MatchMover User Guide

Autodesk

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Getting Started

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About Autodesk MatchMover

Autodesk® MatchMover™ is a camera tracking application that automatically captures 3D camera path and camera parameters from 2D video and film image sequences. After capturing a 3D camera path with MatchMover, you can export the camera data to a number of file formats supported by 3D animation or compositing programs. This allows you to work with the camera data in your favorite animation or compositing application to accurately place 3D objects into a video or film sequence. Providing a straightforward and cost-effective way to mix 2D live-action footage with 3D animation and special effects, MatchMover allows you to take advantage of the 2D world of film and the 3D world of animation.

MatchMover extracts all camera parameters from information contained in a film sequence. From a set of 2D points automatically tracked through an image sequence, MatchMover computes the following:

- The camera path and all the camera internal parameters such as zoom and distortion.
- The coordinates of the 3D points that project onto the 2D point tracks.
- The motion of independent moving objects.

A preview sequence with additional computer-generated objects in the scene can be generated to check the quality of the tracking result. If necessary, post filtering can be used to smooth the computed camera path. The camera data is then ready to export to an animation or compositing program.

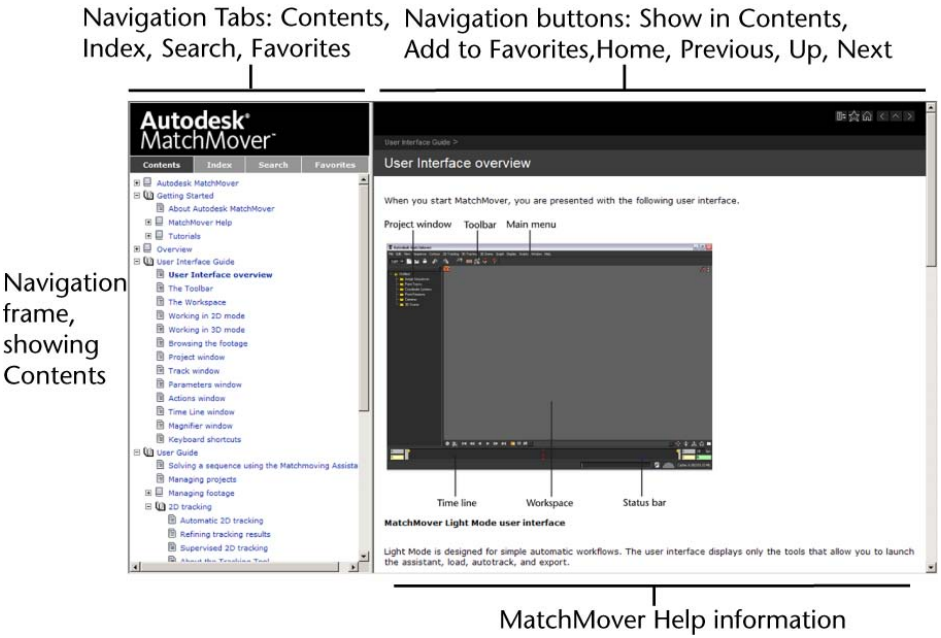
With MatchMover, no geometric data from the set or from the camera is required, but they can be used for faster computation and stronger constraints.

Integrated high-end 2D tracking modes enable very precise camera reconstruction. MatchMover works with any type of camera equipment, any image resolution, and can process any camera path in the most commonly used image formats.

MatchMover Help

MatchMover Help overview

The MatchMover Help is accessible from the Help menu of MatchMover. The MatchMover Help appears in your Web browser and gives you complete access to the online documentation of MatchMover, including Tutorials, Interface Guide, and User Guide.



The left-hand navigation frame gives you tabbed access to Contents, Index, Search, and Favorites. Help information appears in the right-hand frame. When you first open the MatchMover Help, a legend appears in the right side frame, showing the various information types of the MatchMover Help.

Navigation buttons are available on the top of the right-hand frame. These include:

- Show in Contents  the left-hand frame, if necessary, and highlights the current topic.
- Add to Favorites  : adds the current page to the Favorites list.
- Home  : reloads the home page of the MatchMover Help.
- Previous Page, Next Page  .
- Up one level  : opens the parent topic of the current topic.

You can click Please send us your comment about this page at the bottom of each page, to send an email to MatchMover documentation about the current page.

There are also Index, Search, and Favorites pages that you can access by clicking the appropriate button in the left panel.

Index

The index provides you with an alphabetical list of key points in the documentation. Clicking any of the keywords in the index displays the appropriate subject in the right panel.

You can search the index by typing a query into the textbox at the top of the left panel. When you click the View button, the left panel automatically scrolls to the first instance of the queried keyword, whose page is then displayed in the right panel. You can click the Next button to move to subsequent instances.

Search

You can search through the documentation for words or combinations of words using the search menu. Type your query into the textbox and click the Search button. Matches are ranked according to the number of occurrences of the keyword(s) and are listed from the highest rank to the lowest. Search also has a number of options.

Search Method Defines whether to find topics containing any of the keywords (or) or all of the keywords (and).

Match case Considers upper or lower case when searching.

Highlight When on, all instances of the keyword(s) are highlighted in the result pages.

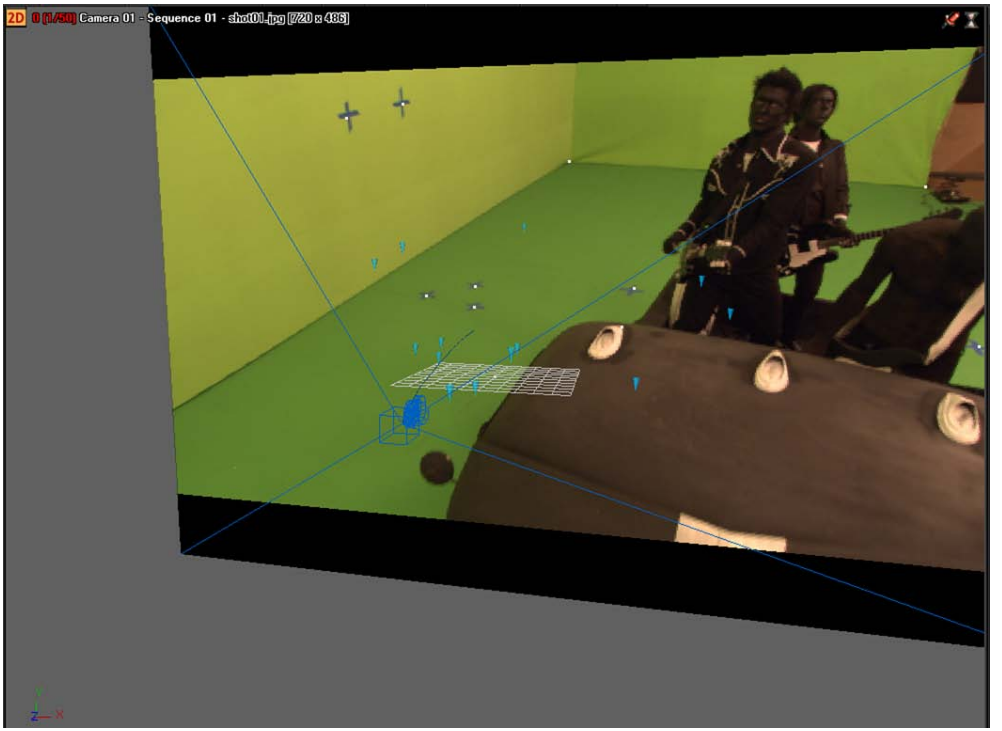
Find whole words only When on, the search does not consider partial matches. For example, when Find whole words only is on, if you search for the keyword model, modeling does not match.

Favorites

Displays a list of pages you've designated as favorites using the Add to Favorites button. You can remove a favorite page at any time by selecting the page and clicking the Remove selected from Favorites button.

Tutorials

Introduction



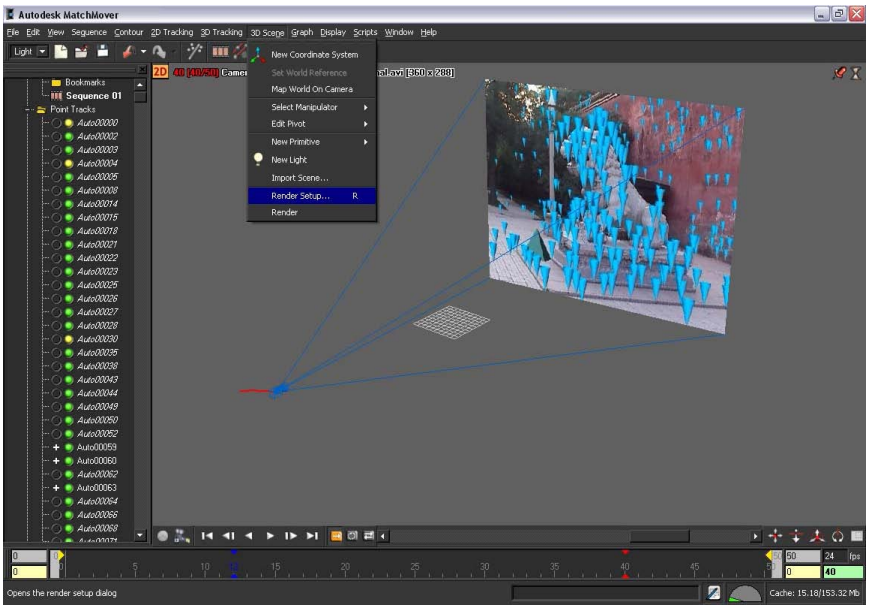
Autodesk MatchMover enables artists to track 3D camera data and motion from videos and film sequences, in order to more easily insert CG elements into a scene. MatchMover combines the ease of automatic tracking with the precise manual control of tracking points.

The lessons in this tutorial describe how to use MatchMover to perform basic matchmoving, which includes loading images sequences, tracking a sequence, and then exporting the tracked rendered 3D data to file that can be used in 3D animation and compositing programs. You will also learn how to create a track manually using supervised tracking and set up survey points.

This chapter includes the following lessons:

Lesson 1: Tracking an image sequence

Introduction



In this lesson you will learn how to track a sequence in 3D using MatchMover's automatic tracking engine, inspect the results, and export the result to one of MatchMover's supported file formats. The automatic tracking feature locates good tracking points in the image, and then tracks them through the sequence.

In this tutorial you will learn how to:

- Load an image sequence.
- Use the automatic tracker to compute the 3D camera path and the 3D scene.

- Navigate in the project with a 3D view to visualize and inspect the tracking results.
- Render a preview sequence.
- Export the tracking results to a supported file format.

Lesson setup

To ensure the lesson works as described, do these steps before beginning:

1. Start MatchMover and ensure that it is set to Light mode.

   To set MatchMover to Light mode, select Light from the MatchMover toolbar.

   Although this tutorial is designed for Light mode, it can be completed using MatchMover Full mode.

2. If you have not already done so, copy the `Tutorials` folder from its installation location to your a project directory.

   The `Tutorials` folder can be found in the `Help` folder of MatchMover's installation location: `Help/Tutorials`.

Loading the image sequence

The first step in matchmoving is to load the image sequence you want to track.

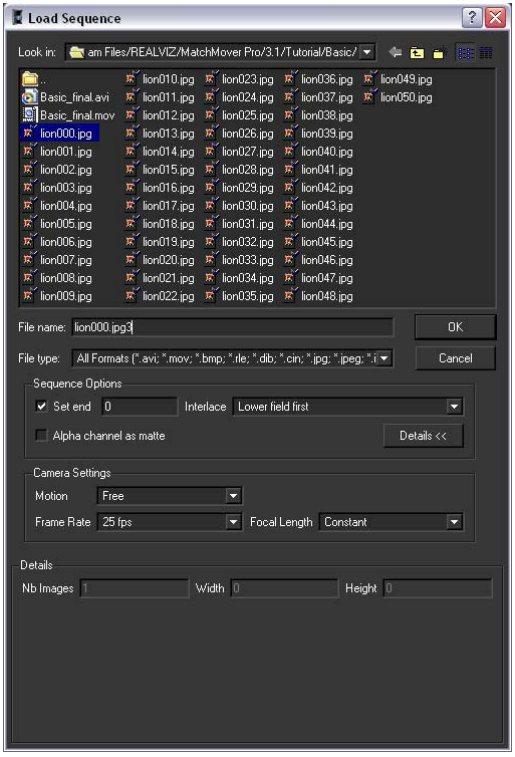
NOTE You can bypass this section of the lesson by openning`Basic_Sequence.mmf`. This file can be found in the `Tutorials/Basic` directory. You can then proceed to Running the automatic tracker on page 10.

To load an image sequence

1. Select File > Load Sequence or click the Load Sequence  icon in the toolbar.

   The Load Sequence window appears.

2 In the Load Sequence window, browse to the location of the MatchMover `Tutorials/Basic` directory, and select `lion000.jpg`, which is the first image in the sequence.



3 Click Details.

Information about the image sequence, such as its length as well as preview images, are displayed in the Details section of the Load Sequence window.

The video you use for this lesson is in the interlaced PAL format, which means you need to set MatchMover sequence options for this type of video.

4 In the Sequence Options section, select Lower field first from the Interlace drop-down list.

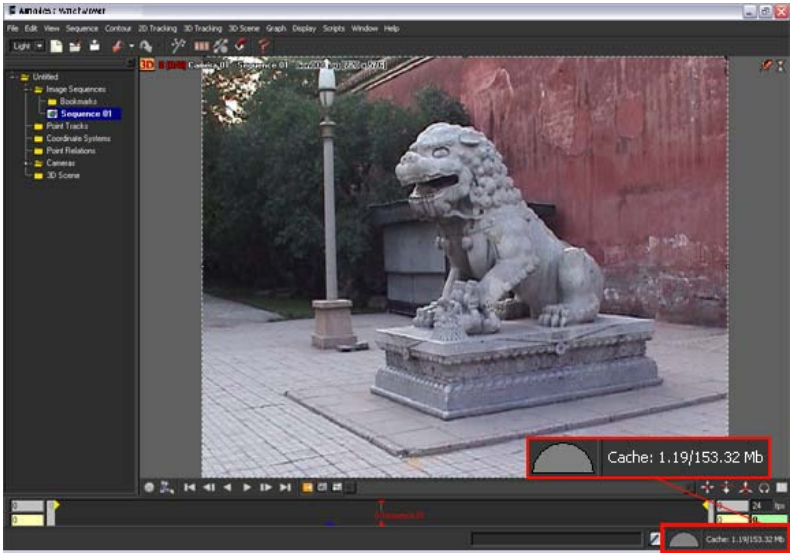
5 In the Camera Settings section, select 25 fps from the Frame Rate drop-down list.

Leave Motion set to Free because in this example, the camera does not follow any of the motion types specified in the list.

To play the image sequence

1 Select Sequence > Play or click the play button  which is in Play Sequence Toolbar at the bottom of the Workspace.

Note that when you play the beginning of the sequence it is slightly jerky. This is because the sequence is loading into your computer's RAM. After the images are in the cache, the sequence plays smoothly. The size of the current cache is displayed in the bottom-right corner of MatchMover user interface.



Since the image sequence is only 50 frames, it plays back too quickly to closely examine. Changing the play mode to PingPong will continuously loop the sequence back and forth, making it easier to check the sequence motion.

2 Select Sequence > Play Mode > PingPong or click the PingPong button  in the Play Sequence Toolbar.

3 To stop the playback, click the Stop button  or press Esc.

TIP To play the scene manually, you can press Ctrl, click anywhere in the image, and drag the pointer to the left or to the right.

4 To go back to the first frame, press Ctrl+Home (Windows) or Command+Home (Mac) or press  .

Running the automatic tracker

You can use the automatic tracking feature to have MatchMover select the best location of place track points in the image sequence.

NOTE You can bypass this section of the lesson by openning`Basic_Calibrated.mmf`. This file can be found in the `Tutorials/Basic` directory. You can then proceed to Checking the tracking results on page 12.

To run the automatic tracker

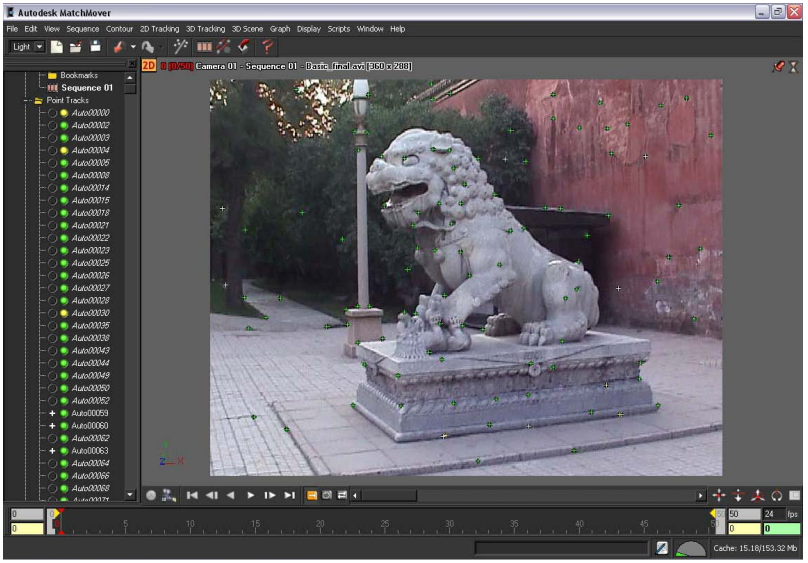
1 Select 2D Tracking > Automatic Tracking or click the Run the Automatic Tracking icon  .

The Automatic Tracking window appears listing the steps in the automatic matchmoving process.

2 Click Run.

Colored indicators display beside the option name to show you the status of each step.

After MatchMover has computed the camera path, a collection of 3D points are displayed as cross-hairs in the Workspace. The points are also represented by colored icons in the Project window in the Point Track > Auto Tracks folders.



The colors indicate the quality of the tracking, where green indicates good, yellow fair, and red bad tracking. Some grayed tracks have not been reconstructed, which means that MatchMover considered them unfit to calculate.

Checking the tracking results

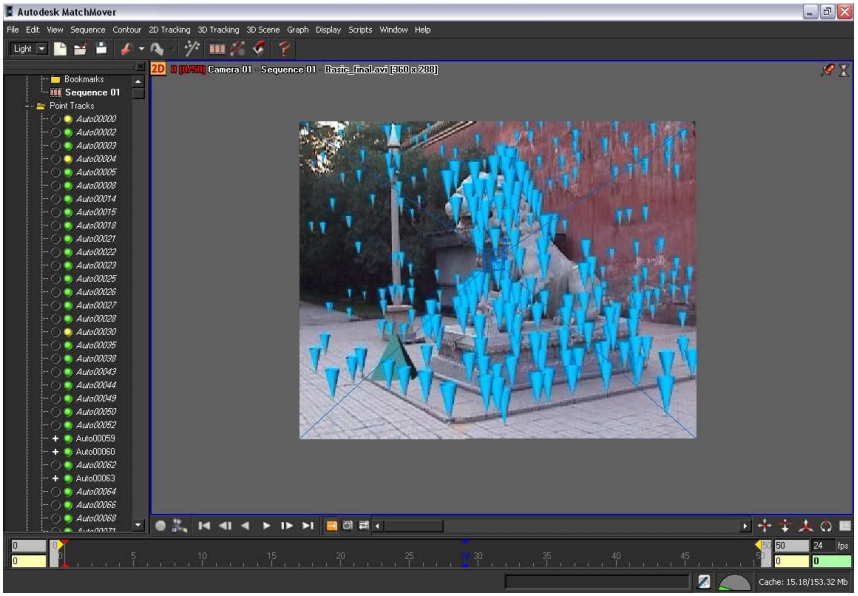
To check the results of the automatic tracking you can:

- View the track quality by looking at the cross-hairs superimposed on the Workspace, or by view the color icons in the Auto Tracks folder. Most of your reconstructed tracks should be green, a few yellow, and none red.
- View the reconstructed 3D scene, and check to ensure that it is consistent with the real scene.
- Render a video sequence where the 3D objects are superimposed on the image sequence and check to ensure that the integration is seamless.

To check the tracking results in 3D space

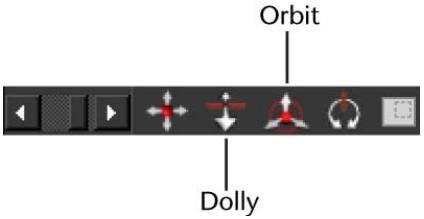
1. Click the 3D space icon  that is located in the top left of the workspace view.

MatchMover switches to 3D mode. The tracks are now displayed as 3D cones rather than cross-hairs.

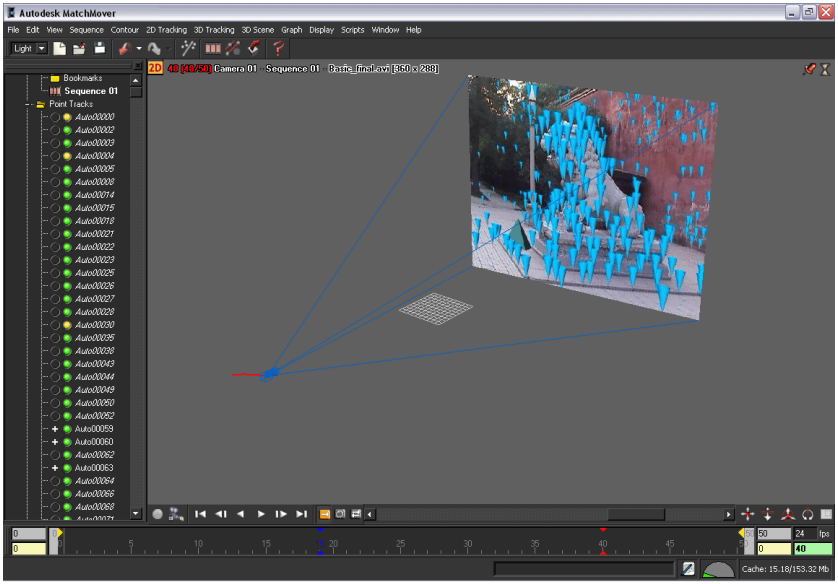


2 Use the following Navigation tools to examine the tracking:

- Click-hold the Dolly icon to move backward and forward in the space.
- Click-hold the Orbit icon to view the space in 360 degrees.
  When orbiting the camera, the 3D View automatically orbits around the selected 3D object, point cloud, or camera.



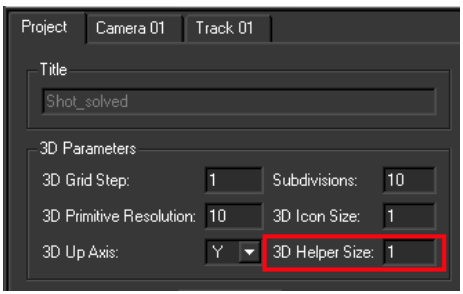
When you navigate in the 3D scene, you can recognize the different elements of the scene, such as the lamppost, statue and wall, as well as the camera path.



3 To center the view on a track, select it, then select View > Look At.

4 To view the Workspace through the computed camera with the image in the background, select View > Lock on Camera or click the  icon. When viewing the Workspace, you can use of the location of the 3D cones to judge the potential orientation of any elements that you might want to introduce into the scene.

5 If the 3D cones appear too big or small, you can change their size by selecting the Project tab in the Parameters window. Change the 3D Helper size value from 1 to 0.5.

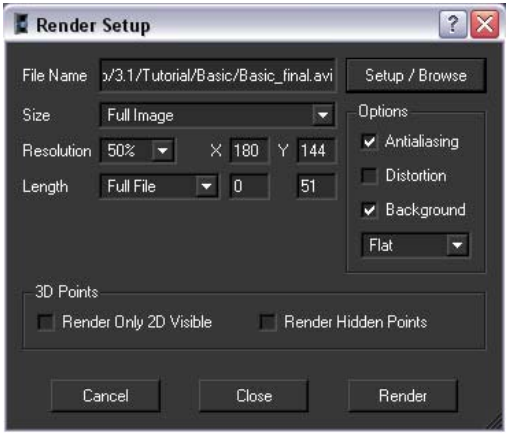


Rendering the tracked image sequence

After you have created and checked the quality of the 3D tracking in the Workspace, you can render the scene in a video format to further check its quality. You can also export the tracked sequence to a file format that you can open in your favorite 3D animation or compositing program.

To render the tracked sequence

1. Select 3D Scene > Render Setup.
   The Render Setup window appears.



2. In the Render Setup window, click Setup/Browse and do the following:
   - Type a file name for your rendered sequence.
   - From the File type list, select an output file format.
   - Click Save.
3. From the Resolution list, select 50%.
4. In the Options section, turn on Antialiasing.
5. Click Render.
   The Render window appears, displaying your rendered sequence with 3D cones composited on your original image sequence. With perfect tracking, the 3D cones should appear as if they were part of the scene. Otherwise, you would notice slight discrepancies between the motions of the real scene and the 3D elements.

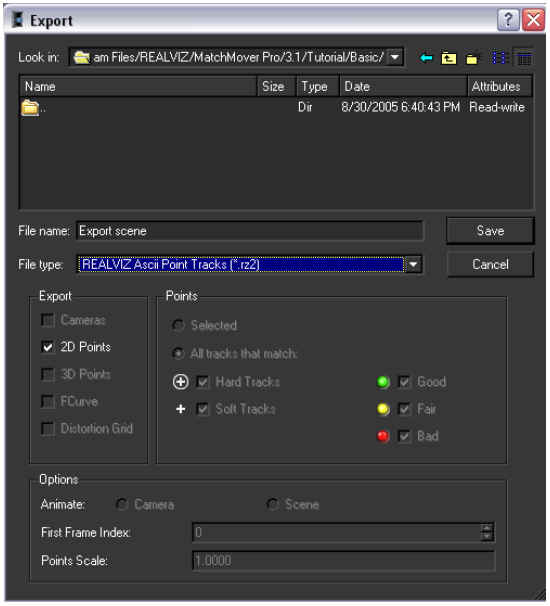
Now that you have automatically tracked a PAL video sequence and verified it by rendering it, you can export the results to a file that can be opened in your favorite animation or compositing software.

6 Select File > Export or click the  icon.

The Export window appears.

7 In the Export window, do the following:

- Type a name for your exported file
- From the File type list, select a format for you exported file. For example, to open your tracked image sequence in Maya, select Maya (*.ma).
- Click Save.



The image sequence is exported to the specified file format for use in your 3D animation or compositing program.

Beyond the lesson

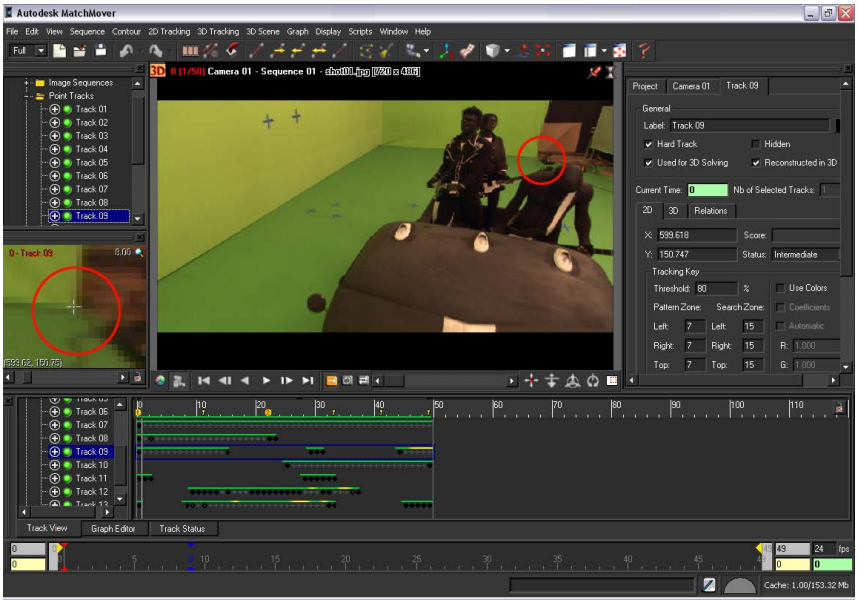
In this tutorial you learned how to:

- Load an image sequence.
- Use the automatic tracker to compute the 3D camera path and the 3D scene.
- Navigate in the project with a 3D view to visualize and inspect the tracking results.
- Render a preview sequence
- Export the tracking results to a file format that is supported by your favorite 3D animation or compositing program.

For more information and related techniques about MatchMover, refer to the MatchMover Help.

Lesson 2: Using supervised tracking

Introduction



For complicated scenes, it may be necessary to manually control the tracking process by editing or deleting tracks that were created by MatchMover's automatic tracking feature. Using a supervised tracking technique, you can place tracks manually by specifying the key points or then edit their location if required. Matchmover then generates a whole point trajectory based on the manually placed points.

In this lesson, you will learn how to place tracks manually in a scene using. The image sequence you use for the lesson was shot against a green background using professional equipment. The green background serves as a typical support for the actors, and would be replaced by virtual decors. The gray crosses on the background will help you accurately place tracking points in the scene.

The image sequence appears courtesy of Clear Ltd.

In this lesson you will:

- Load a sequence.

- Create and edit tracks manually.
- Launch the solver.
- Define a coordinate system.
- Add a 3D object to verify the tracked sequence.

Lesson setup

To ensure the lesson works as described, do these steps before beginning:

1. Start MatchMover and set it to Full mode.

   To set MatchMover to Full mode, select Full from the MatchMover toolbar.

2. If you have not already done so, copy the `Tutorials` folder from its installation location to your a project directory.

   The `Tutorials` folder can be found in the `Help` folder of MatchMover's installation location: `Help/Tutorials`.

Creating a point track

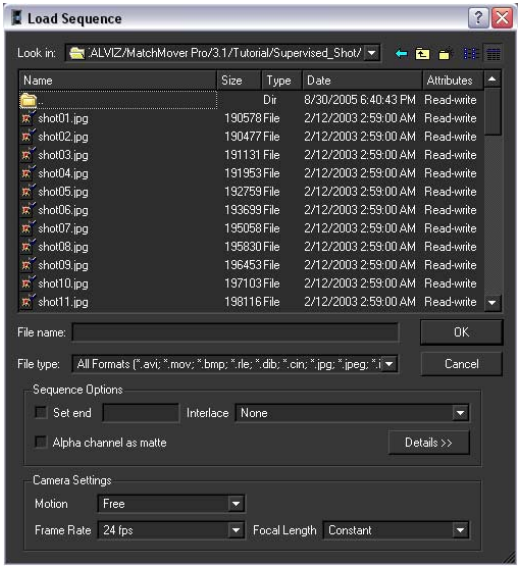
In matchmoving, creating a point track by manually placing points in a scene is also known as a hard track. The automatic process that you completed in lesson 1 is different from supervised tracking in that many tracks are handled at the same time and 3D coherency is used while tracking. For supervised tracking, only one track is handled at a time. Also, when supervised tracks are present before launching the automatic process, they are used in the 3D coherency checking.

NOTE You can bypass this section of the lesson by openning`Shot_tracked.mmf`. This file can be found in the `Tutorials/Supervised_Shot` directory. You can then proceed to Adding tracking points on page 24.

To load the image sequence

1 Select File > Load Sequence or click the Load Sequence  icon.
The Load Sequence window appears.

2 In the Load Sequence window, browse to the location of the MatchMover `Tutorials/Supervised_Shot` directory, and select `shot01.jpg`, which is the first image in the sequence.



3 Click OK.
MatchMover loads the sequence into the Workspace.

Placing a track point

When placing tracks manually, try to cover as much of the scene as possible. The tracked points should be points that can be accurately localized in the image and represent physical points such as markings, corners, or shadows.To help with the accuracy of the manually placed points you will place tracks on the most contrasted areas. In the image sequence, you will use the gray X's that appear on the green background of scene to help position your tracking points.

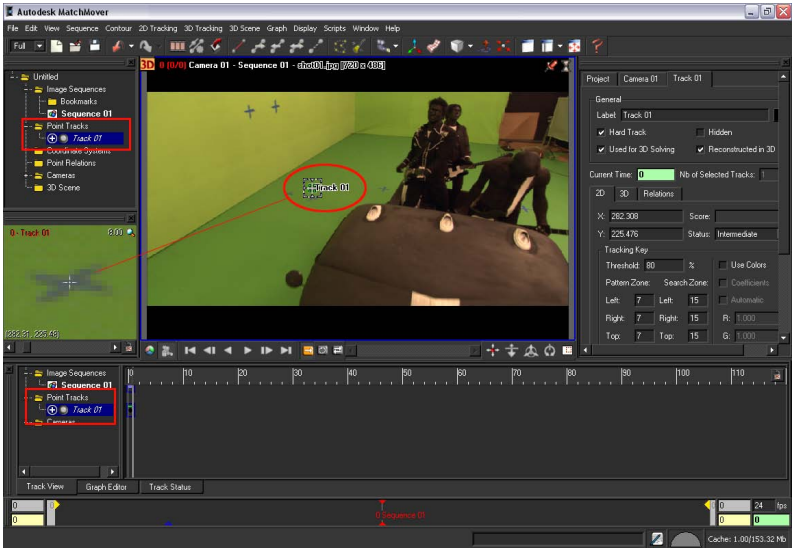
For more information about placing tracks, see Supervised 2D tracking on page 132.

To place a track point in the scene

1 Go to the first frame of the sequence.

2 Select 2D Tracking > New Track or click the New Track  icon.
When you drag the cursor over the Workspace, it changes to cross-hairs.

3 Position the cross-hairs near the one of the gray X's that appear in the scene. Use the location shown in the image below as a guide.



Use the Magnifier window view below the Project window to help you precisely position the location of the new point.

Corner areas are often good locations to place the track points. The extremity areas have less contrast and do not allow you to visually locate the point as precisely as the intersections and can introduce a higher risk of ending up with a “sliding” track point.

4 Click-hold the location of the new point.

A Magnifier window appears around the area you placed the point. This is another window you can use to help place the track point accurately.

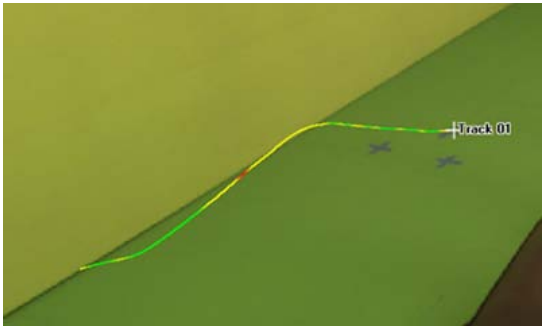
5 Release the mouse button to create the track point.

A window labeled *Track 01* appears in the Workspace. The presence of the window indicates that the track point is still selected.

6 With the track point selected, select 2D Tracking > Track Forward or click the  icon to run 2D tracking for your point.

While the point is being tracked, the Tracking Monitor window appears showing you the tracking progress.

After the point tracking is complete, its trajectory line appears on the image. You may notice that the trajectory line has green, yellow, and possibly, red segments. The red segments indicate areas where the tracking slides or is of low quality.



You can correct the sliding track by manually adjusting the point positions where the track has drifted significantly. In the next section of the lesson, you adjust the point positions to improve the tracking quality.

Editing a point track

To improve the quality of your hard track, you can adjust the location of a tracking point and re-run the tracking process.

To adjust tracking point positions

1. Using the time line controls, go to a frame where the track drifts.

   This is indicated by the red sections.

2. In the Workspace, click-hold the tracking point and move it in the direction that will improve the tracking such as closer to an inside corner of the gray X's.

   Use the Magnifier window that appear around the point to help you adjust the point's position.

3. Release the mouse button.

   Notice that when you release the mouse button, MatchMover clears the end of the trajectory. That is because the tracked data is no longer compatible with new position of the point. This means that you must re-compute the trajectory based on the new point position.

4. With the track point selected, select 2D Tracking > Track Forward or press F3, which is the Track Forward keyboard shortcut.

   MatchMover calculates a new trajectory for the track.

To make the track trajectory smoother, you can update the tracked data between the initial point and the point's new location by using bi-directional tracking.

5 Select 2D Tracking > Bidirectional or click the Run Track Full  icon.

You can check the smoothness of your edited track by centering your view on the current track.

6 Select View > Lock on Track or click the  icon.

7 Play the image sequence in PingPong mode by clicking  followed by  .

Notice that when the sequence plays back section of the sequence you have tracked, the view is locked to the motion of the edited track.

8 Stop the sequence playback by clicking the  icon.

9 To get a close-up view of the track, press Ctrl+Alt and drag the mouse up and down to zoom in and out of the Workspace view. If you are not satisfied with the quality of the track, adjust the point and run the tracking again.

TIP If you notice a jump in the trajectory, you can adjust the point position by pressing the arrow keys. Select Preferences > 2D Tracking to adjust the nudge step. Use shift to multiply the nudge step by 10. If needed, a key point is inserted at the current edited frame.

Adding tracking points

Adding more tracking points to your scene improves the overall quality of the tracking.

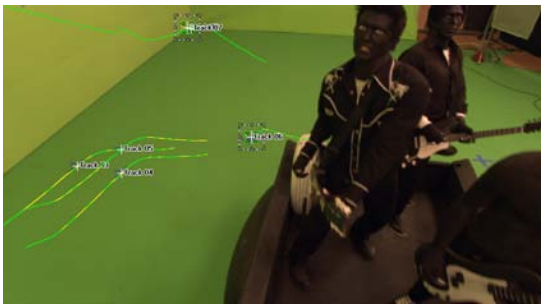
Open the file for the lesson

To ensure this lesson works as described, open the scene file named `Shot_tracked.mmf`. This file is in the `Tutorials` directory that you copied from

the MatchMover installation directory to a local directory: `Tutorials\Supervised_Shot\Shot_tracked.mmf`.

Supervised tracking

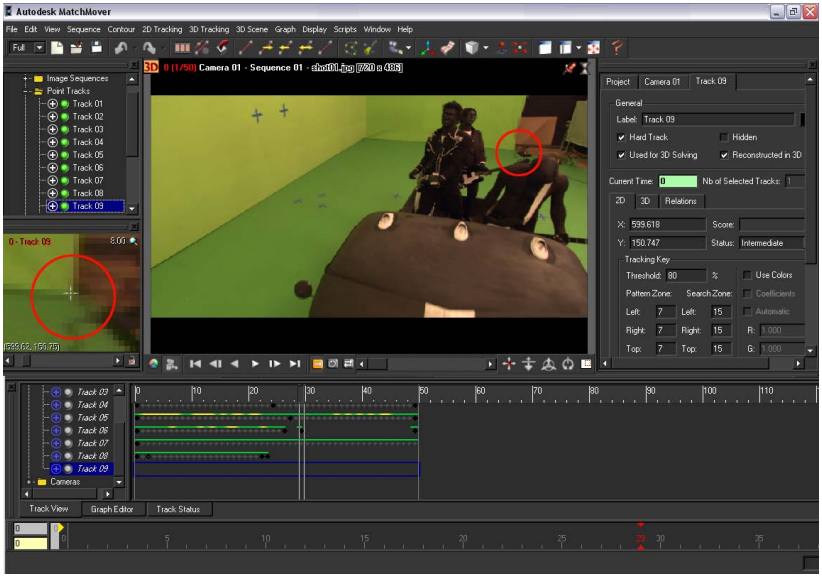
Eight tracks have been added to the image sequence. In this section of the lesson, you will add more tracking points starting with *Track 9*.



To make the tracking process quicker, you can use MatchMover's keyboard shortcuts to create the track and run the forward tracking.

To create a new track

1. Using the image below as a reference, place the mouse pointer in the location shown in the image below. Use the Magnifier window to help find the correct location for the tracking point.



2 Create the tracking point by pressing Shift+right-click.

The tracking begins then stop around frame 15. *Track 09* appears in the Workspace and is also added to the track points in the Project window.

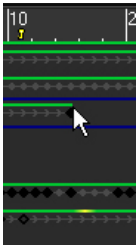
3 To run forward tracking press F3.

A window appears in the Workspace indicates that the tracking quality is too low for MatchMover to continue the trajectory.

4 Click OK.

The reason the tracking quality is so low is that the actor's body hides the area you want track in the sequence.

5 In the time line, double the last frame of the *Track 9* trajectory.

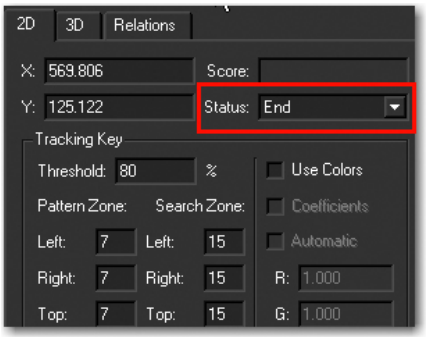


The Parameters window now displays the parameters for the tracked point under the *Track 09* tab.

Since the tracked point's trajectory cannot continue to be tracked, you can change the status of last frame by setting it to an end keyframe. This means that MatchMover will not track forward past this frame.

6 Select 2D Tracking > Set Key > End.

The End status of the keyframe is indicated in the *Track 9* Parameters window in the Status field.



7 With *Track 09* selected, advance the sequence one frame at a time by pressing Ctrl+right arrow key.

As you advance, the tracked point and its trajectory is hidden between frames 16 and 28, then re-appears at frame 29. Since the track is likely to disappear again, this time behind another obstacle, you can track the point frame-by-frame using the Step-tracking mode.

8 To use Step-tracking mode, press Alt+right arrow to continue tracking forward from frame 29.

At frame 31, a window appears indicating that the tracking quality is too low to continue tracking.

TIP Use the Magnifier window to get a better view of the obstacles that are hiding the *Track 09* trajectory path.

9 At frame 31, change the status of the keyframe to End by selecting 2D Tracking > Set Key > End.

10 Go to frame 44 and press F3 to run forward tracking.

Track 09 is now complete and set in the scene.

To check the quality of the track

1 Ensure that *Track 9* is selected in the Workspace.

2 Click the padlock icon  at the bottom right of the Magnifier window. This makes the Magnifier window the only active view.

3 Select View > Skip Untracked or click the  icon.

4 Play the image sequence in PingPong mode by clicking  followed by  .

Notice that MatchMover only plays the sections of *Track 09* that have been tracked. The frames that could not be tracked because of obstacles in the scene are not played.

5 Click the lock icon to make the Workspace window active again.

6 Select View > Skip Untracked so that all frames play when the sequence is played back.

Calibrating the camera

In MatchMover, a camera is characterized by its internal parameters such as Principal Point, Focal Length, Pixel Aspect Ratio, and Distortion. In some cases, you may already have information about the camera. For example, you may know that it is a 24 ×36 mm film back camera with a 35 mm lens. You can then input this information into MatchMover before launching the camera tracker. For this lesson, you will calibrate the camera using MatchMover's default values. This process of calibrating a camera involves reconstructing

the 3D points corresponding to the 2D tracks and computing the camera path for all the sequences or frames and all the objects in one solve.

NOTE You can bypass this section of the lesson by openning `Shot_solved.mmf`. This file can be found in the `Tutorials/Supervised_Shot` directory. You can then proceed to Creating a coordinate system on page 29.

To calibrate the camera

1. Run the calibration by selecting 3D Tracking > Solve For Camera or by clicking the Solve For Camera  icon.
   The camera is calibrated.

2. Click the 3D space icon  that is located in the top left of the Workspace view.
   The view switches to 3D mode and the tracks are now displayed as 3D cones rather than cross-hairs. A camera icon is placed in the Workspace, which represents the camera you calibrated.

3. Select View > Lock On Camera or click the Lock on Camera  icon.

4. Play the sequence to check the tracking.
   Notice the image sequence plays back from the perspective of the camera.

Creating a coordinate system

MatchMover manages a set of user-defined coordinate systems with respect to the cameras and 3D points in the Workspace. If no coordinate system is specified, MatchMover chooses an arbitrary one. You can define a coordinate system in order to facilitate the manipulation of your exported project in a 3D package. If no point relations have been set up, MatchMover aligns the coordinate system on the computed position of the camera for the first frame; the default is the camera looking towards Z and Y as Up axis, but this changes according to your project's 3D parameters if you selected a different up axis.

NOTE You can bypass this section of the lesson by openning `Shot_coordsys.mmf`. This file can be found in the `Tutorials/Supervised_Shot` directory. You can then proceed to Add a 3D object on page 32.

Open the file for the lesson

To ensure this lesson works as described, do the following:

1. Ensure that it is set to Full mode.
   To set MatchMover to Full mode, select Full from the MatchMover toolbar.
2. Ensure that MatchMover is set to 3D mode.
   To switch MatchMover to 3D mode, click the 3D space icon 

that is located in the top left of the Workspace view. If a 2D space icon 

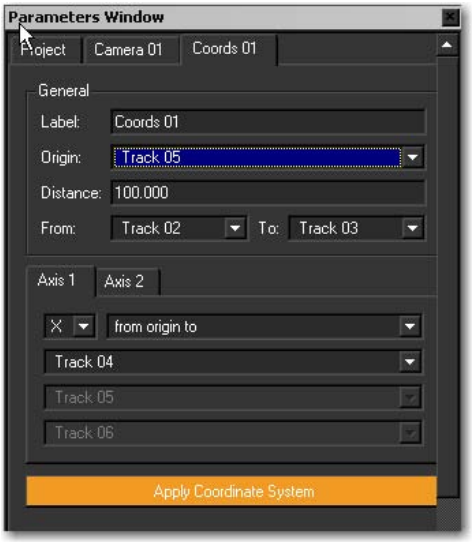
appears instead, then MatchMover is already in 3D mode.
3. If you have not already done so, copy the `Tutorial` folder from its installation location to your a project directory.
4. Open the scene file named `Shot_solved.mmf`. This file is in the `Tutorials` directory that you copied from the MatchMover installation directory to a local directory: `Tutorials\Supervised_Shot\Shot_solved.mmf`.

Setting up the coordinate system

To set up the coordinate system

1. In the Project window, right-click the Coordinate Systems folder and select New Coordinate System from the pop-up menu.

   A grid and coordinate indicators appear in the Workspace.
2. In the Parameters window, click the *Coord 01* tab.
   For your new coordinate system values, you will use Track 05 as the origin. This point is the center of the grid and floor of the scene.
3. In the General section, select Track 05 from the Origin list.



4 To set the grid value, in the General section, do the following:

- In the Distance field, type 20.00.
  This value defines the distance between two points in the scene.
- From the From list, select Track 07.
- From the To list, select Track 09.

These two points provide tracking locations in the corners of the room, making them well suited for defining the boundaries of the coordinate system.

5 Click the Axis 1 tab and do the following:

- Select Y from the X, Y, and Z list.
- Select normal to 3 points from the list to the right of Y.
- For the three points, select Track 03, Track 04, and Track 05 from the lists located under Y.

These settings create a Y-based coordinate system using three points that are located on the ground of the scene.

6 Click the Axis 2 tab and do the following:

- Select Z from the X, Y, and Z list.
- Select through 2 points from the list to the right of Z.

- For the two points, select Track 01 and Track 02 from the lists located under Z.

These settings create a Z-axis as the second axis which is based on the crosses on the wall of the scene background.

7 Click Apply Coordinate System to validate your coordinate settings.

The defined coordinate system appears in the Workspace.

Add a 3D object

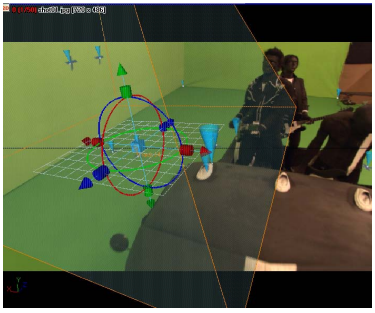
Now that you have defined a 3D coordinate system in MatchMover, you can import an object into the Workspace and check its behavior in the scene.

NOTE You can bypass this section of the lesson by openning`Shot_object.mmf`. This file can be found in the `Tutorials/Supervised_Shot`directory.

To add a 3D object

1 Select 3D Scene > New Primitive > Pyramid or click the  from the primitive list located on the Toolbar.

The pyramid primitive appears in the Workspace at the origin of the coordinate system. A Pyramid tab appears in the Parameters window displaying the pyramids position and scale.

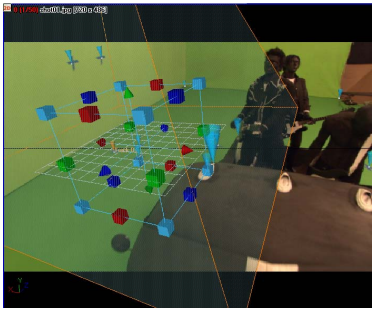


The pyramid is too large for the scene. You can make the pyramid smaller by using MatchMover's scaling tools.

2 If the pyramid is not selected, select it now by clicking it in the Workspace or by clicking Pyramid in the Project window under the 3D Scene folder.

3 Press the Tab key to select the scaling tools.

The scaling tools appear as a series of light blue, dark blue, green, and red cubes surrounding the pyramid.



4 Click-drag one of the light blue cubes inward until the Scale X, Y, and Z values are 0.48, or until the base of the pyramid is on the grid.

Notice that as you drag the cursor, the X, Y, and Z values are scaled uniformly.

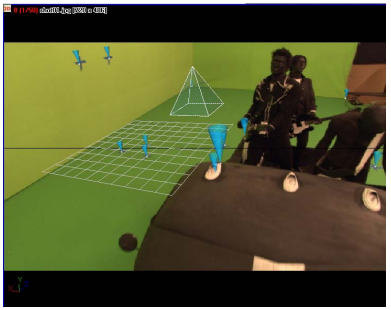
5 Play the sequence in PingPong mode.

Notice that the tip of the pyramid is out of the camera view. You can use the move tool to change the pyramid's position so that it remains in the camera view throughout the sequence.

6 Select the dark blue arrow and move the pyramid along the Z-axis toward the front of the scene until its Pos Z value is about -4.20.

7 Play the sequence in PingPong mode.

Notice that the pyramid remains in the camera view throughout the sequence.



You can now export the sequence and verify its tracking quality in your favorite 3D animation or compositing program.

8 Select File > Export to export the scene to a file format supported by your 3D animation or compositing program.

The Export window appears.

9 In the Export window, do the following:

- Type a name for your exported file.
- From the File type list, select a format for you exported file.
  For example, to open your tracked image sequence in Maya, select Maya (*.ma).
- Click Save.

The image sequence is exported to the specified file format.

Beyond the lesson

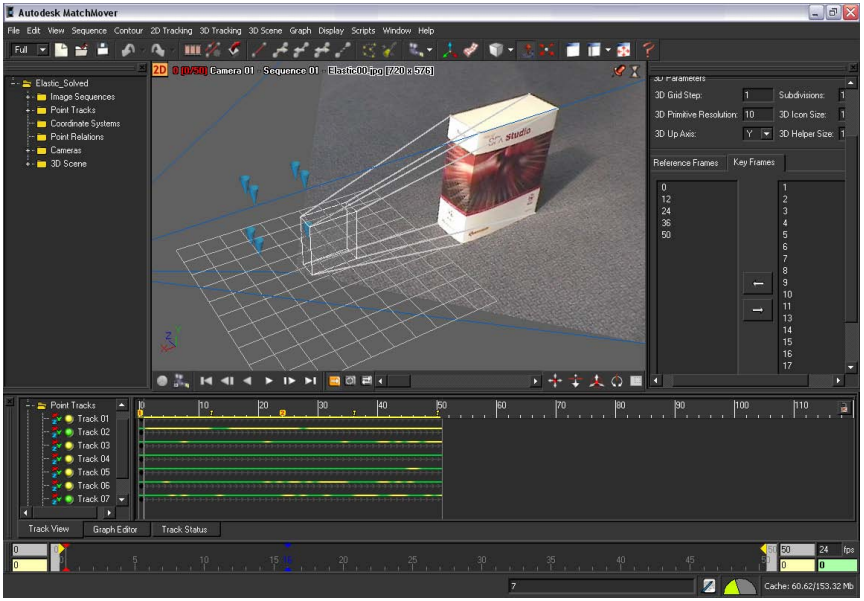
In this lesson you learned how to:

- Create and edit tracks manually.
- Launch the solver and calibrate a camera.
- Create a new coordinate system.
- Add a 3D object to verify the tracked sequence.

For more information and related techniques about MatchMover, refer to the MatchMover Help.

Lesson 3: Object-based tracking

Introduction



In this lesson, you will learn how to track an object, such as an image plane in MatchMover using a 3D model of it. This is a useful technique in situations such as the following:

- Augmenting a real set for which some 3D information is available as manual measurements or CAD data.
- Matchmoving characters from a Cyberware scan.
- Tracking complex shots of a set using data from an active scanning device (LIDAR).

Using this technique ensures that, in any case (even with low or zero parallax), the camera path will be exactly consistent with the 3D geometry of the tracked element.

The image sequence you will use in this lesson was shot using a hand-held DV camcorder.

In this lesson you will learn how to:

- Import a 3D mesh.
- Create tracks and survey points attached to vertices of the mesh, using the "elastics" feature.

Lesson setup

To ensure the lesson works as described, do these steps before beginning:

1. Start MatchMover and set it to Full mode.

   To set MatchMover to Full mode, select Full from the MatchMover toolbar.

2. If you have not already done so, copy the `Tutorials` folder from its installation location to your a project directory.

   The `Tutorials` folder can be found in the `Help` folder of MatchMover's installation location: `Help/Tutorials`.

Importing the 3D mesh

Load the footage

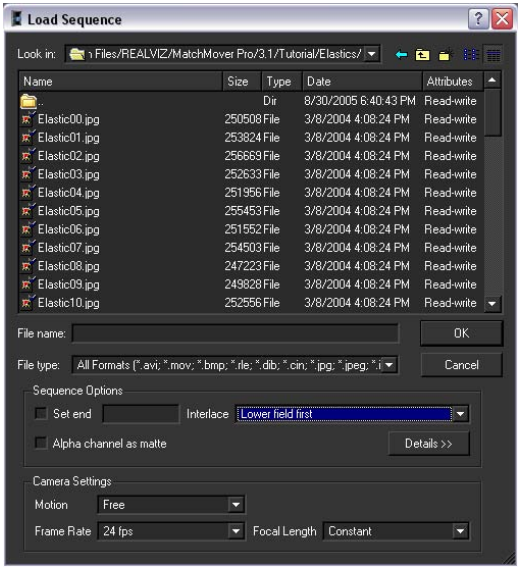
NOTE You can bypass this section of the lesson by openning`Elastic_Import_Scene.mmf`. This file can be found in the `Tutorials/Elastics` directory. You can then proceed to Set up the trackers and the survey points on page 39.

To load the image sequence

1. Select File > Load Sequence or click the Load Sequence  icon.

   The Load Sequence window appears.

2 In the Load Sequence window, browse to the location of the MatchMover `Tutorials/Elastics` directory, and select `Elastic00.jpg`, which is the first image in the sequence.



3 In the Load Sequence window, under Sequence Options, set Interlace type to Lower field first.

4 Under Camera Settings, set Frame Rate to 24 fps (Frames Per Second).

Leave Motion set to its default setting of Free.

5 Click OK.

Import the 3D mesh

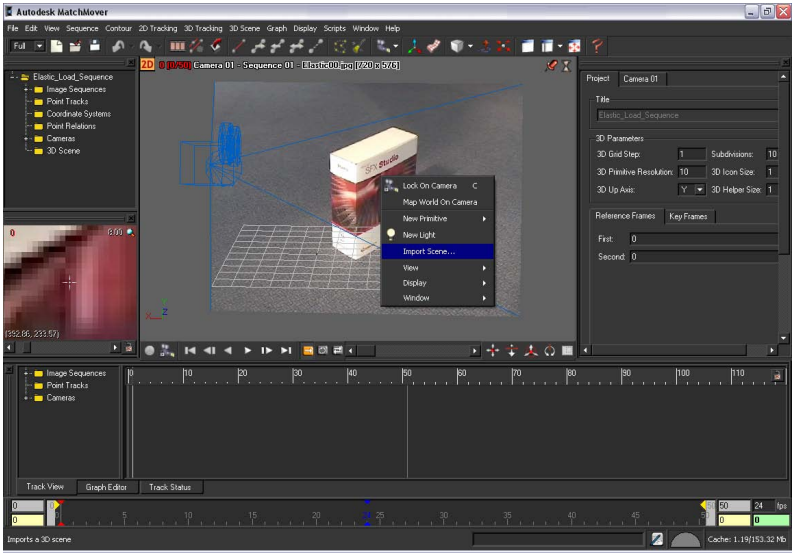
To import the 3D mesh

1 Click the 3D space icon 

that is located in the top left of the Workspace.

The view switches to 3D mode. A camera icon and grid is placed in the Workspace.

2 Select File > Import, or right-click in the Workspace and select Import Scene from the pop-up menu.

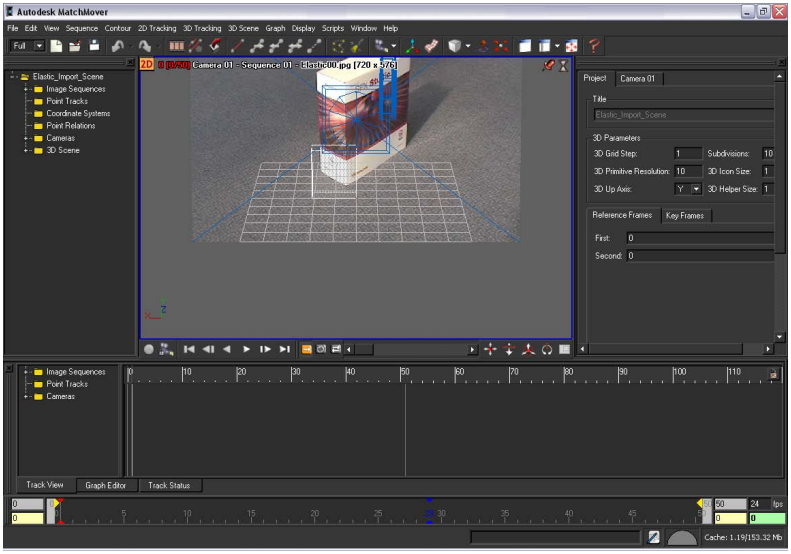


The Import Object window appears.

3 In the Import Object window, select Wavefront Ascii Model (*.obj) from the Files of Type list.

4 Browse to the location of the `Tutorial/Elastics` directory, and select `Box.obj`.

A 3D mesh of the box appears, in wireframe, in front of the image plane. This mesh will now be used as a reference for the 3D tracking. This ensures that the solution will be consistent with this geometry even though this shot holds little parallax.



Set up the trackers and the survey points

You can use survey points to analyze the results of 3D tracking and to isolate specific frames or points where adjustment may be necessary.

NOTE You can bypass this section of the lesson by opening `Elastic_SetUp_Elastics.mmf`. This file can be found in the `Tutorials/Elastics` directory. You can then proceed to Solve and check the tracking results on page 43.

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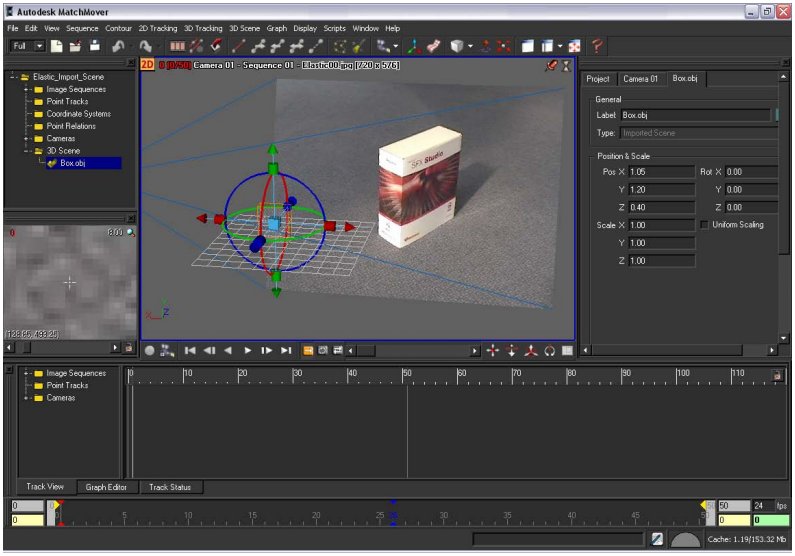
1 Using the Pan and Dolly controls, make sure both the imported 3D object, which represents the shape of the box, and the image plane are clearly visible.

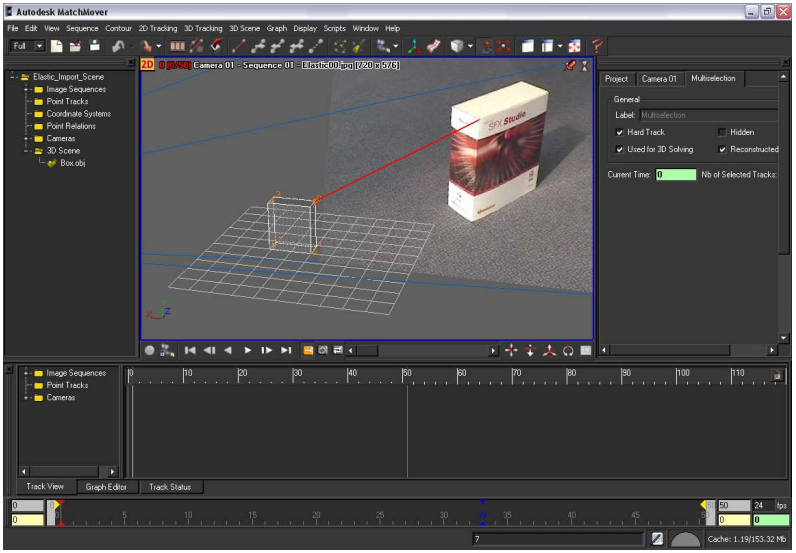
For example, set up your viewing position and angle similar to the image below.



2 Make sure that the Magnifier window is open by selecting Window > Magnifier Window.

3 Click-hold the vertex located at the top right corner of the 3D object and move the cursor to the position of the same corner in the image plane.

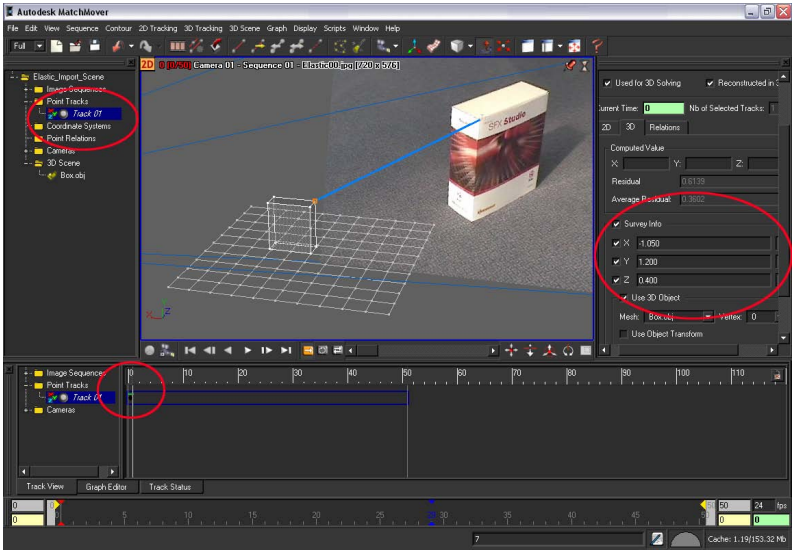
As you drag the curser toward the image plane, a red elastic line follows, joining the selected vertex and the image plane.



NOTE If you want to abort the operation while dragging the cursor, drag the cursor out of the image plane. The elastic line becomes dashed, meaning nothing will happen when you release the mouse button.

4 Release the mouse button.

The elastic is now blue and a new track, Track 01, is created with a point in the current frame (visible in the track view).



Survey point information issued from the selected vertex is automatically associated to the track. You can see this information in the Parameters window under the Track 01 tab. Click the 3D tab and look in the Survey Info section.

5 If necessary, you can adjust the position of the tracking point by clicking it in the Magnifier window.

6 Run forward tracking on the point by pressing F3.

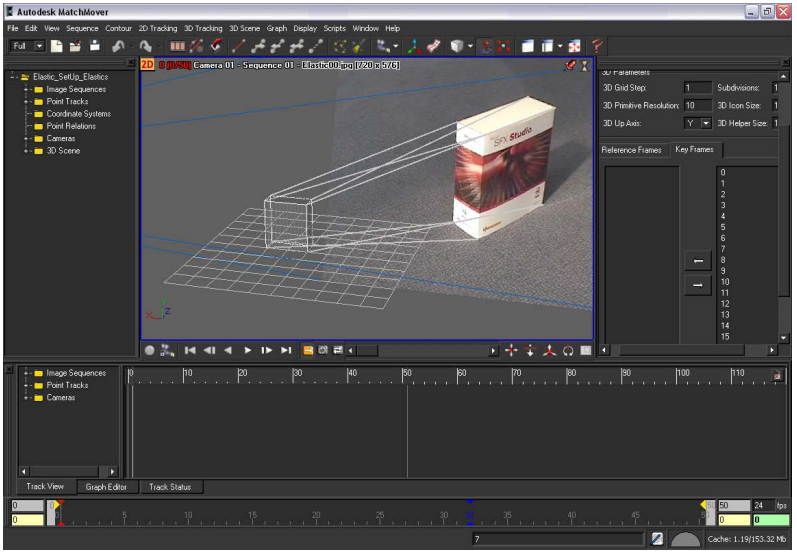
You can check the quality of the new track by playing the sequence.

7 Press F2 to play the sequence.

To get a close-up view of the tracking point, you can lock the sequence play to the Magnifier window. See Supervised 2D tracking on page 132.

8 Go to the first frame and repeat steps 3 to 7 for all the corners of the box.

Your project should now look similar to the image below.



NOTE If needed, you can change the viewpoint to better view the 3D object's vertices and locations on the image plane. You can move and rotate the object in the Workspace by selecting it and using the object manipulator. The transform you apply to the object will not be used in the survey information, unless you specify it by turning on Use Object Transform in the Survey Info section tab of the track Parameters window.

Solve and check the tracking results

To solve and check the tracking results

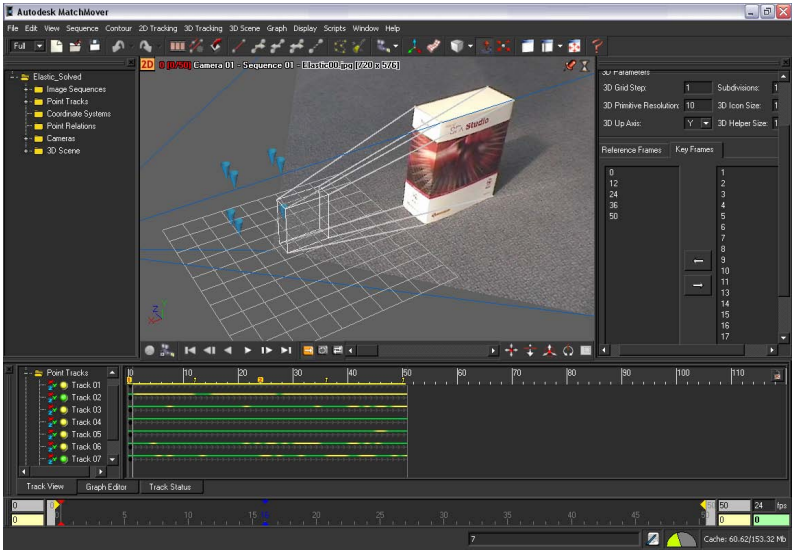
1 Select 3D Tracking > Solve For Camera or press F9.

After the camera completes the solve, blue cones appear at the tracking points on the 3D object and the new tracks appear in the Track window.

When you look in the Track window, notice that some of your new tracks have yellow segments, indicating that acceptable, but not good tracking. This occurs because the constraints induced by the 3D points are quite strong, while the footage quality does not allow the points to reach a high accuracy on the 2D points locations.

2 Select View > Lock on Camera.

The Workspace view now displays the cameras perspective.



3 Press F2 to play the sequence and check the alignment of the mesh with the image.

Beyond the lesson

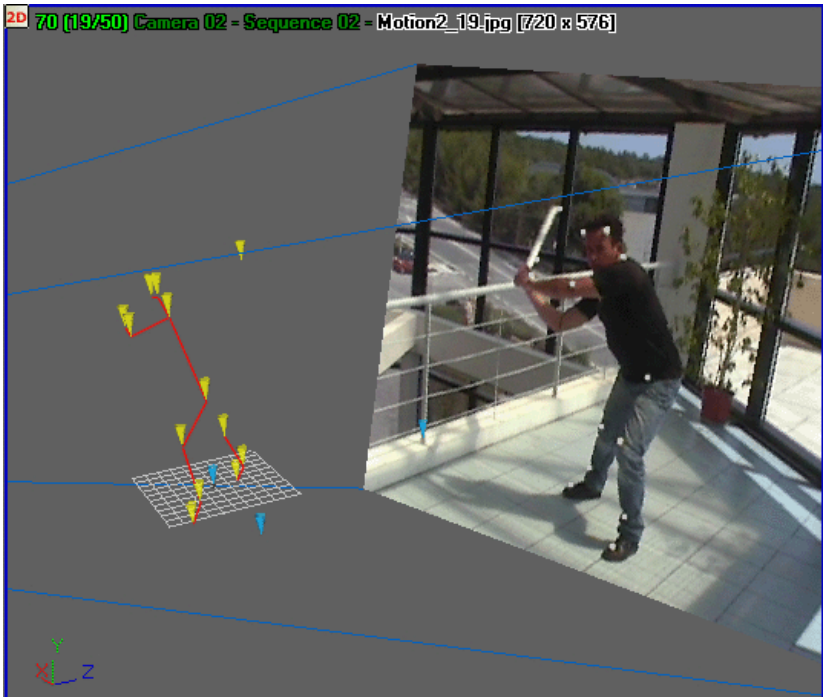
In this lesson you learned how to:

- Import a 3D mesh.
- Create tracks and survey points attached to vertices of a mesh, using the “elastics” feature.

For more information and related techniques about MatchMover, refer to the MatchMover Help.

Lesson 4: Motion capture

Introduction



In addition to conventional matchmoving, such as automatically capturing the 3D camera paths from 2D live-action video sequences, you can use Autodesk MatchMover to perform motion capture. Motion capture is the process of tracking, in 3D, the motion of non-rigid objects such as a human body, face, or a piece of cloth.

In this lesson, you will capture the motion of an animated character from two synchronized videos sequences. The sequences were captured as DV video using two static cameras. This provides you with the basic setup required for motion capture.

In this lesson you will:

- Create a motion capture project.
- Synchronize two video sequences.

- Create motion tracks for two synchronized video sequences.
- Calibrate the camera to obtain camera parameters.
- Build a skeleton line representation of an actor's motion.

Lesson setup

To ensure the lesson works as described, do these steps before beginning:

1. Start MatchMover and ensure that it is set to Full mode.

   To set MatchMover to Full mode, select Full from the MatchMover Toolbar.

2. If you have not already done so, copy the `Tutorials` folder from its installation location to your a project directory.

   The `Tutorials` folder can be found in the `Help` folder of MatchMover's installation location: `Help/Tutorials`.

Synchronizing the sequences

Load two sequences

The first step in synchronizing the video sequences for motion capture is to load both sequences into MatchMover.

NOTE You can bypass this section of the lesson by opening `Load_sequences.mmf`. This file can be found in the `Tutorials/Mocap` directory. You can then proceed to Synchronize the sequences on page 47.

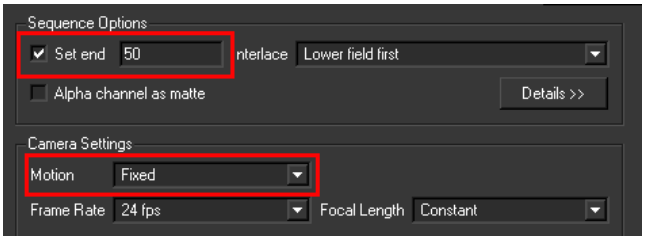
To load the image sequences

1. Select File > Load Sequence or click the Load Sequence  icon.

   The Load Sequence window appears.

2 In the Load Sequence window, browse to the location of the MatchMover `Tutorials/Mocap` directory, and select `Motion1_00.jpg`, which is the first image in the first sequence.

3 In the Load Sequence window, set the following:



- In the Sequence Options section, select Lower field first from the Interlace drop-down list.
- In the Camera Setting section, set Motion to Fixed.
  This setting will impose a constraint attached to the camera, representing a static camera.
- Set Frame Rate to 25.

4 Load the second sequence by repeating steps 1 to 3.

In the Load Sequence window, browse to the location of the MatchMover `Tutorials/Mocap` directory, and select `Motion2_00.jpg`, which is the first image in the second sequence.

The two sequences are represented by different colors in the Track View and Project windows.

Synchronize the sequences

Because you need to adjust these sequences to the same time reference, you will synchronize them by specifying a synchronization tick. To do this, you need to identify a visible event that you can easily see in both image sequences. For example, while you are shooting the sequences, you can use a specific device, such as a flash or a clapperboard, to create the event.

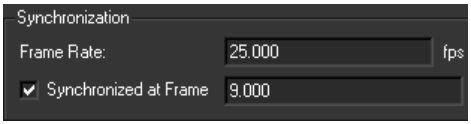
NOTE You can bypass this section of the lesson by opening `Synchronize_sequences.mmf`. This file can be found in the `Tutorials/Mocap` directory. You can then proceed to Creating motion tracks on page 49.

For this lesson, you can use the instant the actor's left foot begins to touch the floor. In *Sequence 01*, it occurs at frame 9 (9/50) and for *Sequence 02* it

occurs at frame 58 (7/50). You can see this information displayed on the top-left corner of the image viewport.

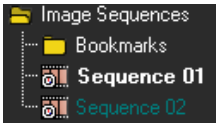
To synchronize the sequences

1. In the Project window, click *Sequence01*.
2. In the Parameters window, in the Synchronization section, turn on Synchronized at Frame and set it to 9.

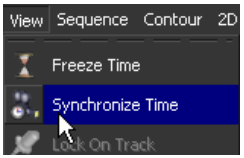


3. Repeat steps 1 and 2 for *Sequence02*, setting the Synchronized at Frame to 7.

Notice that in the Project window the sequence icons have changed, indicating that they each have a specified synchronization frame.



4. To change the workspace viewport so that you can see both sequences at the same time, from the Toolbar, click  icon and select Two Side by Side from the list.
5. Right-click the left viewport and select Synchronize Time from the pop-up menu.



The information displayed in the top-left corner of this viewport is now displayed in bright green, meaning it will update its own time using the synchronization information specified.

6 Right-click the right viewport and select Synchronize Time from the pop-up menu.

7 With the right viewport still active, select any frame between 51 and 101 in the Time line.

You can now play the sequence from this point in the Time Line to check that the sequences are synchronized.

Click the  icon to play the sequence.

When you look at the start of *Sequence 02* at frame 51 in the right viewport, notice in the left viewport that *Sequence 01* is at frame 2. It is this difference that allows us to have a good synchronization between the sequences.

Creating motion tracks

In this section of the lesson, you create a motion track of the actor's movements.

NOTE You can bypass this section of the lesson by opening `Motion_solved.mmf.mmf`. This file can be found in the `Tutorials/Mocap` directory. You can then proceed to Finalizing your motion capture project on page 53.

The first step in this process is to create a new point track group that you will use to place the actor's tracks.

To create a new point track group

1 In the Project window, right-click the Point Tracks folder and select New Group from the pop-up menu.

2 In the Parameters window, click the *Group 01* tab.

3 In the Label field, select *Group 01*and type *Actor*.

4 In the Options section, select Non-rigid (motion capture) from the Motion list.

This option specifies that the point track belonging to the new group will be for the motion of non-rigid objects.

Creating point tracks

In this section of the lesson, you place track point on markers that are attached to the actor. There are 18 markers attached to the actor, but for this section of the lesson, you use only six for your tracking points. When creating a motion track, you must place your track points on the same marker in both sequences. For example, if you place Track 01 on the white marker located on the right side of the actor's head in *Sequence01*, you must also place Track 01 on the same marker in *Sequence02*.

Be aware that some tracks may need manual adjustment as can be the case when using supervised tracking. For example, in a few of the frames, MatchMover confuses the motion of the actor's saber with the motion of the markers on the actor's leg and includes the saber's motion in the track.

The easiest markers to track in both sequences are located on the actor's head and on the legs. In all cases, try to choose the most visible markers in your sequences.

For information about supervised tracking, see Lesson 2: Using supervised tracking on page 18.

To create the track points

1. Go to frame 51 in the Time Line.

   The left viewport now displays the first frame of *Sequence 01*and the right viewport now displays the first frame of *Sequence 02*.

2. Select 2D Tracking > New Track or click the New Track  icon.

   When you drag the cursor over the Workspace, it changes to cross-hairs.

3. In *Sequence 01*, position the cross-hairs over the white mark located on the right side of the actor's head.

   Use the Magnifier window view below the Project window to help you precisely position the location of the new point.

4. Click to create Track01 for *Sequence 01*.

5 In *Sequence 02*, position the cross-hairs over the same marker, and click to create Track01 for *Sequence 02*.

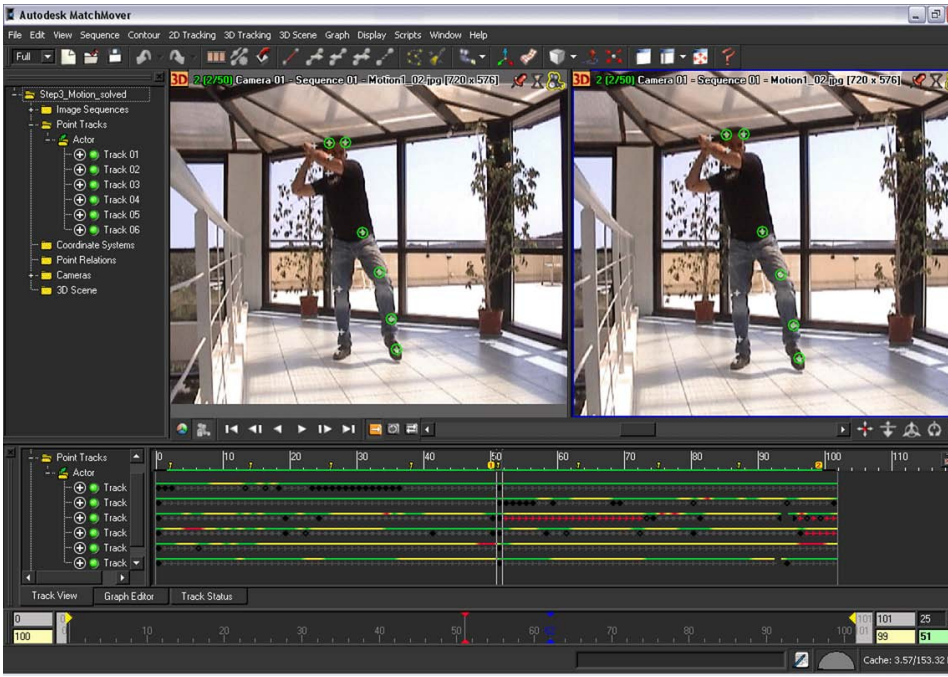
Use the locations shown in the image below as a guide.

Sequence01 Sequence02

6 With the track point selected, select 2D Tracking > Track Forward or click the  icon to run 2D tracking for your points.

7 Using steps 2 to 6, create five more track points.

Your project should look similar to the one in image below.



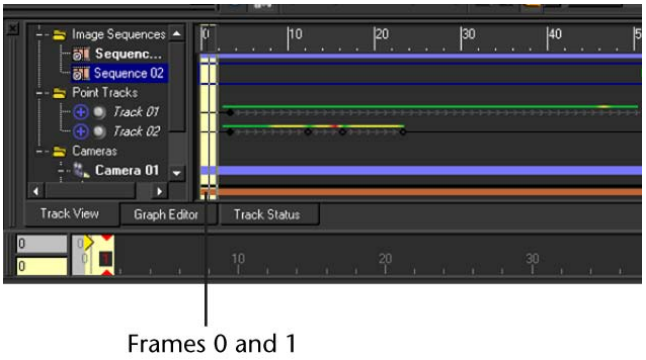
Performing an initial solve

Before you can perform the camera solve, you must remove the two-frame shift between the two sequences.

The first two frames (0-1 in the Time Line) only appear in *Sequence 01*, and the last two frames (100-101 in the Time Line) only appear in sequence *Sequence 02*. Since no 3D information can be derived for these frames, you need to specify that the frames are not solved.

To solve for the camera

1 In the Track View, Shift-select the time interval of the first two frames (0 and 1) of *Sequence 01*.



2 Right-click in the Track View and select Set Frames > Do Not Solve from the pop-up menu.

3 Repeat steps 1 and 2 for *Sequence 02*.

For *Sequence 02*, select the time interval of the last two frames in the sequence (100-101).

4 Deselect the time interval by Shift+right-clicking in the Track View.

5 Solve for the camera by selecting 3D Tracking > Solve For Camera or by clicking the Solve For Camera  icon.

The camera is now calibrated.

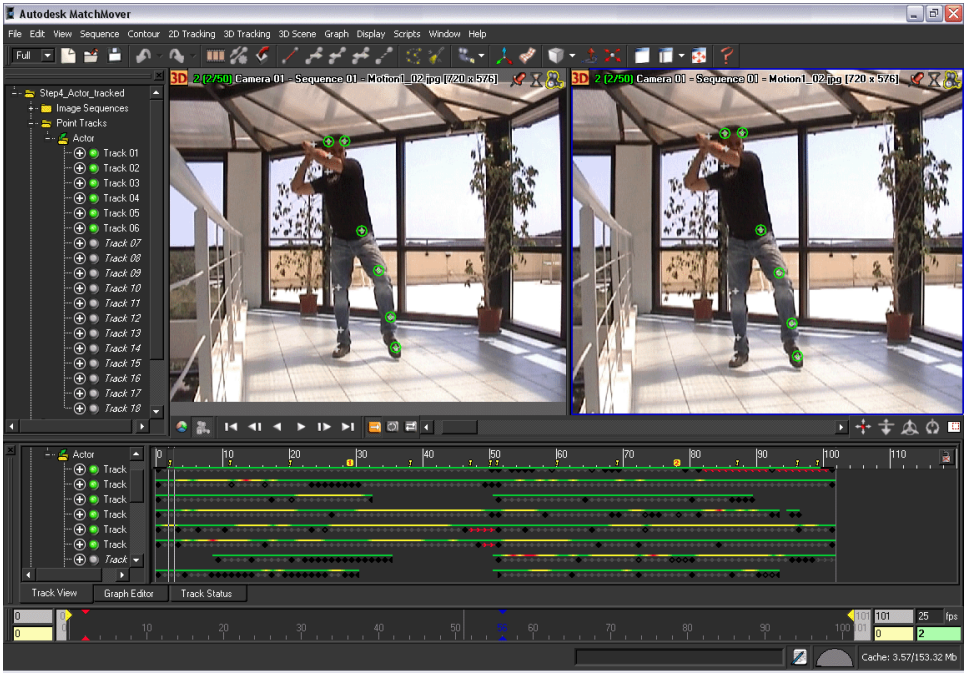
Finalizing your motion capture project

In this section of the lesson, you will add three tracks that correspond to points in the scene's static background. This is the minimum number of points required to define a coordinate system. Creating these tracks defines a 3D coordinates with respect to a world coordinate system attached to the background, which is very useful in motion capture. This step might not be necessary if all you need is to compute the 3D trajectories with respect to an unspecified coordinate system

In the last step of the lesson you will create *skeleton lines* which will better display the motion captured and of the tracked scene.

Since there are 18 markers attached to the actor, each potentially a track point, you can either continue adding tracks to your current project, or you can open `Actor_tracked.mmf` which has tracks already created for all 18 markers. This file can be found in the `Tutorials/Mocap` directory.

You can also start this section of the lesson using `Motion_solved.mmf`. In this file, six markers have been tracked. This file can be found in the `Tutorials/Mocap` directory.



If you want to add the tracks yourself, do so before continuing the lesson.

To create point tracks in the background

1. In the Project window, select the Point Tracks folder.

   Since the point tracks that you will create for the background are for static, rigid objects, selecting the Point Tracks folder ensures that your new point tracks are not added to the *Actor* Point Tracks folder.

2. In the first frame of *Sequence01*, place a track point on the floor of the scene by selecting 2D Tracking > New Track or clicking the New Track  icon.

   You can try to use the square patterns to locate easily recognizable locations on the floor as you will need to place a track point in the same location in *Sequence02*.

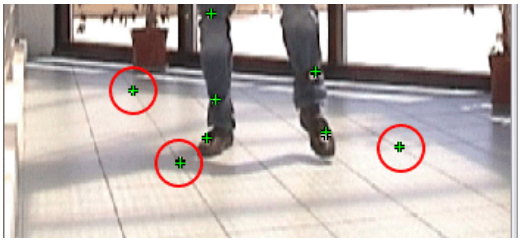
   NOTE You can try to use the square patterns to locate the points on the floor. Once the first track is placed, you do not need to run the Track Forward on it, because the sequence was shot with a fixed camera, and MatchMover detects this through the "fixed" motion constraint.

3. In the first frame of *Sequence02*, place the same track point in same location as you did in the first frame of *Sequence01*.

   This point is reconstructed in space right away, based on the existing camera calibration (solve). If the point is in the wrong location in one of the sequences, the cross-hairs will appear in red. This can often happen if your video sequences are low-resolution, compressed footage.

4. Repeat steps 2 and 3 to create the remaining two track points for *Sequence01* and *Sequence02*.

   The goal is to place track points that define a coordinate system on the ground.



5 Solve for the camera by selecting 3D Tracking > Solve For Camera or by clicking the Solve For Camera  icon.

The camera is calibrated with the a coordinate system on the scene's background. You can now finalize you project by building some *skeleton lines*.

6 Click the 3D space icon  that is located in the top left corner of both viewports.

The view switches to 3D mode. A camera icon and grid is placed in the Workspace.

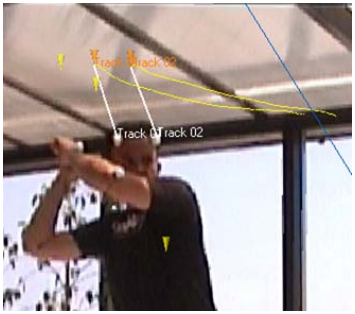
You can also switch back to a single viewport by selecting Single Viewport Space from the Toolbar.

7 In the viewport, select the yellow cone that appears at the right side of the actor's head.

This cone represents Track01.

8 Shift-select the yellow cone that appears at the left side of the actor's head.

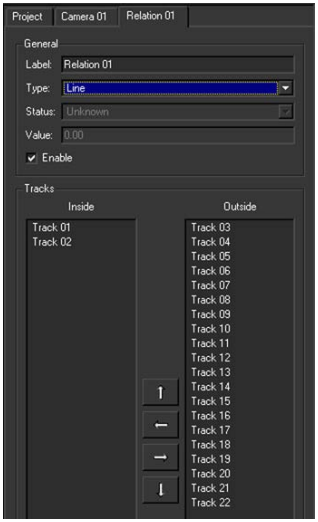
This cone represents Track02.



9 With both cones still selected, select 3D Tracking > New Relation.

10 In the Parameters window, click the Relation 01 tab.

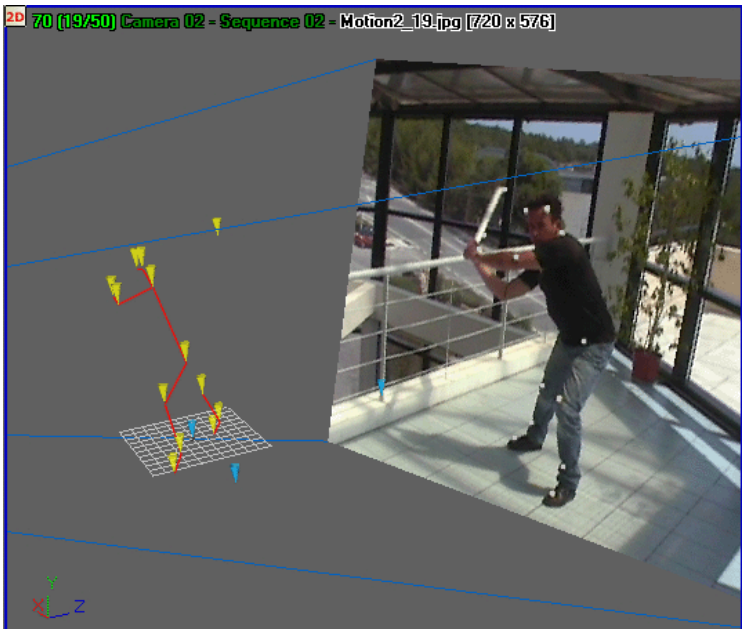
11 From the Type list, select Line.



A line is displayed between the two cones.

12 Repeat steps 7 to 11 for the remaining track points or until you see satisfied with the line reconstruction of your motion capture.

NOTE You can open `Motion_finalized.mmf` to see the entire project. The result should look similar to the one in the following image.



You can export your project to a file format supported by your favorite animation or composition software by selecting File > Export.

Beyond the lesson

In this lesson you learned how to:

- Create a motion capture project.
- Synchronize two video sequences.
- Create motion tracks for two synchronized video sequences.
- Calibrate the camera to obtain camera parameters.
- Build a skeleton line representation of an actor's motion.

For more information and related techniques about MatchMover, refer to the MatchMover Help.

Overview 2

About matchmoving

Matchmoving is the computation of the global 3D geometry of a scene including camera path, internal parameters, and moving object. By exporting the real 3D camera path and parameters to animation software, the position and motion of virtual cameras can be accurately established. With the motion of the virtual cameras, new, matched image sequences can be created whose virtual objects are seamlessly composited into live action footage.

Matchmoving lets you accurately place 3D objects into a film, video or image sequence. For virtual objects to appear as part of the scene, the objects have to be rendered by a virtual camera whose motion exactly matches the motion of the actual camera that shot the film. Using Autodesk MatchMover you can generate the exact camera parameters that match the motion of the actual camera used in the sequence.

Film, video and image sequences

The principle data used by MatchMover is film, video, and image sequences. You can simultaneously use a number of different sequences and image files in MatchMover as long as they all share some 3D information such as different viewpoints of the same scene. MatchMover supports most commonly used video and image formats including interlaced footage. See Importing footage on page 108.

Your footage is used to identify feature tracks either automatically or manually, and these tracks will be used for the solving. In the case of multiple sequences or stills, the same feature can be easily spread and tracked across all the footage

it appears, thus adding information about its position in the 3D space. See Point tracks on page 65 and Helper images on page 60.

When you create a new project, the first step is to load your film, video or image sequence.

Using MatchMover, you can:

- Load image sequences. See Identifying image regions on page 113.
- Load matte sequences. See Identifying image regions on page 113.
- Load helper images. See Loading helper images on page 111.

Helper images

A helper image is an additional shot of a scene taken from another point of view than that of the sequence. This enables you to introduce parallax into your project when the sequence itself has low parallax.

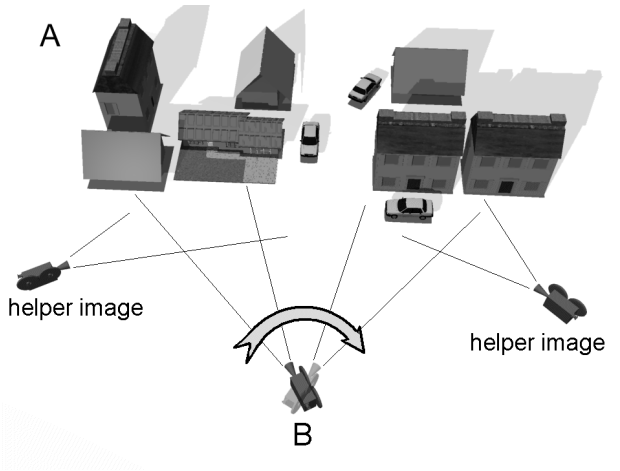
For example, you have a camera pan from point A to point B while focusing on object C. By taking additional shots of object C from other positions, you are providing parallax to the sequence.

When you have a sequence with little or no parallax, for example, no camera translation, you can add helper images to the sequence to aid the MatchMover computation. These helper images are shot from different viewpoints from that of the camera that filmed the main sequence.

They can be taken with either the same camera or a different one. The following sections describe situations where helper images aid in MatchMover calculations.

Using helper images with images taken with a tripod camera

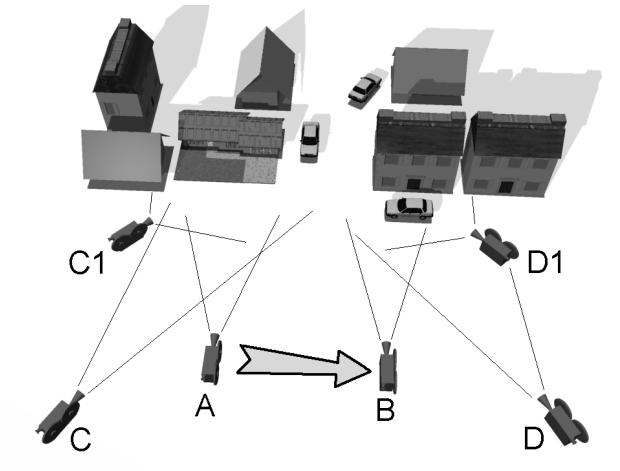
You have an object at position A. The camera is fixed at position B, but there is a rotation of the camera as it pans left and right. You can take one or several helper shots from different positions (two in the example below) and then load them into your project.



Using helper images with images taken with a traveling camera

In the following diagram the camera moves from position A towards position B. At each moment, it sees a small fraction of the scene.

You can use helper images shot from more distant viewpoints (C, D) and/or with a wider-angle camera (C1, D1) that sees a larger portion of the scene, as shown in the following image.



NOTE Helper images are only useful if they see the same elements as your shot.

Loading these helper images into your project helps the camera solving process. Helper images only help MatchMover calculations; they are not compulsory.

TIP Helper images are a very convenient way of matchmoving shots with no or little parallax. You can use the same camera that took the shot to acquire them or any other photographic or video camera.

Frame rate

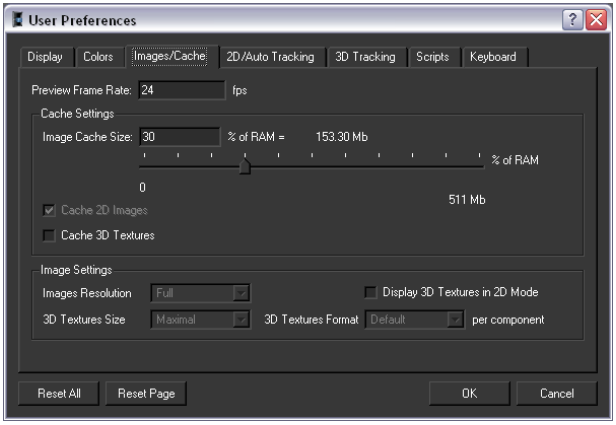
The video and film sequences you use with MatchMover can be in different standard frame rates including 24 fps (frames per second) for film, and 25 fps (PAL) and 29.97or 30 fps (NTSC) for video. In some cases, your footage might have a custom or non-standard frame rate. The frame rate of your sequence is used for playback speed and is exported along with the matchmover data to the 3D package.

TIP The current project frame rate is displayed in the MatchMover time line above the current time. SG needed. You can specify a project frame rate by typing it into the field.

You can set the project frame rate in the MatchMover User Preferences.

To set frame rate in the User Preferences

1. Select **Edit** > **Preferences**.
   The User Preferences window appears.
2. Click the **Images/Cache** tab.



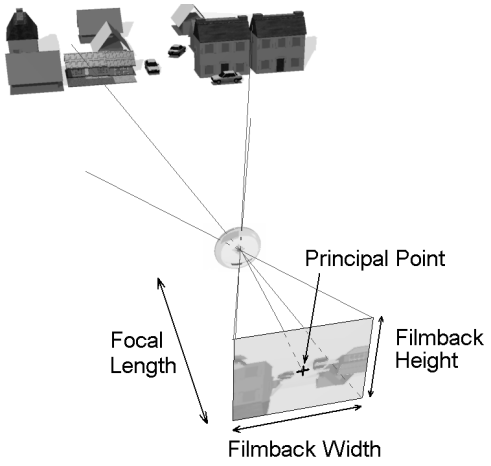
3. In the **Preview Frame Rate** field, type the desired frame rate.

4 Click **OK**.

TIP You can set the frame rate for an image sequence in the **Load Sequences** window. See Loading a sequence on page 108.

Cameras

Cameras represent the different devices used to capture the images. By default, when you load a sequence or helper image, MatchMover creates a camera and assigns it to all images. In MatchMover, a camera is characterized by its internal parameters such as Principal Point, Focal Length, Pixel Aspect Ratio, and Distortion. If you already have information about the camera, for example, you know that it is a 24 ×36 mm film back camera with a 35 mm lens, you can input this information into MatchMover® Pro before launching the camera tracker.



The focal length is the distance between the film and the optical center of the lens when the lens is focused on infinity. The principal point represents the projection of the optical center onto the film back, perpendicular to the film back plane. The film back value represents the size of your film and is proportional to the pixel aspect ratio. See Setting up cameras on page 159.

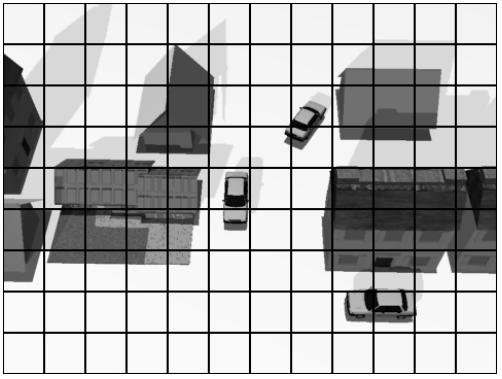
Camera parameters

Each camera parameter has a value that you can input into MatchMover, or you can have MatchMover calculate. The camera parameters Focal Length,

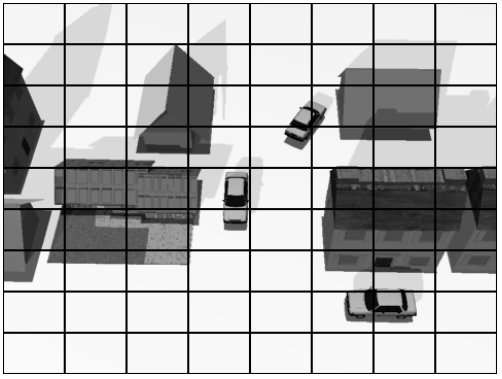
Principal Point, Pixel Aspect Ratio, and Distortion can vary or remain constant throughout the sequence. Depending on the information you have about the cameras used to create the sequence, these parameters can either be known or unknown.

Pixel aspect ratio

Providing extra information to the camera tracker gives more accurate results with a faster calculation time. The pixel aspect ratio defines the aspect ratio of the sequence you render. If the sequence has square pixels, then the pixel aspect ratio is 1.



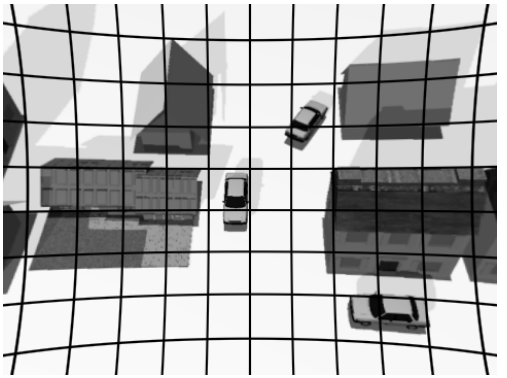
It is common, especially with video footage, to work with non-square pixels, such as in the image below. In these cases, the pixel ratio is different from 1.



You can define the pixel aspect ratio for your sequence. As the pixel aspect ratio is dependent on the film back value, and vice versa, changing the pixel aspect ratio also changes the film back value.

Non-linear distortion

Mathematical models of a perfect camera imply that the image of a straight line is always a straight line. However, real lenses are not always perfect and may introduce distortion into your footage. The effect of distortion is that straight lines become curved as shown in the following image.



You can input the radial distortion of your cameras if you know it, or will compute it if you don't.

Point tracks

To calculate the camera parameters, MatchMover needs points in different images in your sequence that represent the image location across the time of the same physical 3D point. This collection of points is called a point track. The camera solving process uses several point tracks to represent 3D points that follow one rigid motion.A point track is composed of the following data:

- Key points: Key points are Print locations defined in a small subset of the sequence images. These points are seeds that MatchMover uses to build up the whole point trajectory.
- Derived 2D points: Derived 2D points created by MatchMover based on information from the key points. They are derived from using an automatic correlation-based template matching process.

The tracked points should be characteristic points, for example, points that can be accurately localized in the image and represent physical points such as markings, corners, or shadows.

Automatic 2D tracking

MatchMover automatic tracking feature automatically locates “good” points in the images, and then tracks them through the sequence. You can guide this automated process by specifying key parameters and elements. However, using automatic 2D tracking provides you with a tracking solution that does not require manual editing.

Supervised tracking

For complicated scenes, it may be necessary to manually control the tracking process by editing or deleting tracks created automatically by MatchMover. You can also create your own tracks. When creating your own track, you specify the key points, and then MatchMover derives the whole point trajectory. You can mix automatic and supervised tracks in the same project.

Mattes

MatchMover lets you to identify areas within your sequence that you want to exclude or highlight. For example, you can crop unwanted areas of a sequence or import a matte sequence to flag objects as following an independent motion.

You can use MatchMover cropping options to remove unnecessary black borders from image sequences. Cropping the image focuses the tracking process on the area you define, ignoring the unnecessary borders. Cropping is a global operation, meaning that it is applied to all frames in the sequence. Cropping cannot be animated as a matte.

Using a matte, you identify an area in the sequence that has a different motion, such as a a character occluding part of the background you want to track, and have MatchMover ignore the area. You can also have MatchMover compute independent motions for areas lying inside and outside the matte. For example, you can compute the motion of the moving camera with respect to the fixed background, and at the same time, compute the motion of a mobile object appearing in the sequence. In the latter case, both the background and the car will be tracked within the same solve.

You import mattes made in other application into MatchMover or you can create your own mattes by drawing their outline. Mattes created either method can be combined in the same project.

TIP You can combine the results of two cropping operations on an image then exclude specified areas with a matte.

3D objects

MatchMover provides you with a set of objects called 3D primitives. 3D primitives are basic 3D shapes such as cubes, cones or spheres. You can import other objects into MatchMover as long as the object s are in the OBJ format. You can use a 3D object as it appears or edit it, using one of the MatchMover's manipulator tools. These virtual objects are fixed in space, and rendered using the estimated camera parameters. The process is successful when the motion of the virtual objects in the composed sequence is consistent with that of the real scene. You can also use 3D objects to define survey points mapping by dragging the mouse from one vertex to the image plane. See Setting survey points using elastics on page 177.

Camera computation

From the collection of 2D tracks, MatchMover estimates all camera parameter including internal parameters such as focal length and non-linear distortion, camera position and orientation over time, and 3D point coordinates.

Depending on your project, you can provide MatchMover with some specific information about the shot, thus constraining the process by reducing its parameter space.

Keyframes

A keyframe is a frame containing enough parameter data for the camera solving process. Using the data obtained from the 2D tracking process, MatchMover initializes the cameras and creates the 3D points for the sequence. The computation process starts on a solid keyframe pair, called the reference frames (1 and 2). MatchMover automatically selects these frames when the solver is launched or when using the **Select keyframes** command, if it is not locked by the user. Depending on the camera motion, overriding reference frames may help solve complex shots when the selected references are not well located.

Relations on 3D points

Point relations are used by MatchMover to obtain information about the geometry of the scene. For example, this information can be that several points share a coordinate, for example, all points on a horizontal plane, such as the ground, share the same Y value. Or, that some points have known coordinates. This usually happens when you have measured survey points in your on-set. In this case, it may be simpler to use survey points. Providing MatchMover

with information that helps the camera solving process improves the accuracy of the results.

Survey points

If you know some of the properties of a scene, such as measurements, or you have some constraints, you may know the 3D coordinates of some points of the scene. Instead of letting MatchMover compute their 3D coordinates, you can set them before the computation.

You can either set these coordinates manually or use one of your 3D object vertex coordinates.

Camera constraints

Camera constraints tell MatchMover that a parameter is constant over a subset of frames associated with a camera. As it reduces the number of computed parameters, it limits the calculation time and speeds up the process. MatchMover has four types of constraints. **Focal length**, **Nodal Pan**, **Dolly**, and **Planar**.

Motion control

Some hardware devices, such as a Scorpio crane or Flair, output what is known as "Motion Control Data". You can import some of this data into MatchMover using the motion control file parser. This information is directly input in the calibration engine, and used as an initial solution. It can therefore be refined, and additional camera parameters computed. See Importing motion control data on page 181.

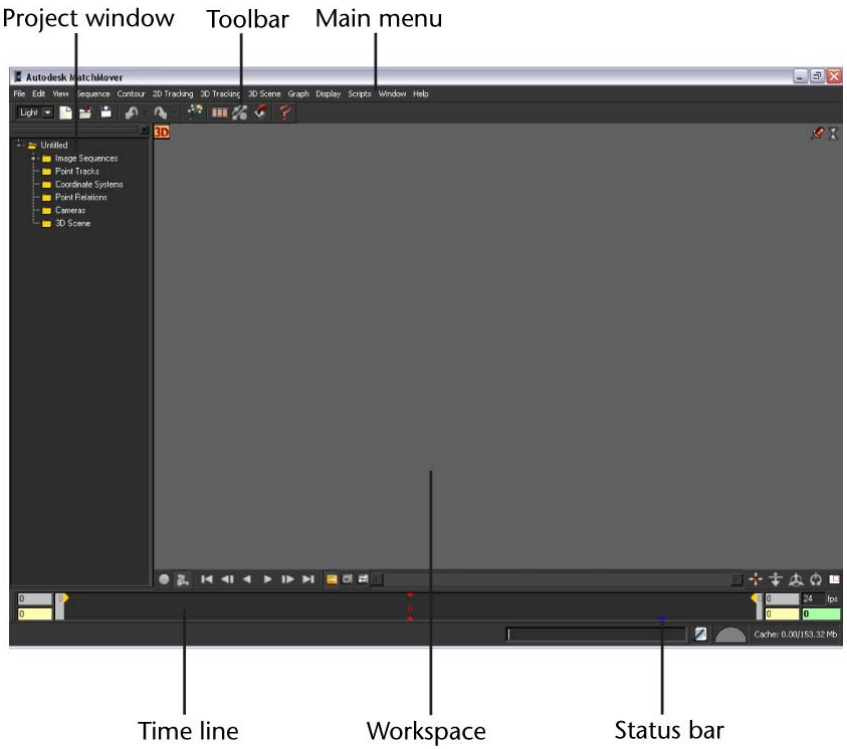
You can also manually input or override specified aspects of this data to constrain the final solution to a valid, specified range before launching the solver.

User Interface Guide

3

User Interface overview

When you start Autodesk MatchMover, you are presented with the following user interface.

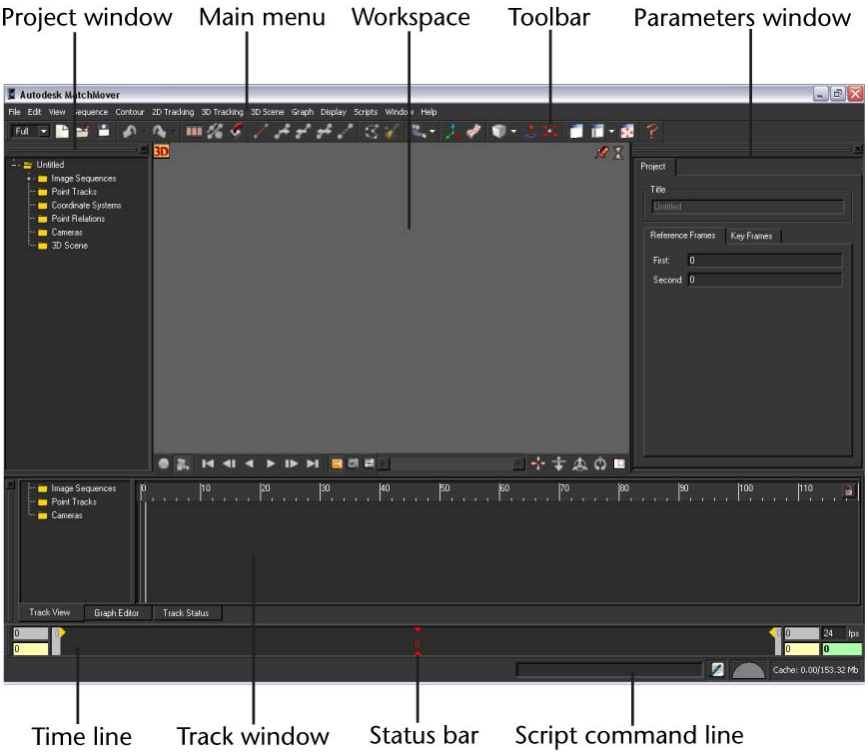


MatchMover Light Mode user interface

Light Mode is designed for simple automatic workflows. The user interface displays only the tools that allow you to launch the assistant, load, autotrack, and export.

NOTE All windows are fully floatable/dockable/resizable/hideable. Double-click a window title to toggle the display status.

Use the interface mode selector in the **Toolbar** to switch the interface to 'Full Mode".

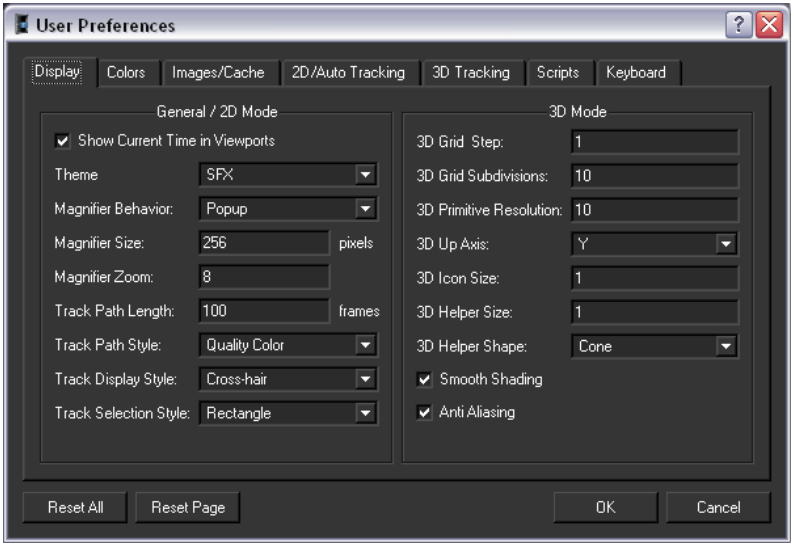


MatchMover Full Mode user interface

- A number of menu items appear in the main menu bar. If a shortcut is available, it is shown next to the menu entry. Some of the drop-down menu functions are available directly through Toolbar icons and keyboard shortcuts.
- The Project window appears in the left pane of the MatchMover interface and hosts the project elements in folders. See Project window on page 86.
- The Workspace is where you do most of your work. When you load a sequence, the images are displayed here.
- The Parameters window displays the properties for the project, the current camera, if any, and the selected project item.
- The Track window shows the time variable elements that MatchMover can manipulate within your project.

- The Time line appears at the bottom of the screen between the Track window and the Status bar and gives a graphic display of the current time and helps you to navigate through your image sequence.
- When you select a menu item or a Toolbar icon a brief description appears in the Status bar, located at the bottom to the interface.
  The cache usage is also displayed in the **Status Bar** in the form of a pie chart that changes from green to red as the cache left memory lowers. The cache details are shown next to it (used cache memory/available cache memory).

NOTE You can change the default theme color in the **Preferences** > **Display** window:



The Toolbar

When you launch MatchMover for the first time, you can access several tools in the Light and Full modes.

Light Toolbar - This toolbar provides functions for managing your files.

In the Full mode:

- **File management tools** - These tools provide functions for managing your files, undoing and redoing actions, switching between the Full and Light modes, and accessing the online Help.

NOTE In MatchMover, you use the **Undo** and the **Redo** icon  to undo or redo, respectively, the last action. The **Undo Buffer** holds data required to undo/redo actions. In addition the **Actions** window shows the most recent undoable actions.
This stack is of limited size. Double-clicking on an action toggles its (and all the next actions) undo/redo status.

- **Tracking tools** - These tools provide functions for importing footage, the management of your 2D tracking process, the camera solving.

- **Object manipulation tools** - These tools provide access to management of the 3D object manipulation.

- **Display tools** - These tools provide access to the track display options and the layout of the Workspace.

The Workspace

The first time you launch MatchMover, the Workspace is empty. Once you load an image sequence, the frames of the sequence are shown in the Workspace. The file name and size of the current frame are displayed next to current time.

Switching between the 2D and 3D mode

By default, a **2D View** (a viewport in 2D mode) is shown. You can reset or change the view type by using **Window** > **New View** and select the required view.

As soon as a sequence or images are loaded, the **3D View** (a viewport in 3D mode) is available, with a default camera looking at the origin. The view can be used for example to estimate distortion, by just shifting its value in the curve editor, or to place 3D object and map survey points.

Use the **2D Mode** button  and the **3D Mode** button  in the top left corner of the Workspace to toggle between the 2D and the 3D views.

For more information on the different views, see Working in 2D mode on page 75 and Working in 3D mode on page 80.

Changing the viewport layout

You can split the Workspace into two or four viewports by selecting **Window** > **Layout** from the main menu and the required split option.

Alternatively, you can click the icons in the **Display** tools to change the viewport layout:

TIP Press the **Spacebar** to return to a single viewport from multiple viewports.

If split, one of the viewports is outlined as the current view. For example, the Project window may be the currently activated window while the last edited viewport remains current and receives any viewing action coming from the Project window or from the main menu.

MatchMover stores the current viewport layout configuration in the project file.

To switch between the **Full Screen** mode and the normal mode, click the **Full Screen** icon  in the Toolbar.

Resizing viewports

When you have several viewports in the Workspace, you can change their size. Click the border of a view and drag the pointer to resize the view.

TIP Re-clicking on the current layout icon just reset to default layout geometry. Re-clicking on single viewport icon just toggle between single and previous layout.

Working in 2D mode

MatchMover provides you with the ability to open different views within the Workspace window to study and manipulate the image sequence and the results of the tracking process.

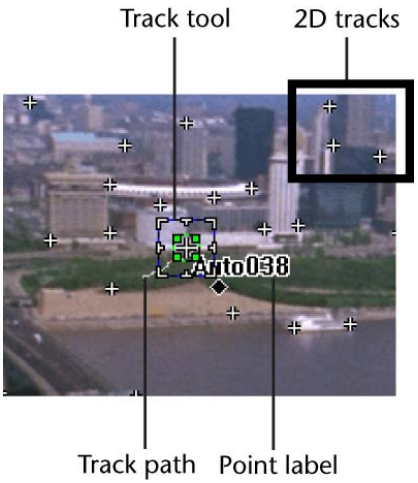
When you load a sequence, the default view is the **2D View**. The **2D View** is designed to display single images, image sequences and tracking information to help in your 2D tracking task. The following list shows all items that are drawn in the **2D View**:

- Images, helper images and matte sequences.
- The current and local times of the frames in the upper left corner.
- **Masks**. See Identifying image regions on page 113.
- Camera **Anamorphism**, expanding the view to fit the anamorphic camera settings.
- Tracking information.
  - **2D Tracks**, showing the position of the point in one frame. 2D tracks can be displayed using the default cross-hairs or in pattern mode. You can customize the display by selecting **Preferences** > **Display** > **2D Mode**.
  - **Point Labels**, showing the point name.
  - **Track Paths**, showing the displacement of the point between frames. The track paths are displayed either in a uniform color or using different colors, depending on current track frame quality, from poorest (red), to best (green). You can customize the display by selecting **Preferences** > **Display** > **2D Mode** and either **Quality Color** or **Uniform Color** from the **Track Path Style** drop-down list.

  To change the **Track Path** length, select **Edit** > **Preferences**, click the **Display** tab, and in the **Track Path Length** text field, enter a number. MatchMover defines the maximum number of frames in which the **Track Path** is shown

from the current time. A value of 100 shows the **Track Path** for 50 frames before and 50 frames after the current frame.

- **3D Tracks**, showing the color-coded 3D reconstructed points (green for good, yellow for fair, red for bad), and a link to its corresponding 2D track, calculated after running the automatic tracking process. Hard tracks are displayed with a surrounding circle to easily identify them.
- **Tracker Tool**, showing the key search size and pattern size.



NOTE To change the color of the **2D View** background, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

Displaying the 2D View attributes

You can display or hide points' attributes by either:

- Selecting **Display** from the main menu then clicking on the attribute in the pop-up menu.
- Right-clicking in the **2D View** and selecting **Display** and an attribute from the pop-up menu.

For the **Masks** and **Anamorphism** options, a check mark beside the option indicates that the option is active. Clicking the option again hides the check mark and deactivates it.

For other attributes, a single diamond  shown beside the attribute in the menu defines that the attribute is displayed for the selected point.

If you click again, two diamonds  appear beside the attribute defining that the selected attribute is displayed for all points. No diamonds means this feature is not displayed. By default the **Point Label**, **Track Path**, **Tracker Tool**, and **Tracking Score** are only displayed for the selected key point or computed point.

NOTE To change the color of the **Track Path** (in uniform color mode) or the key points on the track, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

Changing the time in the 2D View

The **2D View** shows an image at a given time. The current time is shown in the top left corner of the viewport.

- To change the current time, press **Ctrl**+click and drag the pointer. The pointer changes to  .
- To move to the previous frame, press **Ctrl**+left arrow.
- To move to the next frame, press **Ctrl**+right arrow.
- To reset the current time to the beginning of the sequence, right-click the required sequence in the **Image Sequences** folder in the Project window and select **Goto Begin** from the pop-up menu.

To hide the current time, select **Edit** > **Preferences** > **Display** and click in the **Show Current Time in Viewports** check box to disable the option.

TIP If nothing is currently selected, just pressing arrows navigate through time/zoom.

Freezing the time

By default, time changes in the **Time Line** or other 2D views are always synchronized with current time. However, when you "freeze" the **2D View**, changing the time in other views (the **Time Line**, the Track window or other **2D Views**) does not affect the time in the frozen view. Other views are not synchronized with current time.

If you change the time in the frozen view, other views are synchronized with the current time in the frozen view.

The **Freeze Time** mode is useful if you need to study frames at different times, for example, when you have multiple 2D views and need to see them at a certain time, for instance when editing tracks in a helper frame.

The shortcuts **Ctrl**+left arrow or right arrow change the time in the frozen window only if the window is active (blue surround).

To freeze the time in the **2D View**, do one of the following:

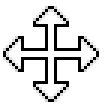
- Select **View** > **Freeze Time**.
- click the icon  in the Workspace.
- Right-click in the **2D View** to show the pop-up menu and select **Freeze Time**.

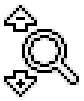
Resetting the current view

To reset the current view, select **Window** > **New View** > **New 2D View** or press **Ctrl+2** (default shortcut).

Navigating in the 2D View

You can access the navigation options in the **View** menu. Alternatively, use the following shortcuts and drag the pointer in the **2D View**, **Track View**, **Graph Editor**, and **Track Status View**

Action	Shortcut	Pointer
Changes the current time	Ctrl+click	
Move to next frame	Ctrl+right arrow	-
Move to previous frame	Ctrl+left arrow	-
Pan#	Alt+click (or scroll bars)	

Action	Shortcut	Pointer
Zoom	Alt+Ctrl+click (or "+" or "-")	
Zoom in an area in the 2D View	Alt+Shift+click	

#Pan horizontally only in the Track View, Graph Editor, and Track Status View

In the **2D View**:

- click the **Pan**icon  in the Navigation toolbar at the bottom of the window and drag the pointer to perform the navigation.
- Use the scroll buttons and slider  to scroll through the images.
- Click and hold the **Navigate** button  to easily pan in the image. A popup window of the entire image appears with a rectangular guide to orientate you in the image.

In addition to the navigation options shown in the previous table, you can right-click in the **2D View** and select the following options from the pop-up menu.

- To center the view on the selected item, select **View** > **Fit to Selection**.
- To set the largest zoom that keeps the entire image contained in the viewport select **View** > **Fit to Viewport**.

NOTE You can also click the **Fit to Viewport**  in the **Toolbar**.icon.

- If you have zoomed the image you can return to the original size with **View** > **Reset zoom**.

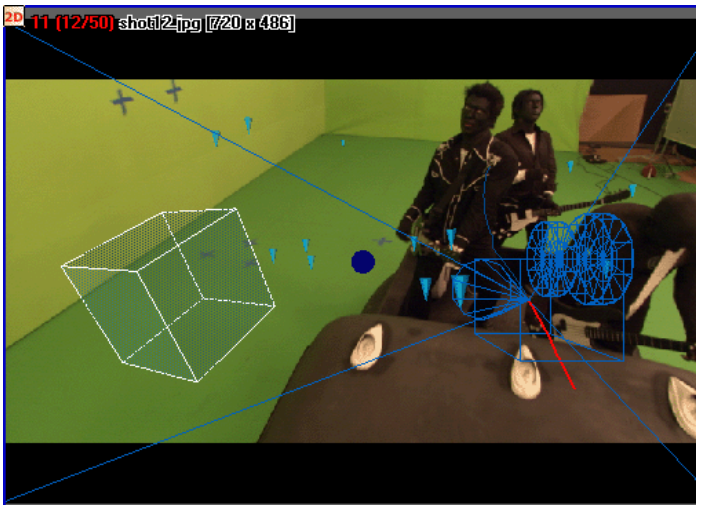
Working in 3D mode

The **3D View** shows the following from an arbitrary viewpoint:

- Cameras
- Tracking information
  - **Point Labels**, showing the point names.
  - **3D Markers**, or 3D Helpers, displaying the estimated 3D points as customizable 3D Helpers (cones, pyramids, crosses). A link is drawn between the 2D reprojections and the corresponding 3D points if available.
  - Manipulator **Axes**
  - A 3D planar **Grid**
  - Non-physical objects: **Lights** and **Relations**
  - Built-in contours
  - The estimated **Camera Path**
- The reference coordinate system
- 3D objects created directly in MatchMover or imported. See Working with 3D objects on page 205.

The default **3D View** is in the **Free Camera** mode with the image plane displayed. By clicking on the image plane, you are able to tweak its displayed depth by using the displayed translation manipulator.

Toggle the image plane display by selecting **Display** > **Background Image**.



In the **3D View** window you can switch to **Lock on Camera** mode. See Lock on Camera mode on page 83. The view constrains the camera to see the image as the background.

When you place a 3D object within the **3D View** window, MatchMover provides manipulators that you can use to edit them. See Editing 3D primitives and objects on page 207.

NOTE To change the color of the **3D View** background, the camera, or the camera path, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

NOTE To reset the current **3D View**, see Resetting the current view on page 78.

You can create tracks in the **3D View** in the same way as in the **2D View**. See Working in 3D mode on page 80.

Displaying the 3D View attributes

By default the **3D View** shows a grid and axes with a perspective viewing, the camera path with its corresponding image plane, and the reconstructed points.

You can display or hide points' attributes by either:

- Selecting **Display** from the main menu then clicking on the attribute in the pop-up menu.

- Right-clicking in the **3D View** and selecting **Display** and an attribute from the pop-up menu.

For **Point Labels** and **3D Marker Styles** attributes, a single diamond defines that the attribute is displayed for the selected point.

If you click again, two diamonds appear beside the attribute defining that the selected attribute is displayed for all points.

No diamonds means that this attribute is not displayed.

For all other options, a check mark beside the option indicates that the option is active. Clicking the option again hides the check mark and deactivates it.

You can also toggle the 3D object display in the **Display** menu:

- **Flat** shading
- **Wireframe**. A backface culling option for wireframe mode also exists in the **Display** menu.
- **Transparent**
- **Texture** mode.

TIP The default shading is smooth. See the **Preferences** window to change it to real flat shading.

Select **Display** > **Inliners** to show only the 3D points that are defined in 2D at the current frame.

Changing the number of wireframe divisions

You can change the number of divisions in the wireframe of a selected object in the **3D View** mode.

1. Select the **Project** tab in the **Parameters** window.
2. Enter a number in the **3D Primitive Resolution** text field. A smaller number reduces the size of the intervals in the wireframe grid; a greater number decreases their size.

Changing the size and shape of the 3D Helpers

To change the size of the 3D helpers:

1. Select the **Project** tab in the **Parameters** window.

2 Select a **3D Helper Shape** from **Cone**, **Pyramid**, or **Cross**. Select **Cross** for a better feedback of the 3D helpers' orientation.

3 Enter a number in the **3D Helper Size** text field. A smaller number reduces the size of the 3D Helpers; a greater number increase their size.

NOTE To change the color of a 3D point or the selected 3D point, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

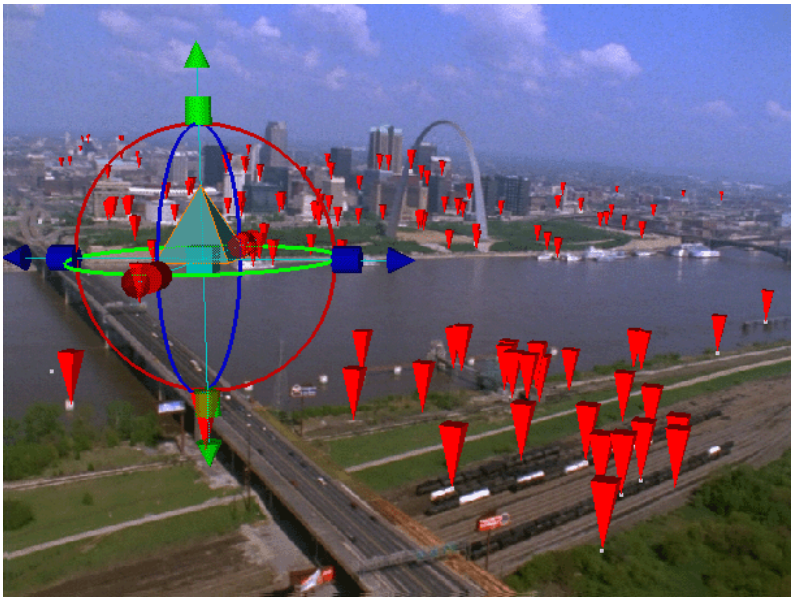
Changing the Grid Step

By default, the **3D Grid Step** has a value of 10. You can change this value in the **Subdivisions** text field in the **Project** tab in the Parameters window.

Lock on Camera mode

The **Lock on Camera** mode allows you to insert virtual objects and constrains the computed camera to view the image sequence as the background.

It can be considered as a 2D view with superimposed 3D objects.



The **Lock On Camera** mode allows you to display the same attributes as the **Free Camera** mode.

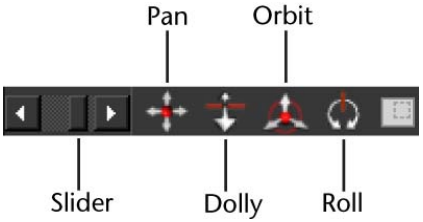
To lock on a camera:

1. Make sure that you are in the 3D mode.
2. Do one of the following:
   - Select **View** > **Lock On Camera**.
   - Right-click in the **3D View** window and select **Lock On Camera** from the pop-up menu.
   - Click the **Lock on Camera** icon  in the Navigation toolbar.

NOTE As the **Lock on Camera** mode includes the image sequence, you are viewing the scene from the position of the estimated camera. Unlike the **Free Camera** mode, you cannot rotate or the scene to view it from a different position.

Navigating in the 3D View

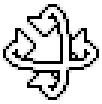
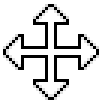
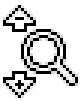
You can access the navigation options in the **3D View** in the **View** menu or in the Navigation toolbar located at the bottom of the Workspace.



Use the slider to scroll through the images.

Alternatively, you can use the following shortcuts and dragging the pointer.

Action	Shortcut	Pointer
Changes the current time	Ctrl+click	
Dolly	Alt+Ctrl+click	

Action	Shortcut	Pointer
Fit to rectangle	Alt+Shift+click	
Move to next frame	Ctrl+right arrow	-
Move to previous frame	Ctrl+left arrow	-
Orbit in the Free Camera mode	Alt+right-click	
Pan	Alt+click (or scroll bars)	
Zoom	Alt+Ctrl+right-click (or "+" or "-")	

NOTE By right-clicking in the **3D View**, you can turn the camera toward the selected item by selecting **View** > **Look At** from the pop-up menu.

Browsing the footage

Once you have loaded a sequence, you can play it by clicking on the **Play Sequence Toolbar** at the bottom of the Workspace.

The **Play Sequence Toolbar** from left to right is described below.

- **First Frame** - Navigates to the first frame of the sequence.
- **Previous Frame** - Changes the current time to point to the preceding frame.
- **Play Reverse** - Runs the play segment backwards.

- **Play/Stop** - Runs the play segment forwards in the current view. The play segment is either the frames contained within the selection, if any, then in the **Work Area**, if any, or all the frames of a sequence. Other views or controls are refreshed only if the hardware performance allows it.
- **Next Frame** - Changes the current time to point to the next frame of the sequence.
- **Last Frame** - Navigates to the last frame of the sequence.

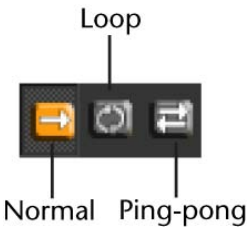
You can also play the sequence forward or in reverse by selecting **Sequence** > **Play** or **Play Reverse** or skip untracked or unsolved frames. See Skipping untracked frames on page 150 and Skipping unsolved tracks on page 150.

Selecting a Play Mode

You can determine how a sequence is played by selecting **Sequence** > **Play Mode** and selecting one of the following options:

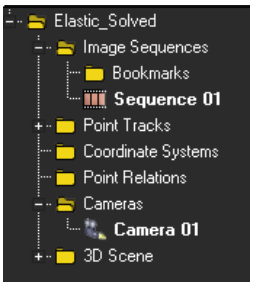
- **Normal** - Plays the sequence from the current frame and automatically stops the playback when the play segment limit is reached.
- **Loop** - Continuously loops the entire sequence or a segment of the sequence (if a **Work Area** is defined).
- **PingPong** - Continuously loops the entire sequence or a segment (if a **Work Area** or a time range is defined) forward and backward.

Alternatively, you can press the corresponding options in the **Navigation Toolbar**.



Project window

The Project window appears in the left pane of the MatchMover interface and allows you to have an overall view of the project.



The Project window shows all the elements that can be manipulated by MatchMover. You can also create, delete or launch an action in the Project window. The tree structure organization aids in arranging and managing your project.

Click  to close the Project window.

To restore the view, select **Window** > **Project Window**.

Some Project window elements appear in bold. Only one element of a given type can be bold at a given moment.

For example, an image sequence label is bold if the current time corresponds to an image of this sequence. A coordinate system label is bold if it is used to calculate or show 3D information. A camera label is bold if it is associated with the enabled image sequence. A constraint label is bold if it is defined for the current time.

Project window folders

The Project window folders contain the elements of your project. To expand or collapse a folder, click the + or - symbols to show the list of all the elements within the folder.

- **Image Sequences** - Contains the list of images, image sequences, contour, mattes and the sub-folders **Bookmarks** containing shortcuts to images.
- **Point Tracks** - Contains the list of point tracks and groups created.
  - All tracks can be sorted in groups. See Groups attributes on page 152.
  - A group can be designated as mobile (designing a rigid moving object) by selecting the **Mobile** option in the Parameters window  .
  - Hidden tracks are dimmed and they are not displayed in the **2D View** or in the **3D View**. Selecting the corresponding option in the **Render** window can still render them.

- **Coordinate Systems** - Contains the list of coordinate systems that can be used to represent the 3D data.
- **Point Relations** - Contains the list of defined relations between point tracks.
- **Cameras** - Contains the list of cameras and their relative sub-folders containing the camera constraints defined for them, if any. Empty constraints are dimmed with “empty” after their label. You should add frames to any constraint before using it.
- **3D Scene** - Contains the 3D scene elements of a project.

Click an element to open its properties in the Parameters window.

Track window

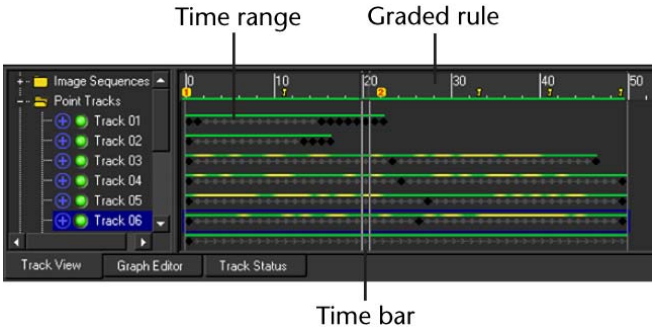
The Track window contains two separate panes; each pane reacts in synchronization with the other, and shows the time variable elements that MatchMover can manipulate within your project.

Scroll through the **Track View**, the **Graph Editor**, and the **Track Status View** by clicking on the tabs at the bottom of the window, just above the Time line. See User Interface overview on page 69.

Click close the Track window. To restore the view, select **Window** > **Track Window**.

The Track View

The Track View is used mainly for supervised 2D tracking. See Supervised 2D tracking on page 132. The left pane is a sub section of the Project window showing the elements contained in your project in relation to time. See Project window on page 86. Within the right pane of the **Track View,** symbols are used to give a graphic representation of the elements and their state.



- The **Time Bar** is a double vertical bar represents the current time. Double-click in the right pane to move the **Time Bar** to the required frame.
- The **Graded Ruler** shows the position of the current time in the sequence. Click and drag the ruler to move it vertically within the pane. Symbols in the **Graded Ruler** indicate whether the frame is a reference frame, 1 and 2 or a keyframe .
- If it is yellow 1 2 , the keyframes are automatically generated and unlocked; otherwise, they are locked.
  The graded ruler also shows information about the 3D solving status of each frame. A lock icon is displayed on the right-end of the graded ruler that enables easy keyframes locking/unlocking .
- The **Time Range** allows you to select a group of frames, also displayed in the **Time Line**. See Time Line window on page 93.

The shape of a point indicates whether the point is a key point or a computed point, and the type of tracking generated. See Editing a key point type on page 138.

Navigation in the Track View

The horizontal zoom is available by pressing **Ctrl**+**Alt**+click and you can fit the entire sequence if possible (one frame has a one pixel minimum width). Just do it by selecting **View** > **Fit To Viewport** ("=" is the default shortcut).

Click a track in the Project window and select **Sequence** > **Track Begin** or **End** (or press **Ctrl**+**Shift**+up or down) to move to the beginning or the end of a track. Panning in this view is done in the same way as any other view (using **Alt**+mouse drag), or just by using the horizontal slider.

Track View folders

The right pane is divided into several rows, each one corresponding to an item in the left pane tree view. If an item in the tree view is selected, its corresponding row in the right pane is surrounded by a colored rectangle.

- The **Image Sequences** folder contains all the footage. A blue colored bar in the right pane indicates which frames correspond to each sequence.
- Colored bars for each track in the **Point Tracks** folder indicate the tracking status and quality according to the **Quality Thresholds** set in the **User Preferences** window. See About key points on page 137.

Color	Tracking Quality
None	Not tracked
Red	Poor
Yellow	Fair
Green	Good

  Hard tracks (manual tracks) are defined by a circle with a cross.

  Soft tracks (automatic tracks) are defined by a cross.

  See also Creating a new track on page 132 for a definition of the symbols used for the track reconstructuon status.

- The **Camera** folder contains the project's cameras and constraints. A blue colored bar in the **Track View** indicates that the camera belongs to the current image sequence.
- For constraints, a small colored line just above the constraint's colored bar indicates the type of constraint.

Color	Constraint Type
Light gray	Unknown
Dark gray	Initialized
Black	Fixed

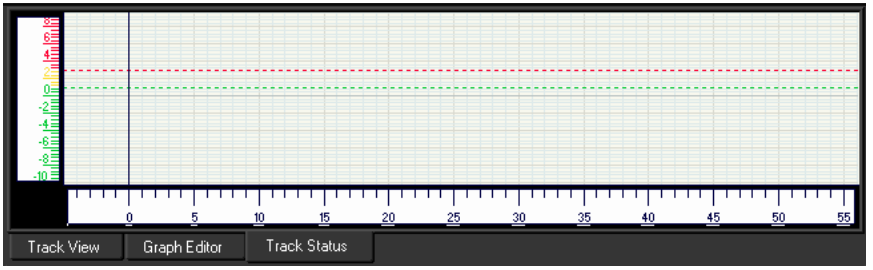
  If the constraint is disabled, the bar is hatched.

The Graph Editor

The **Graph Editor** displays a graphical representation of computed camera parameters as well as providing options to edit the results. Depending on the type of camera motion (hand-held, stabilized, motion-controlled) and the quality of the 2D tracks, it may be useful to smooth some or all of the computed camera parameters. Smoothing can be done by hand, or by using a post filter. See Filtering the results on page 195.

The Track Status View

The **Track Status View** provides read-only information on the computation of track points.



Use the **Track Status View** to survey the quality of pixel residuals for each track.

- **Show Thresholds** - Toggles the display of the threshold parameters. See Configuring the tracker on page 144.
- **Show Track Average** - Highlights the average track residual.
- **Show Global Average** - Displays a curve representing the average pixel residual of all tracks in a sequence.
- **Find Frame Max** - Displays the maximum frame residual.
- **Find Average Frame Max** - Displays the average maximum frame residual.
- **Find Track Max** - Displays the maximum track residual.

> **NOTE** You can also access the above options by right-clicking in the **Track Status View** and selecting them from the pop-up menu.

Click to close the **Track Status View**.

To restore the view, select **Window** > **Track View**.

To fit the graph to the viewport, select **Graph** > **Fit** or right-click in the **Track Status View** and select **Fit** from the pop-up menu.

Parameters window

The Parameters window allows you to visualize the properties for selected project elements and edit project element data and parameters.

The Parameters window describes the following: project properties:

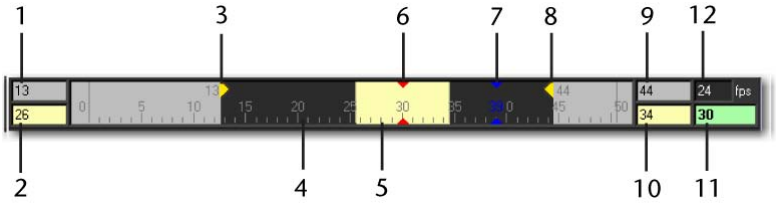
- Global project parameters (displayed when no item is selected, just press **Esc**), such as view settings and keyframes. See Editing reference and keyframes on page 158 and Working in 3D mode on page 80.
- Image sequences parameters. See Managing footage on page 108.
- Bookmarks parameters. See Moving to a bookmarked frame on page 112.
- Contours parameters. See Changing a contour's properties on page 120.
- Matte sequences parameters. See Setting the matte properties on page 115.
- Track groups parameters. See Groups attributes on page 152.
- Tracks parameters. See Creating a new track on page 132.
- Coordinate system parameters. See Defining the coordinate system using the Parameters Window on page 168.
- Point relations parameters. See Creating a point relation on page 173.
- Cameras parameters. See Setting up cameras on page 159.
- Camera constraints parameters. See Creating and enabling a constraint on page 178.
- 3D objects parameters. See 3D primitives and objects Parameters Window on page 211.

Actions window

The Actions window shows the most recent undoable actions. This stack is of limited size. Double-clicking on an action toggles its (and all the next actions) undo/redo status.

Time Line window

The Time Line appears at the bottom of the screen between the Track window and the Status bar and gives a graphic display of the current time and helps you to navigate through your image sequence.



1 Work Area start frame

2 Selected area start frame

3 Work Area begin marker

4 Work Area

5 Time range

6 Current selected frame

7 Slider

8 Work Area end marker

9 Work Area end frame

10 Selected area end frame

11 Current selected frame

12 Frame rate

- The **Work Area** defines the beginning and the end of the sub section of the sequence that you work with. Frames outside the **Work Area** are ignored for tracking and playing purposes. If a **Work Area** has not been defined previously, begin and end markers are positioned at the first and last frames.
- When you load a sequence, the **Slider**, a red pointer, shows the current frame position with the corresponding frame number. The first frame is always 0 and the total number of frames appears on the far right of the sliders.

- The **Numeric Fields** show the **Work Area** start and end frames, the selected area start and end frames, the number of the current frame, and the current output frame rate in frames per second.
- A fourth element, not present at all times, is the **Time Range**, shown in yellow. See Running the automatic 2D tracking on page 127.
  The **Time Range** is used for one-shot operations such as clearing points in several frames, or defining the span of a camera constraint.

When you create a bookmark for a frame, a check in the **Time Line** indicates its position. See Placing a bookmark on page 112.

Double-click the edge of the time line to undock it. Once undocked, click and drag on its edge to reposition it within the interface.

To close the **Time Line**, click the  and restore it by using **Window** > **Time Line Window**.

Changing the current time using the Slider

Click within the **Slider** to change the current time. The blue pointer now points to the new current time with the current time frame number shown above the pointer.

If you load several image sequences, a black vertical bar shows the position of the start frame for each sequence.

Changing the current frame using the Numeric Field

1. Click inside the **Numeric Field**.
2. Enter the current frame number to change to and press **Return**/**Tab** to validate.

MatchMover moves the pointer to point to the required frame.

Defining a Work Area

Before running the automatic tracking process, you can specify a section of the sequence to track, defined by the **Work Area**. The **Work Area** is an interval of frames in a sequence to which you can selectively apply the automatic tracking operation. If you don't specify a **Work Area**, the entire active sequence matching the current time will be processed. If there are other sequences loaded, they will be ignored.

NOTE All frames in the **Work Area** must belong to the same sequence; otherwise, autotracking is disabled. Therefore, MatchMover cannot process scenes with helper frames automatically. However, you can automatically track the main sequence, then edit the helpers before solving the scene.

To define a **Work Area**:

1. Position the pointer at the frame where you want to begin the **Work Area** and do one of the following:
   - Select **Sequence** > **Begin Work Area**.
   - Right-click in the **Track View** and select **Set Current Frame** > **Begin Work Area** from the pop-up menu.
   - Edit the gray **Work Area** start frame box. For a description of the **Time Line**, see Time Line window on page 93.

   The begin marker is set to the current frame.

   NOTE If a **Work Area** has not been defined previously, begin and end markers are positioned at the first and last frames.

2. Position the pointer at the frame where you want to end the **Work Area** and do one of the following:
   - Select **Sequence** > **End Work Area**.
   - Right-click in the **Track View** and select **Set Current Frame** > **End Work Area** from the pop-up menu.
   - Edit the gray **Work Area** end frame box. For a description of the **Time Line**, see Time Line window on page 93.

   The end marker is set to the current frame.

   The background changes color indicating the time range. For a description of the **Work Area**, see Time Line window on page 93.

Alternatively, you can define the **Work Area** by dragging the **Work Area** marker.

Resetting the Work Area

To reset the **Work Area**.

Position the pointer in the Track window select **Sequence** > **Reset Work Area**.

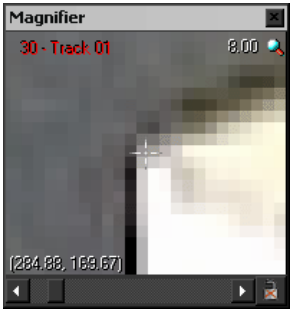
MatchMover moves the begin and end markers to the first and last frames, respectively.

Magnifier window

Always available in either **2D View** or the **3D View**, the docked **Magnifier** window appears by default below the **Project** window. The window is used to zoom the area around a track and to fine tune the currently selected track by simply clicking on it. When a track is selected, the **Magnifier** window stays locked on the track. If you move the pointer over another track, this track is displayed. When you move the pointer out, the locked track is restored.

When the **Magnifier** window is active, other views are frozen. It then can be used to check one track very easily and fast, combined with the **Skip Untracked** option. See Skipping untracked frames on page 150.

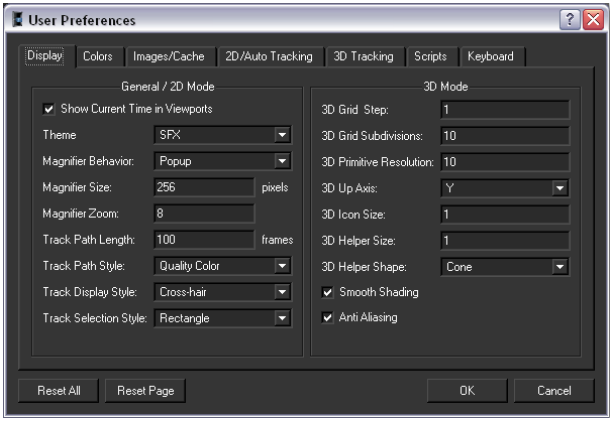
Activate the **Magnifier** window by clicking on the open padlock  on the right of the zoom slide bar. The closed padlock  appears.



Zoom in the **Magnifier** window by moving the horizontal slider.

To change the **Magnifier** behavior when placing 2D tracks:

1. Select **Edit** > **Preferences**. The **User Preferences** window appears.
2. Select the **Display** page.



3 In the **Magnifier Behavior** drop-down list, choose an option:

- **Disabled** - No magnifier is shown.
- **Popup** - Zooms the selected area under the pointer in the **2D View** and the **3D View** (default).
- Toolbox - Use the **Magnifier** window. If you chose this option, enter the size in pixels and the default zoom of the toolbox in the **Magnifier Toolbox Size** and **Magnifier Zoom** fields.

4 Click **OK**.

Keyboard shortcuts

MatchMover provides the following types of command shortcuts:

- The pop-up (shortcut) menus contain commonly used commands, depending on in which window the pointer is located. To access the pop-up menus, right-click an element.
- **User-defined shortcuts**
  Every command can have a user-defined shortcut. Select **Preferences** > **Keyboard** then select a command in the list, for example, **Display** > **Point Label** and then press the new shortcut keys in the indicated box. If the shortcut is already assigned to another command, it will be displayed. Press **Assign** to validate the new shortcut.

Default keyboard shortcuts

The keyboard shortcuts are shown next to the main menu commands or actions.

Action	Shortcut
3D tracks display, toggle	3
2D tracks display, toggle	2
Align Pivot	Page Up
Automatic clean-up	F11
Automatic tracking	F10
Background display, toggle	B
Cancel time range	Shift+right-click
Center Pivot	Home
Change the current time	Ctrl+click
Clear Tracked Points	Backspace
Create or remove keyframe	Ctrl+K
Define a time range	Shift+click
Delete	Del
Dolly	Ctrl+Alt+click
File New	Ctrl+N
File Open	Ctrl+O
File Save	Ctrl+S
Fit	=
Fit to rectangle	Shift+Alt+click

Action	Shortcut
Flat Shading	F
Flush the cache	Ctrl+Del
Frame, First	Ctrl+Home
Frame, Last	Ctrl+End
Frame, Next	Ctrl+right arrow
Frame, Previous	Ctrl+left arrow
Fullscreen Layout	X
Grid display, toggle	G
Import Motion Control	F12
Invert Pivot	Page Down
Key, Next	Ctrl+down arrow
Key, Previous	Ctrl+up arrow
Labels display, toggle	L
Lock On Camera	C
Matte display, toggle	M
New 2D View	Ctrl+2
New 3D View	Ctrl+3
Orbit the camera	Alt+right-click
Pan	Alt+click
Preferences	P
Redo	Ctrl+Y

Action	Shortcut
Render Setup	R
Reset Zoom	0
Sequence, Next	Ctrl+Page Down
Sequence, Play	F2
Sequence, Play reverse	Shift+F2
Sequence, Previous	Ctrl+Page Up
Set key, Begin	F5
Set key, End	F7
Set key, Intermediate	F6
Set key, Single	F8
Single Viewport	Space
Solve for camera	F9
Textured Shading	Alt+T
Track backward	Shift+F3
Track Begin	Ctrl+Shift+Up
Track bidirectional	F4
Track End	Ctrl+Shift+Down
Track forward	F3
Transparency mode	T
Undo	Ctrl+Z
Wireframe mode	W

Action	Shortcut
Zoom	Ctrl+Alt+right-click
Zoom in an area	Alt+Shift+click

User Guide

4

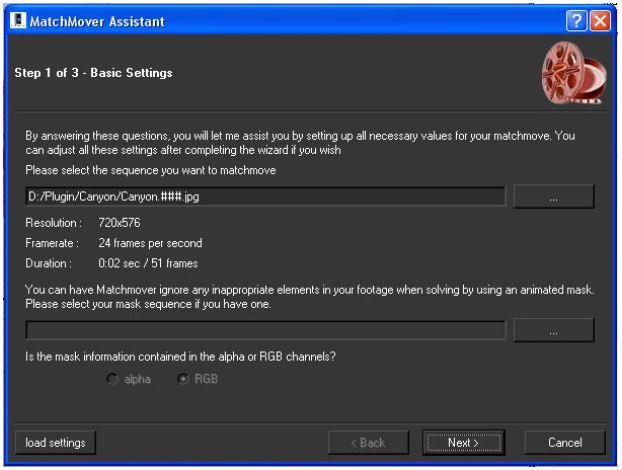
Solving a sequence using the Matchmoving Assistant

Using the Matchmoving Assistant, you can easily set up the values for solving a sequence:

1 You can launch the assistant by clicking on its icon  in the toolbar (in light mode) or by selecting **Help** > **Assistant**.

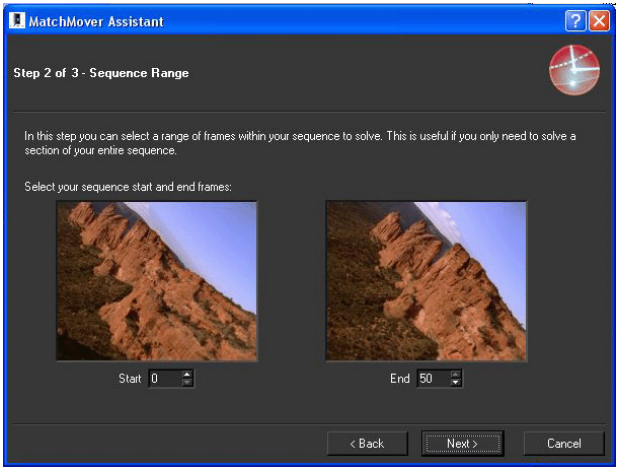
The **Basic Settings** window opens. Select a sequence to matchmove and if required, a mask sequence and the corresponding channel information.

A mask allows you to identify some areas within your sequence to either exclude them (black areas of the mask represent the ignored area). Select the type of the mask: **alpha** to use alpha channel or **RGB** to use the color values.

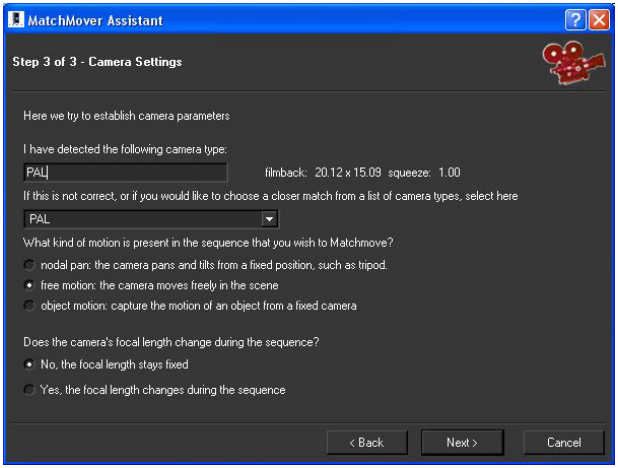


You can also load settings as a MatchMover RZML file. Click the Next button.

2 In the **Sequence Range** window, you can choose the start and end frames of the part of the sequence you want to solve and click **Next**. If you want to matchmove the entire sequence, just click **Next**:



3 In the **Camera Settings** window, the **MatchMover Assistant** displays the automatically detected camera type. If the selected camera is not correct, choose the camera that you want to assign to the sequence from the drop-down list. Select the required camera motion and focal length options.



4 Click Finish to close the assistant. The project will be set up and ready for tracking.

5 Click **Finish** to run the solver.

Managing projects

Projects are the basic elements of file management within MatchMover and it is important that you understand what a project contains. A project is defined as one scene.

MatchMover projects files have the ".mmf" extension. You can load as many image sequences within a project, as long as they are from the same scene and contain points that are common.

To start a new, empty project, do one of the following:

- Select **File** > **New**.
- Click the **New** icon  in the **Toolbar**.

You can load a project previously saved to disk under the (.mmf) format.

To open an existing project, do one of the following:

- Select **File** > **Open**.

- Click the **Open** icon  in the **Toolbar**.
- Drag and drop a project file into the Workspace.

NOTE To open one of the five most recently loaded projects, select **File** and choose a file from the pop-up menu.

If a project is already open, MatchMover prompts you to save it before opening a new one.

To save a project.

1. Select **File** > **Save**  or **Save As** to change the project file.
2. Enter the name of the project in the **Save As** window and click **Save**.

MatchMover saves the project with the ".mmf" extension.

TIP A star is displayed next to the project name in the title bar if the current project has been modified. If you click the save icon of an unmodified project, it will open the Save As window.

NOTE In the event where the application crashes, MatchMover tries to save current project (it may be impossible in some cases). This file is then displayed at the top of the most recently used file list in the **File** menu, at the next execution of the application only.

Setting the project preferences

You can set various project and display preferences in the **User Preferences** window by selecting **Edit** > **Preferences**. For example, in the **Colors** page, you can define the default colors for various project elements.

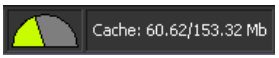
Setting the image cache size

You can also set up the **Image Cache Size**, which refers to the amount of memory (%) used for storing the real time RAM playback. The higher, the smoother the playback and scrubbing you will have. If you are running other applications in the background, or plan to leave MatchMover running on the background then it is suggested to lower the amount.

All 2D images are always stored in the cache. By default, 3D textured images are not stored in the cache, but this can be enabled in the cache preferences. You can opt to display 3D textures, even in 2D Mode.

Flushing the cache

The current **Cache Manager** status is displayed in **Status Bar** as a semi-circle (current memory used in color/memory available in gray).



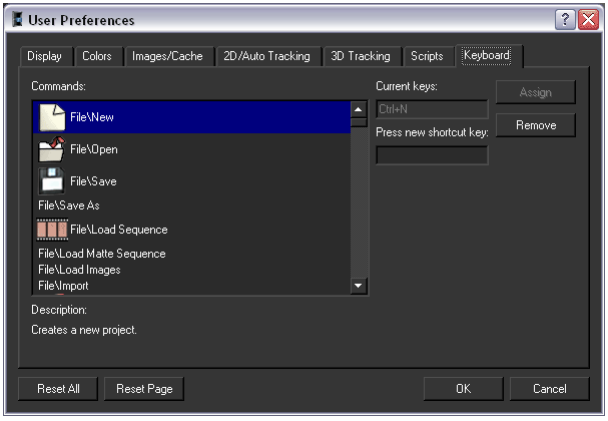
The cache can also be flushed by selecting **Edit** > **Flush Cache** or pressing **Ctrl+Del**.

Resetting the project preferences

The **Reset Page** and **Reset All** buttons at the bottom of the **Preferences** window can be used to change the current values to their default status, either for current page or for all pages. This action can be cancelled by pressing the **Cancel** button in the **Preferences** window, but once the window is closed, it cannot be undone.

Setting user-defined shortcuts

Every command can have a user-defined shortcut that can be set in the **Keyboard** tab of the **Preferences** window.



Managing footage

Importing footage

MatchMover can load image sequences with the following formats:

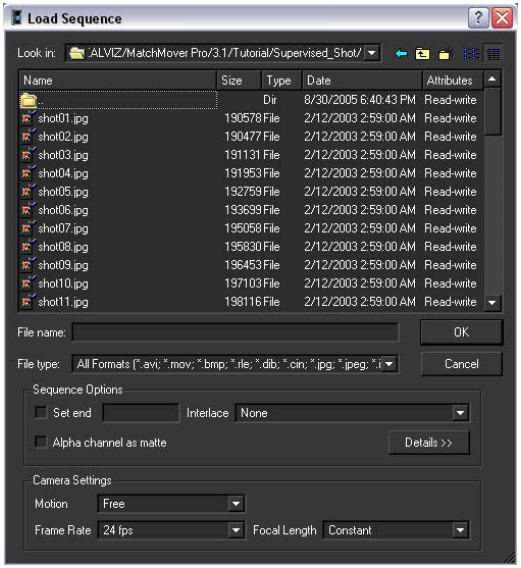
- AVI files (*.avi) (Windows only)
- Cineon files (*.cin)
- JPEG files (*.jpg, *.jpeg)
- Maya Image File Format (*.iff, *.tdi)
- PNG files (*.png)
- PNM files (*.ppm, *.pgm, *.pnm)
- QuickTime (*.mov) (Windows and Mac only)
- SGI files (*.sgi, *.rgb)
- Softimage Pict files (*.pic)
- TGA files (*.tga)
- TIFF files (*.tif, *.tiff)

Loading a sequence

To load a sequence:

1. Do one of the following:
   - Select **File** > **Load Sequence**. The **Open** window appears.
   - Click the **Load Sequence** icon  in the **Toolbar**.
   - Drag and drop a sequence into the Workspace.

NOTE You can also right-click the **Image Sequences** folder in the Project window or the Track window and select **Load Sequences** from the pop-up menu or simply double click this folder.



2 Use the **Details** button to enlarge the window and show a preview of the first and last image of the sequence. The number of images in the sequence, their width and their height are shown at the bottom of the window.

3 Select an AVI or MOV sequence (*.avi or *.mov) or single image. In the case of sequence of consecutive images, you can force the last frame in the dedicated **Set end** edit box.

IMPORTANT A sequence composed of a series of images must contain a minimum of two consecutive frames.

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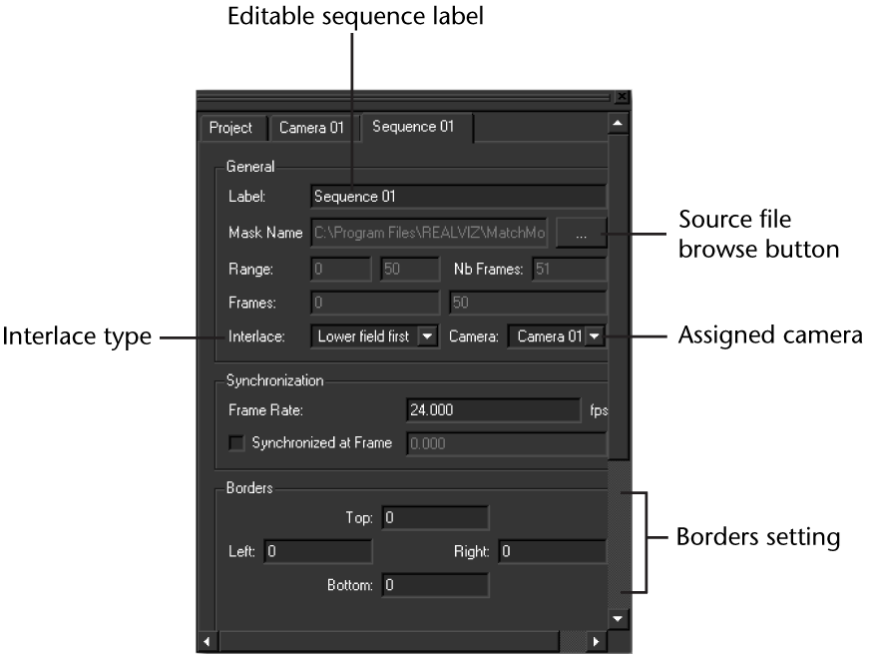
4 If the images are from a video camera, select an **Interlace** type from **None**, **Upper field first**, and **Lower field first** in the corresponding combo box.

5 You can use the following shortcuts to apply a parameter to the entire sequence:

- Choosing a camera **Motion** different from “Free” is equivalent to creating the same constraint later. See Defining camera constraints on page 177.
- Set the **Frame Rate** for the sequence. See Frame rate on page 62.
- Set the camera **Focal Length** constraint to **Constant** or **Variable**. See Setting up cameras on page 159.

6 If you want to use the sequence alpha channel as a matte, check the corresponding option. See Identifying image regions on page 113.

7 Click **Open**.



8 Click the browser button to change the source of the loaded footage. You must only select a footage with the same characteristics (resolution and length).

See Assigning the camera to a sequence on page 160 for camera settings and Cropping an image sequence on page 126 for borders settings.

MatchMover loads the film into the Workspace and creates a new sequence label in the Project window.

File mask naming convention

The file mask name is defined from the image name by replacing the last number found in the filename with:

- An asterisk * (the file img100.jpg, gives the mask img*.jpg).

- With a pound sign #, if the number begins with a zero (zero padding). The mask contains as many # as there are numbers in the filename (the file img0001.jpg gives the mask img####.jpg).

If you select a single image, all the images present in the directory that share this mask and have a higher number than the selected image are loaded, unless Set end is checked. In this case, the numeric field defines the number of the last image to load.

The image numbers must be continuous. If a number is not found, MatchMover assumes the last image of the sequence has been found. All images must be of the same size.

Loading helper images

To load helper images, select **File** > **Load Images** and proceed in the same way as you loaded your sequence. See Loading a sequence on page 108.

All images selected at the same time will be assigned to the same camera. MatchMover assumes they have been shot with the same camera, although in different positions. You can modify this, however, by creating new cameras and associating them with the appropriate images.

Switching between sequences

To switch between loaded sequences, select **Sequence** from the main menu and either of the following options:

- **Previous Sequence** - If the current time points to the beginning of the sequence, this command changes it to point to the start of the previous sequence. If the current time does not point to the beginning of the sequence, it changes it to point to the beginning of the sequence.
- **Next Sequence** - Navigates to the start of the next sequence.

Deleting a sequence

To delete a sequence, do one of the following:

- Select the required sequence in the **Image Sequences** folder in the Project window or the Track window and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.

- Right-click the required sequence in the **Image Sequences** folder in the Project window or the Track window and select **Delete Sequence** from the pop-up menu.

Working with bookmarks

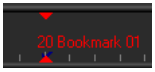
When you have spent a lot of time and effort placing your key points in a certain frame and you wish to find this frame quickly, you can use the bookmark feature.

Placing a bookmark

From the frame you want to bookmark, do one of the following:

- Select **Sequence** > **New Bookmark**  .
- Right-click the **Bookmark** folder in the Project window and select **New Bookmark** from the pop-up menu.

MatchMover bookmarks the frame and places a check mark in the **Time Line** so you can easily move to it.



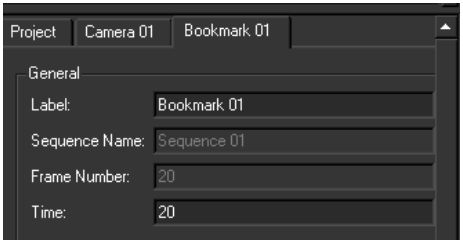
At the same time a bookmark element appears in the Project window.

Moving to a bookmarked frame

To go to a bookmark, do one of the following:

- Select **Sequence** > **Goto Bookmark**. MatchMover changes the current time to the selected bookmark. This option is available only if a bookmark is selected.
- Click the check in the **Time Line**.
- Right-click the **Bookmark** folder in the Project window and select **GoTo Bookmark** from the pop-up menu.
- Modify the value in the **Time** text field in the **Parameters Window**.

The bookmark's **Parameters Window** also shows the bookmarks' **Label** (name of the bookmark), **Sequence Name** to which the bookmark belongs, and the **Frame Number** in relation to the start of this sequence (local time).



TIP By using the **View** > **Freeze Time** option you can lock a view to a specific time. This is particularly useful when navigating between two specific frames. See Freezing the time on page 77.

Deleting a bookmark

To delete a sequence, do one of the following:

- Select a bookmark in the **Bookmark** folder in the Project window and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Right-click a bookmark in the **Bookmark** folder in the Project window and select **Delete Bookmark** from the pop-up menu.

The bookmark is deleted from the project.

Identifying image regions

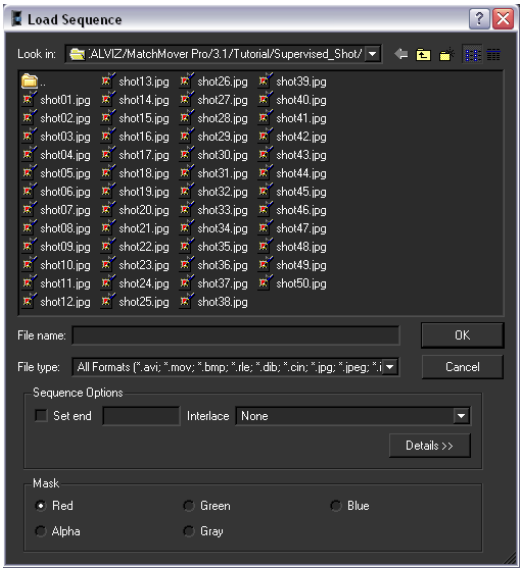
In MatchMover, you can load one matte for each sequence. The matte, however, must have the same resolution and number of frames as those of the sequence.

The matte can be loaded simultaneously with the loading of the actual film sequence if it is included in the alpha channel. In the **File** > **Load Sequence** or **File** > **Load Images** window, check the option "Use alpha channel as matte".

Alternatively, to load a matte sequence:

1 Select **File** > **Load Matte Sequence**.

The **Open** window appears.



2 Click the **Details** button to see thumbnails of the files in your directories.

3 In **Files of type**, select one from among the file types supported by MatchMover. See Loading a sequence on page 108.

4 In the case of sequence of consecutive images, you can force the last frame in the dedicated **Set end** edit box.

5 Select a **Matte Channel**. The default channel used is the **Alpha** channel, which stores selections as 8-bit grayscale images, but you can choose other color information channels. **Red**, **Green**, **Blue**, and **Gray** (for grayscale images). These colors do not affect the actual images.

6 Select an **Interlace type** from **None**, **Upper field first**, and **Lower field first**.

7 Select the matte sequence file you want and click **Open**.

MatchMover loads the matte sequence into the Workspace.

The example shows a black matte that serves to focus the points on a moving car.

Following the child-parent hierarchy, the matte is listed in the Project window and Track window in the **Image Sequences** folder under the sequence it covers.

- The icon  represents a matte with black masking a selected area.
- The icon  represents a matte with white masking a selected area.

Displaying, hiding, and deleting mattes

If mattes are displayed, all the areas masked out are shown with the matte color and transparency in the 2D Mode. You can hide or show mattes by doing one of the following:

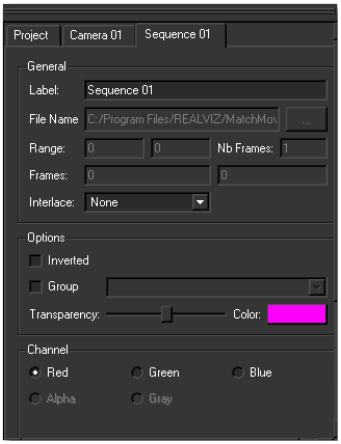
- Select **Display** > **Matte** from the main menu.
- Right-click in the Workspace and select **Display** > **Matte**.

The check mark beside the **Matte** option signifies that the matte is shown. Click the option to deselect it and hide the matte. You will see the full video footage.

To delete a matte, right-click the matte in the Project window and select **Delete Matte** from the pop-up menu.

Setting the matte properties

The **Parameters Window** lists the matte properties.



- The matte's **Label** and **File Name**
- The **Number of Frames** in the sequence
- The beginning and end **Frames** in the range
- The **Range** of frames being used
- The **Interlace** attribute that you can set to **None**, **Upper field first**, and **Lower field first**.
- The displayed color and transparency
- The Group attributes.

You can also select the channel being used by the matte sequence. **Red**, **Green**, **Blue**, **Alpha**, and **Gray** (for grayscale images) channels. However, if a matte has only certain channels, the other channels are grayed out.

Checking the option **Inverted** to invert the area that is masked. Optionally, right-click the matte in the Project window and select **Invert** to check the option.

Each matte is displayed using alpha blending, with customizable transparency and color for each. Mattes also can be tagged as "Group" with a label, and are therefore used to design a coherent rigid mobile object. While autotracking, each object is handled separately, and a group of the specified label is created with its tracks in it, and is calibrated as a separate moving object.

Drawing mattes in MatchMover

MatchMover's **Matte Drawing Tool** allows you to draw binary mattes to identify areas. These areas can be excluded from the automatic tracking process, or used to identify rigid moving objects. Mattes are the result of compositing one or several contours, which are closed, 2D polygons, defined using control points and animated over time.

The **Matte Drawing Tool** allows you to place control points and, therefore, define contours. For any given frame, once you edit a contour, the frame is called a "keyframe" and the contours are interpolated in between keyframes.

- A contour is active at the current frame if it effectively masks an area out. This is true for all frames between the first keyframe and the last keyframe, inclusive.
- A contour is inactive before its first keyframe and after its last keyframe.

You do not need to define a matte for each frame. Defining a matte for some keyframes is sufficient to exclude the required area from the tracking process. MatchMover interpolates the matte in the frames between the keyframes.

You can apply several contours to the same image sequence, either at the same frame or at different frames.

The matte drawing workflow is described as follows:

1. Create and close a contour.
2. Create keyframes and interpolate the contour.
3. Edit the contour, if necessary.
4. Use several contours to mask areas of a sequence.

NOTE Both imported mattes and contours can be used at the same time.

Creating a new contour

When you draw a contour, the last point that was added or edited is the active point. For an open curve, the active point must be the last point of the curve. The active point is highlighted red.

To draw a new contour:

1. Do one of the following:
   - Select **Contour** > **New Contour**.

- Click the **New Contour** icon  in the Toolbar.

MatchMover enters the **Contour Drawing** mode, creates a new empty contour and selects it. The pointer changes to  .

NOTE To exit the **Contour Edition Mode**, select any other element in the project (or press **Esc**).

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2. Click in the Workspace where you want to begin drawing the contour. The newly created control point is added to the curve and it is then selected as the active point.
3. Click in the Workspace to add a second point to the contour. A new point is added to the contour and it becomes the active point.

NOTE Pressing **Del** or **Backspace** deletes the active point.

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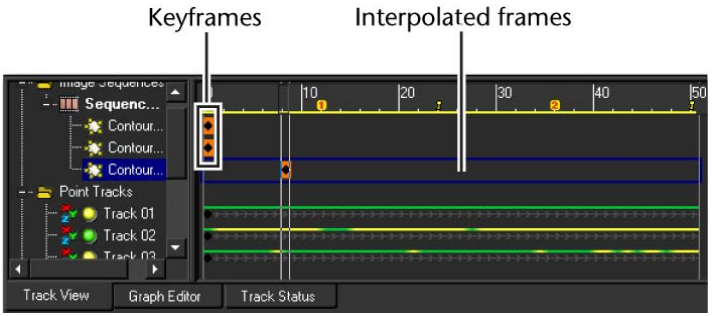
4. Continue clicking in the Workspace until you have defined the contour you want.
5. If you have placed at least three points, do one of the following to close the contour:
   - Press **Enter**
   - Double-click the mouse button
   - Hover the pointer over the first point of the contour. The pointer changes to  . Click the mouse button.

A keyframe is created for the current contour and a new contour is added to the **Contours** folder in the Project window.

When you create a new contour, you create a new matte. The new matte is listed in the Project window as a child of the sequence to which it belongs.

In the Track window, contours are shown as children of the sequence mask.



The Track window shows for each contour:

- Keyframes represented by a dark icon with a central black dot
- Interpolated frames represented by a lighter color
- Frames where this contour is not in use remain with the background color.

Selecting points and contours

In the **Contour Drawing** mode in the **2D View**, you can select:

- A contour by clicking on it in the Project window or the **2D View**
- A control point in a selected contour by clicking on it in the **2D View**. The pointer changes to a  nd the point becomes the active point.

When you select a contour in the **Contour Drawing** mode, it is represented by a thick outline and control points.

Other contours in the selected frame are represented by thin outlines and control points.

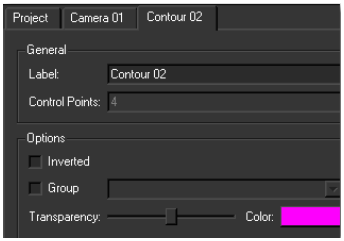
If the selected contour is inactive for the current frame, it is represented by a dashed line.

Inactive contours that are not selected are not displayed.

NOTE While you are working on contours, the resulting matte is not shown in the **2D View**, only the outline is displayed, even if matte display is turned off.

Changing a contour's properties

The image below shows the contour's **Parameters** window.



- To rename the contour, change the name of the contour in the **Label** text field in the **Parameters Window**. The matte's name is updated in the **Image Sequences** folder in the Project window.
- The read-only text field **Control points** displays the number of vertices or control points for the contour.
- Check the option **Inverted** to exclude the area outside the contour instead of excluding the one inside.
- Check the **Group** attributes to specify a rigid moving object and set its corresponding sub-folder name.
- Choose contour displayed color and use the slider to adjust the transparency.

Deleting a contour

Do one of the following:

1. Select a contour and either:
   - Select **Contour** > **Delete**.
   - Right-click in the **2D View** and select **Delete Contour** from the pop-up menu.
   - Press the **Delete** key.
2. Right-click the contour in the **Image Sequences** folder in the Project window or the Track window and select **Delete Contour** from the pop-up menu.

The selected contour is removed.

About keyframes and interpolating the contour

A keyframe is created for each closed contour. When you change the current time, the contour shown in the Workspace depends on the content of the contour at this frame.

- If this is a keyframe, the contour for this keyframe is displayed.
- If the contour is interpolated at this frame, the result of the interpolation is displayed.
- Otherwise, the curve for the closest keyframe will be displayed.

Editing the curve at the current frame creates a new keyframe at the current frame and interpolates it between the other keyframe from which it was copied.

Adding a keyframe

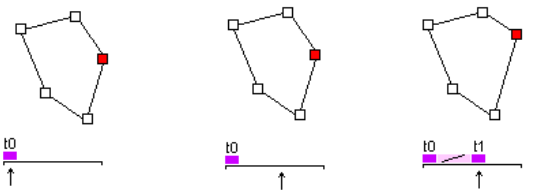
To add a keyframe, do one of the following:

- Select **Contour** > **Add Keyframe**.
- Right-click in the **2D View** and select **Add Keyframe** from the pop-up menu.

MatchMover creates a keyframe for the selected contour at the current frame using either the interpolated curve, if any, or the displayed curve.

If the new keyframe is between existing keyframes, then the interpolated curve is used. Otherwise a copy of the contour at the nearest keyframe is used. This ensures that the domain of definition of a contour is always an interval.

For example, a keyframe is defined at the time t0. When the time is changed to t1, the former curve is still displayed. When the curve is edited at t1, a new keyframe is created and interpolation of the curve will be performed between t0 and t1.



Deleting a keyframe

To delete a keyframe, do one of the following:

- Select **Contour** > **Remove Keyframe**.
- Right-click in the **2D View** and select **Remove Keyframe** from the pop-up menu.

Editing a contour

Once you have created a contour, you can edit it to define the shape of your required matte.

Adding points to a contour

To add a new point to a contour, double-click anywhere on the selected contour.

The point is added for all keyframes of the contour.

Moving a point in a contour

To move a point in a contour:

1. Select a point so that it becomes the active point.
2. While holding down the pointer, drag the point to a new position.

Deleting a point from a contour

To delete a point from a contour:

1. Select a point so that it becomes the active point.
2. Do one of the following:
   - Select **Contour** > **Delete Point**.
   - Press the **Backspace** button on the keyboard.

The active point is removed from the contour and the preceding point becomes the active point. The point is deleted for all keyframes of the contour.

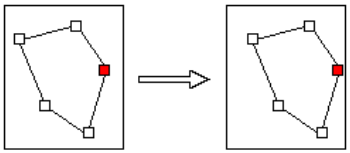
Moving the contour

To translate a contour:

1 Select a contour. See Selecting points and contours on page 119.

2 Click and drag the pointer anywhere in the **2D View**.

The contour and its control points are translated and a keyframe is created at the current frame.



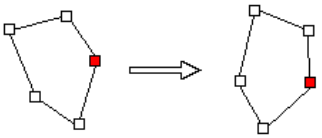
Rotating the contour

To rotate a contour:

1 Select a contour. See Selecting points and contours on page 119.

2 Press **Shift**+click. The pointer changes to  . Drag the pointer anywhere in the **2D View**.

This action rotates all the control points defining the current curve by a constant angle around a given 2D point, determined by the original position of the pointer at the time of the click, and creates a keyframe at the current frame.



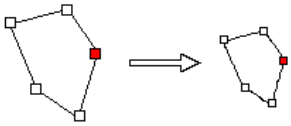
Scaling the contour

To scale a contour:

1 Select a contour. See Selecting points and contours on page 119.

2 Press **Ctrl**+**Alt**+click. The pointer changes to  . Drag the pointer horizontally in the **2D View**.

The center of the scale is the original position of the pointer at the time of the click. The scale factor increases toward the right, decreases towards the left.



Copying and pasting a contour

You can copy and paste a contour at one keyframe only using the **Copy** and **Paste** commands.

To make a copy and paste a keyframe of a contour:

1. Do one of the following:
   - Select a contour to duplicate and select **Contour** > **Copy**.
   - Right-click in the **2D View** and select **Copy Contour** from the pop-up menu.
   - Right-click the contour in the **Image Sequences** folder in the Project window or the Track window and select **Copy Contour** from the pop-up menu.

   MatchMover creates a copy of the contour at the current keyframe and stores it into a buffer.

   NOTE Only one curve can be copied that way; if there is already a curve in the buffer, it is overwritten.

2. Select the contour and the frame where you will paste the contour frame as a new keyframe.
3. Select **Contour** > **Paste**.

Duplicating a contour

To duplicate all keyframes of a selected contour.

Select a contour then do one of the following:

- Select **Contour** > **Duplicate**.

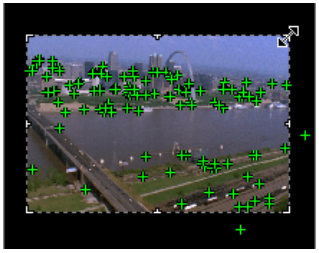
- Right-click in the **2D View** and select **Duplicate Contour** from the pop-up menu.

MatchMover creates an exact copy of the current contour featuring all keyframes. The contour is interpolated between this new keyframe and the existing ones.

Cropping an image sequence

To crop an image:

1. Select the image sequence from the **Image Sequences** folder in the Project window or the Track window.
2. To crop the entire image proportionally, pull a corner handle inward.



If you want to crop only one side, pull a side handle inward.

As an alternative, you can crop the image by editing the sequence's **Parameters Window** window:

1. Click a selected sequence in the **Image Sequences** folder in the Project window or the Track window.
2. In the **Parameters Window**, enter the pixel sizes of the border(s) to crop.

Validate by pressing the **Tab** key to jump to the next field or pressing the **Enter** key.

2D tracking

Automatic 2D tracking

Running the automatic 2D tracking

To run the automatic tracking:

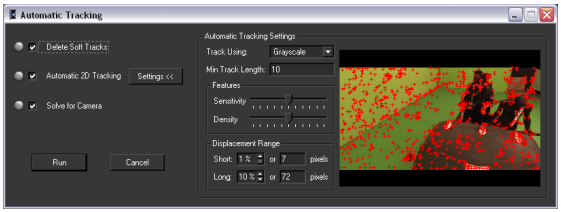
1 Do one of the following:

- Select **2D Tracking** > **Automatic Tracking**.
- Click the **Run the Automatic Tracking** icon  in the Toolbar.
- Press **F10**.

A window appears, listing the steps in the automatic matchmoving process.

- If checked, **Clear Soft Tracks** clears previously generated soft tracks, which are indicated by a single cross in the tree view.
- The next step, **2D Tracking**, extracts relevant information from images within the video sequence as you would do manually. See Supervised 2D tracking on page 132. All tracks generated during this step are flagged “automatic.”
- In **Camera Solving**, the movement of the camera in 3D space and its (the camera’s) settings are calculated. For more details. See Solving for the camera on page 185.

2 The **Settings** button allows you to configure the automatic tracking engine:



- From the **Track Using** drop-down list, choose either **Grayscale** to track the feature's luminance (it's the faster way, and should fit most cases), or **Colors** to take care of each color channel independently.
- Enter the **Minimum Track Length**. Tracks that do not last at least this number of frames will be discarded.
- Use the sliders to set the **Features Sensitivity** (how sensitive is the feature detector) and the **Features Density** (to allow more or less points in an area).
- Set a minimum and maximum **Displacement Range**, expressed as a percentage of the largest dimension of the image. You can also enter this data in pixel unit.

TIP Use the **Colors** option when your sequence contains motion blur or low-contrast images or sequences.

---

3 Now click **Run** to begin the matchmoving process. Colored indicators beside the option name show you the status of the process as well as the status of each step.

- A gray button indicates a task that has not been started yet.
- A yellow button indicates a task in progress.
- A green button indicates a completed task.

Viewing the results

Upon completion of the automatic tracking process, you will have a list of the automatically generated point tracks, marked with a circle in the **Point Tracks / Auto Tracks** folder (and optionally, moving rigid object sub-folders, if any) in the Project window and Track window. Tracks are only generated in areas of the image that are not masked or cropped out. Each track is automatically named "Auto####," where "####" represents the track number.

NOTE All automatically generated tracks will be flagged as soft tracks.

Differences with supervised tracking

Running the automatic tracking is an easy and robust way to track many points simultaneously. The process can be launched whenever needed, on the entire sequence or on a selected time range, on the entire image, or on selected areas only using masks. The automatic process is different from supervised tracking in the sense that as many tracks are handled at the same time, 3D coherency is used while tracking.

Also, when supervised tracks are present before launching the automatic process, they are used in the 3D coherency checking.

The results are different from the kind of tracks you will have when using the supervised tracking, as in this case, each track is handled individually.

As automatic tracking may lead to huge number of tracks, a soft track is not guaranteed to be used in the solving process. An algorithm that automatically selects the best soft tracks to fit the computation in memory is launched before the solving. To convert a soft track into a hard track, simply check the hard track check-box in the track parameters window or pop-up menu. This way you're sure it will always be fed into the engine.

Apart from this difference, the same tools handle automatic and supervised tracks.

Refining tracking results

If you are satisfied with the results of the automatic tracking process, you can export your project at this point. Otherwise, you may want to edit the 2D tracks.

You can do so by:

- Adding tracks. SeeCreating a new track on page 132.
- Deleting unnecessary or unwanted tracks. See Deleting tracks on page 135.
- Cleaning up the 2D tracks. See Cleaning up tracks on page 130.
- Defining point relations. SeeMotion control on page 68.

If you are an expert user, adding track points serves to work around a weakness of the automatic tracker or to add a point necessary for defining a coordinate system which the automatic tracker would not have considered. See Defining coordinate systems on page 167.

Cleaning up tracks

You can run the **Cleanup Assistant** to let MatchMover automatically remove points, based on the parameters you set. This option's main purpose is to reduce the number of tracks, while keeping relevant tracking information, so that manual edition becomes easier.

NOTE As a recommendation, however, do the automatic clean-up only if you are unhappy with the result after running the solver once. It is best to first run the solver with all the tracks.

---

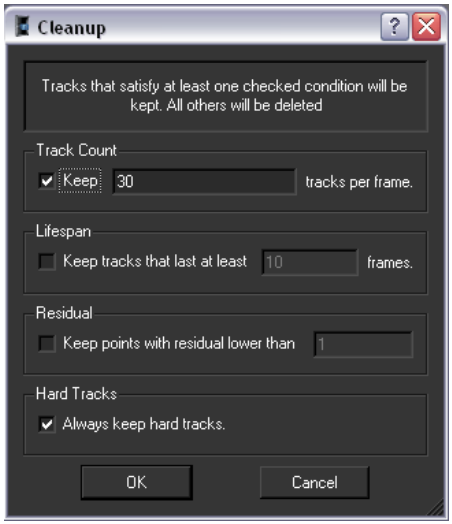
1 Do one of the following:
   - Select **3D Tracking** > **Clean Assistant**.

- Click the **Clean up tracks**  icon in the Toolbar.
- Press **F11**.

The **Cleanup** window opens.

2 Specify the settings.

- **Keep ... tracks per frame** targets an average number of tracks in each frame after the clean up. The default value is 30 frames.
- **Keep tracks that last at least ... frames** deletes all tracks lasting less than the desired number of frames. The default value is 10 frames.
- **Residual cleanup** deletes all tracks with a residual value above a threshold you set.



This can only be done after the solver has finished running.

3 If you do not want to delete manually added tracks, select the option to **Always keep hard tracks**.

For example, if a track satisfies at least one condition, it will be kept. For instance if you set the length > 10 and residual < 0.8, then a track lasting six frames with residual 0.4 will be kept because of the second filter.

TIP The **Automatic Cleanup** option of the previous version of MatchMover is roughly equivalent to keeping 40 tracks per frame.

Supervised 2D tracking

MatchMover allows manual editing of track points. In addition, advanced users may prefer to manually add tracks before running the automatic tracking process to strengthen the result, or after, to refine the result.

Creating a new track

To create a new track.

1 Do one of the following:

- Select **2D Tracking** > **New Track**.
- Click the **New Track** icon  in the Toolbar.
- Right-click in the **2D View** or in the **Point Tracks** folder in the Project window or the Track window and select **New Track** from the pop-up menu.

MatchMover creates an item in the **Point Tracks** sub folder in the Project window and the pointer changes to  in the Workspace. Whenever the pointer has this appearance, you are in the **New Track Creation** mode.

2 Position the pointer where you want to create a key for this track and click.

See Magnifier window on page 96 for the **Magnifier** configuration.

NOTE You can simply create tracks in the same way in the **2D** or **3D** mode using **Shift**+right-click the background image plane. If you select a track group in the Project window, new tracks will be added automatically to the group. See Creating groups on page 153 for more information about track groups.

When you add a track, the following icons appear in the Project window indicating the track status.

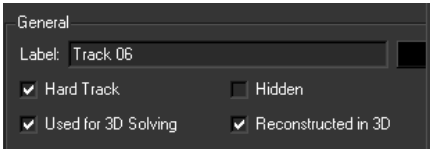
The left part of the icon shows its calibration status:

-  An empty circle indicates a track not used for 3D solving.
- 
- A single cross indicates a soft track (the engine will decide to use it or not).
-  A cross in circle indicates a hard track (always fed into the engine).
-  An xyz indicates a survey points (a track with known 3D coordinates).

The right part of the icon shows its 3D reconstruction status:

-  An empty circle indicates a track that should not be reconstructed.
-  A gray circle indicates a track that can be reconstructed by the engine.
-  A green/yellow/red circle indicates a good/medium/bad reconstructed point.

In the **Parameters Window**, or if you right-click any point in the **Point Tracks** folder in the Project window or the Track window, the following options are checked by default in the pop-up menu and correspond to the icons above table.



- **Use for 3D Solving**, indicating that the point is to be used in the solving process.
- **Reconstructed in 3D**, indicating that the point will be reconstructed in 3D.
- You can access the detailed 3D information of a track in the **3D** tab of its **Parameters Window**.

The window shows read-only fields:

- The point coordinates, **X**, **Y**, and **Z**, calculated by the camera solving process.
- The **Residual at time**, which is the difference in pixels between the 2D point position and the position obtained by viewing the reconstructed 3D point through the calculated camera at the current time.
- The **Average Residual**, which shows the average difference in pixels for all the frames.

For example, you want to track a table corner through an image sequence. In image 0, press **Shift**+right-click the table corner. MatchMover creates the "Track 0" and an intermediate key. The tracker uses this key point to remain on the point track during the tracking process. Now, you can launch the tracker.

The **Relations** tab just shows the list of relations involving this track. Double-click one to select it.

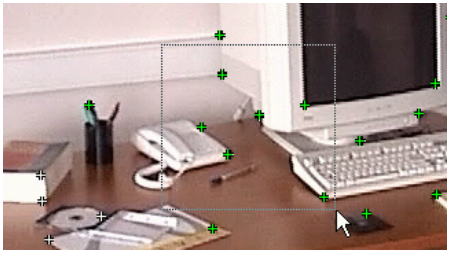
NOTE For 2D configuration, see Setting the parameters of a single key point on page 142 and Color Tracking on page 144. For 3D survey configuration, see Defining survey points and object mapping on page 175.

Selecting tracks

Click a track (either the cross, the pattern, the point or the 3D helper depending on your current view and settings) to select it.

To select several points, do any of the following:

- In the Workspace, hold the **Shift** key and click the points in the image one by one.
- In the Workspace, click the image and drag the pointer to contain certain points in a selection **Rectangle** or click several points to define a polygon **Contour** (2D mode only) then release the mouse button. The selection mode is specified in the **Track Selection Display** drop-down list in the **Preferences** > **Display** window. All tracks with points inside the rectangle or contour are selected.



- To add to the selection, press the **Shift** key. To deselect the points, click any empty area in the image or press **Esc**.
- For a sequential selection, in the folder **Point Tracks** in the Project window, click the first point, press and hold the **Shift** key, and click the last point drag the rubber rectangle to select points.
- For a non-sequential selection, in the folder **Point Tracks** in the Project window, hold the **Ctrl** key and click the points one by one.

NOTE The currently selected track or a track multiselection can be inverted by right-clicking in the **Project Window** and selecting **Invert Selection** from the pop-up menu.

Deleting tracks

To delete tracks, do one of the following:

- Select the track(s) that you want to delete.
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Right-click the track(s) in the Project window or the Track window and select **Delete Track**.

Merging tracks

When 2D features of the scene move out of the view then back in or are occulted by objects in motion causing the tracker to misinterpret them as distinct points, you can merge the keys from several tracks into one.

1 Select at least two track points to merge.

2 Do one of the following:

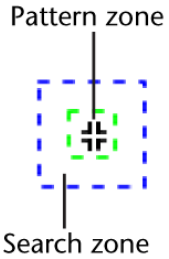
- Select **2D Tracking** > **Merge Tracks**.
- Right-click in the **2D View** or the **Point Tracks** folder in the Project window or the Track window and select **Merge Tracks** from the pop-up menu.

MatchMover checks whether the selected tracks have keys in common (at the same frame) or not. If not, all keys and computed points are copied to the first tracks, and the other tracks are deleted.

NOTE You can configure MatchMover to merge tracks automatically during the solving by selecting **Edit** > **Preferences** and checking the **Automatically Merge Tracks** option in the **3D Tracking** page.

About the Tracking Tool

Tracking Tool in the **2D View** surrounds any track key point.



The **Tracking Tool** is composed of two rectangles, an inner rectangle containing the **Pattern Zone** and an outer one containing the **Search Zone**.

A track is identified through the pixels around it. All pixels in the **Pattern Zone** are considered for this identification. During the tracking process, MatchMover looks for that pattern anywhere in the **Search Zone** in the next frame.

NOTE To change the colors of the **Pattern Zone** and the **Search Zone**, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

By default the size of these zones is determined by the **Default Search Size** and **Default Pattern Size** settings in the **2D Tracking** page of the **User Preferences** window that applies to all new keys created. See Configuring the

tracker on page 144. You can set independent values for each new key with the following procedure:

- Click a corner to uniformly scale the rectangle. The pointer changes to a double-headed arrow.
- Click the center of an edge to size the selected edge only. The pointer changes to a double-headed arrow.

To change the size of the **Tracking Tool** for a selected point, enter the values in the **Pattern Zone** and **Search Zone** fields in the **Parameters Window**. When adding a key to an existing track, they **Pattern Zone** and **Search Zone** sizes will be copied from the closest existing key of this track.

TIP To set the size of the **Tracking Tool** for all tracked points, see Configuring the tracker on page 144.

About key points

Key points are the basic elements of the 2D tracking. Key points can be inserted in any image and anywhere within the image. For each track point the following information is shown in the Track window. See The Track View on page 88.

- The point type
- The track quality
- The tracking direction.

If a point is computed, the shape indicates that MatchMover has generated the point. Computed points appear red if bidirectional tracking is only partially completed. There are five key types and each key type has a different symbol.

Shape	Type of Point
	**Automatic** - Defines a key point added automatically by the tracker when the quality falls below a defined threshold (if the Automatic Key Insertion option is selected in the Preferences).

Start - defines the start of a track segment.

End - Defines the end of a track segment.

Intermediate - Default key type when you create a new track. Use this type of key to constrain the tracker so that it passes through important positions.

Single - Defines a key point that you created manually. The data from this key point is ignored by the 2D tracking but used in the 3D tracking process. Use this type of key to correct the results of the 2D tracker at isolated frames without affecting the rest of the tracker, for example, if a track is obscured in a scene but it's position is known.

In a **2D View**, editing an auto-tracked point automatically turns it into a key point. When you create a key point, it has by default an intermediate key point type. You can create begin, end, intermediate, and single key points. If you edit an intermediate key, computation for the track will be lost if the "Auto Clean" option is set and tracking must be re-run. You can have several tracked segments for one track.

Editing a key point type

To edit a key point type, do one of the following:

- Select **2D Tracking** > **Set Key**.
- Right-click in the **2D View**, the **Point Tracks** folder in the Project window or the Track window to show the pop-up menu and select **Set Key**.

Choose the desired key type from **Begin**, **Intermediate**, **End** and **Single**. See About key points on page 137 for more details on key types.

Notice that the key symbol changes (in the Track window), to show the new status of the key.

Inserting a new key point in a track

Select a track. Click and hold in the **2D View** where you want to place the new key. By default MatchMover zooms in on the area using a pop-up magnifier.

NOTE You can replace the pop-up magnifier with the **Magnifier Window** to help you in placing a key point, see Magnifier window on page 96.

MatchMover places the key. The center of the key point is marked with a cross that is surrounded by two boxes. This is the **Tracking Tool**. See About the Tracking Tool on page 136. The key type symbol and its label are also displayed.

TIP Repeat the procedure for other tracks in the same frame or for other keys for the same track in different frames. If you want to place other key points for the same track, you can use the **Auto Key Match** function.

In editing keys while a **2D View** is in focus, you can use the arrow keys to move the current key. You set the number of pixels for each hit in the **Nudge step** box in **Edit** > **Preferences** > **2D Tracking**. The value can be less than one pixel. See Configuring the tracker on page 144.

If the edited point was not a key, it is automatically turned into one.

TIP Pressing shift with an arrow key will multiply the nudge step by 10.

Moving a key point

1. Select the key point you want to move. The pointer changes to  .
2. Drag the pointer to the new position and release.

NOTE If **Auto Clean** is enabled, this action deletes the 2D computed points that have been created from this key. To recompute these points, you have to rerun the tracking process. To enable or disable **Auto Clean**, select **Edit** > **Preferences** > **2D Tracking** and click the corresponding box.

Deleting a key

1. Select a track then a frame if none is selected.

2 Do one of the following:

- Select **2D Tracking** > **Clear Keys**.
- Right-click in the **2D View** or the **Point Tracks** folder in the Project window or the Track window to show the pop-up menu and select **Clear Keys**.

If you have not created a time range, MatchMover deletes the key at the current time. If you have created a time range, MatchMover deletes all keys within the time range.

Using the Auto Match Key

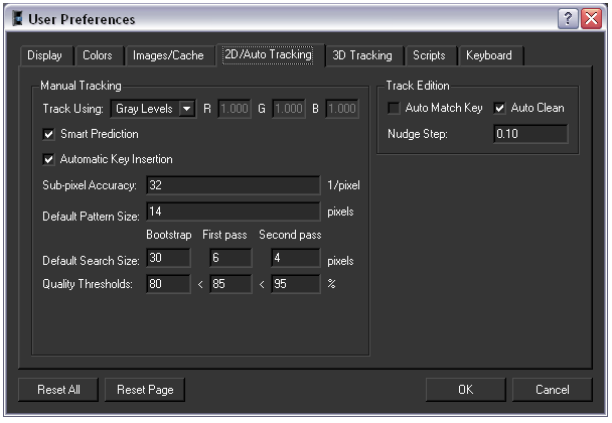
The **Auto Match Key** uses the pattern around the position of the previous key and attempts to find a similar pattern at the current frame. If you do not use the **Auto Match Key** option, you have to be careful to place a key point exactly in the position so that it matches the position of the previous key in the same track. The area to search is defined by the value in pixels in the **First Pass** field. The default value is generally sufficient.

For example, place a key point in frame 1. Then move to frame 5 where you place another key point. In **Auto Match Key** mode, clicking near to the original key point is sufficient for MatchMover to place the new key in the right position.

To toggle the **Auto Match Key** option for the current key point, press **Shift**+click.

If you want to enable the **Auto Match Key** permanently:

1 Select **Edit** > **Preferences** and open the **2D/Auto Tracking** page.



2 Check the **Auto Match Key** check box.

MatchMover now uses this function when you place a key.

Key point placing strategy

When you have examined your sequence you can now concentrate on the strategy of placing your key points to achieve the best results. It is important to understand the difference between the different keys and the effect they have on the tracking process before you begin placing them.

When selecting tracked points, you should choose points that:

- Represent physical 3D points (avoid highlights or the meeting point of a foreground and a background object. See Troubleshooting the solvertroubleshooting:automatic 2D tracking on page 190.
- Can be accurately localized (avoid points in uniform image areas, points located on linear edges that can “slide” along the edge are not good candidates).
- Follow the same 3D rigid motion. Do not track points in a static background and on a moving object in the foreground in the same track group.

All of the 3D calculation depends on the correct choice when placing points.

TIP Before creating your key points within the image sequence, review the sequence and plan the key point positioning. This aids the tracker calculations and saves you time and effort in the later stages.

Scatter - Place the key points over the widest possible area trying to cover the 3D volume. Concentrate on areas where you want to put a 3D object.

Balance - As you move through the sequence some points may leave the frame and other points may enter the frame. Therefore try to keep a balance of the number of points within each frame and avoid a lot of points leaving or entering at the same time.

Depth - Place key points in the background and the foreground of your sequence to enable depth calculations.

Examples

Image masking - You want to track a point from image 1 to image 20. You know that in images 12 to 15 there is a partial masking of the point.

You place a Begin key in image 1 and an end key in image 20. For the images 12 to 15, you may be able to place single keys. The tracker ignores these keys and this part of the sequence. Therefore the tracker tracks from image 1 to image 12 then 'jumps' to image 16. However, the 3D tracker uses the single key points in the same way as other points.

Intermediate keys - You want to track a point from image 1 to 20. However, the point in image 1 and in image 20 is very blurred so you cannot place a begin key or end key. In image 10 the point is clear so you place an Intermediate key and launch a forward track to image 20 and a backward track to image 1. By doing this you succeed in tracking the point throughout the entire sequence despite the blur.

Variable Zoom - If you track a feature with an image size that changes drastically (large motion or zoom), it is better to place a key in a frame where the resolution is high and start tracking from this key towards frames where the feature appears smaller.

Setting key point parameters

By default each key point has a pattern size, search zone and quality threshold, as defined in **2D Tracking** page of the **User Preferences** window. See Configuring the tracker on page 144.

These parameters are global and apply to all key points, however it is possible to set the parameters for each key point separately. In most cases the default values are sufficient to complete a successful track, but you may want to set them.

Setting the parameters of a single key point

To set the parameters of a single key point:

1. Select the point to edit.
2. In the **Parameters Window**, the **Current time** text field shows the current time.

   Refer to the following list for parameters details:

   - The horizontal point position **X** in pixels in the image (if the point is a key, you can modify its position. The origin is the upper left corner of the image).
   - The vertical point position **Y** in pixels in the image.

- **Status** shows the type of key. Select a new key type from **Begin**, **End**, **Intermediate**, and **Single** from the drop-down list.
- **Threshold** is the minimum accuracy of the similarity between two pixels. A value too low causes the tracker to match any pixels. A value too high causes the tracker to stop or to place too many automatic keys.
- **Pattern Zone** is the area to search for in the adjacent image. You can use different values for the different sides. For example, if you track a point within an area of uniform color, the tracker may have problems to follow the point. Increase the template area to include pixels of a different brightness to eliminate this problem.
- **Search Zone** is the area in which to search, in the adjacent image. You can use different values for the different sides. If you see that the point moves a lot through the sequence, make the search area larger, remembering that a larger search size decreases the tracking speed.

The tracker uses these parameters to find the corresponding point in the adjacent image and track the point and the information is updated if you change the current time.

NOTE If the selected point is not a key point, but has been calculated by the tracking process, then you can only read the track point information in the **2D** page.

- **Parameters at time** shows the current time.
- **X** shows the horizontal pixel position of the point in the image. The origin is the upper left corner of the image.
- **Y** shows the vertical pixel position of the point in the image. The origin is the upper left corner of the image.
- **Tracking Score** shows the estimated precision quality of the tracking.
- **Status** shows the type of tracking used to calculate this point. The status can be **Forward**, **Backward** or **Bidirectional**.

Color Tracking

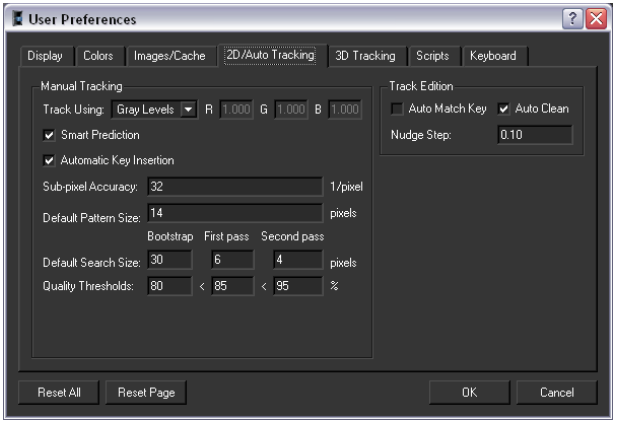
All key points have a separate color tracking setting. For example, a red cross on green background may ignore blue channel.

- **Gray**. Track using luminance information (an average of the R,G,B colors). This is the default option.
- **Color**. Track using all color components independently.
- **Coeff**. Track using a coefficient for each color channel. For example, when a color seems to be too “noisy”, just lower its coefficient. If the coefficient is 0, then the color is ignored.
- **Auto**. Track using a coefficient for each color channel, but coefficient is computed automatically. MatchMover analyzes the image to find the best coefficient.

Configuring the tracker

Before launching the tracker you can configure the parameters to aid the tracking process. When you have a sequence with particular characteristics, such as zoom or rapid movement causing blur, you set the tracker’s parameters to aid the tracking process.

Select **Edit** > **Preferences** and select the **2D/Auto Tracking** page.



Choose the desired options. By default the options **Gray Levels**, **Smart Prediction** and **Automatic Key Insertion** are selected. These options apply to all key points.

- **Track using** - Use **Color** where the contrast between two colors is low. For high-contrast colors, use **Gray Levels**. The **Gray Levels** option is faster, but less accurate than the **Color** option. See Color Tracking on page 144.
- **Auto Match Key** - Toggles the use of automatic key placing. This decreases the possibility of error by placing the key using the position of the neighboring key.
- **Auto Clean** - toggles the automatic removal of all tracked points when editing the originator key. It is enabled by default.
  - **Smart Prediction** - predicts the position of a point in the successive image and reduces the tracking time by a factor of 10. **Smart Prediction** works in smooth sequences so if you have a “shaky” camera sequence toggle the **Smart Prediction** option to off. If there is a smooth camera movement, use the option.
- **Nudge step** - sets the number of pixels for each arrow-key press when editing keys. The value can be less than one pixel.
- **Automatic Key Insertion** - places automatic keys when the quality falls below a certain threshold caused by factors such as camera zoom (the pattern followed by the tracker changes size and resembles less and less the original pattern, causing the quality to decrease).
- If you do not use **Automatic Key Insertion** under these circumstances the tracker halts. You may notice that in some situations the position of an automatic key deviates from the point to track, if this is the case toggle **Automatic Key Insertion** to off.

TIP You want to track a point from image 20 to image 40. If you know that within this sequence there is a zoom, use **Automatic key insertion**. By using the **Automatic key insertion** option the tracker is able to follow the point, despite the zoom.

The other options in the **User Preferences** window refer to the default settings of the key points. Any changes made here affect all new key points. The settings for current key points do not change.

To change values for a single key point, use the **Parameters Window**. See Setting the parameters of a single key point on page 142.

- **Default Pattern Size** defines the area to search for in the adjacent image. The default value of 14 means that the **Pattern Size** is 7 pixels to the left of the point and 7 pixels to the right.
- **Default Search Size**
  - **Bootstrap** - Defines the search area in pixels used by all the key points when **Smart Prediction** is not used. Increase this value if you find that the pixel motion of the point you are tracking moves substantially. If **Smart Prediction** is used the **Bootstrap** value is used up to the point where the prediction process starts.
  - **First Pass** - Defines the search area in pixels when **Smart Prediction** is selected. The tracker starts with the **Bootstrap** value then changes to the **First Pass** value when the **Smart Prediction** process starts. When the sequence is not as smooth as you would like and you still want to use **Smart Prediction**, increase the **First Pass** value.
  - **Second Pass** - Defines the search area in pixels and is only used in a bi-directional tracking. If you have already tracked in one direction, the tracker uses this value for the opposite direction track. The tracker uses the results from the direction already tracked and therefore the search is more localized, the search area is smaller and the tracking process is faster.
- **Sub-pixel Accuracy** - Defines the search precision. For example, a value of 8 means the maximum search distance of the pixel match is 1/8th of a pixel. The tracking process is slightly longer when there is a high accuracy value.
- **Quality Thresholds** - **Stop** defines the minimum quality value. There are two possible situations. If **Automatic key insertion** is not selected and the quality falls below this value, the tracker stops. If **Automatic key insertion** is selected and the quality falls below this value an automatic key is inserted.
  For display purposes the **Poor** and **Good** values determine the on-screen appearance of the points in the Track window. They have no effect on the tracking process itself.

  A quality value between the **Stop** and **Poor** values is shown as red. A quality value between the **Poor** and **Good** values is shown as yellow. A quality value above the **Good** value is shown as green.

Running the tracker

By default when you run the tracker the whole of your sequence is tracked (as defined by the key types). If you want to track points for a subset of your sequence you must create a time range.

You can run the tracker in three ways:

- A forward track
- A backward track
- A bi-directional track

The tracker stops when:

- It reaches the beginning or end of the sequence or time range.
- The match falls below the quality set in the tracking parameters box.
- It reaches a **Begin** or **End** key point.
- The point is about to leave the image.

To check the quality of the tracking you can zoom on the image to view the pixels. Do one of the following then zoom on the track:

- Select **View** > **Lock On Track**.
- Right-click in the **2D View** and select **Lock On Track** from the pop-up menu.
- Click the **Lock On Track** icon  in the Workspace.

About the tracking monitor

When you run the 2D tracking process, the **Track Monitor** appears in a toolbox window. It shows a zoomed view of the point being tracked through the sequence.

Running the tracker forward or backward

You can launch the tracking process in a forward or backward direction. Only one key point is necessary to track either forward or backward, but it must be either a begin key or an intermediate key. Only one point can be tracked at a time. When more than one track is selected, the tracking function is disabled.

To run the tracker forward or backward, either:

- Select **2D Tracking** > **Track Forward** or **Track Backward**.
- Right-click a track in the **2D View**, the **Point Tracks** folder in the Project window or the **T**rack Window to open the pop-up menu and select **Track Forward** or **Track Backward**.
- Click the **Run/Stop Track Forward**  icon or **Run/Stop Track Backward**  icon in the Toolbar.

MatchMover launches the 2D tracker. Notice that by default the Tracking Monitor opens showing the point being tracked through the image sequence. A colored line in the **Track View** shows the track as it is tracked.

TIP To obtain the best results, when you have placed two key points in a sequence, use the option **Bidirectional**.

Running the tracker in bidirectional mode

This option launches the tracking process in a forward and backward direction. There must be at least two key points enclosing the segment or sequence to track. Use this option when there is some deviation of the point through the track sequence.

By blending the two trajections produced by forward and backward tracking, MatchMover guarantees that the final point track has a smooth trajectory that passes exactly through the two enclosing key points.

To run the tracker bidirectional, do one of the following:

- Select **2D Tracking** > **Track Bidirectional**.
- Right-click a track in the **2D View**, the **Point Tracks** folder in the Project window or the **T**rack Window to open the pop-up menu and select **Track Bidirectional**.
- Click the **Run/Stop Track Bidirectional**  in the Toolbar.icon

MatchMover launches the 2D tracker.

Computed 2D points

The tracker automatically creates and places computed 2D points, using information from the key points, in the sequence, that are used in the camera solving process. The type of computed point generated depends on the type of tracking process that you run to create them.

There are three types of computed 2D points shown by the following symbols that appear in the Track window.

Shape	Type of Point
	Forward computed point
	Backward computed point
	Bi-directional computed point

Clearing computed points

1. Select a track(s) and then a frame(s) range.
2. Do one of the following:
   - Select **2D Tracking** > **Clear Tracked Points**.
   - Right-click **2D View**, the **Point Tracks** folder in the Project window or the Track window to show the pop-up menu and select **Clear Tracked Points**.
   - Press the **Backspace** key.

If you have not created a time range, MatchMover deletes the point at the current time. If you have created a time range, MatchMover deletes all points within the range.

Locking tracks

Locking a track protects a track against modification or deletion. For example, a locked point will not be removed from the project when you cleanup the tracks.

To lock a track:

1. Select a track(s).
2. Enable **Locked**. In the Project window and Track window, you will also notice that the track point is now represented with a lock.

A **Locked**  icon appears beside the corresponding point track in the Project window and the Track window indicating that the point track is locked. Alternatively, simply right-click a track point in the **2D View** or in the **Point Tracks** folder in the Project window or the Track window and in the pop-up menu, select **Locked**.

Track color display

Each track is displayed with a specific configurable color, either in 2D or 3D Mode. If the track color is the default one (black), it's displayed as such.

- 2D Mode: Label is black, pattern uses the 2D point color (from user preferences)
- 3D Mode: Label and 2D point uses the 2D point color. 3D helpers use the 3D point color.

If a custom color is set, then this color will be used for the 2D label, the 2D track and the corresponding 3D helper (3D reconstruction).

Checking tracks

Skipping untracked frames

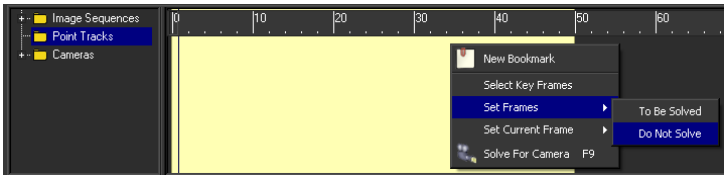
MatchMover allows you to navigate through the tracked frames only. For example, you may want to fine-tune the frames in a track.

By selecting **View > Skip Untracked**,  any navigation command (except direct mouse click or a user input) skips the frames where the selected track is not defined. The icon appears next to the **Lock on Track** icon.

Skipping unsolved tracks

If you are working only on a part of your sequence, for example, you loaded a 100 frames sequence, but the frames 30 to 60 are not important, you can set those frames to Do not solve and select **View > Skip Unsolved** to activate

the option. After calibration, any navigation command (except direct mouse click or user input) skips the frames that are not solved. See Setting frames to solve on page 185.



The Magnifier's fast refresh

When the **Magnifier** window is locked by clicking on the padlock to the right of the zoom bar, you can click a track and play the sequence to check the track's path. See Magnifier window on page 96.

Note that in this case, and if the format allowed it, only the **Magnifier** displayed area is loaded for a faster refresh.

Troubleshooting the tracker

If the tracker fails, it is often because the aspect of the tracked pattern has changed significantly between the reference frame (the track start frame) and the current frame.

If the solver has already been launched, you can verify the distance in pixels between a 2D point and the projection of a 3D point on the camera in the **2D View** or in the **Survey View**. You can examine the residuals for all the points and frames. Sort them by frame and check if any points have a high residual value. See Examining the computation quality in the Survey Window on page 189.

If so, it is probably because the point has been poorly located by the 2D tracker. If a frame has a high error, viewed in the **Frame** mode, this may be due to the bad positioning of a 2D computed point within the frame.

By examining the errors on the points in the **Points** mode, it is possible to find the computed 2D point responsible for the high error. It is then useful to restart the tracker from an intermediate frame (insert an intermediate key), where the tracked position is correct, and the aspect is more similar to the current frame.

You can also check the track path for bumps. If the track path is jagged, it means that either the camera follows a jerky motion, or that the point suddenly drifted during tracking. In this case, you should return at the time the track

jumped, and correct it by creating a new key at the appropriate coordinates and resuming tracking.

Another potential cause for the tracker to stop is when the point image motion is so fast that the search area of the tracker becomes smaller than the point displacement between two consecutive frames.

If this is the case enlarge the search area and re-run the tracker from the last correct frame, then reduce the search area to a normal size.

When a point that is being tracked starts to leave the image, MatchMover shows a warning message and the 2D tracker stops. When the quality of the tracking falls below the defined threshold a warning message appears and the tracking stops.

TIP Do not forget that in **Smart Prediction** mode, the search area defined with the tracker tool is only used in the first and the second frames, then the size used is the one defined by **First Pass** in the **2D Tracking** page of the **User Preferences** window.

Groups attributes

To make complex supervised tracking a little easier, related tracks can be grouped together. The group hierarchy will be exported and should be the same in the final 3D package.

Each group has the same set of attributes as a track. The group has a label, which is the name of the item displayed in the Project window. All other attributes reflect the tracks stored in this group.

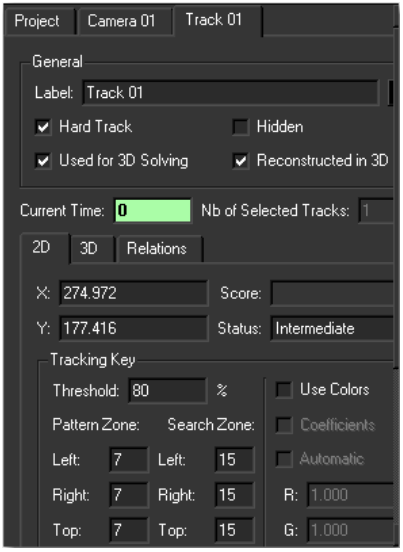
- An unchecked option means that none of the tracks have this attribute.
- A checked option means that all of the tracks have this attribute.
- A dimmed option means that all of the tracks do not share the same value for this attribute.

By simply setting a group attribute, you apply the attribute to all the tracks in the group.

Each group also has the “mobile” rigid object attributes. See Moving objects on page 154.

In addition, the group **Parameters** window shows the statistics of all its tracks: number of tracks, shortest, longest and average length. This is a good measure

of the quality of an automatic process that generated a huge number of tracks. A good average length is usually synonymous of robust tracking.



Creating groups

You can create track groups by either:

- Right-clicking in the **Point Tracks** folder in the Project window and selecting **New Group** from the pop-up menu.
- Selecting **2D Tracking** > **New Group**.

Managing groups

There are several ways to put tracks in a group.

- Right-click a group and select **New Track** from the pop-up menu to create a track directly in this group.
- Select tracks in the Project window, and then right-click and select **Send to Group**. You can then send them in an existing group or in a new group.
- Drag and drop a track selection in the Project window into a group.

To delete a group (and of course, all its tracks), either press **Del**, or select **Edit** > **Delete**, or right-click and select **Delete** from the pop-up menu.

NOTE The track folder is the default group, and behaves exactly like additional groups, except that it's never a mobile object.

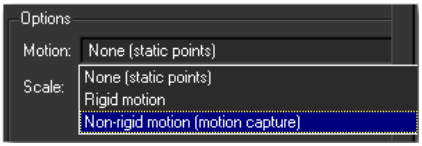
Moving objects

Groups can be used to identify rigid moving objects. If the group has been created by the automatic process, which means that we have a matte with the group attribute sets, then it is automatically filled up with its corresponding tracks, and the mobile attributes is set.

You can manually create as many mobile groups as needed and fill them with corresponding tracks. For a mobile object to be calibrated, it must have enough tracks (as for the main camera. See Camera solving on page 154.

When running the camera solving process, the background static tracks (all the ones that are not in a "mobile" group) will first be used to compute the main camera path, then all mobile groups will be processed and merged in the final scene, creating mobile points.

As it is not possible to recover the scale between a mobile object and the background with a single camera, each group has a scale attribute that can be tuned directly in the group parameter's corresponding edit box or by using the slider.



Camera solving

Keyframes

Keyframes are specific frames for which the system first computes the camera parameters and 3D points using a powerful optimization process. Once keyframes and 3D points are computed, the system computes the intermediate frames by first interpolating between the keyframes, as in a standard animation package, then refining the camera parameters using the estimated 3D point information.

MatchMover chooses automatically the keyframes to compute using the following criteria:

- If the focal length is known, at least four 3D points are needed.
- If the focal length is unknown, at least six 3D points are needed. These points should not all lie on the same plane.

In most situations the keyframes chosen by MatchMover are sufficient, however in some cases (e.g. where there is jagged camera motion), it can be useful to position the keyframes manually.

By default, keyframes, and indeed reference frames are chosen automatically. The number of keyframes is determined by the **keyframe Step** value and **Maximum keyframes** value. The **keyframe Step** value is the maximum number of frames between each keyframe. A low step value gives a higher accuracy, but computation is slower. See Reference frames on page 155.

The **Maximum keyframes** value determines the highest number of non-automatic keyframes allowed in a sequence. This value is only an indication, as the number of keyframes generated may be larger, especially in shots where a large number of points enter or leave the image.

TIP Use enough keyframes to "cover" all the tracks, but bear in mind that too many keyframes slow the solving process. If there is a very smooth camera movement, very few keyframes are needed. keyframes should cover the movement in a sequence.

Reference frames

Reference frames are 2 specific keyframes that will be used to bootstrap the camera solving. They should therefore be rock-solid ones with good parallax. MatchMover chooses the reference frames automatically when you run the 3D tracker.

The data from 2D tracking is used to choose them, therefore if you change the data (e.g., you create a new point track), MatchMover may automatically choose two new reference frames.

MatchMover examines the image sequence and compares frames using two methods.

Method 1. Where all the intrinsic parameters are known (through camera information and constraints), it checks that there are either:

- At least four 3D points with known coordinates are common to two frames.
- At least seven points (of potentially unknown coordinates) are common to two frames.

Method 2. Where all the parameters are unknown (except nonlinear distortion, which must have an approximately value), it checks that there are at least six known 3D points between two frames.

Ideally, they should include views of the same scene from a different position, which induces parallax between the images.

The automatically generated reference frames, if not locked, are recomputed when you select **3DTracking** > **Solve for Camera** (**F9**) or when you use **3D tracking** > **Select keyframes**.

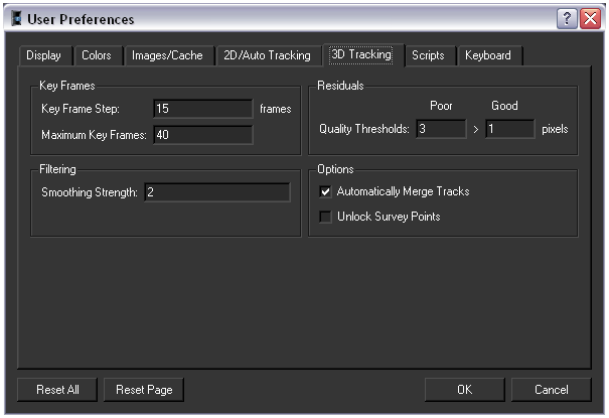
They are locked either when the user edited them, or when the lock icon at the right end of the **Track View Graded Ruler** graduation window is toggled. When locked, all the keys and references frames are grayed,  otherwise they are highlighted in yellow,  .

NOTE If **MatchMover** cannot initialize the two reference frames, it warns you that there is not sufficient data to run the camera tracker. In this case, you have to provide added information by creating extra point tracks in the two frames or by defining 3D point coordinates using relations, where possible.

Changing the keyframe default settings

To change the keyframe default settings

1 Select **Edit** > **Preferences** and open the **3D Tracking** page.



2 Enter the **keyframe Step** value. A step of approximately 15-20 keyframes is generally a good trade-off between computation speed and accuracy.

3 Enter the **Maximum keyframes**. This value allows you to limit the calculation time regardless of the sequence size.

See Keyframes on page 67.

Selecting reference and keyframes

After the 2D tracking process is complete, do one of the following:

- Select **3D Tracking** > **Select keyframes**.
- Right-click the **Image Sequences** folder in the Project window or in the Track window and select **Select keyframes** from the pop-up menu.

Note that if the keyframes are not locked this step is automatically launched when running the solver. See Reference frames on page 155.

Once all the required keyframes are selected, user settings are applied to fill the gaps, with the non-automatic keyframes.

At this point you can run the camera solving process using the reference and keyframes chosen by MatchMover, or you can choose your own by manually editing them.

If you make any manual changes and want to return to automatic initialization, just click the lock icon  or relaunch the **Select keyframes** command. Manual initialization is designed for an advanced user.

Under most circumstances the automatic initialization option is sufficient as MatchMover suggests optimum reference and keyframes. If you are not satisfied with the suggestion, you can edit the results.

Editing reference and keyframes

In complex sequences involving lots of camera movement, you may decide to choose your own reference frames and keyframes. If so, you must use the manual initialization option before you change the reference or the keyframes.

Method 1

1. Select the **Image Sequence** folder in the Project window.
2. In the **Parameters Window** in the **Reference Frames** tab, enter the frame number for the first or second reference frame.
3. Use the **Enter** key to validate the value.
4. In the **Keyframes** tab, the right box shows the list of all the frames of the sequence. The left box shows the list of all the current keyframes.
5. Select the frame(s) that you want to use as keyframes from the right box and add them to the keyframe list using the left arrow button.
6. To remove a keyframe, select it from the keyframe list and use the right arrow button.

Method 2

From the right pane of the Track window:

1. Do one of the following:
   - Select **3D Tracking** > **Set Current Frame**.
   - Right-click the required frame in the right pane of the Track window and select **Set Current Frame** from the pop-up menu.
2. Select either **First Reference** to set the current frame as the first reference, **Second Reference** to set the current frame as the first reference, or **Key** to set the current frame as a keyframe.

The Track window updates automatically.

TIP To create or delete a keyframe quickly, use the shortcut **Ctrl+K**, which toggles between the two actions.

NOTE If you select non-valid reference frames, MatchMover warns you that camera solving is not possible during the solving process.

After editing reference or keyframes, if you change the 2D data (for example, you add a new point track), you should either re-select the keyframes so that MatchMover can incorporate this new data in the choice of reference frames and keyframes, or run the camera solver without reselecting frames. MatchMover then uses the current reference and keyframes.

Browsing the keyframes

To change the current time to point to the previous keyframe, press **Ctrl+up** arrow. To change the current time to point to the next keyframe, press **Ctrl+down** arrow.

Setting up cameras

Since MatchMover automatically assigns a new camera for each loaded image or sequence, you usually do not have to create a camera. However, there are a few situations where you should create a new camera. For example, when you load a number of helper images, MatchMover assigns the same camera to all of the images. If you know that a different camera was used for one of the helper images, you should create a different camera for that image.

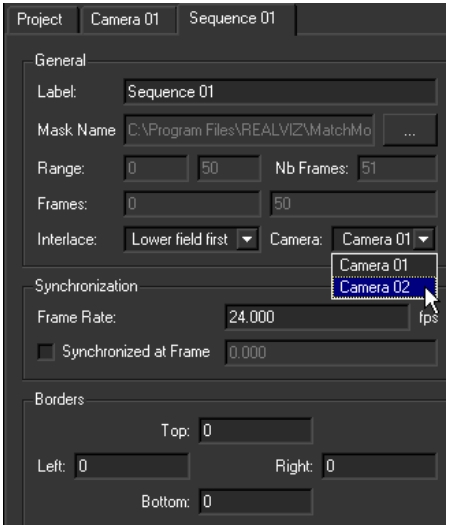
To create a new camera, do one of the following:

- Select **3D Tracking** > **New Camera**.
- Right-click the **Cameras** folder in the Project window or the Track window and select **New Camera** from the pop-up menu.

MatchMover creates a camera label in the Project window and Track window.

Assigning the camera to a sequence

Once you have created a camera, you can assign it to a sequence. Click a sequence and in the **Parameters Window**, choose the camera that you want to assign to the sequence from the **Camera** drop-down list.



Notice that the enabled camera is shown in bold in all the tree views.

Setting up a camera

NOTE Some advanced camera parameters are not displayed while the interface is in Light mode, because they're mostly useless in simple cases. Be sure to switch the interface to Full mode to make use of all the functions.

Click the camera to view its properties in the **Parameters Window**. Note that computed camera values are grayed out in the **Parameters** window if they do not correspond to the current camera.

Time Range

If needed, select a time range. Using a time range is needed when you want to tweak a parameter over a given time interval. For example, you know that the focal length between frames 20 and 30 is fixed.

The camera parameter window time range is synchronized with the time line: when you move to a new frame, it automatically switches to this frame. When you select an interval, it switches to “Use Selection” with this interval. You can also simply select “Global Time” to apply your changes to all the frames.

Camera type settings

1 Select the type of camera from the **Type** drop-down list. The drop-down list contains standard camera types. These provide you with default parameter values for the selected camera type.

For example, selecting **Type PAL** gives you a camera with the principal point in the center of the image; a pixel aspect ratio of 1.06667, a focal length initialized at 50 mm and a non-linear distortion set to 0. If you

set **Type** to **User** in the camera **Parameters Window**, you can define your own parameters for the camera.

NOTE The camera **Type** reverts to **User** if you change any value. Since the default camera types feature an image size, the camera will revert automatically to **User** if your sequence or image has a different size.

NOTE All the predefined camera types are stored in the **Data** > **Camera Types** subdirectory of your installation. Each camera is stored in a simple ".cam" ascii file. You can easily add/edit/remove those file to customized your camera database. Just look at one of these file, and you'll see how to do it!

2. The **Film Back** shows the **Height** and **Width** of the film back, either in mm or inches (use the unit combo box at the top to switch). If you change the height or width, the pixel aspect ratio changes, accordingly.
3. If an anamorphic camera was used to shoot the footage, the **Lens Squeeze Factor** may be different from the default value of 1.0. If this is the case, change the value in the corresponding text field.
4. Three read only fields show the image resolution. **Width**, **Height** and **Ratio** giving the size of the loaded image. **Ratio** is the value of the **Width** divided by the **Height**.

Camera parameter types

There are five different camera parameter types as explained in the following table. When you create a new camera, by default the three intrinsic (or internal) camera parameters-- principal point, pixel aspect ratio, and non-linear distortion-- are of the type fixed. The focal length is of the type "constant initialized".

Type	Description
Constant Initialized	Estimates the parameter value, starting from an approximate value that you provide and the value remains constant for all the frames.
Constant Unknown#	Computes the parameter value with no value input from you and the value remains constant for all the frames.

Type	Description
Fixed	Uses the parameter value you provide and does not modify it.
Variable Initialized	Estimates the parameter value, starting from an approximate value that you provide. The value can change across the frames.
Variable Unknown#	Computes the parameter value with no input from you. The value can change across the frames

#This option is only available for the focal length parameter

All these types are in fact a combination of two settings. One controls the way the parameters vary over time: is it constant  or variable  . The other one controls the way the computation starts: unknown  , initialized  , or fixed  .

These two settings are easily set though simple push buttons in the camera parameters window.

Not all the parameters can use all the settings combination.

- Extrinsic parameters (translation/rotation) are always variable.
- Distortion / Aspect Ration / Principal point cannot be unknown.

Intrinsic and Extrinsic parameters

Each camera has four intrinsic (or internal) parameters: focal length, radial distortion, pixel aspect ratio, and principal point, and some extrinsic parameters: translation (or optical center position), and rotation angles.

Intrinsic parameters are, by default, given by the camera type (shown by a little camera icon at the end the row). These parameters can simply be overridden by changing their default value or their type. for type They can also be “motion controlled” by providing a valid range for each (then shown with the icon  or ). See Camera parameter types on page 162.

Extrinsic parameters are, by default, undefined (it's what we want to find in MatchMover!). So they're basically user defined as variable unknown (shown as ).

As intrinsic parameters, each of them can be "motion controlled", either directly by the user or by importing motion control file (shown with an icon ). See Importing motion control data on page 181.

The **General** tab shows the information for the **Focal Length** and all the camera extrinsic parameters (translation, a.k.a optical center position, and rotation angles).

Click the first row button to define if the corresponding parameter is constant  or variable  over time. For example in shots where the zoom does not change throughout the sequence, set the **Focal Length** to fixed or constant. If you change the focal length parameter type to variable, you can then define constraints for this parameter.

- The first editable box represents the currently computed values. This can be simply edited or overridden once your shot have been calibrated for fine tuning (it has the same effect as editing the corresponding curve in the **Graph Editor**).
- Next, you have a button showing how the computed value relates to the initialization value. It can simply be a totally unknown parameter  , or its computation can starts with an initialization value  , or it can be fixed to a given value  .
  Clicking on it toggles through initialized to fixed. Just empty the initialization value for "unknown" status.
- The next editable box (with a light blue background) shows the computation initial value. Next to the initialization value, you have a text box that sums up the parameter behavior (with a little popup to show the whole message if needed). For example, it will display the validity interval set by the user.
- Finally, the last button shows where the parameter configuration comes from. Either from the camera type  , from the user  , or from on

externally imported file  . Depending on the current parameter configuration, clicking on it will enable following actions:

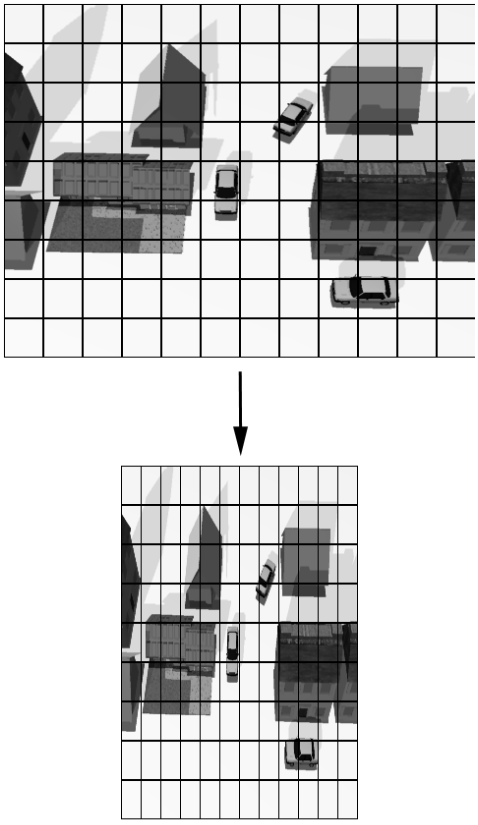
- Setting up a validity range
- Removing motion control data

TIP If you want to export the results to software that does not handle non-linear distortion or non-centered principal points (which is the case for most 3D software), do not change the default values. MatchMover compensates for the error on these parameters by adjusting the other parameters.

NOTE If an export format supports anamorphism, the appropriate parameter will be set. Otherwise, the pixel aspect ratio will be enlarged in the exported file to account for the squeeze.

About the lens squeeze factor

The **Lens Squeeze Factor** changes the image or sequence shown in the **2D View**. The following image shows the default image (top) the effects of applying a smaller lens squeeze factor that the default setting (bottom). This can be used in the case of anamorphic lenses.



Deleting a camera

To delete a camera, do one of the following:

- Select a camera in the **Cameras** folder in the Project window or the Track window and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Right-click a camera in the **Cameras** folder in the Project window or the Track window and select **Delete Camera** from the pop-up menu.

The camera is deleted from the project.

Defining coordinate systems

MatchMover manages a set of user-defined coordinate systems with respect to which the cameras and 3D points are expressed. If no coordinate system is specified, MatchMover chooses an arbitrary one. You can define a coordinate system in order to facilitate the manipulation of your exported project in a 3D package. If no point relations have been set up, MatchMover aligns the coordinate system on the computed position of the camera for the first frame; the default is the camera looking towards Z and Y as Up axis, but this changes according to your project's 3D parameters if you selected a different up axis.

If no coordinate system is defined, MatchMover tries to create one from the point relations or the survey points you defined (it needs at last 4 non colinear survey points to do so).

There are two main advantages in defining a particular coordinate system, described below.

Advantage 1 - It makes manipulation easier and more intuitive in the next stages, when virtual objects are inserted in the scene. For example, if a virtual object such as a car has to be placed on a flat surface, e.g., a road, it is very helpful to have two coordinate axes, e.g., X and Y, in the plane of that surface.

Advantage 2 - It allows you to impose strong constraints on the computed 3D points and the camera move, based on clear alignments in the scene inferred from the image sequence.

For example, two points that are at the same height above the floor, where the X and Y coordinate axes lie, have the same Z coordinate. These constraints help the system to compute data that is more accurate and closer to reality. In practice this applies to a lot of cases such as house walls and floors, any flat surface etc.

To set a 3D coordinate system, you specify two directions. Each direction is defined as one of the following:

- Passing through the origin and one point, selected from the tracked points.
- Passing through two points, selected from the tracked points.
- Normal to three points, selected from the tracked points.

The coordinate system is then defined in 3 steps.

- The first direction defines the first coordinate axis.

- The second direction defines, with the first direction, the half-plane in which the second axis is chosen.
- Using the two axes, MatchMover finds the third and final axis that is used to build a direct orthogonal coordinate system.

You can define a coordinate system to the scene using two methods:

- Defining points for the coordinate system in the coordinate label's **Parameters Window**. See Defining the coordinate system using the Parameters Window on page 168.
- Snapping the axes of the **Coordinate System Manipulator** to 3D points in the **3D View**. See Defining a coordinate system using the Coordinate System Manipulator on page 170.

NOTE You can move, rotate, and scale the **Grid** like any 3D object to manually adjust the coordinate system. See Editing 3D primitives and objects on page 207.

Defining the coordinate system using the Parameters Window

1. Select the points you want to include in your coordinate system.

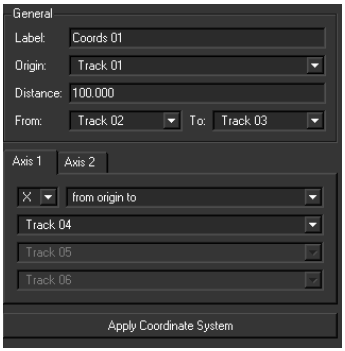
   See Selecting tracks on page 134.

2. Do one of the following:
   - Select **3D Tracking** > **New Coordinate System**.
   - Click the **New Coordinate System**  icon in the Toolbar.
   - Right-click **Coordinate System** in the Project window to open the pop-up menu and select **New Coordinate System**. MatchMover creates a new coordinate label.

   NOTE Only the points you have selected when you created the coordinate system will appear in the **Parameters Window** drop-down list later. See Creating a point relation on page 173.

   By default, no points are selected and all the points will appear in the list. However, if there is a long list of points, you might find it difficult to select from such a long list. That's why there is a way to pre-select points.

3 In the **Parameters Window**, select the point track that serves as the center of your coordinate system from the **Origin** drop-down list.



4 In **Distance**, enter the distance between two tracks.

5 From the other two drop-down lists (below **Distance**), choose the two tracks for which you have defined the distance.

6 Select either **X**, **Y** or **Z** from the **Axis1** and **Axis2** drop-down list.

7 From the drop-down list to the right of **Axis1**, select either:

- **from origin to** - Defines an axis from the origin to the selected track point.
- **through 2 points** - Defines an axis from the first point to the second point.
- **normal to 3 points** - Defines an axis as the normal to the plane defined by three points.

8 From the activated drop-down lists, below, select the appropriate tracks to define the axis.

9 Repeat the above process for **Axis2**.

10 Click the **Apply Coordinate System** button.

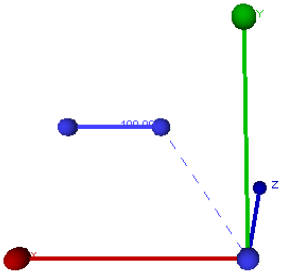
The coordinate system is now defined and the coordinates you set are listed in the **Coordinate Systems** folder in the Project window.

NOTE If you have deleted a point track that is used by a coordinate system, you will be given a warning message during the calculation process and offered the option of redefining the coordinate system.

Defining a coordinate system using the Coordinate System Manipulator

The **Coordinate System Manipulator** makes creating the coordinate system easy. The manipulator is displayed in the **3D View** whenever a coordinate system is selected or a new coordinate system is created.

You can drag and snap the vertices of the manipulator's three axes (red: X-axis, green: Y-axis, blue: Z-axis) to 3D points in the scene and use the independent, light blue distance line for determining the scale of the scene by measuring the distance between two points.



To create a coordinate system:

1. Click and drag the origin of the manipulator and snap it to a 3D Helper.
2. Click and drag the sphere at the end of an axis and snap it to a 3D Helper. The sphere changes color when it overlaps a 3D Helper. The first axis to be snapped to a 3D point is assigned as the "1st axis" and is equivalent to the first axis defined in the coordinate label's properties in the **Parameters Window**. See Defining the coordinate system using the Parameters Window on page 168.
3. Click and drag another axis and snap it to a 3D Helper. The second axis that you snap to a 3D point is assigned as the "2nd axis", defining a plane with the 1st axis. The 2nd axis is defined as the normal to the first axis that lies in that plane.
4. Resize the light blue distance line by snapping its ends to 3D Helpers. This scales the scene to using the arbitrary distance between two tracks. The first point of the line is linked to the origin by a thin, dashed line.

NOTE You must snap both ends of the distance line to a 3D Helper to properly define the coordinate system; otherwise it will not be taken into account. The only way to change the distance (or to define an axis using three points) is to edit it in the coordinate system's properties in the **Parameters Window**. See Defining the coordinate system using the Parameters Window on page 168.

To change the color of the manipulator axes and distance line, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

Understanding locked axes

When an axis is defined as "1st axis" or "2nd axis", it is locked, meaning that although it can be moved and snapped to another point, it still retains its quality of being first or second axis.

The origin can also be moved and snapped to a different point, and although the manipulator's axes remain in the same direction, they are now defined between two points instead of being defined from the former origin to their snap point.

Deleting a coordinate system

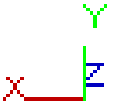
To delete a coordinate system, do one of the following:

- Select a coordinate system in the **Coordinate Systems** folder in the Project window and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Right-click a coordinate system in the **Coordinate Systems** folder in the Project window and select **Delete Coordinate System** from the pop-up menu.

The coordinate system is deleted from the project.

Setting the world reference

When you have created several coordinate systems, you can select one to define the world reference, shown by the three axes in the bottom left corner of the Workspace.



To set the world reference:

1 Select a coordinate system from the Project window.

2 Do one of the following:
   - Select **3D Scene** > **Set World Reference**.
   - Right-click and select **Set World Reference** from the pop-up menu.

Mapping the coordinate system to a camera

You can also center the coordinate system on a camera at the current frame by selecting **3D Scene** > **Map World on Camera**. This defines the coordinate system from the computed camera at the current frame so that the origin is at the optical center and the axes are that of the camera (Z is the optical axis and Y is the up axis).

Defining point relations

Point relations appear within the **Point Relations** folder in the Project window. When you run the camera tracker, MatchMover uses the enabled point relations.

TIP You can start running the solving process without point relations. Then, if needed, add them to improve the results.

Point relations apply to the coordinate values of one or several points. When setting a coordinate constraint, you define the coordinate (X, Y, or Z) that is shared by the selected point or points.

Then, you set the parameter type as follows:

- **Unknown** - The program computes the value without any input from you.
- **Initialized** - The program estimates the parameter, starting from the approximate value you provide.
- **Fixed** - The program uses the value you provide and does not modify it.

For each point, you can independently set point relations for all three coordinates (X, Y, or Z).

TIP If you know the coordinates of 3D points in the scene, from manual measurements or from a map, you can provide MatchMover with this information. You can either create three point relations for each survey point, one involving each coordinate and setting their parameter to **Initialized** or **Fixed**, depending on the accuracy of the survey data or you can directly enter those coordinates in the corresponding track 3D parameter tab, as survey info.

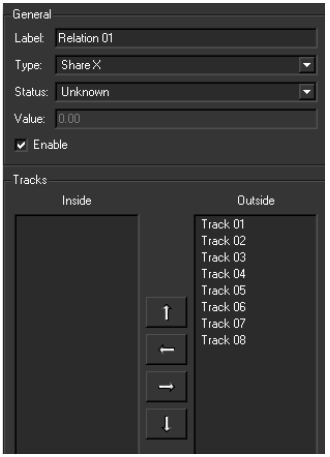
A relation involving one point and whose parameter is set to **Unknown** does not provide any information and will not be used for calibration.

Creating a point relation

To create a point relation:

1. Select the points you want to include in the relation from the **Point Tracks** folder of the Project window.
2. Do one of the following:
   - Select **3D Tracking** > **New Relation**.
   - Click the **New Relation** icon  in the Toolbar.
   - Right-click the **Point Relations** label in the **Relations** folder in the Project window and select **New Relation** from the pop-up menu.

   A new relation is created featuring all the points that were selected. A new **Relation** label appears in the **Point Relations** folder. All featured points are listed (the points selected from the **Point Tracks** folder) in the **Parameters Window** and can be sorted using the up and down arrow keys.



NOTE If no points are selected from the **Point Tracks** folder, a new relation is created containing no points.

3 You can add extra points:

- By selecting them from the right list box and add them to the left list box using the left arrow button.
- By selecting track(s) in the Workspace, right-click a relation in the Project window, and select **Add Selection**.
- By dragging and dropping tracks directly from the **Point Tracks** folder in the Project window into the **Point Relations** folder.

To remove points:

- By selecting them from the left list box and add them to the tight list box using the right arrow button.
- By selecting track(s) in the Workspace, right-click a relation in the Project window, and select **Remove Selection**.

4 In the **Parameters Window**, from the **Type** field, select the relation type for points that share a coordinate. **Share X**, **Share Y**, or **Share Z**.

5 From the **Status** field, select the status for this relation. It can be **Fixed**, **Initialized** or **Unknown**.

6 If you select **Fixed** or **Initialized,** enter the value in the **Value** field. If you select **Unknown**, the **Value** field is disabled.

7 To enable this point relation, click the **Enable** box to check the option.

NOTE If a point belongs to several point relations of a given type (X, Y, Z), only one of these can be enabled.

Relations are shown in the **3D View** as a semi-transparent rectangle in the appropriate plane. The rectangle's edges are normal to the coordinate system axes. The relation rectangle is the smallest that contains all points featured in the relation; however the rectangle has a minimum width and height that ensures that it is not restricted to a thin line if all points are aligned on one axis.

NOTE To change the color of the relations displayed in the **3D View**, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

To show or hide relation planes in the **3D View**, select **Display** > **Relations**.

Deleting a relation

To delete a relation:

- Select a relation in the **Relations** folder in the Project window and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Select track(s) in the Workspace, right-click a relation in the Project window, and select **Delete Relation**.

Defining survey points and object mapping

The main goal of the matchmoving is to compute both the camera motion and the scene. If you know some of the properties of a scene, because you took measurements, or you have some constraints, you may know the 3D coordinates of some points of the scene. Instead of letting MatchMover compute their 3D coordinates, you can set them before the computation. Setting these "3D Survey points" has several advantages:

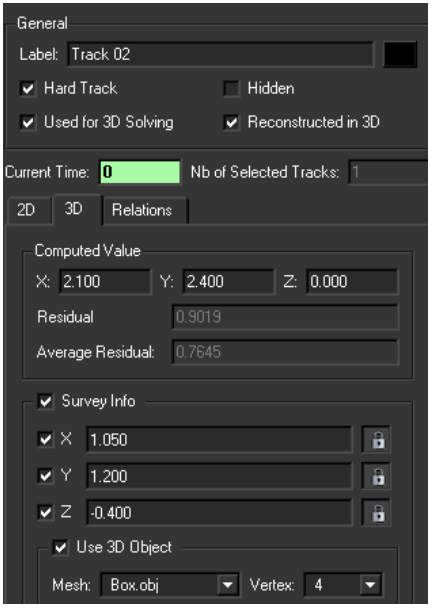
- The coordinates of the points at the end of the computation will be exactly what you entered.

- The points help MatchMover automatically finding the appropriate coordinate system that matches your measurements of the scene.
- The computation will be more robust, as all the survey points will help MatchMover finding other points in the scene.

A minimum of four survey points is required to define the coordinate system. You can either set these coordinates manually or use one of your 3D object vertex coordinates.

Setting survey points manually

1 Select a track. The track's properties are shown in the **Parameters Window**.



2 Check the **Survey Info** options and either enter each known 3D coordinates directly in the corresponding edit box or check the **Use 3D Object** option, then select a 3D object in the **Mesh** drop-down list and a **Vertex** number. You can view the vertex number by selecting **Display** > **Mesh Vertices** to toggle the display of each vertex index of a 3D object from "none", through "selected vertices" to "all vertices".

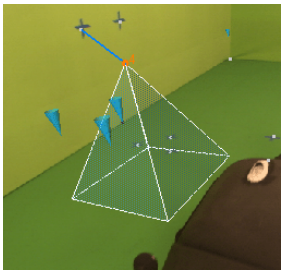
3 Click the **Use Object Transform** checkbox if you want to be able to alter the original shape of your object.

4 Click **Commit Changes** to validate.

Setting survey points using elastics

You can create a survey point simply by using a 3D object vertex.

In a **3D View**, select the object. Drag the vertex to a position on the background image or an existing track point to make a link. You can then fine-tune its 2D position by clicking in the **Magnifier** window.



A new survey point is created with coordinates mapped on the 3D object's selected vertex. The mappings can be edited in the **Parameters Window**. See Setting survey points manually on page 176.

TIP When drawing an elastic from a large object to the image plane is complicated, you can select the vertex you want to link and check the **Use 3D Object** option in the **3D** tab of the track **Parameters** window. The selected vertex creates a new survey point with coordinates mapped on the 3D object's selected vertex.

Defining camera constraints

Constraints are listed the **Cameras** folder with the enabled constraint name in bold type. Constraints with no frames are shown as dimmed and with "empty" next to their name, to show the user that these are useless. Don't forget to add frames to your constraints!

Focal length constraints

With the camera focal length parameter set to **Variable**, it is possible to set a "constant" constraint on the focal length that can be applied to a part of your sequence.

The focal length camera constraint can be of three types:

- **Fixed** - Uses the parameter value you provide and does not modify it.
- **Initialized** - Estimates the parameter value, starting from an approximate value that you provide.
- **Unknown** - Computes the parameter value without any input from you. This is the default.

When using a focal length constraint there are three main steps. First you create the constraint, and then you edit the constraint providing MatchMover with information on its type and value. Finally, you decide which frames use this constraint for the tracking process.

Nodal pan constraints

The nodal pan constraint fixes the optical center of the camera and limits the camera movement to rotation only. All nodal-only features (2D tracks that have no keys out of the nodal pan) are reconstructed with a median default depth.

Dolly constraints

The dolly constraint fixes the camera motion in one direction only, either along the X-, Y-, or the Z-axis.

Planar constraints

The planar constraint fixes the camera motion in two directions, either along the XY, XZ, or YZ planes.

Creating and enabling a constraint

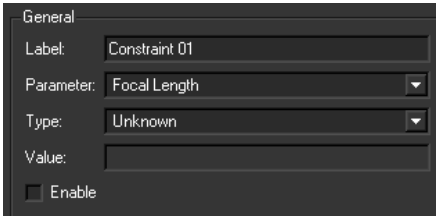
You can create as many constraints as you like and toggle them by using the enable/disable check box in the constraint **Parameters Window**.

To create a new constraint:

1. Select the camera for which you want to add a constraint in the Project window or the Track window.
2. Do one of the following:
   - Select **3D Tracking** > **New Constraint**.

- Right-click the camera for which you want to create the constraint in the Project window to open the pop-up menu and select **New Constraint**.

3 Select the constraint parameter from the drop-down list in the **Parameters Window**.



4 When needed, select a **Type** from the drop-down list and enter the value in the **Value** text field.

5 In the **Label** text field, enter the name of the constraint.

6 Use the **Enable** check box to activate or disable the constraint for the required frame(s) of your sequence. See Adding frames to a constraint on page 179.

NOTE If you choose to create a focal length constraint and the camera focal length parameter is not variable, a message box opens telling you that the camera constraint will be disabled.

The frames to which the constraint applies are shown by a colored rectangle in the Track window. The enabled constraint appears in bold in the Project window and the Track window.

NOTE To toggle the constraint, right-click a constraint in the **Constraint** folder in the Project window or the Track window and select **Toggle Constraint** from the pop-up menu.

Adding frames to a constraint

On creation, a constraint is not applied to any frames and you have to add frames to the constraint and enable it. MatchMover can only use the constraint when you have provided information concerning the frames to which the constraint is applied.

To do this, configure MatchMover to use the constraint on specified frames by creating a time range and adding or removing frames that use the constraint in the camera solving process.

In the Track window:

1. Select the time range for the constraint by pressing **Shift**+click and drag the pointer from the first frame to the last frame to include in the time range.
2. Do one of the following:
   - Select **3D Tracking** > **Edit Constraint** > **Add Frames**.
   - Right-click in the Track window and select **Add Frames** from the pop-up menu.

The frames within the selected time range now have the camera constraint applied to them and MatchMover uses this information in the tracking process.

The constraint label appears in bold in both the Project window and Track window to show that it is enabled and it applies to the current time.

If another constraint already exists for the added frames, it is disabled automatically.

For example, you have a sequence of 400 frames and you know that there is a fixed zoom for the first 300 frames and a variable zoom for the last 100 frames. In the camera **Parameters Window**, set the **Focal Length** to variable and initialized.

You create a new focal length constraint and then define a time range from frames 0 to 300 in the **Track View** or in the **Time Line**. Using the function **Add Frames**, you apply the constraint to the frame sin the range. Finally, you set the **Type** according to your knowledge of the focal length in the constrained time range.

Deleting frames from a constraint

In the Track window:

1. Select the time range to delete from the focal length constraint by pressing **Shift**+click and drag the pointer from the first frame to the last frame to include in the time range.
2. Do one of the following:
   - Select **3D Tracking** > **Edit Constraint** > **Remove Frames**.

- Right-click in the Track window to show the pop-up menu and select **Remove Frames**.

Deleting a constraint

To delete a constraint select a constraint in the **Constraint** folder in the Project window or the Track window and either:

- Select **Edit** > **Delete**.
- Press the **Delete** key.
- Right-click a constraint in the **Constraint** folder in the Project window or the Track window and select **Delete Constraint** from the pop-up menu.

Importing motion control data

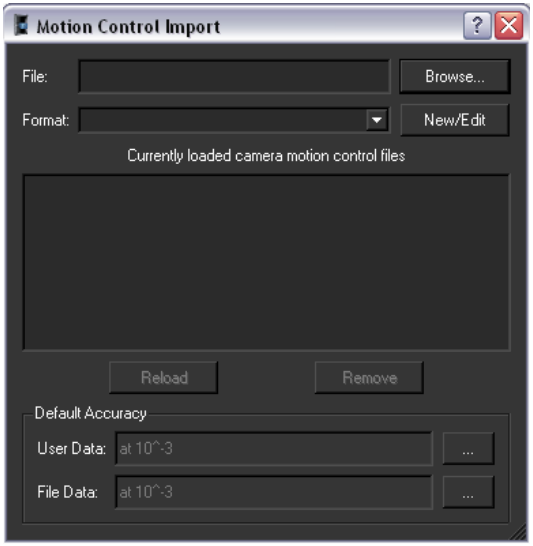
Specifying import format

Some hardware devices are able to output what we call "motion control data". That is, information about its position, rotation and/or internal parameters. All this information can be fed into the MatchMover solver.

It can be used as an initial solution, and MatchMover will then compute the remaining missing parameters, or simply to fine-tune these data, usually not so accurate.

The only need to do so is that the motion control data is stored in an ascii file, which can be easily sequentially processed (that's to say the data are stored frame by frame). You can then use the **Import File Format** window to describe and parse your custom files.

1 Select **3D Tracking** > **Motion Control Import**  or press **F12**.



2 The **Currently Loaded Files** list displays any files that you have loaded. To remove one, select it and press **Remove**. You can also reload it by pressing **Reload** if data have changed.

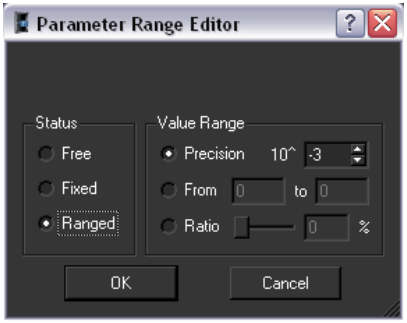
3 Either select an existing file format from the drop-down list, or create a new one using the **New/Edit** button (see next paragraph for details).

4 Click the **Browse** button to import an existing file.

NOTE Click the button to the right of the **User Data** or the **File Data** text fields  .

---

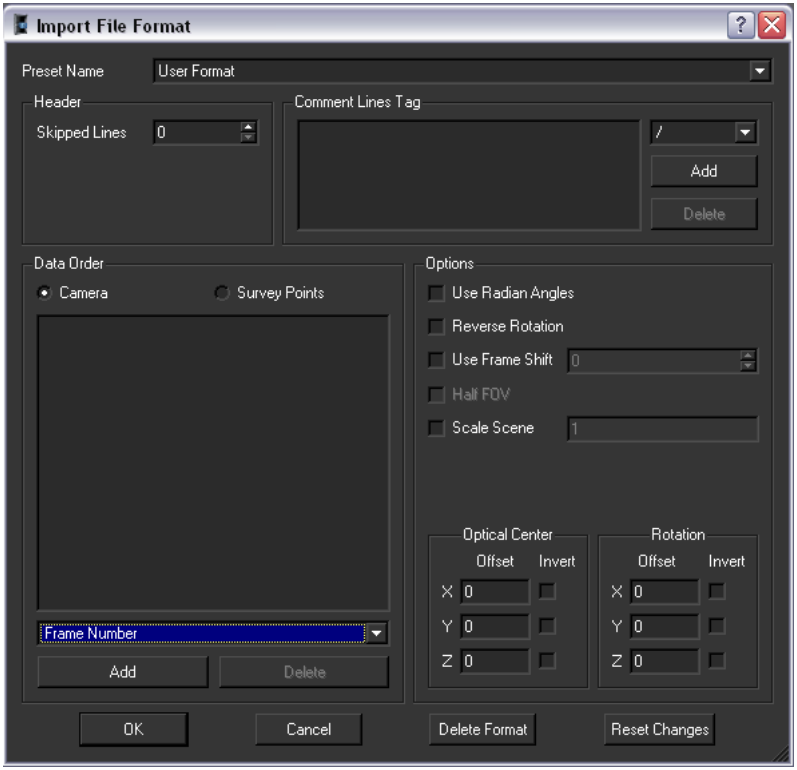
5 Set the **Default Accuracy** of the motion control data (either from file or from user).



6 Set the **Status** and **Valid Range** if needed.

Specifying the import format

Click the **New/Edit** button of the **Motion Control Import** window to edit a file format. The **Import File Format** window opens.



For example, this corresponds to the dummy file.

```
>> begin of sample file
This is motion control data
These 2 lines will be skipped
# these are comments lines
# camera 0 with focal 25.65
# data is frame number, OCX, OCY, OCZ
0 12.34 5 2.56
1 45.3 6 3.45
1 44 7 4.55
<< end of sample file
```

For a new format, enter a name in the **Preset Name** text field or select an existing one to modify it. Press **Delete** to remove the current one from the list.

- The **Skipped Lines** size specifies the number of header lines to skip not counting comments and empty lines.
- The **Comment Lines Tag** is used to specify a list of single characters selected from the list or user entered. Each line starting with such a character will be ignored. Click the **Add** or **Del** button as appropriate.
- The **Data order** specifies how data is read for each frame. Select an item from the drop-down list and click **Add**. Dummy data type can be used for any value/word to ignore. The default frame number starts at 0 and increases after each read frame if not specified.
  Options.
  - **Use Radian Angle**: Default angles are specified in degrees.
  - **Reverse Rotation**: Rotation angles are reversed after import.
  - **Use Frame Shift**: Specifies an offset for the frame index.
  - **Default Value Range**: This range will be applied to all imported data. You can also set these parameters in the **Motion Control Import** window.
  - **Default Optical Center**: This value is added to all imported optical center.
  - **Default Rotation**: This value is added to all imported rotation.

  All changes can be reset using the **Reset Changes** button.

Motion control is then automatically applied for all imported data.

A dummy motion control constraint is then created under the corresponding camera, to show where motion control data is available and used.

Solving for the camera

This process reconstructs the 3D points corresponding to the 2D tracks and computes the camera path for all the sequences or frames and all the objects in one solve. There are several stages:

1. Select key and reference frames
2. Solve the two reference frames
3. Solve all the keyframes
4. Solve all other frames
5. Solve all the 3D points.

This process is done first for the main camera (looking at a static scene), and then for all the mobile rigid objects.

At the same time the process computes the camera parameters and reconstructs the 3D coordinates of the 2D computed points.

NOTE Camera solving is an automatic step in the Automatic Tracking process. See Running the automatic 2D tracking on page 127.

Each camera parameter--focal length, principal point, pixel aspect ratio and non-linear distortion-- has a value that varies or remains constant throughout the sequence and is either known or unknown.

Optionally, you can specify these parameters. Doing so helps the camera solver to give more accurate and faster results. See Setting up a camera on page 160.

Setting frames to solve

By default, MatchMover processes all frames in the **Work Area**. However, you may have for example, blurred images or an obscured frame, for which the camera will not solve. You can select the frame that you want to solve and therefore ignoring the frames that will not solve.

1. Use **Shift**+click and drag the pointer to define a time range in the **Work Area**. See Defining a Work Area on page 94.

2 Do one of the following:

- Select **3D Tracking** > **Set Frames**.
- Right-click in the **Track View** and select **Set Frames** from the pop-up menu.

3 Select one of the following:

- **To Be Solved** - When you run the camera solving process, MatchMover process the marked frames.
- **Do Not Solve** - When you run the camera solving process, MatchMover does not process the marked frames.

NOTE Frames that will not be solved are marked with a black bar in the Track window graded ruler.

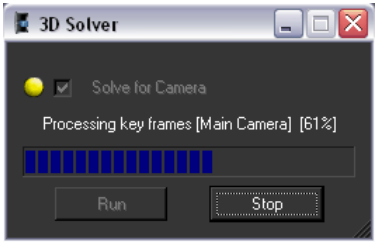
Running the camera solver

To run the camera solver, do one of the following:

- Select **3D Tracking** > **Solve for Camera**.
- Click the **Run/Stop Camera Solving**  icon in the Toolbar.
- Right-click in the **Cameras** folder in the Project window or the Track window and select **Solve for Camera** from the pop-up menu.
- Press **F9**.

A blue progress bar appears in the status bar, showing the progress of the solving process.

A popup window also opens to show you the current solving step:



You can press the **Stop** button inside it at any time to stop the solver (this may take a little time before the computation thread really safely stops).

NOTE The process halts if you attempt to run the solver with no frames initialized. If the tracking fails for any reason, an error message is displayed to give some hints to the user on how to fix it. It may be, for example, that some frames do not have enough tracks, or that the coordinate system definition is bad with respect to some survey points, etc.

Extending the computation

In some tough case, you might prefer tracking your shots pieces by pieces. You basically start from a rock-solid frame range that you track the best you can.

If you want, you can extend your solve by adding more frames into it. You can do it in three ways in MatchMover:

- Add frames, either by setting them "to be solved" or by extending 2D tracks to them, or by adding them in the **Work Area**, then you relaunch the solver.
- If you consider your existing solution as a good starting point, use the **Extend camera** command  . This option starts the solver, but first initializes the solution with the current one. The solver can refine current frames in this case, and any additional data will be computed.
- If you know your current tracking is good, and do not want MatchMover to modify it, use the **Extend camera fixed** command  . All additional data are computed, but currently computed tracks are locked and will not be modified.

In some cases you may need to tweak the keyframes settings to cope with your new configuration.

NOTE Shots solved with extend camera tools may not give the same result if solved from scratch. So the user needs to keep track of its solving steps in order to solve it again, if needed.

Fine-tuning the results

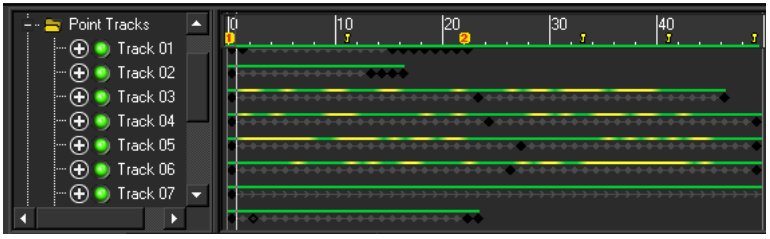
Inspecting the results

Inspecting the results

Once your shot has been solved, you will need to check the quality of the solving. Is it accurate enough to fit your needs or are there some frames that are not solved correctly? MatchMover provides several ways to check the tracking.

Checking the computation quality in the Track window

The quickest and simplest method is to examine the colored line in the Track window graded ruler that corresponds to the residual value for a given frame (the average of all the track residuals present at that frame). See The Track View on page 88.



This colored line indicates the quality of the tracking according to the residual value thresholds set in the **Preferences** window. See Configuring the tracker on page 144.

Gray lines indicate frames that are not computed and black lines are ignored since these frames were set to “do not solve” before the camera solving process. Green lines mean good solving, through yellow (fair) to red (bad). So, you have an instant feedback of the average quality of all your frames. It’s almost the same for all the track points.

You can really easily spot out the bad areas, a bad time range, or bad tracks, if any, and concentrate on them. Anyway, for further inspection, MatchMover provides the other solutions detailed in the next sections.

Checking the position of 3D Helpers

Another quick and simple method of checking the results involves using a **3D View**. When working in the **3D View**, each reconstructed track is displayed using a 3D helper. The tracks are displayed by a default 3D cone, but can be changed to a pyramid, or a cross in the **Preferences** window. So if you look through the computed camera (using **Lock on Camera**)  , you should easily see if orientation and relative depth of the helpers fit the real footage. By playing the sequence, you'll also be able to check how accurate the 3D helpers reproject on the background. Accurate tracking results in natural and synchronized helper motion. Mobile points are displayed with a different customizable color, and are animated while sequence is played.

You can easily change the 3D helper size, either in the global parameter window, which is displayed when nothing is selected (just hit **Esc**), or in the **Preferences** window (press **P**).

Examining the computation quality in the Track Status View

The **Track Status View** shows a graphical representation of the pixel residuals for each track in a frame. Use this to isolate quickly the tracks or frames with a high-pixel residual. See The Track Status View on page 91.

Examining the computation quality in the Survey Window

Use the **Survey Window** to analyze the results of 3D tracking and to isolate specific frames or points where adjustment may be necessary.

Select **Window** > **Survey Window**.

The **Survey Window** shows values of the distance in pixels between a 2D point and the projection of a 3D point on the camera. These are called the residuals. Numeric information is shown for the points and/or frames and their average error values.

By default the **Survey Window** shows two columns, the points and the 3D residuals, but you can display a maximum of four columns.

To change the display:

1. Do one of the following:
   - Select **Display** > **Survey Mode**.
   - Right-click in the **Survey Window**.

2 Select either:

- **Points** to show the point number and 3D tracking residual data.
- **Frames** to show the frame number and 3D tracking residual data.
- **Points & Frames** to show the point number, frame number, the 2D tracking quality residual data, and 3D tracking residual data. The 2D tracking quality residual data ranges from 0 to 1. A score of 0 indicates a poor tracking quality; 1 indicates perfect tracking quality.

Selecting **Points** mode allows you to double-click a track in the first column to select the track in all views. Selecting **Frames** or **Points and Frames** allows you to double-click in the first column to change the current time.

By default, the data is sorted for the **Points** column in ascending order.

To sort the data in the **3D Residual** column:

1 Click the **3D Residual** column header to sort the data in descending order.

2 Click the **3D Residual** column header to sort the data in ascending order.

A sort can be done for other columns by repeating the above procedure substituting the required header.

Inserting 3D objects and using them as references

The next method involves inserting virtual objects in a **3D View** and producing a preview of the composed sequences in any output format. See Working with 3D objects on page 205.

The virtual objects are fixed in space (with respect to the tracked rigid object) and rendered using the estimated camera parameters. The process is successful when the motion of the virtual objects in the composed sequence is consistent with that of the real scene. Previewing allows you to study the results of the tracking process and make any modifications, if necessary.

Troubleshooting the solver

Unable to solve for frames

If you get the error message “Cannot process frames. X X X. Check that you have provided enough track information.”, the solver did not have enough information to complete the reconstruction process for some frames. To correct

this, you need to manually add some tracks that will cover all concerned frames, then run the solving process again.

Incorrect reconstruction

Pay special attention to the reference frames in such a situation. They are used to bootstrap the computation and should contain plenty of relevant information and tracks in common.

It is important that depth information can be extracted from these two frames.

Motions that feature a still optical center, such as panning and zooming, do not provide that information. Orbitals and lateral travelings are your best bets. Keeping that in mind, you may manually edit the reference frames; this may greatly improve the calibration process.

The quality of tracked points in the reference frames is paramount. Although MatchMover is usually able to filter out inconsistent points, in some cases the low signal-to-noise ratio hinders the sorting process between relevant and inconsistent tracks, resulting in some of the latter getting through.

If several bad tracks (with the red helper icon) are listed, it is a good idea to review the quality of your tracks. First of all, run the **Automatic Clean up** (**F11**) in order to restrict the number of tracks. Do not hesitate to start solving only a subset of your shot, and then extending it smoothly in case of really complex shots. It'll then be easier to isolate tough frames. You can extend the solving in 3 different manners. See Camera solving on page 154.

Look for the following issues:

- Jumpy tracks.

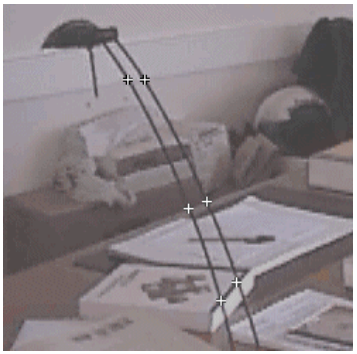
Jumpy tracks can be found by carefully looking at track paths. A sudden bump in the path may mean that the track "jumped" from one feature to

another or it may also be caused by a jerky camera motion. Usually these can be manually edited and corrected or simply deleted.

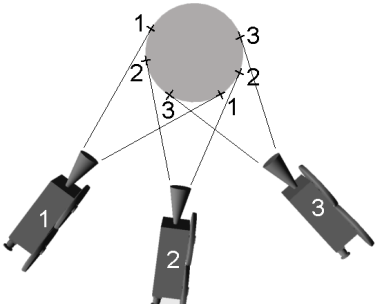
- Periodic textures, such as windows of a building.

This is a special case of jumpy track, the tracker was fooled by the repeating pattern. Make sure the corners match or remove the tracks altogether.

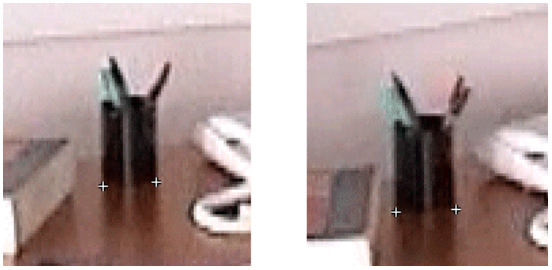
- Non-physical points.



The intersection of the border of an object and a line in the background represents a 3D point whose position in space changes with the camera position; it is not a physical 3D point. More generally, any 3D point whose position in space depends on the camera position (for example, the occluding edge of a cylinder) should be removed.



In some cases, this is harder to figure out. The apparent corners of a bottle or any other cylindrical object placed on a table will not represent the same 3D point when you orbit around it. Specular highlights should also be removed.



- Moving objects.
  If there are points left of objects in motion, when you intend to track the scene, the information they will provide, while relevant to the object, can be confusing for MatchMover. Deleting such point tracks will help solve the issue. You can also use mattes to mask moving objects.

  Mattes must be drawn before running the automatic tracker, not afterwards.

Ghosted object

If an object moves out of the camera field then back in, MatchMover may not recognize it and so may add new tracks on it. Inaccuracies during computation may then produce a "ghost" of the object; two copies of the object, slightly offset, will be reconstructed.

Editing the 2D tracking will get rid of this problem; use the **Merge Tracks** option on all tracks that represent the same physical point (see Merging tracks on page 135). Note that the solving can do that automatically.

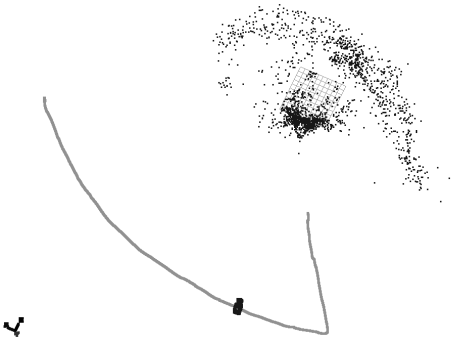
Noise in camera path

If a part of the computed path is noisy, quivering, uneven, or otherwise incorrect, there is a big chance that the corresponding frames are marked red. This is usually the first symptom of the issue, which can also be diagnosed in **3D View**.

Keyframes are usually the way to obtain a smoother motion. If the area contains only a few keyframes or none at all, adding some will improve the result. To manually add a keyframe, select the frame, right-click it, and in the pop-up menu select it as a keyframe or decrease the average step between keyframes in the **Edit** > **Preferences** > **3D Tracking** window.

Zoom computed as a dolly

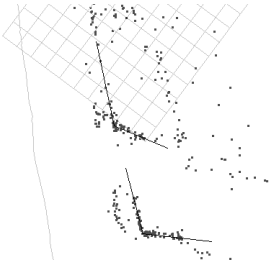
If you have set the camera to have a constant focal, which is the default setting, MatchMover will see motions instead of zooms.



Fixing this problem is simple. Open the camera's **Parameters Window** and set the focal length to **Variable**, then re-run the camera solver.

Skewed scene structure

The symptom is that some angles are either too sharp or not enough. This is most obvious with angles that should be right but are not reconstructed as such.



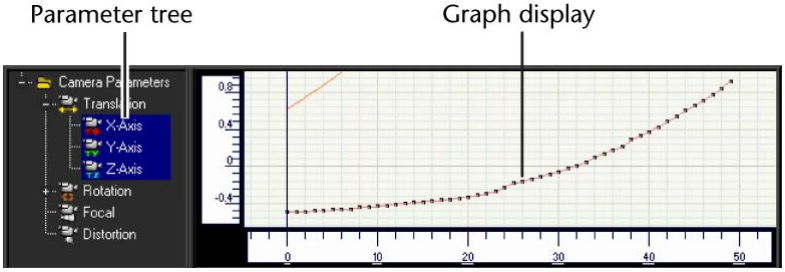
This condition can be improved using point relations. Constraining points on a wall to share the X coordinate and point on the other wall to share the Z coordinate will force the angle to be right. To do this, however, you need to define your coordinate system in a way that your axes are parallel to the aforementioned walls.

Filtering the results

The Graph Editor

The **Graph Editor** displays a graphical representation of computed camera parameters as well as providing options to edit the results. Depending on the type of camera motion (hand-held, stabilized, motion-controlled) and the quality of the 2D tracks, it may be useful to smooth some or all of the computed camera parameters. Smoothing can be done by hand, or by using a post filter.

Switch to the **Graph Editor** by clicking on the **Graph Editor** tab at the bottom of the Track window.



In the **Parameter Tree**, you can select the parameter you want display. The corresponding curve is then shown in the graph display.

The available parameters are:

Folder	Description
Translation	Contains the three components of camera translation, named X-, Y-, and Z-axes
Rotation	Contains the three components of camera rotation, named X-, Y-, and Z-axes
Focal	Shows how camera focal length varies over time
Distortion	Shows how lens distortion varies over time

The **Graph Display** shows the curve representing the selected parameter value over time. The X-axis always represents the time in frames, and the Y-axis represents the parameter value.

For example, rotation is expressed in degrees, translation is in the units defined in the coordinate system, and the focal length is in millimeters.

Each curve is shown as a continuous line joining the points calculated for each frame. The color of a curve is determined by the parameter it represents. One or more parameters can be selected and displayed at a time by using **Shift** or **Ctrl**+right-click.

The points used to extrapolate a curve are displayed in the **Graph Display** and can be edited.

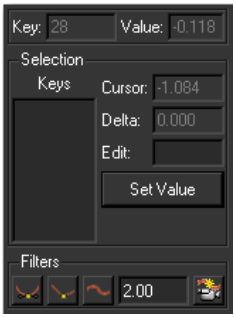
Click to close the **Graph Editor**.

To restore the view, select **Window** > **Track Window**.

To fit the graph to the viewport, select **Graph** > **Fit** or right-click in the **Graph Editor** and select **Fit** from the pop-up menu.

The Graph Editor Toolbox

The **Graph Editor Toolbox** is displayed when you open the **Graph Editor**.



This toolbox provides access to the MatchMover post-filtering options. As you move the pointer over the graph, the **Graph Editor Toolbox** displays information on the position of the cursor (time and position) and the key number and its value in read-only fields.

If you select a key, or multiple keys using a rubber band selector or pressing **Shift** while selecting more keys, the keys are listed and you can set their value by entering a number in the **Value** field and clicking on **Set Value**.

The filter options are displayed in the **Graph Editor Toolbox**. After you have edited a camera parameter, use the recompute function  to recalculate the effects of editing on the other parameters. See Smoothing a curve using post filters on page 198.

Toggle the **Graph Editor Toolbox** display by selecting **Graph** > **Graph Editor** > **Editor Toolbox** or use the pop-up menu.

Toggling the display grid

To toggle the grid display in the **Graph Editor**:

1. Click in the **Graph Display** to select it.
2. Do one of the following:
   - Select **Graph** > **Show Grid** to display the grid.
   - Right-click in the **Graph Editor** or the **Track Status View** and select **Show Grid** from the pop-up menu.

A check mark appears beside the option indicating that the option is activated.

Locking the grid axes

To lock the X- or Y-axis of the grid, either:

- Select **Graph** > **X Locked** or **Y-Locked**.
- Right-click in the **Graph Editor** or the **Track Status View** and click **X Locked** or **Y-Locked** in the pop-up menu.

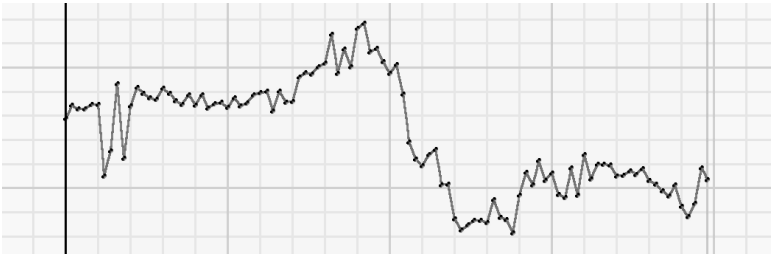
A check mark appears beside the option indicating that the option is activated.

Smoothing a curve using post filters

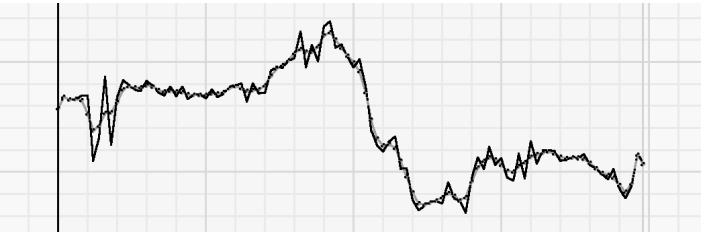
The **Graph Editor** allows you to modify curves and point values using post filters. MatchMover has four types of post filter.

- **Spline** - Replaces frame parameters with the values obtained from spline interpolation of the neighboring values. This is useful when one frame looks "jumpy" and neighboring frames are not. In this mode, you can change the tangent of the curve at a given point to create a smoother curve.
- **Linear** - Replaces frame parameters with the values obtained by creating a linear curve between the first and last selected frame.
- **Smooth** - Applies a smoothing filter to the computed values. This is useful to remove the small vibrations that can appear in the computed camera path even when the actual camera motion is smooth.

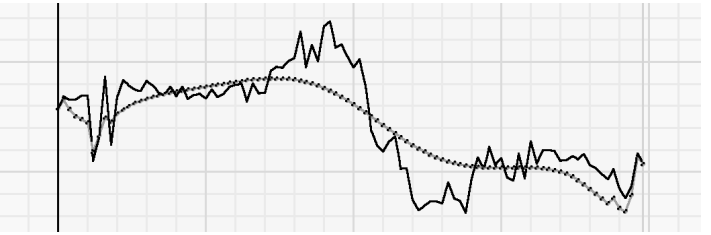
For example, if the original camera path computed by MatchMover is too jagged, as shown below, we will use the smoothing function to improve it.



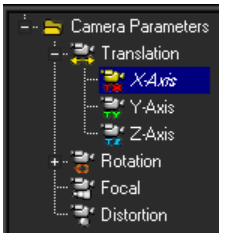
A low-strength smoothing operation polishes the curve while keeping the general motion.



However, if the smoothing is too strong, it will erase details and flatten the curve. Smoothing has worsened the result and the smoothed path is further from the solution than the originally computed one was.



Each time you modify a curve, its name in the Project window and the Track window changes to italic font and its corresponding icon changes to yellow.



This indicates that the value has been modified and some recomputation may be needed.

To smooth a curve using a post filter:

1. Click the **Graph Editor** tab.
2. Select the parameters to edit it in the left pane of the **Graph Editor**. Its curve will then be displayed in the **Graph Editor**.
   - To select more than one parameter use **Shift+click** to add new items to a current selection.
   - Use **Ctrl**+click to remove parameters from a selection.

TIP If you select more than one parameter in the left pane of the **Graph Editor**, several curves will be displayed in the graph area.

3 Do one of the following:

- Select a frame range. A frame range is a set of frames. In some situations, you may find that you only need to edit a limited part of your sequence. In the graph area, press **Shift+click** and drag the mouse horizontally to include the frames you want to select.
- Select a curve point by clicking on it. This will turn the point into a small red circle. If you are in the **Spline** mode, it will also activate the display of the curve tangents at this point.

NOTE If a time range exists, the filter is applied only to the frames within the time range. Frames outside the time range are unaffected. If no time range exists, the whole of the current sequence is filtered.

4 Select the relevant filter from the **Graph Editor Toolbox**.

-  to convert a time range to spline.
-  to convert a time range to inear.l
- 

to smooth a time range. Edit the number in the corresponding text field to define the strength of the smoothing.
- You can also set this value in the **Smoothing Strength** text field by selecting **Edit** > **Preferences** > **3D Tracking**.
- Right-click in the **Graph Editor** and select **Filter** and then a post filter from the pop-up menu.

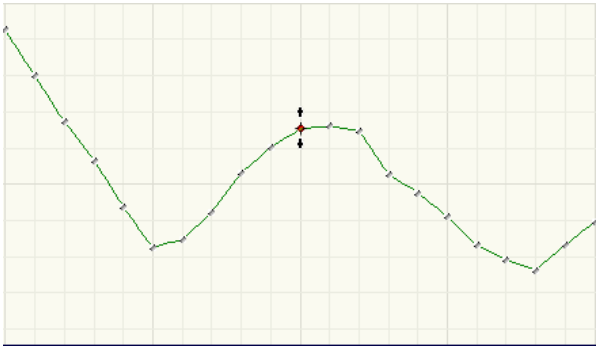
MatchMover applies the post filter to the selection.

Modifying a curve manually

For more controllable editing of a curve, you can edit points manually.

1 Place the pointer over the curve point you wish to edit. The pointer changes to  .

2 Click the point. The point changes to a red label with a pencil indicating that it is selected.



3 Drag and drop the point to its new position.

TIP You can do exactly the same using multiple points selection.

NOTE You can show or hide the original curve by toggling the option **Graph** > **Graph Editor** > **Show Ghost** or right-clicking in the **Graph Editor** and click **Show Ghost** in the pop-up menu. A check mark appears beside the option indicating that the option is activated.

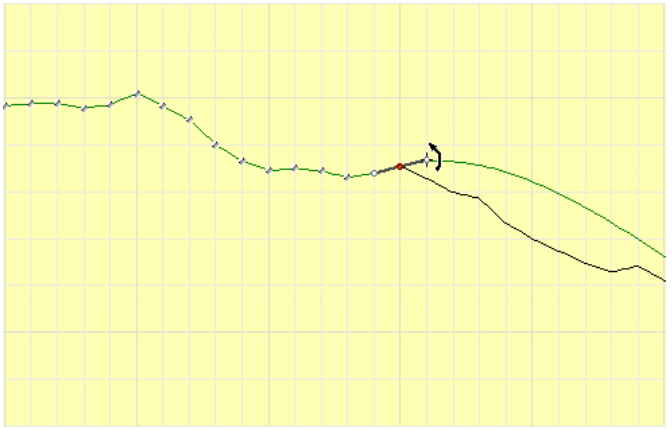
Editing tangents

You can also edit the tangents. By default, the two vectors are aligned and synchronized. If desired, you can desynchronize the two tangents and set them independently.

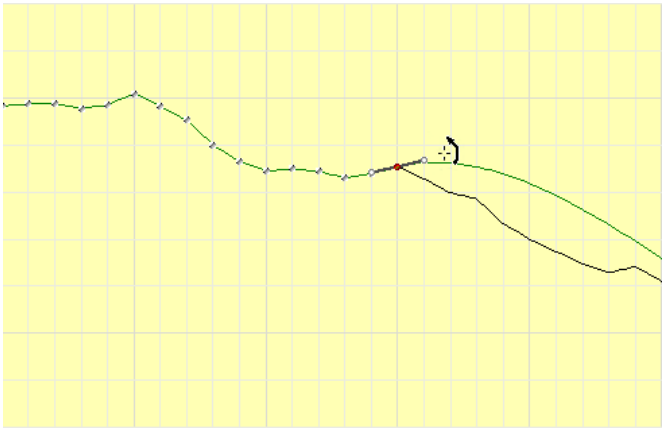
1 Run a **Spline** filter on a curve.

2 Select a point.

3 Place the pointer over a tangent of the point to edit.



4 Move the pointer up or down to set the tangent.



To edit tangents freely:

1 Do one of the following:

- Select **Graph** > **Free Tangents**.
- Right-click in the **Graph Editor** and click **Free Tangents** in the pop-up menu.

A check mark appears beside the option indicating that the option is activated.

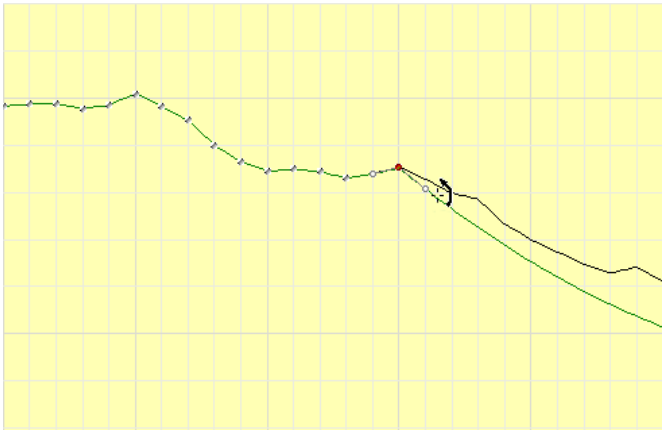
2 Run a spline filter on a curve.

See Smoothing a curve using post filters on page 198.

3 Select a point.

4 Place the pointer over a tangent of the point to edit.

5 Move the pointer up or down to set the tangent.



NOTE The **Free Tangent** mode causes discontinuities in the smoothness of a curve and should be used by advanced users only.

Adding keys to and deleting keys from the curve

To add a key to the curve, do one of the following:

- Select **Graph** > **Graph Editor** > **Add Key**.
- Right-click in the **Graph Editor** and select **Add Key** from the pop-up menu.

To delete a key from the curve, select it and do one of the following:

- Select **Graph** > **Graph Editor** > **Delete Key**.
- Right-click in the **Graph Editor** and select **Delete Key** from the pop-up menu.

Resetting the curve

To restore the curve to its initial state, do one of the following:

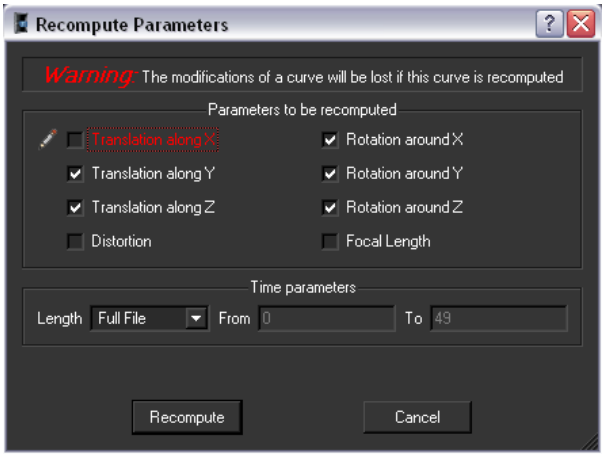
- Select **Graph** > **Graph Editor** > **Reset Curve**.

- Right-click in the **Graph Editor** and select **Reset Curve** from the pop-up menu.

Recomputing parameters

Once you have edited a camera parameter, use the recompute function to recalculate the effects of editing on the other parameters. To recompute the parameters:

1. Do one of the following:
   - Select **Graph** > **Graph Editor** > **Filter** > **Recompute**.
   - Click the **Recompute** icon  in the **Graph Editor Toolbox**.
2. Select the parameters to recompute by checking the associated option as appropriate in the **Recompute parameters** window.
3. After editing a curve, MatchMover selects automatically which curves should be recomputed based on the modifications made. Check or clear the appropriate toggle box to set the **Parameters to be recomputed**. Red options indicate the parameter is already edited. It also suggests parameters for recomputation and checks them automatically.



4. Select a time frame in the **Time parameters** text fields or drop-down menu. Choose from **Full File**, **Time Range**, or **User**.
5. Press the **Recompute** button.

NOTE When recomputing camera parameters in the Graph Editor, the items **Distortion** and **Focal Length** in the **Recompute parameters** box are by default disabled to keep the focal length and the distortion constant.

MatchMover re-estimates the specified camera parameters from the 3D points, the 2D tracks and the modified camera parameters without changing the 3D points. For example, with a variable zoom, it is common for the system to produce a camera path that is jagged along the depth axis. MatchMover compensates for slight errors along this axis by adjusting the focal length.

To avoid this, you can first filter the focal length then re-compute the rotation and translation.

Working with 3D objects

MatchMover provides you with a set of objects called 3D primitives. 3D primitives are basic 3D shapes such as cubes, cones or spheres. It is also possible to import an object or a scene in the OBJ format. You can use a 3D object as it appears or edit it, using one of the manipulators. The virtual objects are fixed in space, and rendered using the estimated camera parameters. The process is successful when the motion of the virtual objects in the composed sequence is consistent with that of the real scene. You can also use 3D objects to define survey points mapping by dragging the mouse from one vertex to the image plane. See Setting survey points using elastics on page 177.

To insert a new primitive:

1. Do one of the following:
   - Select **3DScene** > **New Primitive**.
   - Right-click in the **3D View** or on the **3D Scene** folder in the Project window and select **New Primitive** from the pop-up menu.
2. Select the type of new primitive from the sub menu. **Plane**, **Cube**, **Pyramid**, **Dihedron**, **Sphere**, **Cylinder**, **Cone**, or **Light**.

Alternatively, you can select a primitive from the Toolbar by clicking on one of the primitive icons. See User Interface overview on page 69.

MatchMover inserts the new primitive in the scene at the origin of the coordinate system and selects it.

Importing 3D objects

You can import 3D objects as files in the OBJ format. Only polygonal objects are imported. The imported objects are imported along with texture information, and can be manipulated in the same manner as the 3D primitives.

1. Do one of the following:
   - Select **3D Scene** > **Import Scene**.
   - Right-click the **3D Scene** folder in the Project window or anywhere in the **3D View** and select **Import Scene** from the pop-up menu. The **Import Scene** window opens.
2. Select the OBJ file to import and click **OK**.

Viewing 3D primitives and objects

You can position the viewing camera to view the different faces of a 3D object or primitive by selecting **View** > **Set 3D Viewing** and one of the following options.

- **Front** - Shows the front view of the object relative to the active coordinate system.
- **Top** - Shows the top view of the object relative to the active coordinate system.
- **Side** - Shows the side view of the object relative to the active coordinate system.
- **Perspective** - Changes the scene's perspective.

- **Orthographic** - Shows the scene without perspective.

Deleting a 3D primitive or an object

To delete a primitive or a 3D object, do one of the following:

- Select an object in the **3D Scene** folder in the Project window or in the **3D View** and either:
  - Select **Edit** > **Delete**.
  - Press the **Delete** key.
- Right-click an object in the **3D Scene** folder in the Project window and select **Delete Object** from the pop-up menu.

The object is deleted from the project.

Editing 3D primitives and objects

You can either edit primitives in the **Parameters Window** or by using MatchMover's three manipulators. See 3D primitives and objects Parameters Window on page 211.

- **General manipulator**
- **Translate/Scale manipulator**
- **Alignment manipulator**

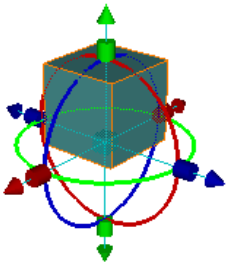
The different manipulators provide specific object manipulation possibilities, enabling you to edit any object placed within the **3D View**. By default, when you create a new primitive or new light, the **General manipulator** surrounds the object.

1. To access the manipulators either:
   - Click an object and select **3D Scene** > **Select Manipulator**.
   - Right-click an object in the **3D View** and select **Select Manipulator** from the pop-up menu.
2. Choose **General**, **Translate/Scale**, or **Alignment**.

The manipulator changes. Notice that the same manipulator is assigned to all new objects. Toggle between the manipulators using the **Tab** key.

NOTE To change the color of the manipulator or the manipulator's active handle, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

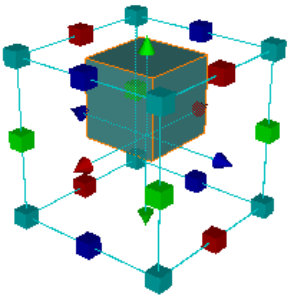
The General manipulator



The **General manipulator** allows you to carry out the following actions:

- Independent scaling along to the selected axes by clicking and dragging the cylinder.
- Rotation around the selected axes by clicking and dragging one of the three circles surrounding the object.
- Translation in the plane perpendicular to the camera by clicking and dragging the cone.
- Translation along two axes by clicking and dragging the central cube.

The Translate/scale manipulator



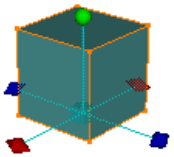
The **Translate/scale manipulator** allows you to carry out the following actions:

- Independent translation along the selected axes by clicking and dragging the cone.

- Translation in the plane of the selected manipulator face by selecting and dragging a face.
- Symmetrical scaling in relation to the center of the manipulator by clicking and dragging a cube in the edge of the manipulator.
- Symmetrical scaling in relation to the center of the manipulator along three axes by clicking and dragging a corner cube.

The Alignment manipulator

The **Alignment** manipulator, more complex than the other two manipulators, defines the alignment of manipulator axes and pivots.



The **Alignment manipulator** allows you to carry out the following actions:

- Align the object with the principal axis by clicking and dragging the sphere.
- Align the object with the central pivot by clicking and dragging the center cube.
- Align the object with the orientation axes by clicking and dragging the cone.
- Snap the manipulator to an object's vertex, edge, or faces, track points, and other primitives in the scene (see below).

Snapping the manipulator to elements

Press **Shift** and drag and drop a manipulator element on a vertex, an edge, or a face of the object, track points, and other primitives. The orientation axes and principal axis align an object whereas the center cube translates it.

When you place the pointer over an element, it changes to reflect the type of element you are snapping to.

 when snapping to a vertex or a 3D Helper.

 when snapping to an edge of an object.

 when snapping to a face of the object.

Aligning the manipulators' pivot

MatchMover allows you to align the manipulators' pivot with object elements.

When any of the manipulators are activated:

1 Do one of the following:
- Select **3DScene** > **Edit Pivot**.
- Right-click an object in the **3D View** and select **Edit Pivot** from the pop-up menu.

2 Select from the pivot alignment options in menu:
- **Orient Pivot** - Aligns the pivot with a face of the selected object. See Orientating the manipulator's pivot on page 210.
- **Align Mesh** - Aligns the pivot with the mesh. See 3D primitives and objects Parameters Window on page 211.

The following additional options apply only when the **Alignment manipulator** is activated:

- **Center Pivot** - Aligns the pivot with the center of the selected object.
- **Align Pivot** - Aligns the pivot with the coordinate system.
- **Invert Pivot** - Inverts the pivot at its current position.

Orientating the manipulator's pivot

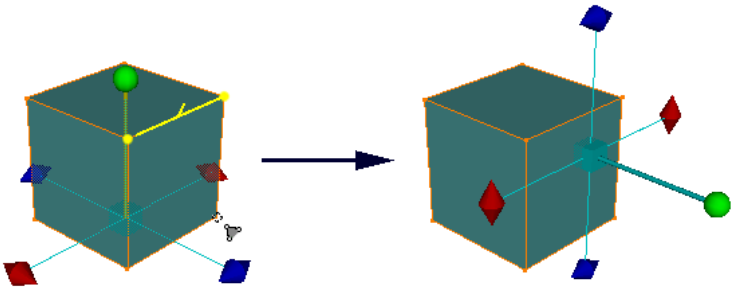
The **Orient Pivot** option aligns the pivot with a face of the selected object.

1 Do one of the following:
- Select **3DScene** > **Edit Pivot** > **Orient Pivot**.
- Click the **Orient Pivot** icon  in the Toolbar.

The pointer changes to. .

2 Place the pointer over a vertex. It changes to , indicating that you can select the vertex.

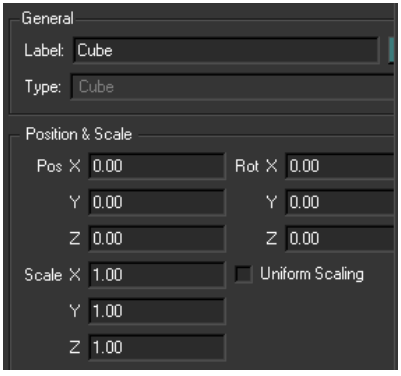
Select three vertices to define an alignment with the principle axis aligned with the normal of the triangulation.



3D primitives and objects Parameters Window

You can change the name, position, rotation, scaling and color of a 3D primitive and objects in the **Parameters Window**.

1 Click an object label in the **3D Scene** folder of the Project window to open its properties in the **Parameters Window**.



2 Enter the values you want to change.

- **Label** - Shows the name of the object.

- **Type** - This field is read only. Shows the type of 3D object. **Primitive** for a simple object created by MatchMover, **Imported scene** for an imported file or a light.
- **Pos. X, Y, Z** - Shows the object position in the active coordinate system.
- **Rot. X, Y, Z** - Shows the object rotation in the active coordinate system.
- **Scale X, Y, Z** - Shows the scaling value for each axis.

NOTE Click the **Uniform Scaling** option to scale in all three directions at the same time.

- **Color** - Shows the object color. Click the Color box to open the color editor and to modify the colors.

NOTE The color is used in **Flat**/**Transparent** modes only.

Stacking objects

You can stack or reposition objects by defining a plane to which a 3D object snaps.

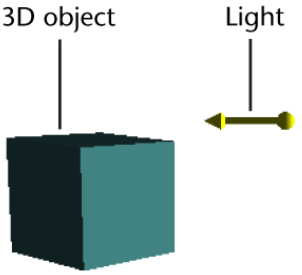
1. In the **3D View**, select a 3D object that you want to stack or reposition in the scene.
2. Do one of the following:
   - Select **3DScene** > **Edit Pivot** > **Align Mesh**.
   - Click the **Align Mesh** icon  in the Toolbar.
3. Place the pointer over a 3D Helper. It changes, indicating that you can select the 3D Helper. Select three 3D Helpers in either a clockwise or counter-clockwise direction using the same method for selecting track points. See Selecting tracks on page 134.

The object snaps to the plane and the principle axis is aligned with the normal of the triangulation.

NOTE To change the color of the mesh, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

Illuminating your scene

Lights are used to illuminate your scene. Lights in the **3D View** are directional lights. They are created at the origin of the 3D world. By default, a diffused, ambient light illuminates the whole of the scene.



Creating a new light

You can move lights around in the **3D View** without changing the lighting; only the light orientation is important.

As soon as you insert a new light, the effects of the default lighting disappear.

To create a new light, do one of the following:

- Select **3D Scene** > **New Light**.
- Click the **Light** icon  in the Toolbar.
- Right-click the **3D Scene** folder in the Project window or anywhere in the **3D View** and select **New Light** from the pop-up menu.

A new light appears in the **3D Scene** folder of the Project window.

NOTE To change the default color of the lights, select **Edit** > **Preferences**, click the **Color** tab in the **User Preferences** window, and change the color of the corresponding sample box.

Editing lights

By default, when you place a light within a scene it is surrounded by the **General manipulator**. Lights are edited in the same manner as physical 3D primitives. See Editing 3D primitives and objects on page 207.

Changing the size of the non-physical objects

To change the size of any non-physical objects in a scene, for example, lights and cameras:

1. Select **Edit** > **Preferences** > **Display**.
2. Enter a number in the **3D Icon Size** text field. A smaller number reduces the size of the non-physical object; a greater number increases their size.

The **3D Icon Size** is also reported in the **Global Parameters Window**.

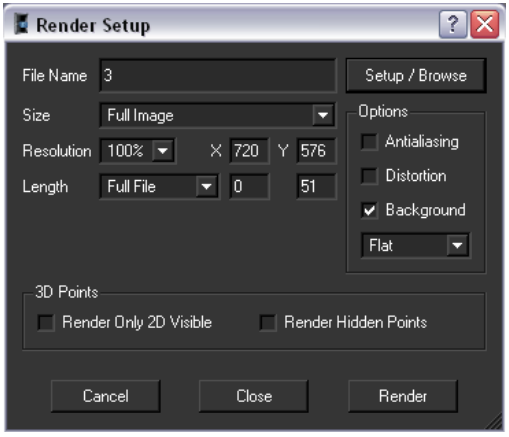
Rendering the sequence

To generate a preview sequence you can create a sequence of any available format, depending on your platform, for example, AVI, QuickTime, single image files, using the **Render** function. By doing this you can examine the estimated camera path quality.

If you have configured the render process, select **3D Scene** > **Render**.

If you have not configured the render process:

1. Select **3D Scene** > **Render Setup**. The **Render Setup** window opens.



2. The **File Name** field automatically points to the last directory used for rendering. If you click **Render** without entering a filename, a window pops up asking you to enter one. If this is the case, choose a destination directory and enter a **File Name**.

3 From the drop-down **Size** list, choose the size you want for the rendered image. **Full image** renders the whole image. **Crop to viewport** only renders the portion of the image visible in the current viewport at the moment you open the **Render Setup** window. Each time you open it the area to render is updated.

4 From the **Resolution** drop-down list, choose the resolution percentage. Choose the option **User** to define a custom size.

5 To determine the section of the sequence to render, select an option in the **Length** drop-down list.

- **Full Length** renders the whole sequence.
- **Time range** renders the sequence within the time range at the moment of the render.
- **User** renders the sequence frames entered in the adjacent fields.
- **Work Area** renders the sequence within the selected **Work Area**.

6 Check the **Antialiasing** box if you want the object edges to have a clearer appearance. This is important if you want to check for very small, sub-pixel vibrations of the object, but slow down the process.

7 If you have distortion in the original image, check the **Distortion** box. This applies the non-linear distortion to the object while leaving the background image intact.

TIP If you do not check this box in a shot where you computed a non-zero distortion, the objects appear to slide slightly with respect to the background image motion. This is normal, as they are rendered without taking into account the geometric parameters of the camera.

---

8 Select a render opacity for the 3D objects from the drop-down list:

- **Flat** - Solid objects
- **Wireframe** objects
- **Texture** - Solid objects textured with the background from the corresponding imported objects.

9 Click the **Render Only 2D Visible** checkbox to render only the 3D points in a frame if the corresponding 2D track is defined for this frame.

10 Click the **Render Hidden Points** checkbox to render hidden tracks. Hidden tracks are not rendered by default.

11 Click **Setup** if you want to customize the output format (compression factor).

12 If you want to save and run the rendering process immediately click the **Render** button. If you want to save your setup but not run the rendering process click the **Close** button.

Importing and exporting

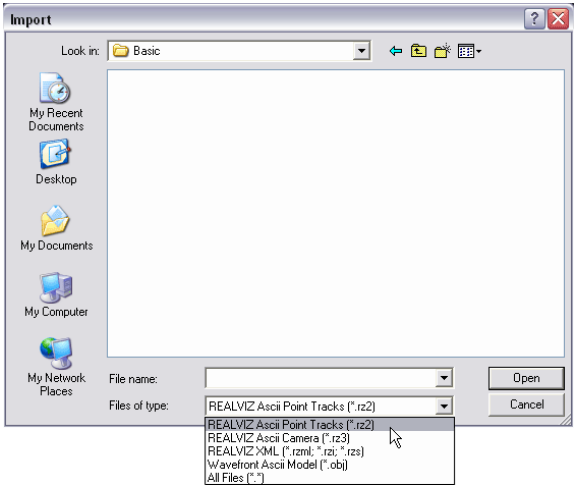
Importing files

You can import files with the following formats:

- REALVIZ Ascii Point Tracks (*.rz2)
- REALVIZ Ascii Camera 3D Tracks (*.rz3)
- REALVIZ XML (*.rzml; *.rzi; *.rzs)
- Alias|Wavefront Ascii Model (*.obj).

To import a file:

1 Select **File** > **Import** to open the window.



2 Use the **Files of type** drop-down list to show files with the same format only or select **All Files** to show all files.

3 Select the file to import and click **Open**.

TIP You can simply drag and drop any kind of known file in the Workspace area to automatically import it.

Importing REALVIZ Ascii files

If you have a REALVIZ Ascii Point Tracks RZ2 file containing data on point tracks, you can import it into MatchMover.

TIP If you have re-scaled the film, the points are re-scaled when you import them to match the new resolution of the images.

If you have a REALVIZ Ascii Camera 3D Tracks RZ3 containing either cameras/and or points, you can re-import it. If no 2D tracks correspond to the imported 3D tracks, dummy tracks are created.

Importing REALVIZ XML files

You can import REALVIZ XML file within MatchMover. This file can come from any other REALVIZ software, such as ImageModeler. This format is also used to communicate with the MMTrack plugins family. This imports a whole scene, so it's suggested to start a new project before importing such a file.

Importing Alias|Wavefront Ascii Model

If you have an Alias|Wavefront OBJ file it can be imported into MatchMover. When imported, MatchMover treats the file as a scene keeping the original polygonal geometry along with the colors and textures within the original file.

You can only import polygonal objects. See Importing 3D objects on page 206.

NOTE Textures are loaded only if they are in a MTL file with the same name as the corresponding OBJ file.

Exporting files

Export file formats

MatchMover supports the following file formats.

File format	Extension
3ds max	*.ms
Cinema 4D	*.c4d
Combustion	*.cws
Digital Domain NUKE*	*.nk
Discreet Flame	*.action
Discreet Flint	*.action
Discreet Inferno	*.action
LightWave 3D	*.lws
Maya	*.ma
QuickTime	*.mov
REALVIZ Ascii Camera 3D Tracks	*.rz3
REALVIZ Ascii Point Tracks	*.rz2
REALVIZ RZML	*.rzml
SOFTIMAGE|3D	*.xsi
SOFTIMAGE|XSI	*.xsi
Visual Basic	*.vbs

*Using a Perl script

Setting the up axis

Before exporting your project, you may want to set the up axis to facilitate the manipulation of your scene in your 3D package.

To set the up axis:

1. Select **Project** tab in the **Parameters** window.
2. From the **3D Up axis** drop-down list, select either **X**, **Y**, or **Z**.

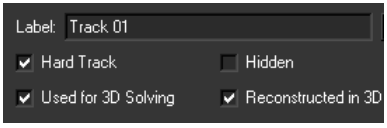
MatchMover sets the up axis as required.

NOTE You should set up the up axis before launching the solver, this way it will be taken into account correctly.

Reconstructing 3D points for export

You may want to add more point tracks to a scene, for example, to export them to a 3D package, or manually track them. See Supervised 2D tracking on page 132.

In MatchMover, you can construct them in 3D automatically without re-running the calibration process. 3D point reconstruction is triggered when the **Reconstructed in 3D** option in the point track **Parameters Window** window is checked.

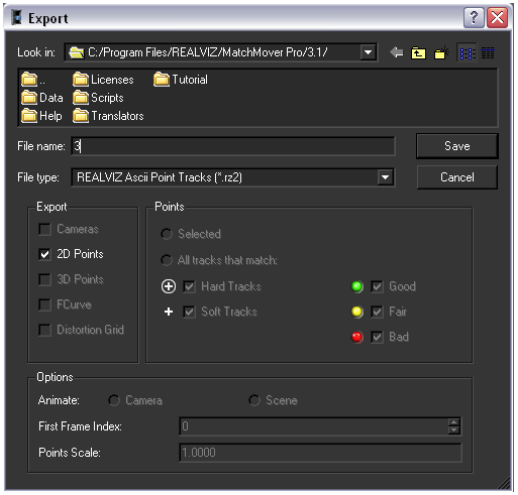


The option is checked by default. If you edit a track, add a key, edit a key, or merge tracks, reconstruction is performed automatically providing that enough 2D information is available on the key or computed points in a minimum number of frames.

NOTE If you right-click any point in the **Point Tracks** folder in the Project window or the Track window, the option **Reconstructed in 3D** is checked in the pop-up menu, indicating that the point is reconstructed in 3D.

Exporting a project

1 Select **File** > **Export**  . The **Export** window opens.



2 In **Save as type**, select a file format from the drop-down list of formats supported by **MatchMover**.

3 Type a **File Name** in the corresponding text field.

4 In **3D Points**, click either:

- **Selected** (if you want only those point tracks you have selected).
- **All tracks that match** at least one criterion in each column. **Manual**, **Automatic**, or both, and the quality of the points (**Good**, **Fair**, **Bad**). For example, if you check Manual and Good and Fair, only hard tracks with yellow and green icons will be exported. Regardless of quality, no soft tracks will be exported.

5 Choose an **Animate** radio button. For certain formats both **Camera** and **Scene** radio buttons are available. If you select **Camera**, the 3D points are fixed and the camera moves. If you select **Scene**, the camera position is fixed and the 3D points move.

- If enabled, you can set a **first frame index** to select the frame in the 3D package when the current solve will start.

- If enabled, you can set a **point scale** that will be used to scale all the exported 3D tracks.

6 Click **Save**.

NOTE The **Export** toggle boxes show the type of data to export. All track groups are exported as such, and mobile points are animated.

Exporting REALVIZ Ascii Camera 3D Tracks (.rz3)

Use the procedure described in the *Exporting a project* section. See Exporting a project on page 220. From the **Save as type** drop-down list, select **REALVIZ Ascii Camera (.rz3)**.

MatchMover exports only the camera and static 3D tracks associated to the current sequence (contained in the current time).

NOTE If you have several sequences you must change the current time to export the associated camera of each sequence.

MatchMover creates an Ascii file as follows.

```
imageSequence "Sequence00"
{    720 576
f("\\Spirou\public\images\MatchMoving\sgi320.avi" )          b(
0 238 1 )   -even}
Camera
{0    F ( 943.095 )   Pr ( 1.06667 )   Pp ( 360 288 )   K ( 0 )
    Oc ( -42.4206 67.3594 -19.604 )
    Rot ( 0.793155 0.598043 -0.115111 -0.158493 0.38519 0.909125
0.588035 -0.702832 0.400301 )1
F ( 943.095 )   Pr ( 1.06667 )   Pp ( 360 288 )   K ( 0 )
    Oc ( -41.9334 67.8446 -19.764 )
    Rot ( 0.795385 0.594972 -0.115633 -0.157956 0.387665 0.908166
 0.58516 -0.704077 0.402323 )
}PointTrack Track00 (4.79921 0.0732729 1.00537)
PointTrack Track01 (-0.00894661 0 0)
PointTrack Track02 (-0.00894661 1.37239 10.0013)
```

- The label imageSequence contains the name of the sequence in the Project window.
- The values 720 and 576 refer to the size of the image.

- `f( "\\Spirou\public\images\MatchMoving\sgi320.avi" )` gives the full path name of the sequence.
- `b( 0 238 1 )` refers to the begin, end and step values.
- `-even` defines the type of interlace which can be `Upper field first` or `Lower field first`. The default value is no interlace if no type is specified.
- Camera
  The first line gives the frame number.
  - `F` indicates the focal length in pixels, defined as focal length (mm) times image width (pixels)/film back width (mm).
  - `Pr` indicates the pixel aspect ratio.
  - `Pp` indicates the position of the principal point.
  - `K` indicates the distortion value.
  - `Oc` indicates the Camera position (X, Y, Z).
  - `Rot` indicates the three lines of the Matrix of rotation. The last line of the Matrix, the last three coefficients, also represents the direction along which the camera is pointing, expressed with respect to the reference coordinate system.
  - The remaining lines of code give the Point Track label and its X, Y and Z coordinates.

You can edit this file and re-import it into MatchMover.

Exporting REALVIZ Ascii Point Tracks (.rz2)

Use the procedure described in the *Exporting a project* section. See Exporting a project on page 220. From the **Save as type drop-down list**, select **REALVIZ Point Tracks (.rz2)**. MatchMover exports only the point tracks of the current sequence.

TIP If you have several sequences you must change the current time to export the point tracks of each sequence.

You can edit this file then re-import it into MatchMover.

The file created contains four object type descriptions, the tracks, the computed 2D points, the keys and the sequence corresponding to the file (a file equals a sequence).

Sequence

This is the first information contained in the file.

```
imageSequence "Label"
{360    243 f("path") b(0 38 1) -Upper field first/-Lower field
first}
```

The label can contain letters, numbers, spaces and underscores. It must be contained within quotation marks and is optional.

The numbers 360 and 243 correspond to the film resolution, width followed by height.

The path indicates the position of the file. It is shown by f("...").The path is optional.

b(0 38 1) indicates the start, end and step of the sequence and determines the tracked point Id. Start, end and step are whole numbers. This element is optional and if omitted the start value is 0.

For example, if b(15 50 1), the tracked point Id is numbered between 15 and 50. When you open the file with a sequence that starts at 0, the tracked point Id is automatically re-numbered between 0 and 35. However, if you want to keep the original Id you must change b(15 50 1) to b(0 35 1).

`-Upper field first/-Lower field first` specifies the interlacing of the film. If there is no parameter, there is no interlacing. Otherwise, you must specify it with `Upper field first` or `Lower field first`.

Track

```
pointTrack "Label" -nc -nr rgb( 64 0 128 )
{
...
}
```

The label can contain letters, numbers, spaces and underscores. It must be contained within brackets and is optional. The Label is useful to complete a track when one sequence follows another (there are two files). During the import of the second file, the tracks with the same label are completed.

If nc is specified this indicates that the track is not used for 3D calibration.

If nr is specified this indicates that the track is not reconstructed in 3D.

The color rgb (red, green, blue) is optional.

The track contains the points and the corresponding keys.

Keys and points

For the keys:

```
Id X Y kb(threshold)  s(top bottom right left )   p(top bottom
right left)
```

- Intermediate key -> ki (threshold).
- Automatic key -> ka (threshold).
- Begin key -> kb (threshold).
- End key -> ke (threshold).
- Single key -> ks (threshold).
- s(...)corresponds to the search area.
- p(...)corresponds to the pattern area.

For the points:

```
Id X Y p+( score )  -ncp
```

`Id` indicates the frame number relative to the start of the sequence.

`X` and `Y` indicate the coordinates of the key or point from the upper left corner.

For the points:

- p+(score) Point obtained from a backward track.
- p-(score) Point obtained from a forward track.
- p*(score) Point obtained from a bi-directional track.

If ncp is specified, this indicates an incomplete track point.

If there is only Id X Y, this means the creation of a single key with default parameters.

Creating a minimal rz2 file

For each track:

```
Track point
{
Id CoordX  CoordY
Id CoordX  CoordY
Id CoordX  CoordY
Id CoordX  CoordY
Id CoordX  CoordY
... }
```

Maya export

The Maya export function allows you to create a Maya Ascii file (*.ma) to import all MatchMover's 3D geometry into Maya software versions 2.0 and later. All 3D geometry is exported as such, and mobile points are animated.

The generated file includes:

- A root object called **rzGroup** that you can use to move the entire scene exported from MatchMover.
- A camera object with animated transformation, focal length and clipping planes (the clipping planes are initialized to bind the reconstructed points cloud. You may need to modify them if you add some objects to the scene).
- All 3D objects in the project.
- An image plane, eventually undistorted, attached to the camera with a size and coverage initialized to assure the right matching between the camera aperture and the tracked sequence.
- A set of locators for each reconstructed point track.
- Presets for render resolution.
- Synchronized cameras with their respective image planes in case of a MOCAP project.

Depending on your default Maya preferences parameters, you may need to adjust your viewport settings in order to display the textured sequence:

1. Apply shader using **Shading** > **Smooth Shade All**.
2. Texture sequence using **Shading** > **Hardware Texturing**.

You can now look through the tracked camera using **Panels** > **Perspective** > **rzCamera1**.

Create or import some scene objects and lights and set their positions using the predefined locators transformations, then render some preview images with **Render** > **Render into New Window**.

For more information about Maya camera and image planes, refer to "Maya User Guide."

SOFTIMAGE|3D export

MatchMover generates an Ascii file of the type XSI that can be imported into SOFTIMAGE |3D using the following procedure.

NOTE MatchMover has separate exporters to Sotfimage |3D 3.8 (.xsi version 1.3) and Softimage |3D 3.9 (.xsi version 3.0). The latter is more complete and can perform camera animation using constraints, which is easier to manipulate than the motion paths used in the former.

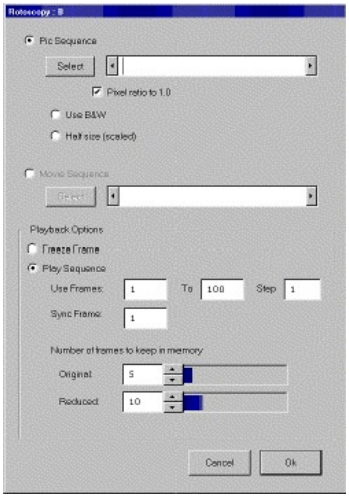
---

1. Select **Tools** > **Import** > **Objects** > **Ascii Import**. A window opens.
2. Select the XSI file exported by MatchMover. When the process is complete, the camera and the 3D points have been imported into Softimage.
3. To verify the import, choose a Perspective viewport and move the time line.

Compositing in Softimage (Rotoscoping)

The images must be of the Softimage (PIC) format. To convert an AVI sequence or images into another format. See Conversion of AVI and other formats to Softimage PIC format on page 227.

1. In the Perspective viewport, go to **SHADE** > **Rotoscope (wire)**. The **Rotoscopy** window opens.



2 Click the **Select** button and choose the image sequence.

3 Choose **Play Sequence** in the **Playback** options.

4 Adjust the **Use Frames** fields and if necessary the **Sync Frame** field when there is a difference between the number of the first frame exported by MatchMover (generally 0) and the number of the first image.

Conversion of AVI and other formats to Softimage PIC format

The Softimage image format defines the image Pixel Ratio and this is taken into account for the image display in the viewports. It is crucial that you export the image with the correct pixel ratio, which by default is always 1. Amongst the executable files supplied by Softimage, tga2soft allows you to specify the Pixel Ratio with the option -p. One solution is to convert the AVI into PIC, then the PIC into TGA then the TGA into PIC.

To convert file formats:

1 From the MS DOS prompt window, move to the directory containing the Softimage binaries.

2 Use the following commands provided by Softimage.

- Avi2soft
- Soft2tga
- Tga2soft

For example, to convert an avi file composed of 25 images with PAL pixel aspect ratio (1.0666) into the Softimage PIC format, enter: avi2soft sequence.avi sequence -s 1 25 1, soft2tga sequence sequence -s 1 25 1, tga2soft sequence sequence -s 1 25 1 -p 1.0666.

SOFTIMAGE|XSI export

When exporting for SOFTIMAGE|XSI, MatchMover creates two files: a dotXSI file and a *.vbs* file. You don't need to import dotXSI file by yourself, open the *.vbs* file in the script editor and it will load the exported scene and set all needed parameters for rendering:

1. Open the script editor using: **Application** > **Views** > **Script Editor**.
2. Select **File** > **Open...** in the script editor.
3. In the window that open. Select the ".vbs" file exported by MatchMover.
4. Select **Run**.

The XSI format does not specify whether the FOV is horizontal or vertical. SOFTIMAGE|3D reads it as vertical, while SOFTIMAGE|XSI reads it as horizontal.

You will therefore need to adjust it when import completed.

The imported scene includes:

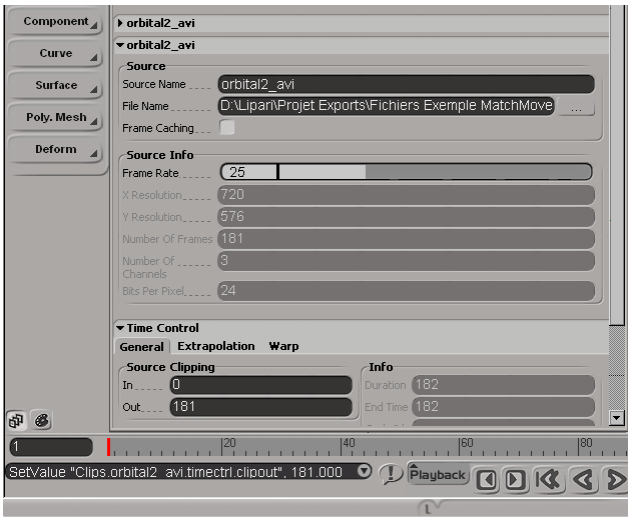
- A root object called **rzGroup** which you can use to move the entire scene exported from MatchMover.
- A camera object with animated transformation and focal length.
- All 3D objects in the project.
- An image plane, eventually undistorted, attached to the camera with a size and coverage initialized to assure the right matching between the camera aperture and the tracked sequence.
- A set of locators for each reconstructed point track.
- Presets for render resolution.
- Synchronized cameras with their respective image planes in case of a MOCAP project.

You may need to adjust your viewport settings in order to display the textured sequence.

If you wish, you can delete this image plane and use rotoscopy options of SOFTIMAGE|XSI:

1 Select the **Rotoscope** mode.

2 Edit the **Rotoscope** options.



3 Select **Camera Rotoscopy** > **General** > **New** > **New from file**.

4 In the window that opens, select your video file.

5 In **Source Info**, adjust the frame rate if necessary.

6 In **Time Control** > **Source Clipping**, adjust “out frame” to your video length-1 (number of frames displayed in **Source Info**).

LightWave 3D export

The LightWave 3D® scene exported by MatchMover can be imported as is in LightWave 3D.

MatchMover produces a LightWave 3D scene file, a LightWave object for each 3D object in the project and a LightWave object used to create an image plane for each exported camera.

Select **File > Load Scene**. The scene contains the tracked camera, the 3D points as “null object” and information about the pixel aspect ratio. The output size is also automatically set.

The scene contains:

- A root object called **rzGroup** which you can use to move the entire scene exported from MatchMover.
- A camera object with animated transformation and focal length.
- All 3D objects in the project.
- An image plane, eventually undistorted, attached to the camera with a size and coverage initialized to assure the right matching between the camera aperture and the tracked sequence.
- The 3D points as “null object”.
- Presets for render resolution.

Synchronized cameras with their respective image planes in case of a MOCAP project.

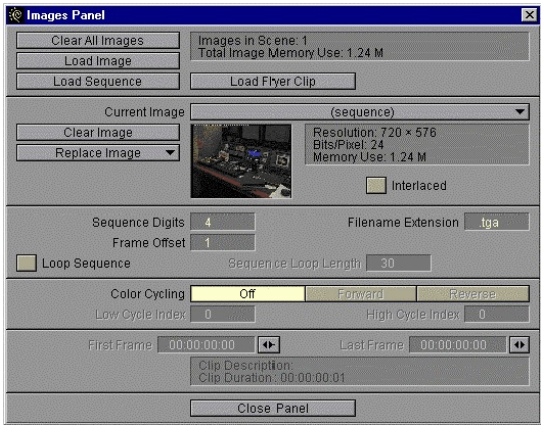
Compositing in LightWave 3D

If you wish, you can delete the image plane and use the sequence in LightWave 3D as a background image.

Refer to “LightWave 3D User Guide” for more information.

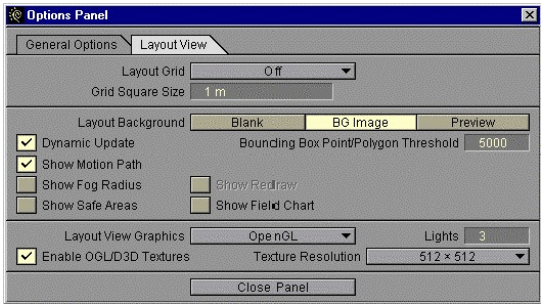
To use the sequence as a background image:

1. In the **Images Panel** choose **Load Sequence**, and choose an image in your sequence.

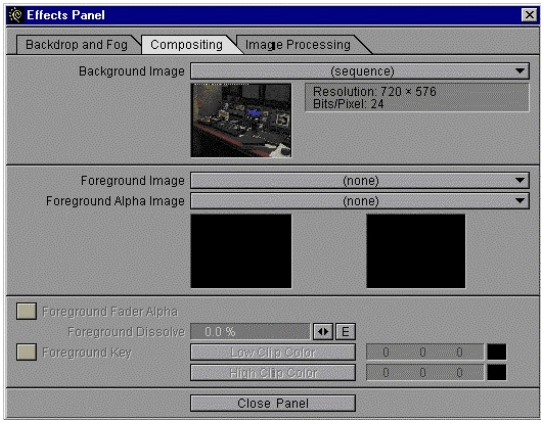


NOTE Correctly set the frame offset. If your sequence numbering does not begin at 0 and you enter 1, this would mean that "foo0001.tga" corresponds to frame 0 in your animation.

2 In the **Options Panel** choose **OpenGL** as **Layout View Graphics** and **BG Image** as **Layout Background**.



3 In the **Effects Panel**, click the **Compositing** tab and select your sequence from the **Background Image** combo.

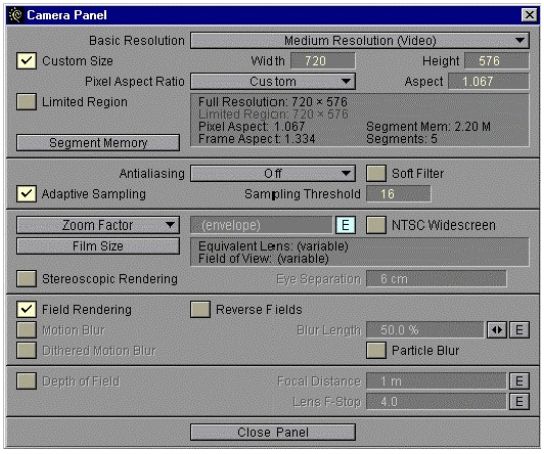


Now you can start animation on top on the tracked sequence.

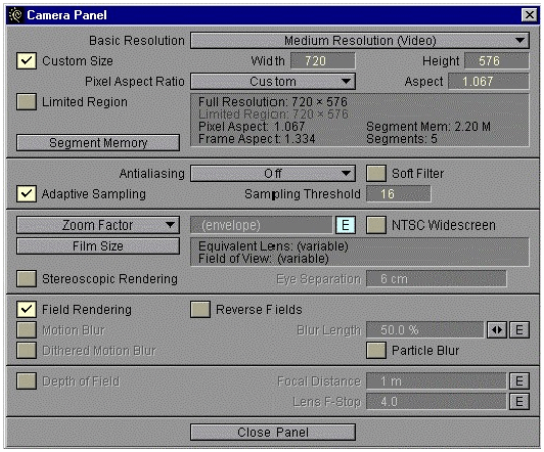
Working with interlaced sequences

If your background sequence is interlaced, you should check the **Interlaced** box in the **Images Panel**.

1 In the **Camera Panel**, check the **Field Rendering** box.



2 If you chose **Lower field first** as the interlace type in MatchMover, check the **Reverse Fields** box.



Now you can render your interlaced sequence.

TIP If there is a slight apparent motion of the virtual objects with respect to the background image, make sure that you have chosen the right field rendering type and the right frame offset for your sequence.

MAXScript export

The MaxScript generated by MatchMover allows you to import the camera trajectory and the 3D points calculated by MatchMover.

1. Choose **Utilities** > **MAXScript** > **Run Script**.
2. In the **File** window, load the MAXScript that you have just created with MatchMover.

After the loading the scene contains:

- A root object called **rzGroup** which you can use to move the entire scene exported from MatchMover.
- A camera object with animated transformation and focal length.
- All 3D objects in the project.
- An image plane, eventually undistorted, attached to the camera with a size and coverage initialized to assure the right matching between the camera aperture and the tracked sequence.

- The 3D points as “null object”.
- Correct render settings.
- Synchronized cameras with their respective image planes in case of a MOCAP project.

Rendering

Select **Rendering** > **Render** from the menu or **Render Scene** from the toolbar.

Interlaced sequence

If the original sequence is interlaced and you want to keep the same fluidity of movement, you have to render in interlaced mode. To do this, check the **Render to Fields** box.

When you do this you must keep the exact original image size so that each synthesized frame superimposes exactly on the original sequence.

To keep the frame order the same as that used in MatchMover, it may be necessary to modify

the frame order in 3ds max.

1. Select **File** > **Preferences** from the main menu and open the **Rendering** page.
2. Select the correct order in the **Field Order** radio buttons.

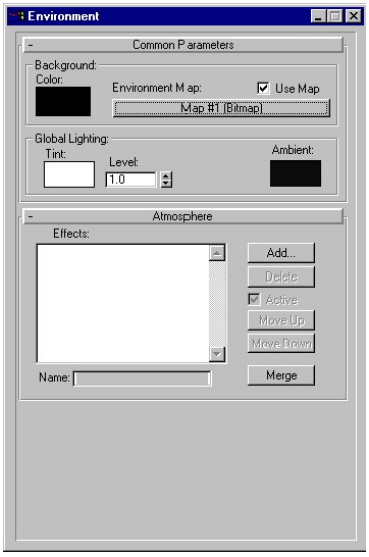
Compositing in 3ds max

It is possible to do the compositing directly in 3ds max in order to merge live action with a computer-generated model.

If you wish, you can delete the image plane and use the sequence as a background image.

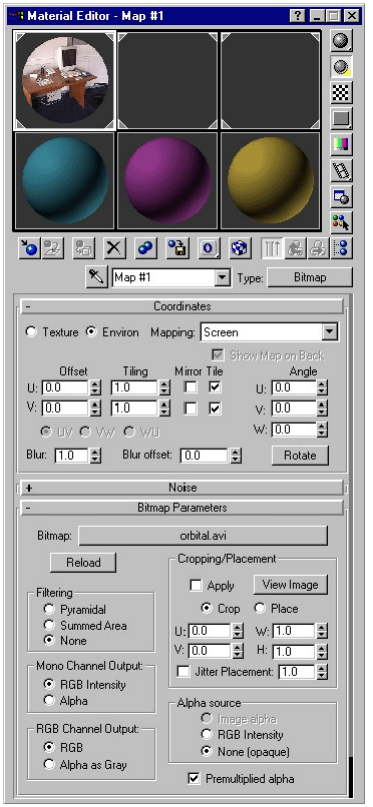
The following procedure represents the simplest way to define a background image concerning the pixel aspect matching. When this is done correctly, the background image should exactly match the 3D.

1. Select **Rendering** > **Environment**.



2 Define an **Environment Map** of the type **Bitmap**.

3 While keeping the **Environment** window open, open the **Material Editor** from the toolbar.



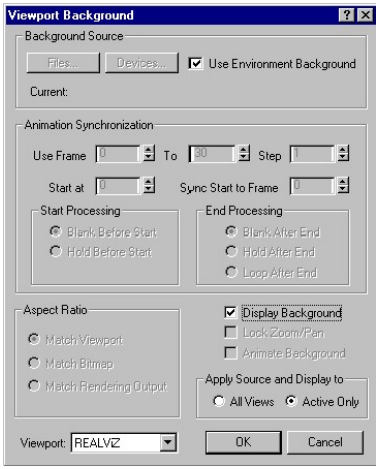
4 Drag and drop the **Map #1** (Bitmap) to a channel of the material editor using the **Instance** method.

5 In the **Material Editor**, choose the image to use as the background.

6 Set **Bitmap** > **Parameters** > **Filtering** to **none**.

7 Set **Coordinates** > **Mapping** to **Screen**.

8 Select **Views** > **Background Image** and check the **Use Environment Background** box.



If the matching between the background image and the 3D is not “clean”, there are two possible reasons.

- The start of the sequence does not correspond to the start of the camera trajectory. In **Material Editor** > **Time**, change the **Start Frame** field for the environment map.
- The background image is interlaced but when 3ds max does a filtering, you have the impression of a mismatch in the camera view. However the render is okay. You can solve this display problem by creating a non-interlaced sequence and by using it as the background image while keeping the interlaced environment map.

Other problems

Sometimes, when your sequence contains very far points, the 3ds max camera can have problems calculating the clipping planes (the objects situated in front of the camera are not visible in the camera view). If this is the case, you must use the manual clipping mode and define the near and far parameters of the clipping.

Exporting to combustion from Discreet

Exporting your **MatchMover** project to combustion--the paint, animation, and 3D compositing software from Discreet--is a straightforward process.

1 Save your project with the combustion extension *.cws (combustion workspace).

The file contains essential MatchMover information, such as the camera or helper path, the camera FOV animation, link to the video or sequence of images, and other video information.

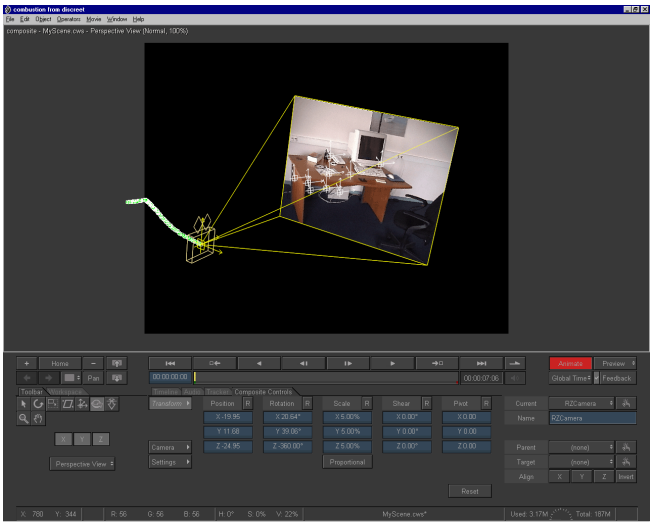
2 Run combustion.

3 Open the file by doing one of the following:

- Select **File** > **Open Workspace**.
- Press **Ctrl+Shift+O**.

4 Select **Workspace**. When the CWS file is opened, **combustion** loads the video or image sequence.

5 Now edit the project.



Shake export

Shake track files

All chosen tracks are exported as individual **Track Files** in order to be used as input for the Shake® *MatchMove* or *Stabilize* nodes. While these files only contain 2D information, the exported values are not simply the result of 2D

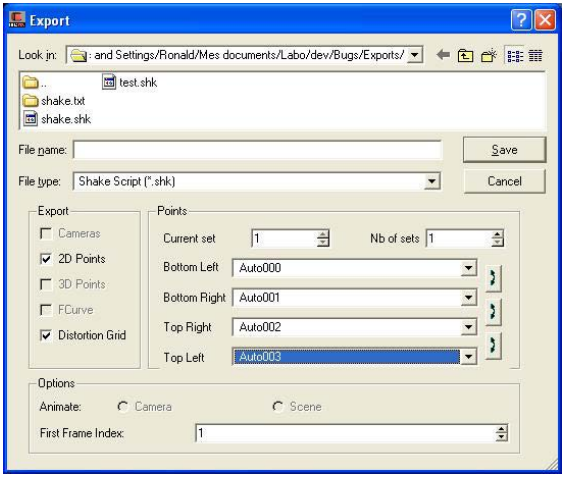
tracking, but the 2D projection of the 3D reconstructed points. The main advantage is that the point coordinates are known even though a point may move out of the image.

Shake script

MatchMover generates a Shake script containing the following information:

- Four point tracks that will be used as input data by a *MatchMove* node to perform corner pinning.
- A warping grid to apply distortion to your CG elements so they can integrate perfectly with distorted footage.
- A warping grip to remove distortion from the original footage.

The window controls for this export are quite different from the other ones. Unlike other exports formats, you cannot have an arbitrary number of points. Shake controls require you have one, two, or four points for a matchmoving process.



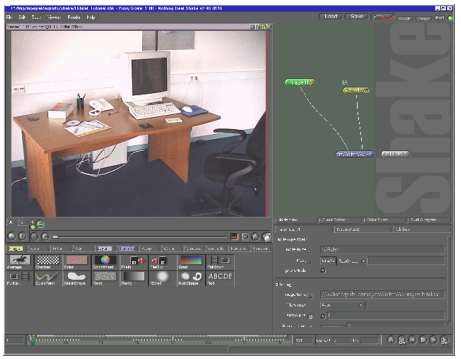
Use the drop-down boxes to choose the points to export. The corner indications are only valid if you want to perform a four-point corner pinning.

Point order is important: the arrow buttons swap points and let you reorder them.

NOTE You can provide several sets of 4-points that will each generate a corresponding MatchMove node. Set the total number of sets in the “Nb of sets” spin-box, and select the current one in the “Current set” spin-box.

TIP The boxes contain initially the first four points in the selection, if any. Selecting your points of interest before calling the export window will save you time and effort.

In Shake, load the script by selecting **File** > **Open Script** and choose your file.



The **Node View** then contains the following nodes:

- **rzVideo** is a “FileIn” node containing your video. You may edit the **imageName** if it is incorrect, which may happen if you are working not on the same computer that you used to run MatchMover.
- **rzMatchMove** is a “MatchMove” node containing all the information to perform your composition operation. Load another image or video, connect it to the second input of the **rzMatchMove** node, then enable it by opening its properties, toggling the **applyTransform** parameter to **active**, and change the **outputType** to **Over**. You may also have to change the source X and Y positions if your source is of a different size of you want to crop it.

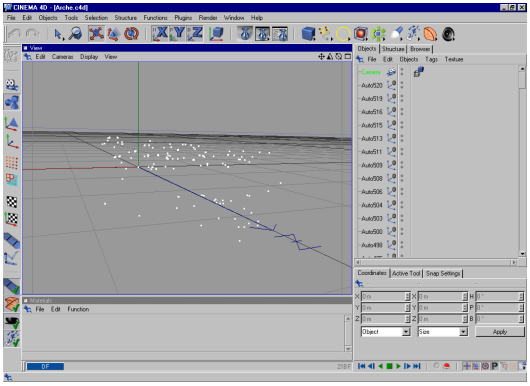
  NOTE If several sets of points have been provided, additional nodes will be numbered (e.g., rzMatchMover 2 ...).

- **rzDistort** is a “WarpX” node designed to apply distortion to any CG element before compositing it with your footage. If the latter has no distortion at all, this node is no use to you and you can delete it safely. r**zUndistort** is a “WarpX” node designed to remove the distortion from the original footage.

Cinema 4D export

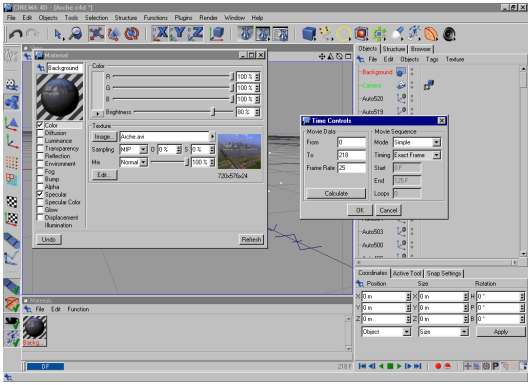
Scenes exported by MatchMover can be read directly in Cinema 4D™; all points are exported as Null objects.

Select **File** > **Open** and choose the *.c4d file exported by MatchMover.



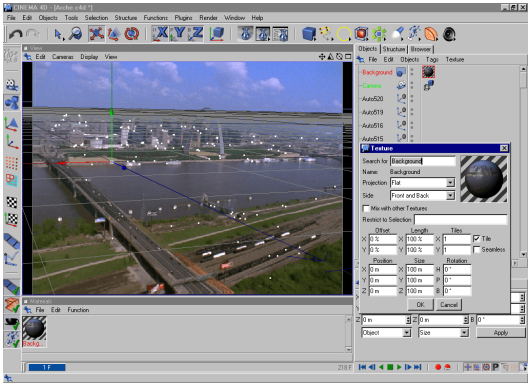
Compositing with your footage requires some extra manipulations.

1. Create a background object by selecting **Objects** > **Scene** > **Background**.
2. Open the **Material Manager** window and create a new Material by selecting **File** > **New Material**.
3. Open the **Material Editor** by double-clicking on the newly created material.
4. Open the image browser by clicking on the **Image** button and choose your video file.
5. Press **Edit** to open the **Time Controls**.



6 Set the first frame, last frame and appropriate **Frame Rate**. Also set the **Timing** to **Exact Frame**.

7 Add a **Texture** property to your **Background Object**.



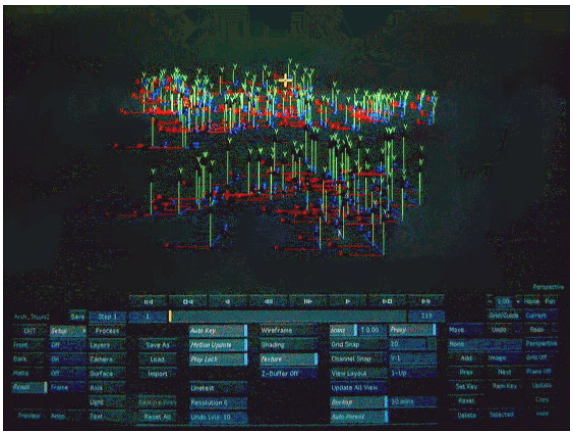
8 Set it to the newly created material. Change the projection to **Planar**.

Inferno export

MatchMover generates an Actionsetup that can be read by Discreet's Flint, Flame, and Inferno.

1 Open the Action module and choose your clips for composition.

2 Select **Setup** > **Load** then choose the **Action** setup exported by MatchMover. All points appear as individual helpers in the **Perspective** view.



TIP Each point will have its own node in the **Schematics** view. Automatic tracking will generate hundreds of points, which, without filtering, will quickly clutter your **Schematics** view. It is therefore recommended to select the points of interest and export these only. See Reconstructing 3D points for export on page 219.

Motion Capture Module 5

About the Motion Capture Module

Motion Capture is the ability to track in 3D the motion of a non-rigid object, like a human body or face or a piece of cloth. This is a special case compared to rigid moving objects or standard matchmoving, because, for each frame of the footage, the position of any non-rigid track is totally independent from any other previous position, or any other track. Therefore, its 3D position cannot be computed from a single view. To be able to compute the depth of such a track, you must see it through at last two different viewpoints.

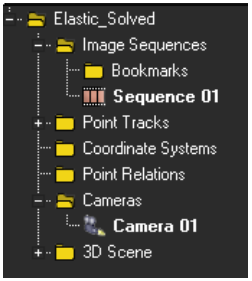
So, the basic setup for doing MOCAP (Motion Capture) is to have two synchronized cameras shooting at the same scene, therefore producing two different viewpoints of the same deformable scene.

The MatchMover Motion Capture module is able to cope with any number of synchronized cameras, at different frame rate and resolution each, although it's easier if all the cameras share at last the frame rate. Cameras can be either fixed or moving. If all cameras moves, the camera motion in respect to the background should be computable through standard matchmoving process using the scene background.

Loading and synchronizing your sequence

Loading

The sequence loading process is almost the same as for standard matchmoving. The only difference is that you have to load the two synchronized sequences last. A new "fixed" camera constraint is added to handle fixed camera cases (no rotation, no translation...). You can easily set this constraint directly in the Load Sequence window. Note that each camera device associated with each loaded sequence is assigned a different color:



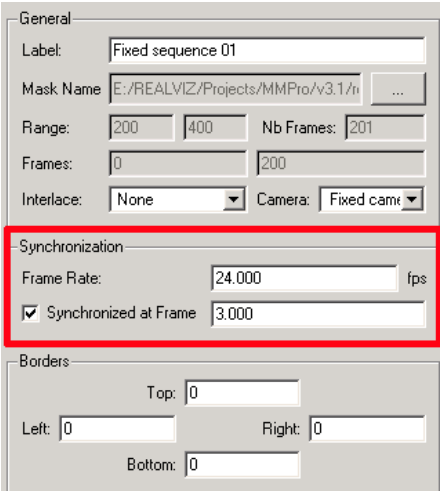
This color can later be changed in the camera's Parameters window, and is used to quickly identify which data goes with which camera.

The camera color will be used for:

- The Project window: the camera label and corresponding sequence label
- The Track View: the camera frame bar and the corresponding sequences ones
- The viewport: the camera / sequence labels displayed at the top, and the 3D camera icons.

Synchronization

Synchronization information is displayed in each sequence's Parameters window under the General settings:



Here is the information that should be provided:

- Frame rate: Enter the frame rate of the sequence. See note below about using different frame rates.
- Synchronized at Frame check box is used to specify if this is a synchronized sequence. You should then enter a “synchro frame”. This “synchro frame” is used like a synchronization tick, which means it is just an absolute time reference that will be used to synchronize all sequences. For example, the frame number 10 in sequence 1 is shot at the same time as frame 25 in sequence 2. Then you can use these values for the synchronization tick.

NOTE You can use here floating values for the synchro tick, like 10.5, if you know accurately your setup. Note that a sequence icon is shown with a little clock  in the Project window to show that it is synchronized.

Viewport configuration

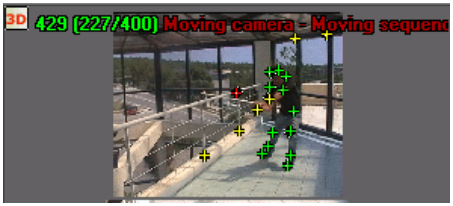
You can configure the viewports to automatically synchronize their content.

Just toggle the Synchronize Time  icon for each viewport you want. In this case, when a viewport is synchronized, it will stay locked on its current sequence, and display the frame synchronized with the global current frame.

To change the current sequence of a viewport, select the viewport and set time to a frame of the new sequence. For example, switch to two viewports layout, and toggle Synchronize Time for both. Select the first viewport and jump to a frame in the first sequence, then select the second viewport and jump to a frame in the second sequence. Then when you play, both viewports should be synchronized.

Synchronous frame navigation

The current camera and sequence information, colored with respect to the camera, is displayed at the top of each viewport next to current time, displayed in green for synchronized viewports so you can easily identify your setup.



When on a synchronized viewport, you can easily switch to the synchronized frame in other sequences using different methods, either using the menu entries (Next/Previous Synchro Frame, default shortcuts PgUp, PgDn), or by right/left clicking on the camera label at the top of the viewport. If the viewport is in 3D free navigation mode, all the synchronized cameras will be displayed, with non-current ones darker.

You can also simply click any camera icon to select it and switch to its corresponding synchronized frame.

NOTE Although the solver is able to cope with different frame rates, this setup will of course introduce more complexity in the process, and is not recommended. Note that in this case, the first loaded sequence will be used as the time reference, and other sequences will be mapped onto it. That means that the exported project will share its frame rate with the first sequence (this might be customizable in a future version).

Building and tracking a MOCAP group

Building a MOCAP group

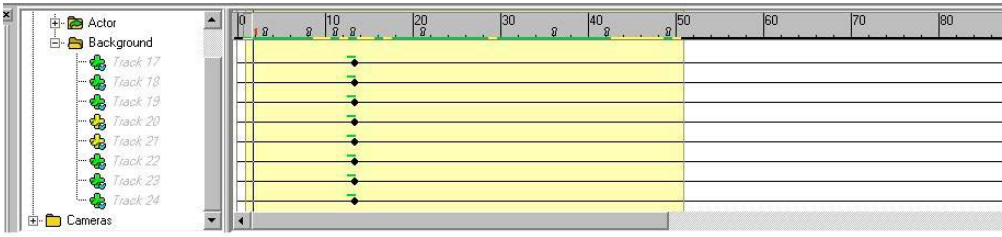
Building a MOCAP group is as simple as building a group for a rigid moving object: just create a track group, and select “non-rigid motion” in its options attribute. Then, all tracks located in this group will be considered as non-rigid ones. MOCAP groups are displayed with green arrows in the tree view  .

Adding MOCAP tracks

You have to create your tracks and track them as in a standard matchmoving workflow, except that automatic tracking will not make the match between several sequences. Note that if the MOCAP group or a MOCAP track is already selected when creating a new one, the new track will automatically be added to the MOCAP group.

Adding other tracks

Of course, you’re still able to add other kind of tracks, fixed, or rigid ones. These one can be used to make the solution more robust or track the motion of a moving camera. Note that for fixed cameras, fixed tracks need to be set only on one frame of the sequence. Other frames will then automatically be displayed as “implicit” in the Track View.



Solving

The solving is done the same way: just hit F9! Note that some special things are done with keyframes/reference frame: they are automatically set on all synchronized frames. For example, if you add a keyframe in the first sequence, the synchronized frame in all the other sequences will also be set as a keyframe. This should be the same for reference frames if the project contains only motion capture tracks: the solver will not be able to start if the reference frames are set on two non-synchronized frames.

Glossary

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Glossary

When working with Autodesk MatchMover you have to understand a few of the basic key concepts from the worlds of 2D and 3D.

Angle - Field of view (FOV) in degrees. 30 corresponds to the normal lens of 35 mm still camera.

Antialiasing - Antialiasing is sub pixel interpolation, a technique that makes edges appear to have better resolution. Antialiasing is process to render an image at a higher resolution than the screen can display (typically two to four times higher linear resolution). This high-resolution result is then filtered down to the screen resolution, eliminating most visible rendering errors.

Cache - A block of memory, generally of fixed size, that is used to store data loaded from the hard disk. Reading data from cache memory speeds up processing as it is faster than reading data from disk.

Channel selection button  to help optimize 2D tracking shown in the bottom left corner that toggles display of a single color channel. Clicking on it cycles through RGB, R, G, B, and Alpha, when available.

Dolly - Moves the camera along the line of sight, i.e. close and far from the target. Term originally refers to the carriage under the camera stand, pushed on wheels along rails.

Film Back - Value that represents the size of your film.

FOV - Field of view.

Interlace - Division of video frames into halves (odd and even), or fields, increase the frame rate without increasing the needed bandwidth.

Motion blur - A method of blurring images to create the effect of speed and movement.

Occlusion - The effect of one object in 3D space blocking another object from view.

Pan - Rotates the camera along vertical axis, that is, moving camera target sideways.

Parallax - Changes the perspective between two adjacent pictures caused by the camera position changing between shots.

Pixels - Array of picture elements, usually consisting of red, green, and blue color values, each with five to sixteen bits of precision.

Rendering - The process used by MatchMover to create images from the data files.

Rendering algorithms - Algorithms that create images from models.

Rendering Engine - Generically applies to the part of the graphics engine that draws 3D primitives, usually triangles or other simple polygons. In most implementations, the rendering engine is responsible for interpolation of edges and 'filling in' the triangle.

Rendering packages - programs that implement rendering algorithms

RGB - Red-green-blue color models.

Roll - Rotates the camera along the line of sight. If animated, a swaying effect is achieved.

Scene - Defined by a data structure known as the scene database.

Scene database - Database which provides a mathematical representation of the virtual objects in the scene and their position relative to each other.

Scene management - The process of updating the scene database definitions as objects move or change.

Scene space or world space - The coordinate system of a scene.

Screen space - The 2D coordinates of pixels on the display device plus a third coordinate that defines the distance from the view point.

Sub-pixel accuracy - A method of estimating movement to the nearest 1/5th of a pixel rather than one pixel.

Tilt - Rotates the camera along the axis perpendicular to the line of sight, i.e moving target vertically. If animated, a nodding effect is achieved.

Transformation - Change of coordinates; a series of mathematical operations that act on output primitives and geometric attributes to convert them from modeling coordinates to device coordinates.

Track - A track is anything that is animated over time. In MatchMover Pro, these are the point tracks

Vector - Segment showing the displacement of a given pixel from one frame to the next one.

View point - A virtual camera (analogous to the position of the camera in photography).

Z values - (x, y) distance values.

Zoom - Changes the field of view.

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