan settings.

This selection is available when a photograph is open.

Pan

Pick up the pan tool. With this tool you can move the contents of a zoomed in window.

This selection is available when a photograph is open.

Help Menu

This menu contains information about how to use PhotoModeler product. Help is available for all PhotoModeler features as well as on the theory of measurement.

Using Camera Calibrator...

Displays the table of contents of the on-line help for Camera Calibrator and PhotoModeler.

This selection is always available.

Help Search...

Searches for a specified topic in the on-line help for Camera Calibrator.

This selection is always available.

About...

A summary of information about the Camera Calibrator and its developers.

This selection is always available.

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).

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.

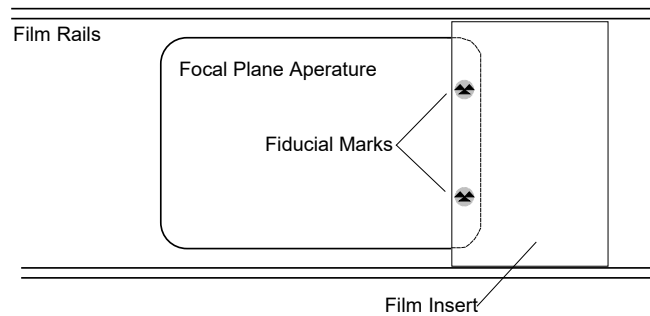
We can reconstruct the position of the film at the time of the exposure using fiducials. Every photograph has a rectangular border which is the image of the rectangular hole in the camera body between the lens and the film. In a 35mm camera this hole is approximately 36mm by 24mm. This hole is part of 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).

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

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).

Camera Calibration Requirement

For PhotoModeler to function correctly it needs information about the physical characteristics of the camera that took the photographs. It needs to know the physical format size, the position of the optical axis in the camera and the lens focal length. To get excellent measurement results it also needs to know the distortion characteristics of the lens.

For some cameras, this type of information can be read from specification sheets and entered manually by the user. Even then the focal length listed on most lenses is only a nominal figure and the true focal length can differ by as much as 5%. For other camera types, getting this information can be quite difficult (e.g. the format size of the CCD or of the resulting film/scanner combination can be very hard to determine).

The result is that you generally want to perform a calibration step on any camera/lens combination that you use for measurement. This calibration step usually only needs to be run once on any one camera/lens combination; unless the camera has been damaged. See the [Camera Calibration](#) section for more detail on calibrating cameras with PhotoModeler.

Considering the whole chain

The whole imaging chain needs to be calibrated since each part can contribute to changes in pixel size and distortion characteristics. A digital camera has an imaging chain of: lens - camera - computer. A film camera with scanner has an imaging chain of: lens - camera - scanner - computer. A video camera has an imaging chain of: lens - camera - digitizer board - computer. If any one of these components is changed (except for the computer) the calibration needs to be redone. When one camera is used with many lenses, the calibration can be done with each lens and PhotoModeler will allow the user to switch between them as needed.

Please refer to the section of the manual that discusses Eos Systems Camera Calibration program. You can use the Camera Calibrator program to create camera descriptions that can be used by PhotoModeler.

Glossary

This section lists some commonly used terms in this User Manual and in 3D measurement and modeling in general.

3D Face

Three connected points which define a triangular surface. This is the term used in AutoCAD to describe surface patches.

3D Model

A connected set of 3D points, lines, curves, and surfaces which can be used to represent an object or scene.

3D Point

A point with a location in space. Using Cartesian coordinate axes, a 3D point has values along the X, Y and Z axes. These values uniquely define one point.

Absolute measurement

A measurement of some quantity taken relative to a standard. A unit of time is considered an absolute measurement since it is implicitly relative to the time standard set up by the world standard organizations with their highly precise cesium clocks. Contrast with relative measurement.

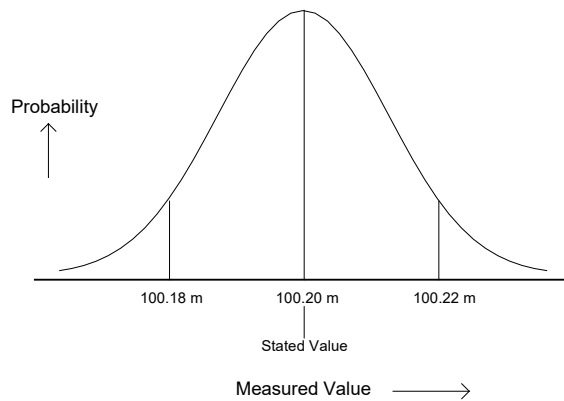
Accuracy

The degree of conformity with a standard, or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result and is distinguished from precision which relates to the quality of the operation by which the result was obtained. Accuracy refers to the agreement of a value with the "true" value. 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. 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.

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.

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 Calibrator program. 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).

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 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.

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.

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.

Control Point

A point with some known quantities that is used to control some other quantities. In the context of the Camera Calibrator, a Control Point defines one of four known locations on the calibration slide. In the context of PhotoModeler, 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.

Decimate

To reduce the resolution of a photograph. A large image of 1536 by 1024 pixels uses 1.5 MB of memory. This image will be slow to load from disk and will limit how many other images can be loaded at the same time. If the image is decimated by a factor of two, then it will be 768 by 512 pixels, taking up only 0.375 MB. PhotoModeler will decimate photographs, under some circumstances, to increase the photograph handling speed and to increase the number of loadable images.

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.

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 your 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.

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, image chip or button). noun: An attribute of a user interface object when it has been flagged for special user attention.

PhotoModeler uses three 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.

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.

Mark

A location on a single photograph representing the image of some physical feature.

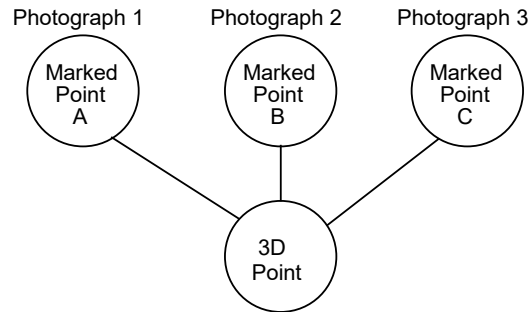
Marking

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.

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.

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.

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.

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.

Photogrammetry

The art and science of making measurements from photographs.

Point

Refer to definitions of 3D Point, Marked Point and Referenced Point.

Point ID

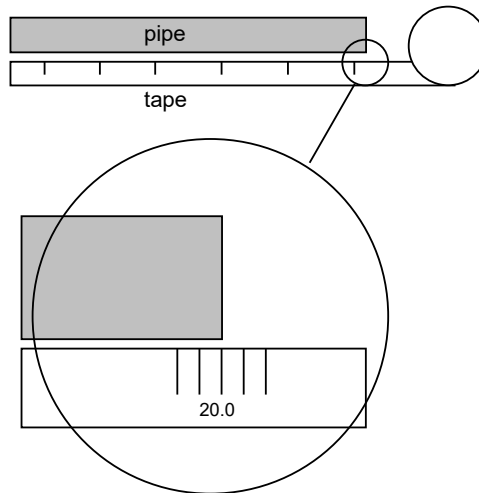
A unique number identifying each 3D model point in PhotoModeler. This number stays the same for a point the life of the Measurement Project within it resides. Point IDs are displayed on the status bar when points are selected, are displayed in the

Point Audit Dialog, are written out in the Text Export file and are written out in DXF export as text entities and optionally displayed on photographs.

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.

Example: We are measuring a length of pipe with a tape measure:



We get four people to take the measurement and we get the following results: 20.10, 19.85, 20.20 and 30.01 meters. Leaving out the last measurement and looking at the variation between 19.85 and 20.20 we can see the **random error** of this measurement system. The last measurement is called a **gross error**. The manufacturer of the tape is a little loose on the QA and this particular tape measure is stretched 2%. The measurements that result from this tape will all be off 2%. This is a **systematic error**.

The random error effects the **precision** of the system. The precision, gross errors and systematic errors all effect the **accuracy** of the system. So if the gross errors and systematic errors are zero, the accuracy will be same as the precision.

In the output of PhotoModeler (i.e. the Measure Dialog), 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 two standard deviations of a normal Gaussian probability curve. The "true value" may or **may not** fall within the precision of the estimated value and so this is **not** a measure of accuracy. The Measure Dialog does not take into account gross errors or systematic errors and hence shows only precision. These precision numbers can be used as estimates of accuracy if the gross errors and systematic errors can be assumed to be negligible.

Compare with accuracy.

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

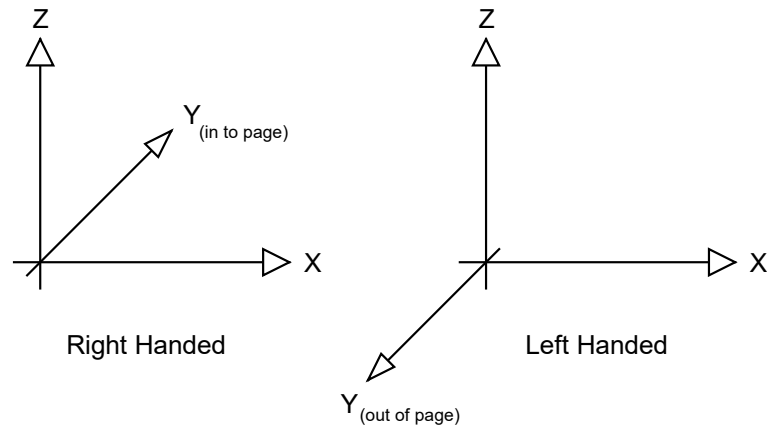
A means of imaging a grid of points or crosses onto film during exposure of a photograph. The reseau can be in the form of a glass plate with a grid of crosses that cover the image area or it can be a set of LEDs or lights that shine through the back of the film in a grid pattern. Reseaus are used to calibrate and remove the effects of film distortion and can also be used as fiducials. See [Fiducial](#).

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.

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.



Surface

An object composed of three or more points, edge points or curves. Those objects define a closed path that defines a boundary between two regions. A Surface looks solid or opaque in the 3D Viewer and can be assigned Materials such as color and photo-texture.

Tightness

A value used to indicate the accuracy of an Object Point's photo markings.

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.

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.

Index

This index provides a cross-reference to words and concepts used in this document. If you are looking for a word that does not appear in the index but you think it should, please take a note of it and send it to Eos Systems for inclusion in a future index.

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