

Tgi3D[®] SU PhotoScan

CalibrationTool

Reference Guide

(revision 1.1.11)

**Tgi3D SU PhotoScan v1.26
and higher**

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1. Introduction

The Tgi3D[®] CT (Tgi3D[®] SU PhotoScan Calibration Tool) is a photogrammetry software that facilitates an interface to mark matching points on multiple images for camera calibration and taking measurements between the marked points. The Tgi3D[®] CT Reference Guide contains all the reference material pertaining to the program.

Note for Mac OS X Users: Effective usage of the Tgi3D SU PhotoScan Calibration Tool requires a 3-button mouse. If you do not have a 3-button mouse, we recommend you to use a program like KeyRemap4MacBook (<http://pqrs.org/macosx/keyremap4macbook/>) to generate scroll wheel, middle-button and right-button click events (e.g. command-control-cursormove, command-click and control-click respectively).

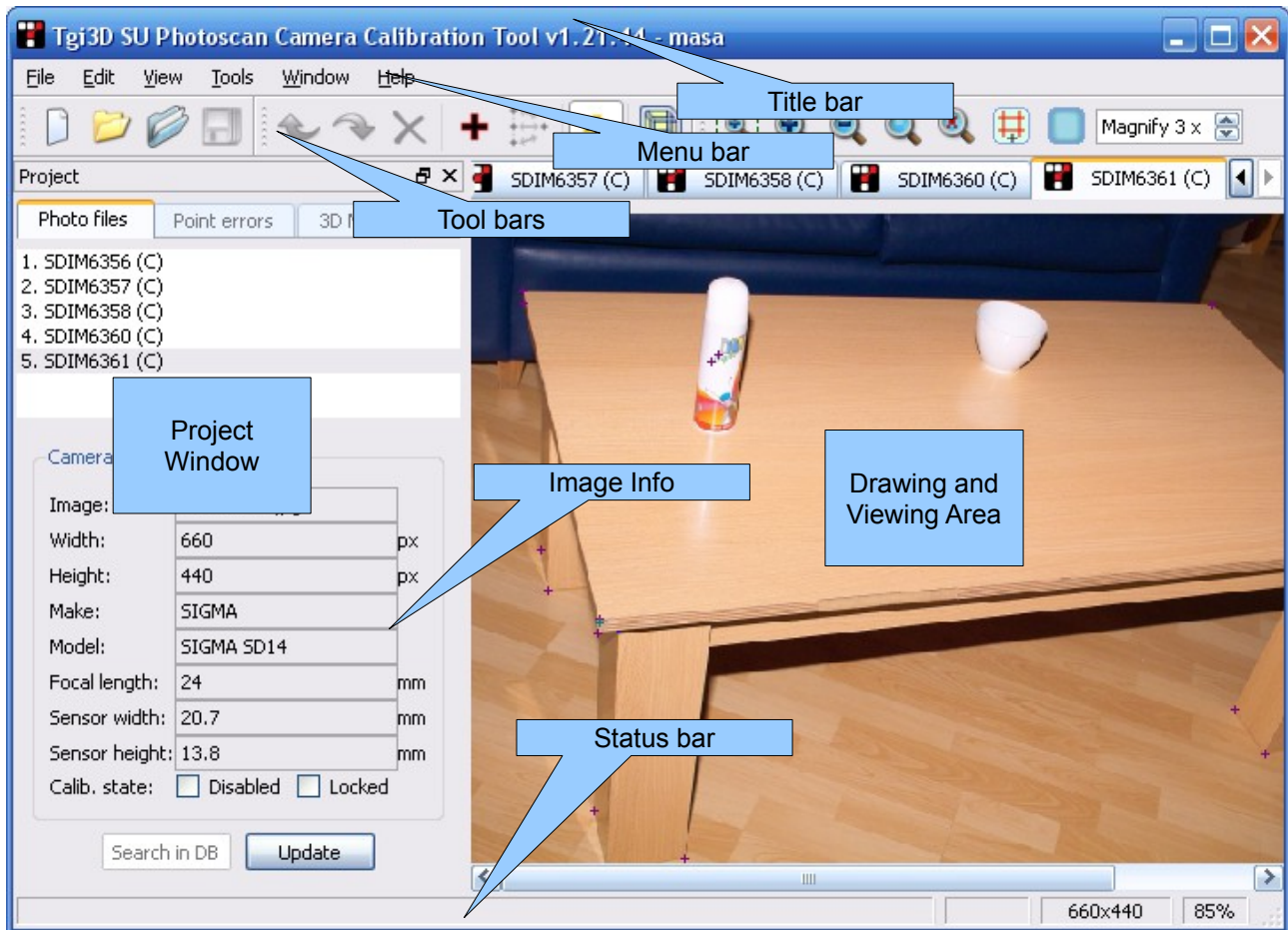
2. Tgi3D® CT User Interface

This section of the reference guide covers the Tgi3D® CT user interface, including menus, tool bars, dialog boxes, and the drawing and viewing area.

2.1. Application Window

Main parts of the Tgi3D® CT application window are title bar, menu bar, tool bars, (dockable) project window, the 3D drawing and viewing area.

Following is an image of the Tgi3D® CT user interface on Microsoft Windows:



2.2. Title Bar

The title bar at the top of the application window contains the standard Microsoft Windows controls (minimize, maximize and close) on the right, and Tgi3D® CT edition and version identifier with the name of the currently opened project on the left.

2.3. Menu Bar

Menu bar is located below the title bar. The majority of Tgi3D® CT tools, commands, and settings are available within the menus found in the menu bar. The menus on the menu bar are File, Edit, View, Tools, Window, and Help.

2.4. Tool Bars

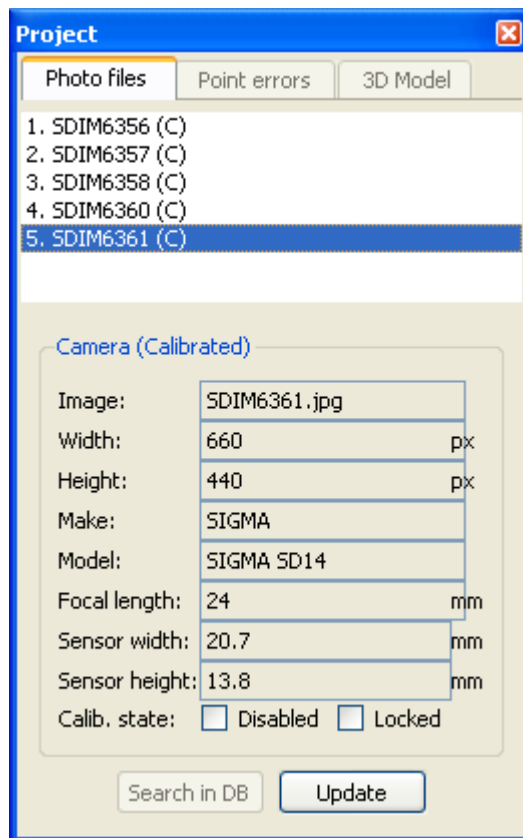
Tool bars appear below the menu bar. Each tool bar contains a set of related controls. By default the Tgi3D® CT includes the File, Edit and Zoom tool bars. You can toggle the visibility of the tool bars by clicking the right mouse button on the toolbar and menu bar area and checking or unchecking the tool bar name on the context menu that appears.

2.5. Project Window

By default, the “Project Window” appears docked on the left side of the Application Window. It facilitates navigation through the images used in the project, provides information on the current status of the calibration project and displays technical image and camera information of the selected photograph. It has three pages: “Photo files”, “Point errors” and “3D Model”. Under “Photo files” page, you can navigate through the images in the current project. “Point errors” page reports the model mismatch errors of the last camera calibration process. Clicking on the “3D Model” tag will switch to 3D viewer displaying the reconstructed points overlaid on the photograph and “3D Model” page will display the calibrated camera names (i.e. image titles) in the 3D model. The *Image Info* is displayed on the bottom side of the project window.

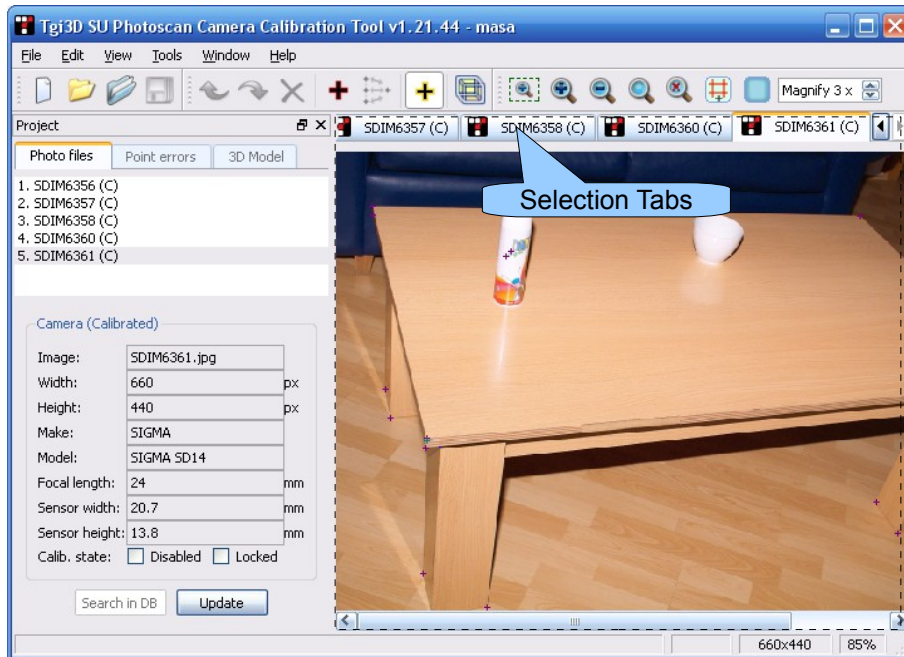
The project window can be shown and hidden by clicking the right mouse button on the toolbar and menu bar area and checking or unchecking the “Project Window” item on the context menu that appears. Both the project window and the image info section inside it can be shown or hidden by checking and unchecking the corresponding items in the *View* menu.

To dock or undock the project window, click and hold the left mouse button on the Project Window title bar and move it. Screen shot of an undocked project window is shown below.



2.6. Drawing and Viewing Area

The *Drawing and Viewing Area* is a collection of sub-windows containing the image and the calibration points or the 3D model. The area is marked with dotted lines in the figure below. The sub-windows could be accessed via the selection tabs on the upper side of the area as shown on the left below. The window menu and the project window can also serve the same purpose.



There are two types of sub-windows in the *Drawing and Viewing Area*

- 1) Image viewer, which displays and facilitates drawing of calibration points in 2D.
- 2) 3D viewer, which displays the reconstructed points in 3D and facilitates
 - entering a distance measurement from the real-world in order to-scale the cameras and the points to the real-world,
 - defining the world coordinate frame by providing the origin and a number of axes vectors,
 - seeing the 3D coordinates of the reconstructed points,
 - making measurements between the reconstructed points.

2.7. Status Bar

Status bar is located at the bottom of the Tgi3D® CT Application Window. It displays information about current scaling, image size and status messages on selected menu items, clicked image locations etc.

3. Menus

Menus contain the majority of Tgi3D® CT tools, commands, and settings. When clicked over it, each menu shows a drop down list containing a collection of related items. The list also contains icons of the identical buttons on the related toolbar as well as the shortcut keys for the same operations.

Note: Items in each menu could be enabled (highlighted) or disabled (get grayed out) depending on the current context. For example, Save menu item in the File menu will be grayed out until you make a change in the project.

The default menus in Tgi3D® CT are:

3.1. File

“File” menu contains items that relate to Tgi3D® CT project files. It includes commands to create, open, close, save, project files, and export calibration results, open most recent projects, and add images to, and remove images from the project.

3.2. Edit

“Edit” menu contains items that relate to the editing operations that include editing camera database, preferences, standard undo-redo commands and a toggle switch for enabling/disabling calibration point entries.

3.3. View

“View” menu contains items that relate to the viewing operations like zoom and rotation and showing/hiding project window and the image info window.

3.4. Tools

“Tools” menu contains camera calibration, model reconstruction and exporting functions.

3.5. Window

“Window” menu mainly contains items for navigating through the images and the 3D model.

3.6. Help

“Help” menu contains items related to help and information on Tgi3D® CT.

4. Toolbars

Tool bars appear below the menu bar. Each tool bar contain a set of related controls. To toggle the visibility of the tool bars, click the right mouse button on the menu bar and the tool bar area and check or uncheck the tool bar name from the context menu.

Note: Buttons on the tool bars get enabled (highlighted with color) or disabled (get grayed out) depending on the current context. For example, Save All button on the File tool bar will be grayed out until you make a change in the project.

Tgi3D® CT user interface includes the following tool bars:

4.1. File

“File” tool bar contains most commonly used menu items related to the Tgi3D® CT project files. These items are New Project, Open Project, Add Images, and Save All as shown in the figure below.



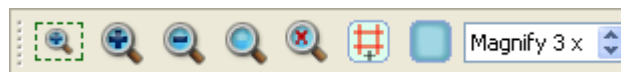
4.2. Edit

Firstly, “Edit” tool bar contains buttons for standard editing operations, namely Undo and Redo. The calibration related editing operations of deleting, marking and matching calibration points are located in this tool bar. It is also possible to show and hide projections of 3D reconstructed points using the “Show point projections” button. Building and viewing the resulting 3D model is the final command in the Edit toolbar.



4.3. Zoom

“Zoom” tool bar contains the tools to move the view in and out. These items in left to right order are: Zoom Box, Zoom In, Zoom Out, Fit to Screen, Normal Size, Zoom to selection, Magnifier and finally the zoom level for the magnifier used in marking points.



5. File Menu

The “File” menu contains items that relate to Tgi3D® CT project files. It includes commands to create, open, close, save projects, add images to the project, and export calibration results.

5.1. New Project...

“New Project...” menu item closes the current project and launches the *Browse* dialog box that allows you to create a new folder and open a new Tgi3D® CT project. The name of the selected folder is also the name of the project.

Note: If you have another project in the folder that is selected as a placeholder for the new project, that project is opened instead of creating a new one.

When a new project is opened, the name of the new project appears on the title bar and the project is empty at the beginning i.e. there are no images listed in the project window and the drawing and viewing area is empty.

Keyboard Shortcut: **Ctrl+N (Windows), command-N (Mac)**

Toolbar Icon: 

5.2. Open Project....

“Open Project...” menu item closes the current project and launches the *Open Project* dialog box that allows you to select a previously saved project. Tgi3D® CT project file has the **.prj** extension.

When an existing project is opened, the name of the project appears on the title bar, the list of images included in the project will be listed in the Project Window and the drawing and viewing area will show the images together with marked points.

Keyboard Shortcut: **Ctrl+O (Windows), command-O (Mac)**

Toolbar Icon: 

5.3. Close Project

“Close Project” menu item closes the current project without closing the program.

5.4. Add Images...

“Add Images...” menu item launches the *Add Images* dialog box that allows you to browse for and select the image files you want to add to the project. Tgi3D® CT supports the following image types: JPEG Image (.jpg), Windows Bitmap (.bmp), Portable Network Graphics (.png), Graphics Interface Format (.gif), Portable Pixmap (.ppm) and Portable Graymap (.pgm).

Keyboard Shortcut: **Ctrl+I (Windows), command-I (Mac)**

Toolbar Icon: 

5.5. Remove Image from Project

“Remove Image from Project” menu item removes the current image from the project.

Caution: You cannot “undo” image removal. Once the image is removed from the project all the work done on that image will be lost.

5.6. Save

“Save” menu item saves the work done on the current image.

Keyboard Shortcut: **Ctrl+S (Windows), command-S (Mac)**

5.7. Save All

“Save All” menu item saves all the work done in the project.

Toolbar Icon: 

5.8. Export...

“Export..” menu item launches the *Export Settings* dialog box (See Section 22. for details). From this dialog box you can select the desired output format and the image resolution level for exporting the camera parameters, images and the reconstruction of points used in calibration.

Keyboard Shortcut: **Ctrl+E (Windows), command-E (Mac)**

5.9. Exit

“Exit” menu item closes the program.

Note: On Mac OS X, this menu item resides under the *Tgi3D Calibration Tool* menu as “Quit Tgi3D Calibration Tool” menu item instead.

5.10. MRU Project List

For fast access, MRU (Most recently used) Tgi3D projects (at most five projects) are listed at the end of the “File” menu.

6. Edit Menu

The “Edit” menu contains items that relate to the editing operations that include editing camera database, preferences and marking points, as well as the standard undo-redo commands.

6.1. Undo

“Undo” menu item takes back the last edit operation.

Keyboard Shortcut: **Ctrl+Z (Windows), command-Z (Mac)**

Toolbar Icon: 

6.2. Redo

“Redo” menu item performs the last edit operation that was undone.

Keyboard Shortcut: **Ctrl+Y (Windows), command-Y (Mac)**

Toolbar Icon: 

6.3. Clear Current Selection

“Clear current selection” menu item clears the selection in the current image

Keyboard Shortcut: **Esc (Windows and Mac)**

6.4. Clear all selections

“Clear all selections” menu item clears the selection in all the images in the project.

Keyboard Shortcut: **Ctrl+M (Windows), command-M (Mac)**

6.5. Delete

“Delete” menu item deletes the selected point from the project.

Keyboard Shortcut: **Del (Windows), Forward Delete (or fn-Delete) (Mac)**

Toolbar Icon: 

6.6. Camera Info...

“Camera Info...” menu item launches the *Camera Info* dialog box, where you can search and edit the sensor size parameters of existing cameras and add new cameras to your local database, which is set in the preferences dialog box. See Section 17. for detailed information.

6.7. Preferences...

“Preferences...” menu item launches the *Preferences* dialog box, where you can set the preferences related to memory and camera database and measurement unit. You can limit the number of images loaded into RAM and set/change the external user camera database file, and set a unit for displaying measurements. See Section 18. for detailed information. Also you can change the marker size.

Note: On Mac OS X, this menu item resides under the '*Tgi3D Calibration Tool*' menu.

6.8. Calibration Point

“Calibration Point” menu item has a toggle feature used for enabling/disabling new calibration point insertion on photographs. If the menu item is in checked state, then left mouse click inserts a new unmatched

calibration point in the photograph at the cursor point. However this new calibration point will be active when it is matched with its counterpart calibration points in other photographs. Matching operation is activated by first selecting the corresponding points in different photographs and then clicking the right mouse button in one of the photographs containing a selected point. Once a point is matched it will be assigned a unique Matched Point ID available by pressing 'Q' key (or 'B' key if point is selected) on the keyboard. In order to unmatch the matched points, first press 'M' key on the keyboard and an overlaid window will be displayed on top left corner of the image window. Then click on the Matched Point ID to select all the matched points in the corresponding photographs. Then click on the right mouse button in one of these photographs and click the "Unmatch" button on the displayed dialog. If you want to assign a 3D coordinate to a calibration point (Note: 3D coordinate can only be assigned to matched calibration points), right click on the point (when there are no points selected in other photographs) and a 3D coordinate interface dialog box will open enabling a 3D coordinate assignment to the calibration point. See Sections 12.1., 12.1. and 12.4. for more information.

Keyboard Shortcut: Press and hold 'C' key (Windows and Mac)

Toolbar icon: 

6.9. Match points

"Match Points" menu item matches the points selected on all images to create a new calibration point.

Mouse Operation: Right click on a point

Toolbar icon: 

6.10. Assign 3D coordinate

"Assign 3D coordinate" menu item is used for assigning a 3D coordinate to a calibration point. This command is enabled when there no multiple selections.

Mouse Operation: Right click on a point

7. View Menu

The “View” menu contains items that relate to the viewing operations like zoom and rotation on the image.

7.1. Enable Mouse Wheel Zoom

“Enable Mouse Wheel Zoom” menu item is used to toggle the zooming ability via the mouse scroll wheel. If this item is checked in the View menu, you can zoom in and out on the image using the scroll wheel, otherwise the mouse-wheel is used for vertical scrolling.

7.2. Orthographic View

“Orthographic View” menu item is used in 3D viewer. You can toggle between orthographic and perspective views by checking or unchecking this menu item. If the model is not yet reconstructed this item will be disabled (not selectable) in the View menu. In the *orthographic view*, parts of the object are always the same size no matter how far away they are as opposed to perspective *view* where parts that are farther away are smaller. The default view is the perspective view.

7.3. Rotate Left

“Rotate Left” menu item rotates the image to the left by 90 degrees.

7.4. Rotate Right

“Rotate Right” menu item rotates the image to the right by 90 degrees.

7.5. No Rotation

“No Rotation” menu item is used to revert the image rotation back to its original orientation.

7.6. Zoom Box

“Zoom Box” menu item is used to zoom the image to a rectangular area selected by the user. After selecting the menu item, the program is in zoom box mode, where the user can draw a rectangular area to zoom in the picture by clicking the left mouse button and dragging the mouse while keeping left mouse button clicked.

Keyboard Shortcut: Press and hold 'Z' key (Windows and Mac)

Toolbar Icon: 

7.7. Normal Size

“Normal Size” menu item is used to zoom the image to its actual dimensions.

Keyboard Shortcut: 0 (zero) (Windows and Mac)

Toolbar Icon: 

7.8. Zoom In

“Zoom In” menu item zooms in to the image.

Keyboard Shortcut: + (Windows and Mac)

Toolbar Icon: 

7.9. Zoom Out

“Zoom Out” menu item zooms out of the image.

Keyboard Shortcut: - (Windows and Mac)

Toolbar Icon: 

7.10. Fit to Screen

“Fit to Screen” menu item resizes the image view to fit to the viewing area.

Keyboard Shortcut: . (dot) (Windows and Mac)

Toolbar Icon: 

7.11. Zoom to Selections

“Zoom to Selections” menu item zooms all the views to the selections in all the images of the project.

Toolbar Icon: 

7.12. Show point projections

It is possible to show and hide projections of 3D reconstructed points using the “Show point projections” menu item.

Toolbar Icon: 

7.13. Show matched points

“Show matched points” command displays a list of calibration point ids (i.e. Matched Point IDs) on the top left corner of the viewer window.

Keyboard Shortcut: Press and hold 'M' key (Windows and Mac)

7.14. Show selected point info

“Show selected point info” command displays the id of the selected point in the current image by the point marker.

Keyboard Shortcut: Press and hold 'B' key (Windows and Mac)

7.15. Show all point infos

“Show selected point info” command displays the ids of all the points in the current image by their markers.

Keyboard Shortcut: Press and hold 'Q' key (Windows and Mac)

7.16. Hide point markers

“Hide point markers” command hides the markers of the points on the images so that the underlying photographs can be inspected without interference

Keyboard Shortcut: Press and hold 'W' key (Windows and Mac)

7.17. Magnifier

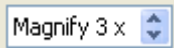
“Magnifier” menu item displays information on how to use the magnifier. In order to activate the magnifier over the cursor location, you need to press and hold the 'Shift' key inside image area. Releasing 'Shift' key closes the magnifier.

Toolbar Icon: 

Keyboard Shortcut: **Press and hold 'Shift' key (Windows and Mac)**

7.18. Magnifier magnification

You can change the magnification ratio of the magnifier using this spin box.

Toolbar Icon: 

7.19. Project Window

“Project Window” menu item shows or hides the Project Window.

7.20. Show Image Info

“Show Image Info” menu item show or hides the “Image Info” sub-window inside the Project window.

8. Tools Menu

The “Tools” menu contains functions that relate to camera calibration and model reconstruction operations.

8.1. Build 3D Model

“Build 3D Model” menu item reconstructs the calibration points and launches the 3D viewer to display the calibration points in 3D.

Keyboard Shortcut: **Ctrl+R** (Windows), **command-R** (Mac)

Toolbar Icon: 

8.2. Camera Calibration...

“Camera Calibration...” menu item launches the *Camera Calibration Settings* dialog box (see Sections 19. and 20.), which contains the settings to be used during the camera calibration process. Clicking the “Run” button on this dialog executes the camera calibration process according to the given settings.

8.3. Export...

“Export..” menu item launches the *Export Settings* dialog box (see Section 22. for details). From this dialog box you can select the desired output format for exporting the camera parameters and the reconstruction of points used in calibration.

Keyboard Shortcut: **Ctrl+E** (Windows), **command-E** (Mac)

9. Window Menu

The “Window” menu contains items to change the display of the windows used in the Drawing and Viewing Area.

9.1. Close 3D Model

“Close 3D Model” menu item closes the 3D Model window.

Keyboard Shortcut: **Ctrl+F4 (Windows), command-F4 (Mac)**

9.2. Last Active

“Last Active” menu item toggles between the last active and current image window (or tab).

Keyboard Shortcut: **Ctrl-Tab or Ctrl+T (Windows), ctrl-Tab or command-T (Mac)**

9.3. Next

“Next” menu item activates the next tab (or window) in the Drawing and Viewing Area.

Keyboard Shortcut: **Right, Down or Ctrl+plus (+) (Windows), Right, Down or command-plus (+) (Mac)**

9.4. Previous

“Previous” menu item activates the previous tab (or window) in the Drawing and Viewing Area.

Keyboard Shortcut: **Left, Up or Ctrl+minus (-) (Windows), Left, Up or command-minus (-) (Mac)**

9.5. (image list)

At the end of the “Window” menu the names of image files included in the project is listed. Selecting the menu item with a specific image file name activates the image file (i.e. brings it on top ready to be worked on). For the first 10 items in the list, a set of short cut keys are also provided according to the position of the image file in the list.

Keyboard Shortcut: **Ctrl+(a number between 0 and 9) (Windows), command-(0-9) (Mac)**

10. Help Menu

The “Help” menu contains items related to getting help with Tgi3D® CT.

10.1. Help

“Help” menu item launches the help document.

10.2. Check for updates

“Check for updates” menu item connects to the internet and checks if any update is available.

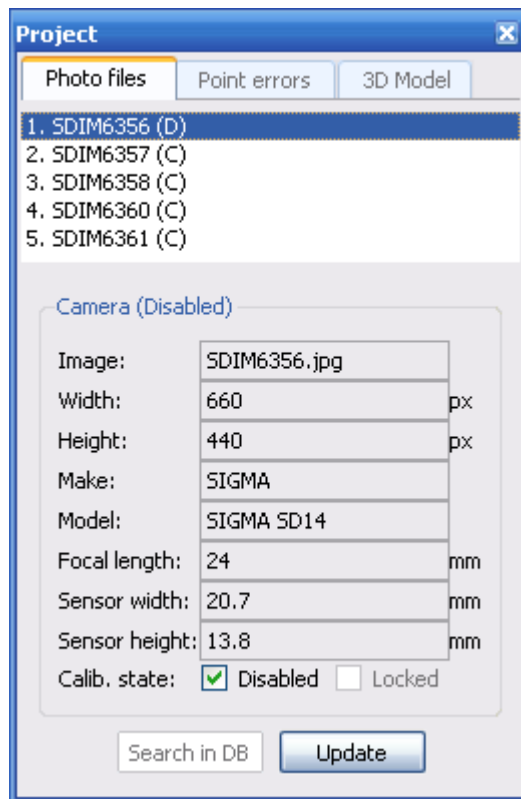
10.3. About...

“About...” menu item launches the *About Tgi3D® CT* dialog box which displays information about version of the program, licensing and copyrights.

Note: On Mac OS X, this menu item resides under the *Tgi3D Calibration Tool* menu as “About Tgi3D Calibration Tool” menu item instead.

11. Project Window

The “Project Window” facilitates navigation through the images used in the project and provides information on the current status of the calibration project. It has three pages: “Photo files”, “Point errors” and “3D model” and a sub-window that shows and allows editing of image information as shown below.



11.1. Photo files

“Photo Files” page lists the photographs used in the project. The file extensions of the images are stripped and the each image corresponds to a camera to be calibrated. Additional indicator text may follow the camera name according to the state of the system:

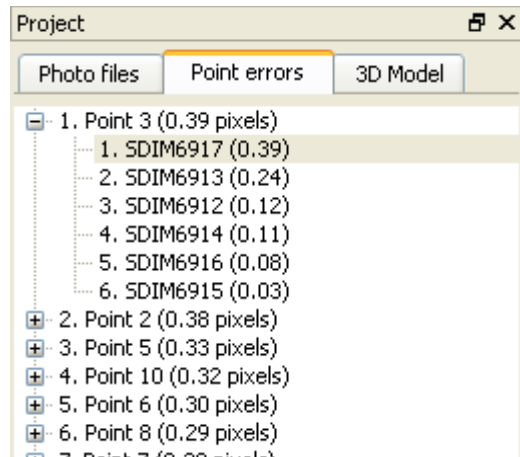
- **(C)** : Indicates a calibrated camera.
- **(D)** : Indicates a disabled camera
- **(L)** : Indicates a locked camera
- **(p+)** : Indicates that a point is selected in the corresponding photograph.
- ***** : Indicates that there are unsaved modifications made on the photograph or points.

You can select an image (or navigate through the images) using a single click of the left mouse button. You can also navigate through the images using the Left-Right and Up-Down keys. Active window in the Drawing and Viewing Area will switch to the selected image in the list.

11.2. Point Errors

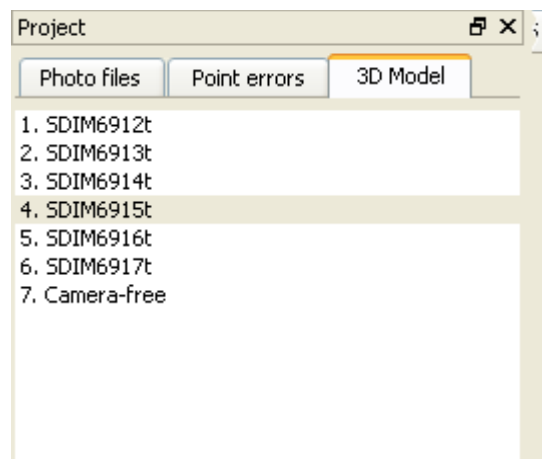
“Point Errors” page lists the calibration points with high projection errors. For each point the highest projection error and errors on each camera are displayed. Selecting a camera displays the image and selects the point in the drawing and viewing area. High error rates indicate poor calibration quality and is the result of bad or even false localization of calibration points on each image. You may determine such badly placed points using the point error page. The point error list contains at most 10 calibration points that have

high calibration errors.



11.3. 3D Model

“3D Model” page contains a list of images similar to the “Photo Files” page, but this time they facilitate switching to the camera corresponding to the selected image in 3D view of the reconstructed points. The image is also placed in the background so that the 3D calibration points can be viewed overlaid on the image. An additional item “Camera-free” refers to an arbitrary view without any background images. See Section 13. for details.



11.4. Image Info

“Image Info” sub-window is displayed at the bottom side of the project window. It contains the information about the image and the camera used to take the picture and the state of the camera in calibration process. If the photograph EXIF information exists then the camera related is read-only. If the camera in the EXIF information can be found in the built-in or local database, its sensor size will be displayed; otherwise it is going to be assumed to be a typical point and shoot camera. In order to override this assumption, you need to enter required information using the *Camera Info* dialog box, which can be activated using the “Search in DB” button in the sub window or the Camera Info menu item in the Edit menu.

If the image does not include any EXIF information, you will be allowed to choose a camera from the database by filling in the make and model fields and pressing the “Search in DB” button. If the camera can be found in the database the correct sensor size will be displayed otherwise the *Camera Info* dialog box will show up to let you enter a new camera with the make and model you provided. If you do not want to create a new camera or choose an existing one, just enter an estimate of the focal length for a typical point and shoot camera, which is assumed to has 10 mm wide sensor. If you don't enter anything a default focal length is supplied by the program.

Note: The sensor size does not have to be accurate since calibration tool can compute the actual ratio (sensor size)/(focal length). The sensor width and height together with the focal length are used as initial guesses for the ratio, and calibration tool is able to compute the correct values even with 30% initial error.

(a) EXIF info exists

(b) EXIF info does not exist

The fields

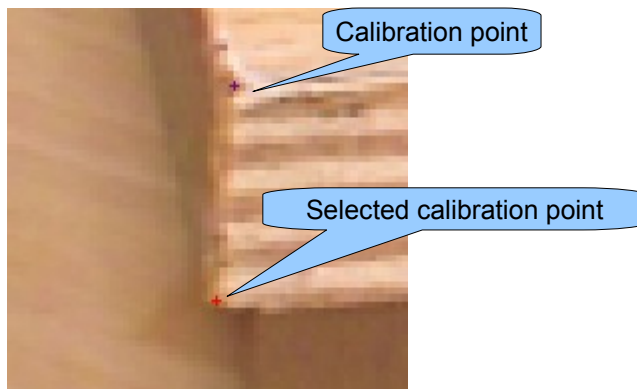
- **Image:** The name of the image file.
- **Width:** The width of the image.
- **Height:** The height of the image.
- **Make:** The producer company of the camera.
- **Model:** The model of the camera.
- **Focal length:** The focal length of the camera.
- **Sensor width:** The width of the sensing area of the camera.
- **Sensor height:** The height of the sensing area of the camera.
- **Disabled:** Check this option to prevent the camera to be included in the calibration process
- **Locked:** Check this option to prevent the camera to freeze the calibration parameters of the camera

The Command Buttons

- **Search in DB:** Search the camera given in the make and model fields in the built-in and local database. If it is found, the sensor size fields are filled in automatically; otherwise the *Camera Info* dialog box (see Section 17.) to enter a new camera or select an existing one.
- **Update:** Update the camera information

12. The Image Viewer

Image viewer displays the image and allows manipulation of calibration points on each image. The basic drawing operation in this viewer is creating calibration points to be used in camera calibration and reconstruction of the real world. A calibration point refers to a unique point in 3D space. This point can have projections on the images in the project. For example, the corner of a table is a calibration point in 3D and its projections are its 2D location on the photographs that see the corner. In the image viewer, the projections are marked on each image and then, they are matched to let the system know that the selected points at the moment refer to the same calibration point. Because of this equivalence, we refer both the point itself and its projections as calibration point.



The calibration points are displayed with a small red marker as shown below. A highlighted red marker indicates a selected point. Matching the selected points, browsing and selecting calibration points, and manipulating the markers are the basic operations available in the image viewer. Various mouse and keyboard actions are utilized for the manipulation of the markers, thus the calibration points.

12.1. Manipulating Calibration Points

Adding, moving, selecting, and deleting calibration points are the main editing tasks in the image viewer. You can also enter real-world coordinates of the points if available.

To add a calibration point:

1. Use, "*Calibration point*" toggle item in the *Edit* menu or the toolbar, or just press and hold the 'C' key on the keyboard.
2. A left mouse click on the photograph places a calibration point marker at that location.

To select a point:

1. A left mouse click on its marker selects the point

To delete a point:

1. Select it
2. Press 'D' or 'Del' key on the keyboard, or use the "Delete" menu or toolbar item.

To move a point:

1. Drag (click, hold and move) the point using left mouse button.

To enter 3D coordinate for a calibration point:

1. Right click on one of its projection, when there are no selected points on other frames
2. Fill in the coordinate field in the *3D Value* dialog box (see Section 14.) that shows up.

12.2. Matching Calibration Points

In order to reconstruct a 3D point, it should be visible on at least two cameras, therefore the marker points on the images are of no use if they are not matched to any point on another photograph. Matching points lets the system know that the matched points are the projections of a unique 3D point in space.

To match points:

1. Select the points to be matched on the photographs
2. Right click on one of them (or inside the photograph)
3. Click on *Match* button in the *Match/Unmatch Selected Points* dialog box that shows up.

Unmatching a group of points is handled through the “Calibration Point List”.

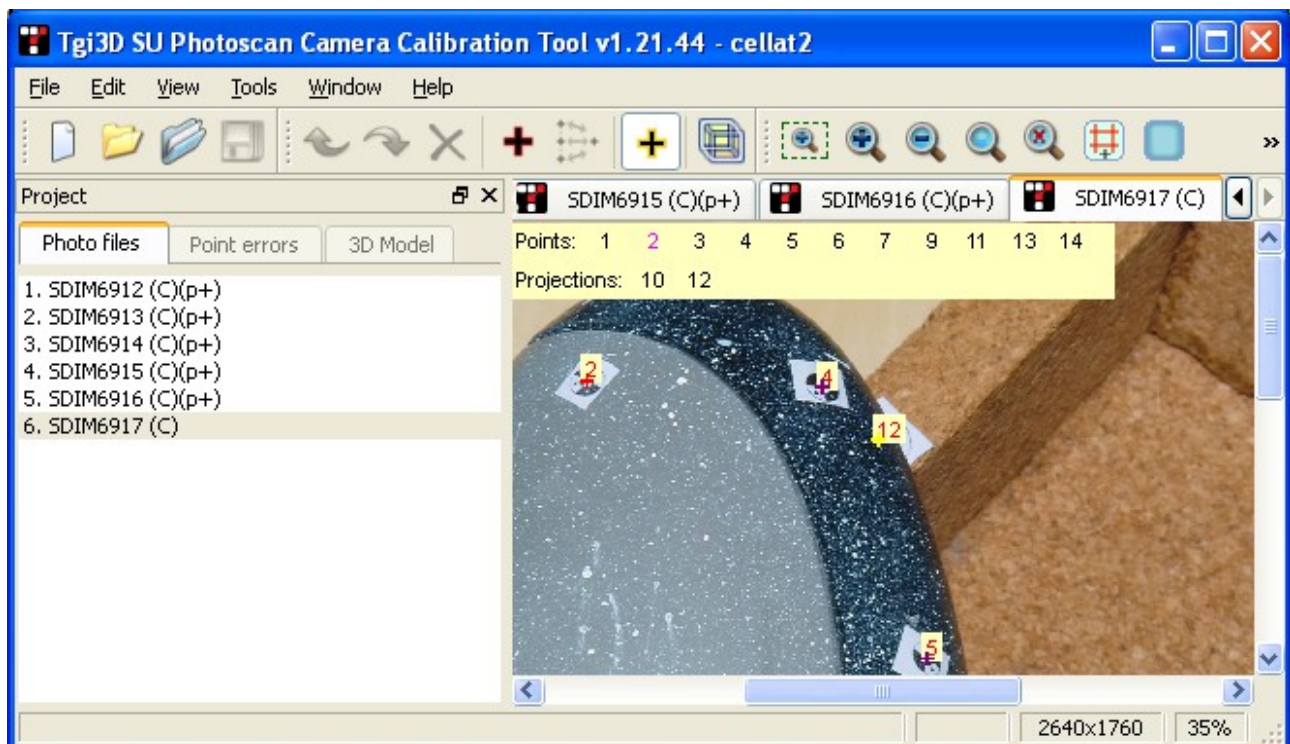
12.3. Matching Projections of 3D Points

It is also possible to create matching points using the projection of a point in the 3D model on a calibrated camera. This operation help increase the accuracy of the calibration. Make sure the “Show point projection” item in the Edit toolbar and the view menu is checked. If a point in the model does not have a matching point on an input image then its projection is displayed with a yellow marker. For matching point creation

1. Click on the yellow marker to select all the matching points of the corresponding 3d point on the rest of the images.
2. Check the existing projections to see the corresponding feature in the scene.
3. Click on the marker again to add the point as the matching point for the feature.
4. Drag the point to the center of the corresponding feature.

12.4. Calibration Point List

Pressing 'M' key on the keyboard displays a list of calibration point ids (i.e. Matched Point IDs) on the top left corner of the viewer window. The list stays there as long as the key is pressed. Left-clicking on any of the ids causes all the projections of the corresponding point to be selected. These selections can be tracked using the 'p+' text on the label of the image in the projection window or the selection tab.



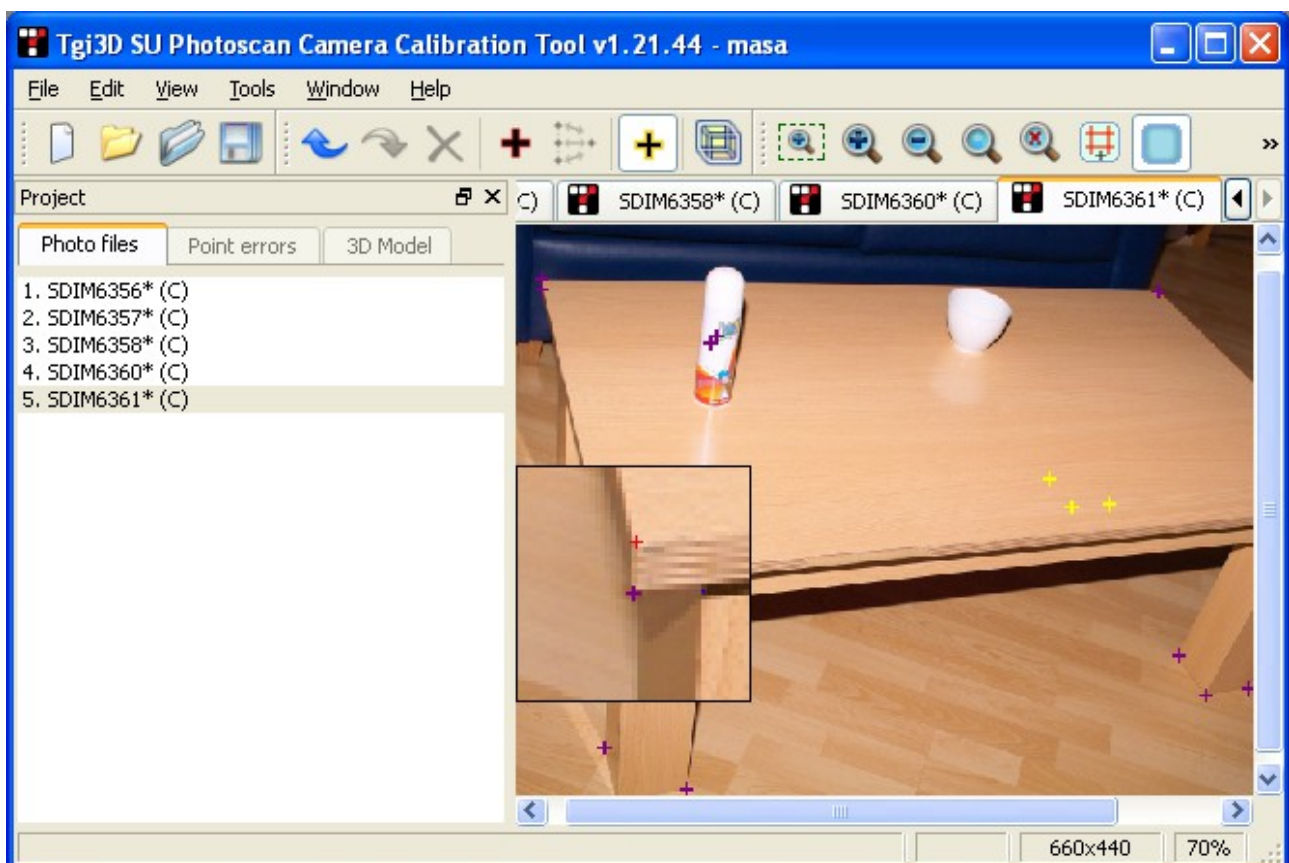
To unmatch a group of points or equivalently delete a calibration point in the list

1. Select it in the overlaid “calibration point list” window
2. Right-click on one of the points on the images
3. Press “Unmatch” button in the *Match/Unmatch Selected Points* dialog box that shows up

12.5. The Magnifier

Precise localization of calibration points on the image requires the use of high zoom levels, on the other hand finding a matching point on another image may requires a lower zoom level where a large part of the image is visible to avoid false matches. For example in case of table or a desk one should be able to look at the whole table and the surroundings to locate the same corner on all the images; then zoom at that corner to be able to mark it with sub-pixel precision. The magnifier is a small size rectangular window, that pops up on the image view area and shows the image at a higher zoom level than the base viewer, as shown in the figure below. The amount of magnification is determined by the magnification ratio spin-box on the zoom tool bar (see Section 4.3.). The mouse and keyboard control for zooming, panning, editing etc. of the magnifier content is similar to the image viewer, with a few limitations. You can think of it as a small size image viewer.

Press and hold the 'Shift' key to show the magnifier. When the key is pressed it will show up centering the current mouse location but you can drag it over the image using the right mouse button.



12.6. Mouse and Keyboard Actions

Mouse and keyboard actions available on the *Drawing and Viewing Area* are listed below.

a) Left Mouse Button

The left mouse button has the following functions:

- **Select a point:** You can select a point by clicking close to that point
- **Moving a point:** Click, hold and move the cursor to move a point over the image.
- **Add new point:** If the calibration point mode is activated from the menu or the tool bar or if the 'C' key is pressed, clicking on an empty point on the image creates a new calibration point at that location.

b) Middle Mouse Button

- **Panning:** When the image is displayed at a zoom level that does not fit in the viewer window, drag (click, hold and move) the image using the middle button to see the other parts of the image.

c) Mouse Wheel

- **Zooming:** Moving the wheel allows you to zoom in and out when “Enable Mouse Wheel Zoom” menu item is checked or used inside the magnifier. Mouse wheel also works as vertical scroll when “Enable Mouse Wheel Zoom” menu item is unchecked.

d) Right Mouse Button

The function of right mouse button depends on the selected points on the current image and other images and inside the magnifier..

- **Match/Unmatch selected points:** If there selected points on other photographs, right clicking on any of the selected points launches the *Match/Unmatch Selected Points* dialog box where you can match, unmatch, or deselect the selected points.
- **Enter/Remove 3D Point value:** If there are no multiple selections, right-clicking on a point, that has a match on at least one more image, allows you to enter a 3D coordinate for the corresponding calibration point.
- **Drag the magnifier:** You can move the magnifier by right-clicking on it, holding and moving the mouse cursor.

e) Keyboard Commands

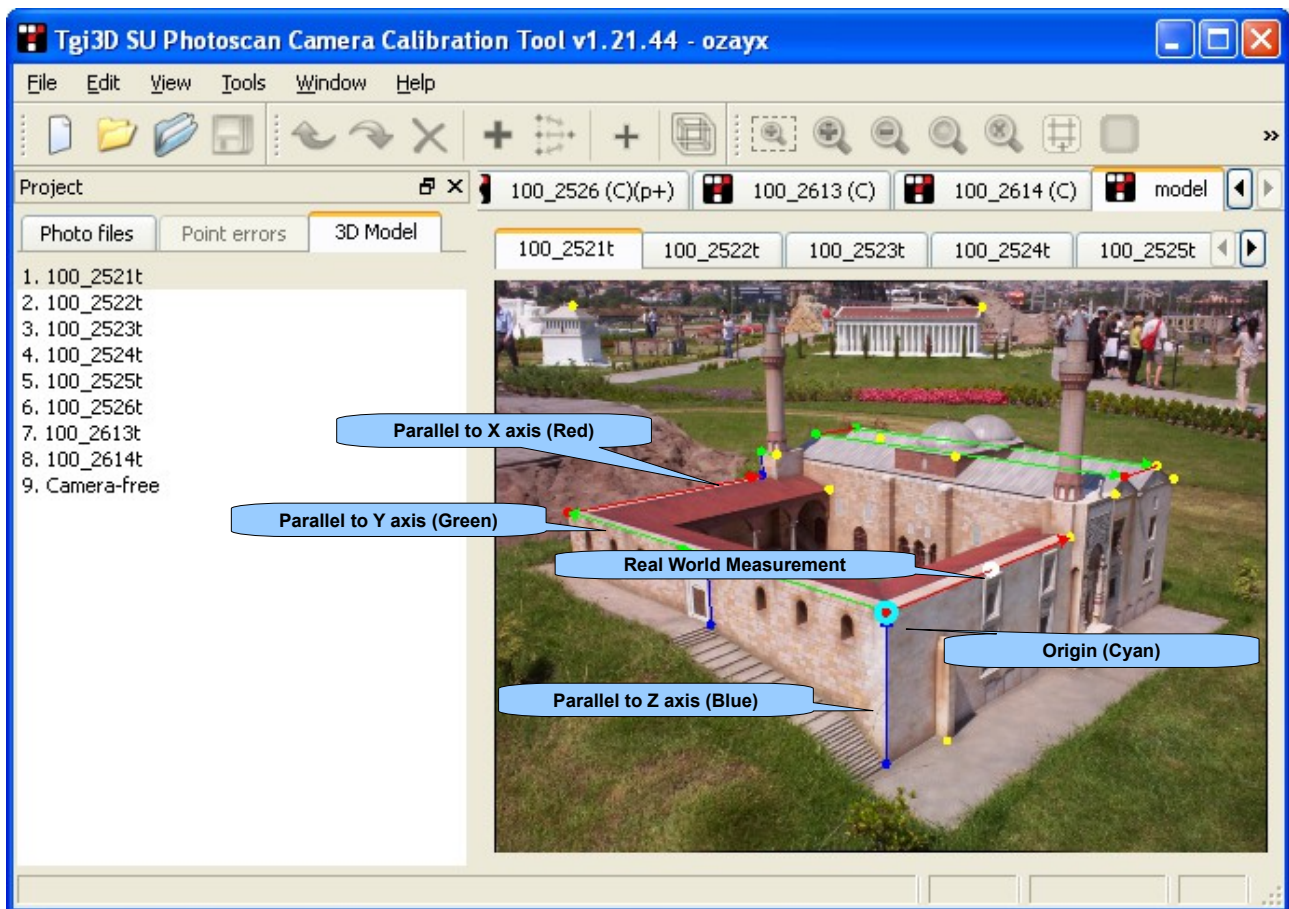
- **'D' or Del :** Delete a selected point.
- **'M' :** Display a list of calibration points (i.e. matched points) visible on that image.
- **'B' :** Display the id of the selected point.
- **'Q' :** Display the id of all the points on the image.
- **'W' :** Hide all the points on the image so that the underlying photographs can be inspected without interference
- **'Z' :** Box zoom mode is active as long as the key is pressed.
- **'C':** Calibration point mode is active as long as the key is pressed.
- **Esc:** Clear the selection
- **Shift:** The magnifier is shown as long as the key is pressed.

13. The 3D Model Viewer

The 3D Model viewer displays the reconstructed points in 3D and allows entering a distance measurement from the real-world in order to scale the cameras and the point reconstructions to fit the real-world, see the 3D coordinates of the reconstructed points and make measurements between the reconstructed points and define a world coordinate system by entering an origin and vectors parallel to the world frame axes.

13.1. Calibrated Camera Views

Selection tabs and the “3D Model” page in the project window (both containing entries corresponding to the calibrated cameras) enable switching between the 3D views of the calibrated cameras. When an entry is selected, the 3D viewing camera is set to the parameters of the corresponding camera and the corresponding image is set to be the background so that the 3D points are overlaid on the image as shown in the figure below.



The overlaid view lets you

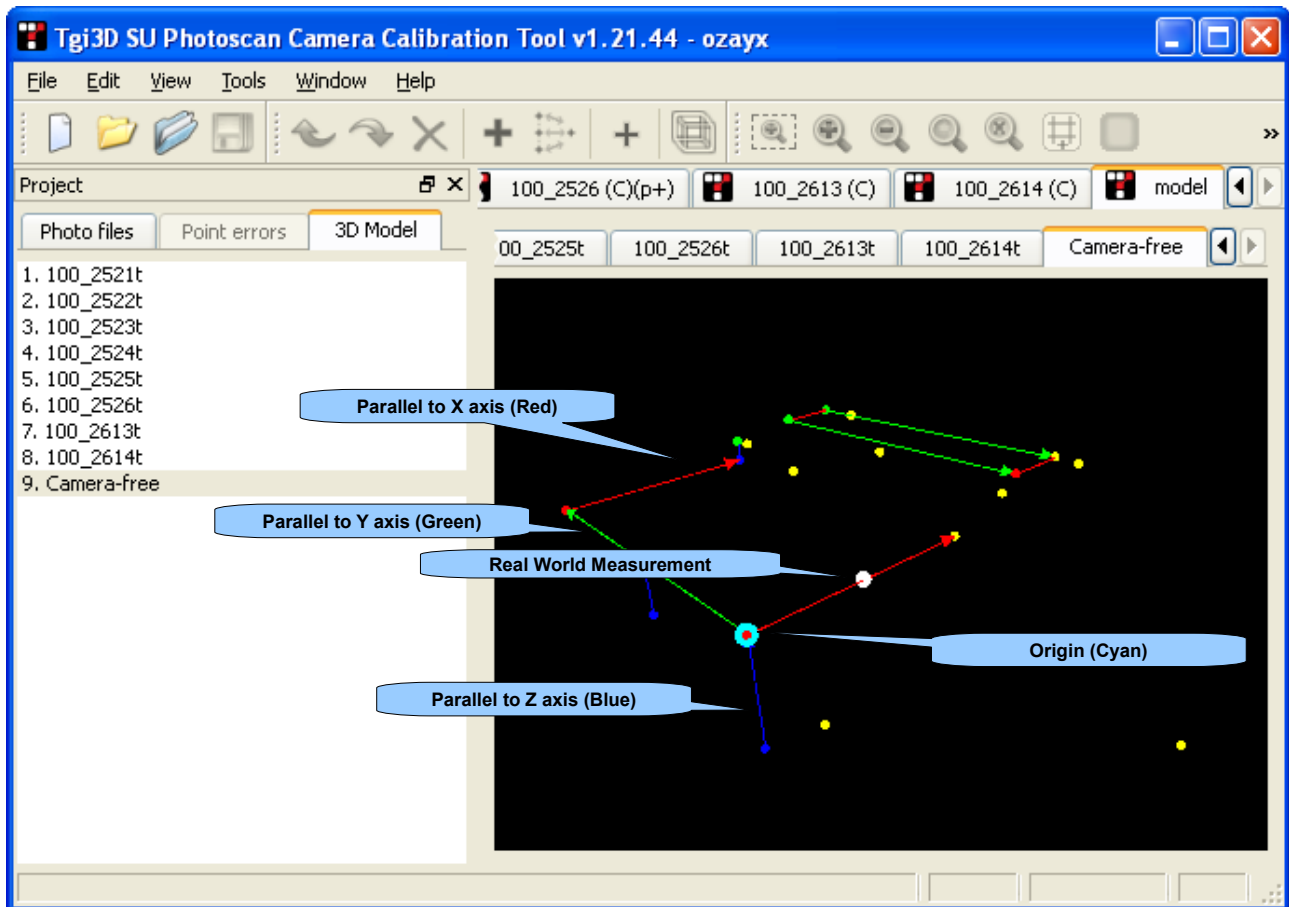
1. Identify calibration points
2. Make meaningful measurements in the scene.
3. See the difference between the projection of reconstructions and the corresponding feature, to get an idea about the quality of calibration.
4. Correctly locate a feature in an image where it can not be easily found due to the presence of periodic structures or very large shifts in locations due to wide angular differences between cameras.

To switch to a camera view: Select the camera entry in either one of

- 3D Model page in Project window
- Selection tabs above the view

13.2. Camera-Free Views

It is also possible to see the reconstructed points freely from an arbitrary viewing angle different from the calibrated cameras as shown in the figure below.



The points are displayed as yellow dots on a black background. Middle mouse button and wheel is used for this purpose.

To change the viewing angle: Drag using the middle mouse button.

To change the zoom level: Use the mouse wheel.

13.3. Coordinates of the reconstructed points

In both types of views if the mouse cursor stands close to a reconstructed point for about a second, a small windows pops-up to display the position of the reconstructed point in 3D space.

13.4. Real-world Measurements and the World Coordinate System

As it is impossible to know the scale of the world from photographs, the point and camera locations computed in the calibration process are correct up to a scale factor. If you want to build models without any scale and coordinate system ambiguity or make real measurements using Tgi3D® CT, you need to resolve the scale ambiguity.

Another ambiguity arising in the calibration process is the coordinate system of the reconstructed world. If you want to have control over the world coordinate system, you need to set an origin and directions of X, Y and Z axes.

Entering the real world coordinates of calibration points as described in Sections 12.1. and 14. is one way to resolve the ambiguities mentioned above. Setting two point coordinates is enough to resolve the scale ambiguity. Entering the third point coordinate will completely define the world coordinate system.

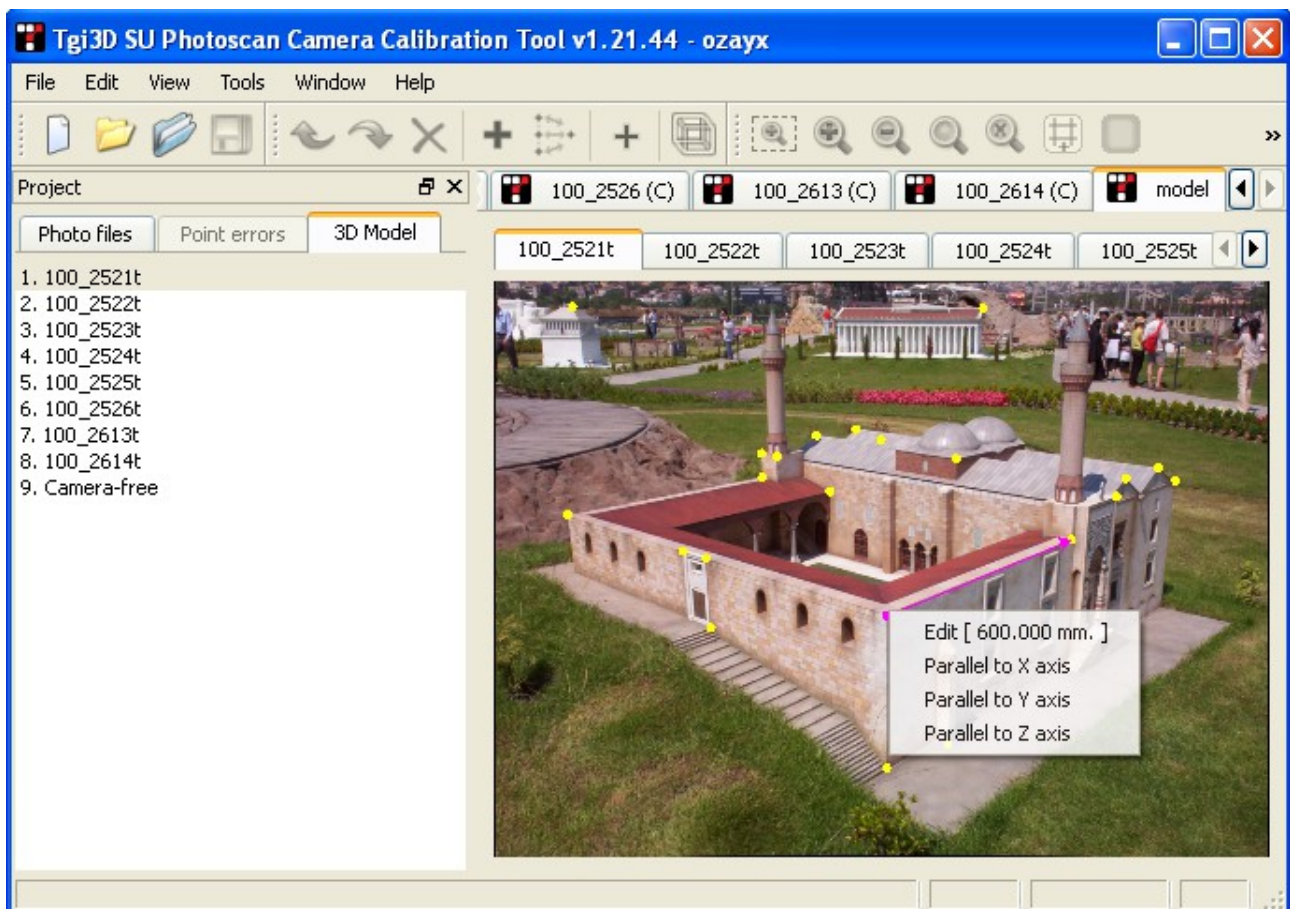
The 3D model view lets you control the world coordinate system in an easier way by

1. Entering the distance between two points through the *Measurement Result* dialog box (see Section 15.)
2. Setting one of the calibration points as the origin of the world.
3. Setting a vector between two points as parallel to one of the X, Y, and Z axes.

To enter a real world measurement or set axes constraints:

1. Right click on a point in the 3D model. The point turns magenta after clicking.
2. Right click on the second point. A magenta line is drawn between the two points and a context menu shows up containing
 - the current value of the distance between the two points and a command for editing it,
 - commands for setting the vector between the points parallel to one of the world coordinate frame axes

as shown in the figure below:



3. If you select the “Edit” command the *Measurement Result* dialog box (see Section 15.) pops up to let you enter the real world distance between the two points.

Note: Only one measurement can be saved for a 3D model; therefore the previous measurement value is lost, when the current measurement is saved.

4. If you select one of the axes, the vector between the points is used as a constraint in the next camera calibration process.

Note: You can set as many vectors as you like to be parallel to the any of the axes as long they are not incompatible with each other.

5. Click the “Edit” button in the dialog box

To set the origin of the world coordinate system:

Do one of the following:

- Right double click on the point you want to set as the origin.
- Apply two clicks on the same point as if you are making a measurement. A context menu for setting the origin will show up.

Note: Only one point can be set as an origin therefore your previous origin setting will be overwritten with the new origin.

To delete a measurement, axis or origin:

1. Right click on the constraint you want to delete
2. Select delete in the context menu that shows up.

13.5. Mouse Actions

a) Left Mouse Button

- Use the left mouse button to select points. When a calibration point is selected it is displayed in red and all of its projections on the photographs are selected as well.

b) Middle Mouse Button

- Dragging using the middle mouse button changes the viewing angle.

c) Mouse Wheel

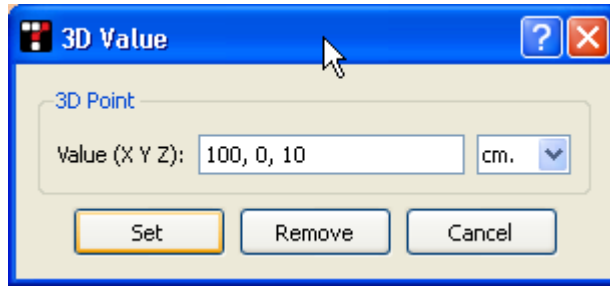
- Moving the wheel allows you to zoom in and out in the current view

d) Right Mouse button

- Right click on two consecutive points to display enter real world measurements, world origin and axes constraints.
- Right click on the real-world measurement, axis constraint or origin to edit the corresponding distance measurement, or axis constraint

14. 3D Value Dialog Box

3D Value dialog box is used to enter a 3D coordinate in specified units for a calibration point.



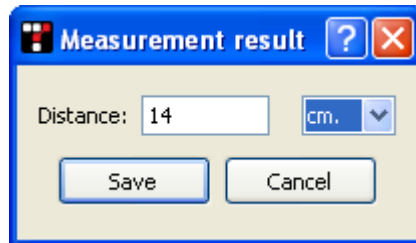
The following are the actions associated with *3D Value* dialog box:

- **Point value and unit:** Enter the X Y Z coordinates separated by space or commas of the point in the "Value" field and choose the unit from the combo box beside it
- **Set:** Click "Set" button to set the 3D coordinate of the selected point
- **Remove:** Click "Remove" button to remove the 3D coordinate associated with the selected point.
- **Cancel:** Click "Cancel" button to close the dialog box without changing anything.

15. Measurement Result Dialog Box

Measurement Result dialog box is used to display and set the distance between two selected points in the 3D model. To enter or edit a measurement

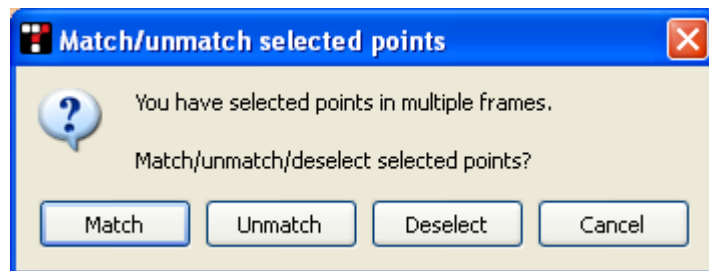
- Enter the measurement value in the distance field and choose the unit.
- Click save to save the measurement. Only one measurement can be saved for a 3D model; therefore the previous measurement value is erased, when the current measurement is saved.



16. Match/unmatch Selected Points Dialog Box

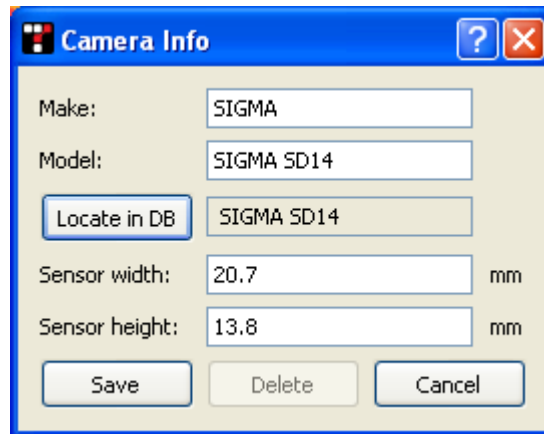
Match/unmatch Selected Points dialog box shows up when there are selected points on multiple photographs. It is only used to issue the following commands:

- **Match:** The selected points are matched, which means that the selected points are the projections of the same 3D point in the scene.
- **Unmatch:** The unmatch command is active only when the points are selected using Calibration point list sub-window in the image viewer (see Section 12.4.). The points are unmatched or equivalently the 3D calibration point associated with the matches is removed.
- **Deselect:** The deselect command is active only when the points are selected using Calibration point list sub-window in the image viewer (see Section 12.4.). The points on all the photographs are unselected with this command.
- **Cancel:** Close the dialog box without doing anything.



17. Camera Info Dialog Box

Camera Info dialog box lets you search and edit the sensor size parameters of existing cameras and add new cameras to your local database, which is set in the *Preferences* dialog box (see Section 18.). Tgi3D® CT comes with a built-in database including information on more than a thousand cameras. If your camera is not included in the database (you can check that using the “Locate in DB” button in the dialog box) then you need to enter and save the make, model and the sensor size parameters of your camera. Typically you can find that information through the internet or from the camera manual. The make and model should be similar to the make and model parameters provided in the EXIF section of the digital images taken by your camera. Knowing the sensor size allows the calibration tool interpret the focal length information provided in the EXIF section correctly.



The fields

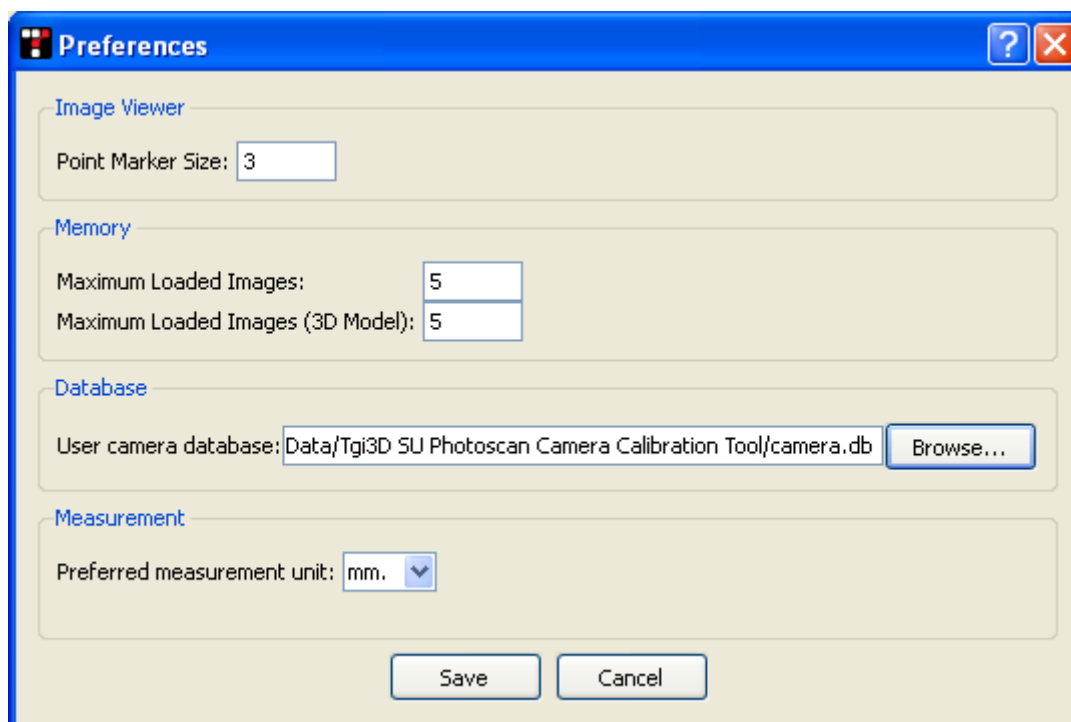
- **Make:** The producer company of the camera.
- **Model:** The model of the camera
- **Sensor width:** The width of the sensing area of the camera
- **Sensor height:** The height of the sensing area of the camera

Command Buttons

- **Locate in DB:** Use this button after filling in the Make and Model fields. The given camera is searched in the database (both the local and the built-in database). If the camera is found, the make and model registered in the database is displayed in the text box on the left side of the button; and the sensor width and height fields are filled in; otherwise “Unknown camera” is displayed.
- **Save:** Update or save the camera information provided to the local database.
- **Save and Select:** This button shows up when the dialog box is launched from the *Image Info* dialog box (see Section). Apart from saving, the current record is selected to fill in the camera fields in the *Image Info* dialog box.
- **Delete:** Delete the camera if it is found to be in the local database.
- **Cancel:** Close the dialog box without doing anything.

18. Preferences Dialog Box

Preferences dialog box contains options to set the preferences related to image viewer, memory, camera database and measurements. You can set the size of markers to display points, limit the number of images that are kept in RAM, choose to include camera info from an external file saved in another Tgi3D® CT project and set the preferred unit for displaying measurements.



Settings Related to Image Viewer

You can specify the size of the matching point markers (i.e. the plus sign) in pixels.

Settings Related to Memory

Tgi3D® CT keeps a number of images in RAM for faster access to speed up the user interaction on the images. The following settings on the *Preferences* dialog box allow you to set them.

- **Maximum Loaded Images:** Specifies the maximum number of images to be kept in computer's RAM for faster access during editing operations.
- **Maximum Loaded Images (3D Model):** Specifies the maximum number of images to be kept in computer's RAM for faster access during 3D viewing of the reconstructed model.

Depending on the size of your computer's RAM you can increase or decrease the number of images to be kept in RAM.

Settings Related to Database

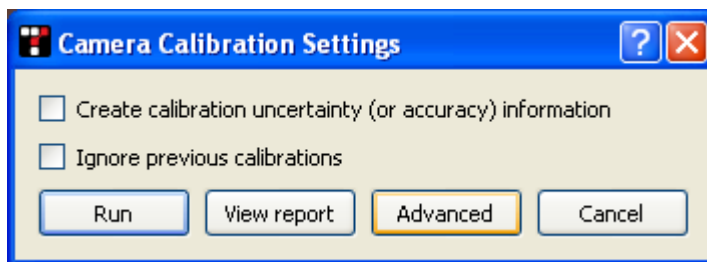
Tgi3D® CT has an extensive internal camera database that recognizes more than 1300 cameras available in the market, however considering the very large and rapidly changing market there is a possibility that your camera may not be included in the built-in database. In that case, you can define and save new camera models in a file determined by the *user camera database* setting.

Settings Related to Measurements

Tgi3D® CT can display the distance between any pair of calibration points. The *preferred measurement unit* setting allows you to set the desired unit for displaying measurement results.

19. Camera Calibration Settings Dialog Box

Camera Calibration Settings dialog box contains the settings to be used in the camera calibration process. After setting the options click “Run” button to calibrate the system. It is possible to view a report on the calibration process and also switch to the advanced calibration mode within this dialog box.



Calibration Options

- **Create calibration uncertainty (or accuracy) information:** You need to check this options if you want the measurements to be reported with uncertainty information (95%, i.e 2- σ ; confidence interval is used in reporting uncertainties). Checking this options causes a slightly slower camera calibration.
- **Ignore previous calibrations:** Check this option if you want the calibration process start from scratch ignoring the previous camera calibration results. In a typical project you may want to calibrate the system every time you add a calibration point or add new images to the project. We recommend ignoring the previous calibrations every now and then to avoid the system trapping at a local minima.

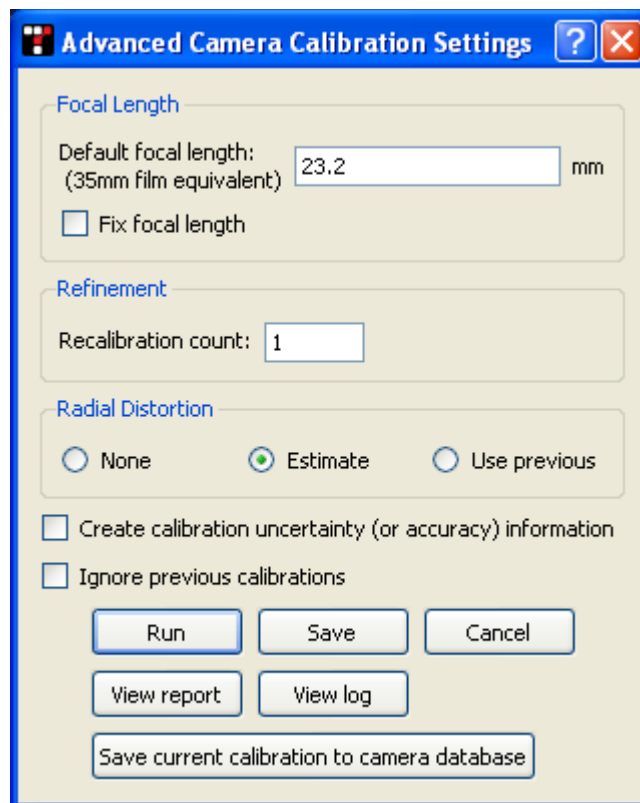
Command Buttons

- **Run:** Executes the calibration process.
- **View report:** See an evaluation of the calibration results by clicking the “View Report” button. The report provides information on the estimated internal parameters of the cameras calibration results and accuracy.
- **Advanced:** Launch the *Advanced Calibration Settings* dialog. Advanced calibration is meant to be used in case of difficult calibration projects, where the EXIF or similar information on the camera parameters is not available or the available calibration points results in a semi-stable system.
Note: The best way to cope with calibration failures is to provide more and more calibration points visible on as many cameras as possible. Advanced calibration is the very last resort meant for users with basic technical knowledge on image formation and parameter estimation process.
- **Cancel:** Cancel the calibration process and close the dialog box.

20. Advanced Camera Calibration Settings Dialog Box

Advanced Camera Calibration Settings dialog box contains some options to be used in the camera calibration process. These setting refer to the focal length estimation, calibration refinement process, radial distortion estimation and the basic parameters of calibration explained in the *Camera Calibration Settings* dialog box (See the previous section for the explanation of these parameters). After setting the options click “Run” button to calibrate the system. The dialog box contains command buttons for saving the current calibration parameters, viewing the report or the log file of the calibration process. It is also possible to save the estimated focal and radial distortion to the camera database for re-using them in other calibration projects.

Note: Option changes here are only effective for advanced camera calibration run! Basic camera calibration run is not affected by option changes here.



Settings Related to Focal Length

- **Default focal length:** The default focal length is an initial estimate of the unknown focal lengths. This parameter applies to the cameras, whose corresponding image files do not contain any EXIF information and the user did not provide a value through the *Image Info* dialog box.
- **Fix focal length:** If the “Fix focal length” option is checked, then the camera calibration process does not estimate focal length, instead uses the initial estimate provided in the EXIF info, or the value user provided through the *Image Info* dialog box or the default value entered in this dialog box.

Settings Related to Refinement

- **Recalibration count:** In the final stage of camera calibration the system goes through an bundle adjustment process for the refinement of estimated parameters. The refinement count determines the number of refinements to be applied. Ideally one refinement step is enough to reach to a local minimum, but in case of a shallow minimum the process could be repeated to get the system to a better state. 10 should be enough for most cases. If you increase this number much above 100, then the calibration process will take a long time to finish.

Settings Related to Radial Distortion

- **None:** It is assumed that there is no radial distortion on the images
- **Estimate:** Estimate the radial distortion in the images
- **Use previous:** Set the radial distortion parameters to the previously estimated value and do not re-estimate.

Command Buttons

- **Run:** Executes the calibration process.
- **Save:** Saved the current calibration parameters for future use
- **Cancel:** Cancel the calibration process and close the dialog box.
- **View Report:** See an evaluation of the calibration results by clicking the “View Report” button. The report provides information on the estimated internal parameters of the cameras calibration results and accuracy.
- **View Log:** The calibration process produces a log file located in the project directory. It is meant to be used by the developers for debugging purposes.
- **Save current calibration to camera database:** This command saves the estimated focal length and radial distortion parameters to the camera database. This option is useful only if you will be using the same camera with exactly the same lens at the same focal length in many other projects.

21. Calibration Report

The calibration report provides information on the estimated internal parameters of the camera calibration results and accuracy. It consists of three sections:

```
Camera Calibration Results

Camera SDIM6912: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix)
Camera SDIM6913: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix): -2.74364
Camera SDIM6914: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix): -2.74364
Camera SDIM6915: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix): -2.74364
Camera SDIM6916: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix): -2.74364
Camera SDIM6917: SIGMA SIGMA SD14
    focal length: 67.2027 radial (r = 1320 pix): -2.74364

Projection error over 6 cameras and 14 / 14 points
Average Error SDIM6912 = 0.191028 over 10 points
Average Error SDIM6913 = 0.165243 over 12 points
Average Error SDIM6914 = 0.142597 over 13 points.
Average Error SDIM6915 = 0.210634 over 10 points.
Average Error SDIM6916 = 0.146645 over 10 points.
Average Error SDIM6917 = 0.241007 over 11 points.
Global Average Error = 0.181376

Predicted user error: 0.313767

.
```

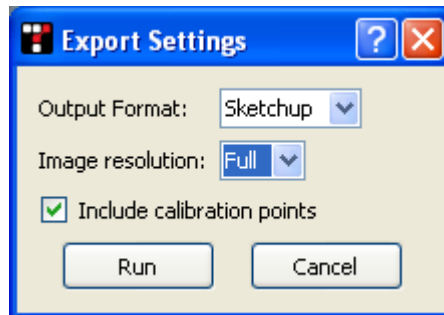
The diagram shows three blue callout boxes with white text and a pointer. The first callout, labeled 'Internal Parameters', points to the focal length and radial distortion values for Camera SDIM6912. The second callout, labeled 'Projection Errors', points to the 'Average Error' line for Camera SDIM6913. The third callout, labeled 'User error estimation', points to the 'Predicted user error' line.

- **Internal parameters:** The focal length and the radial distortion of each camera are reported in this section. The radial distortion is reported as the radial shift in pixels at a specific radius to give an intuitive idea on the strength of radial distortion. The sign indicates the direction of radial shift.
- **Calibration Error:** When the cameras are calibrated the calibration points are reconstructed. Due to the unavoidable error in calibration point locations on images the reconstruction will not project on exactly the marked locations. The difference between the projection of reconstructed points and the marked points is an indicator of calibration quality. The average projection on each camera and the overall projection error is reported in this section.
- **User Error:** User error rate is the prediction of the uncertainty in point locations. It depends on the user and the quality (e.g. sharpness) of features.

22. Export Settings Dialog Box

Export Settings dialog box allows you to select an output format, image resolution level and determine whether the reconstructed points will be exported. Currently exporting the calibration points and image resolution is an active option only for SketchUp and Tgi3D format. In exporting to SketchUp, the cameras are used to create the “*Photo-Match*” pages which lets you draw over the images. If the “*Include calibration points*” option is checked, reconstructed points used in camera calibration are exported as well. The image resolution determines the size of the images to be used in the photo-match pages.. The Tgi3D format is an internal format to be used by other Tgi3D products. It contains the camera parameters, the reconstructed points and the radially undistorted images.

For other formats, the calibration points are the only entities that are exported; therefore the option is always checked. The images are not exported at all.



Export Options

- **Output Format:** The output format combo box lists the currently available output formats for export.
- **Include calibration points:** If you check this option the reconstructed calibration points will be exported.

Command Buttons

- **Run:** Prompts for a file name and executes the export process.
- **Cancel:** Cancel the export and close the dialog box.