3D-Equalizer V2 Manual

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Overview

Introduction

The perspectively correct combination of computer graphics with life action material is an interesting special effect used in art, science and entertainment. Nevertheless its practical realization has turned out to be rather tricky, especially in presence of complex camera movements.

The whole problem can be divided into two separate areas: the perspective adaptation of CG-models and real objects on one hand, and their composition on the other hand. In many cases compositing is not very complicated. For the more complicated cases several products are already available. However, the perspectively correct adaptation either requires a great expense of hardware or it is a painstaking hand-work.

The basic problem is to reconstruct the time dependent geometric relation between the camera and the real objects, that means to find out the precise position and orientation of the camera for each frame, used for recording the real scene and to use this camera motion path in the computer model for rendering the CG-models. One way of „finding out“ the camera motion path consists in inverting the problem: the real camera is attached to a robot-like installation and controlled by computer. In this method, which is known as „motion control“ the motion path is used for generating the camera movement for recording the real scene and for rendering the animation as well. Another way is to examine the real scene and to adapt the CG-objects by hand frame by frame, which is rather difficult without any mathematical support by some appropriate software.

The method used by 3D-Equalizer is more similar to the latter frame-by-frame adaptation, since one does not need any additional hardware. However, the frame-by-frame adaptation has been automated. The reconstruction of the camera motion path is done by evaluating the images of the real scenery and some (optional!) geometrical data called the constraints, which

can be obtained by simple measurements in the real scenery. There are essentially three different situations which can occur, namely:

1. A camera moves within the scenery and the CG-models are related to fixed real objects.
2. The camera is fixed relatively to the scenery and the CG-models are related to moving real objects.
3. The camera moves within the scenery and the CG-models are related to moving real objects.

For each of these cases the work flow is the same. In the tutorials all of these cases will be covered. The difference between cases 1 and 2 appears when the 3D-Equalizer data are being exported. The user specifies if the camera is moving or the real objects to which the CG-models are related. Case 3 is handled as case 1 and 2 depending on the respective situation (see tutorial).

User interface and conventions

The graphical user interface has been designed according to the Silicon Graphics Indigo Magic Style Guide. All colors of interaction components mentioned in this manual are valid for the desktop color scheme “Indigo Magic”.

Menus and pull-down menus are expanded by pressing the left mouse button. In the current release of 3D-Equalizer there are no pop-up menus, except in the Open Inventor interaction components. Most of the menus and pull-down menus are provided as tear-off menus. A text field can be typed in as long as it is touched by the mouse pointer. Removing the mouse pointer confirms the entry.

In this manual the menus are referred to as selectors, and pull-down menus are simply called menus. The left mouse button is denoted by MB1, the middle mouse button by MB2 and the right mouse button by MB3.

Terminology

As mentioned, the basic problem in perspective adaptation is the reconstruction and modelling of a realistic camera and its movements. Let us start by fixing the terminology used in this manual and in the 3D-Equalizer user interface.

The real camera geometry in our model is essentially defined by the quantities *filmback width*, *filmback height*, *focal length* and *nonlinear distortion*.

The filmback width and height specify a rectangular plane on the *filmback plane*, i.e. on the plane on which the real environment recorded by the camera is projected by means of the lens system.

The focal length is the distance between the hole of the pinhole camera and the filmback plane. In the current release of 3D-Equalizer this parameter is considered as time independent, i.e. it must not vary while recording the real scene.
The relations between focal length, filmback width and height on one hand and various definitions of the aperture angle of the lens turret on the other hand are explained in the chapter „Selected Topics“, section „Camera Adjustment“.

Nonlinear distortion means the deviation of the real optical system from a linear optical system. This type of distortion normally appears in panorama lenses and especially in fisheye lenses. 3D-Equalizer is able to compensate nonlinear distortions within certain limits.

When a real scene is recorded, the camera is moved by the camera operator through three-dimensional space and the direction of view changes time dependently. At every time during the sequence the camera is described by a *position* and an *orientation*. We call the curve in position space and in orientation space resulting from this movement the *real camera motion path*. For reasons of plasticity it is sufficient to imagine the camera motion path as a more or less complicated line in three-dimensional space associating a point to each frame.

When recording the real scene the camera produces the *real sequence* that consists of *sequence frames*. We choose this expression in order to distinguish them from the so-called *reference frames*, which are explained in the chapter „Selected Topics“, section „Reference Frames“ and the section “Tutorial 4: Reference Frames”.

The real sequence represents part of the input data for 3D-Equalizer. The sequence frames have to be digitized and provided in some common image format in order to be acquired by the system. Since any frame is displayed as rectangular pixel area on a screen it is necessary to introduce two further expressions, namely the *field of view width* and *height*. These quantities represent the size of the frames in pixel and generally depend on the process of digitizing. Assume you are given a videotape containing the real sequence. In the process of digitizing one normally tries to acquire the entire image and, in order to prevent any loss of information, one leaves a small edge on the left and on the right of the screen when digitizing. 3D-Equalizer enables the user to adjust the field of view, which is necessary for performing the perspective adaptation precisely.

Another important quantity involved in the screen representation of frames is called the *pixel aspect*. In order to define it consider a square-shaped object recorded by a camera with linear optics. The object may be recorded in a way so that in the screen representation its edges are aligned to the screen’s edges. The ratio height in pixel by width in pixel of the resulting displayed rectangle is called pixel aspect. The relation between the quantities filmback width, height, field of view width, height and pixel aspect is explained in the chapter „Selected Topics“, section „Camera Adjustment“.

Since the main purpose of 3D-Equalizer is the perspectively correct combination of real objects and rendered objects, we have to fix the terminology for the latter as well.

A perspectively correct adaptation of rendered objects to real objects based on the on-screen evaluation of the real sequence is done by modeling the geometry and the motion path

of the real camera. We shall refer to this camera model as the *reconstructed camera*.

A realistic camera is quite difficult to describe, in particular effects resulting from the complex arrangement of lenses forming the lens turret. For our purposes it is sufficient to consider a simplified, idealized camera model. Instead of a lens system we use the pinhole camera with an additional model for nonlinear distortions (lens distortion).

A reconstructed camera is a mathematical object associated to the real sequence. It consists of the *reconstructed camera geometry* and the *reconstructed camera motion path*. The reconstructed camera motion path describes the real camera motion path within certain error limits. The reconstructed camera geometry can appear to be very different from the real camera geometry, producing however the same result when the scene is rendered.

In addition to the real sequence further input data is required by 3D-Equalizer. These data are explained in the following. In the process of perspective adaptation the software reconstructs the camera position and orientation by means of *points* which are designated by the user in the real scene. Their purpose will become clear in the tutorial. For the moment it is sufficient to keep in mind, that all designated points have to be mutually fixed during the entire sequence.

In the screen representation of the real sequence the designated points are displayed frame dependently. For each frame the user marks the position of each point on the screen (of course supported by techniques like motiontracking). These screen representations of the points will be referred to as *screen points* in the following.

3D-Equalizer provides three different calculation methods. In the next chapter their differences are briefly discussed. For one of these methods it is necessary to enter the so-called constraints. They are only needed in some rare situations. There are two types of constraints, namely the *distance constraints* and the *plane constraints*.

A distance constraint is obtained by a simple distance measurement between to points in three-dimensional space.

A plane constraint is simply an ensemble of points which are declared to lie within a plane. The use and profit of this feature will become clear in the tutorial.

Work flow

At this point it is useful to compare the current version 2 of 3DE to version 1. The most important change is, that now there are three different calculation methods for the perspective adaptation. These methods are called the distance constraint free method, the user-defined-positions method and the distance constraint method. Before discussing the work flow we shall briefly point out the difference between the three methods.

The distance constraint free method (DCFM) (new in version 2!)

In this method the perspective adaptation is based exclusively on the on-screen evaluation of the real sequence (and optional reference frames). No measurement or any other geometric data from the set is required. The only essential conditions are a sufficient number of points and a sufficient amount of perspective information, i.e. either the camera must assume different points of view or the recorded object must exhibit various alignments during the shot. Since no geometric information from the set is required, this method is in general the only possibility for handling stock material. In many experiments it turned out that - if the requirements above are fulfilled - this method is more flexible, more robust and more precise than the other two methods described below, although less information is given to 3DE. The reason is, that in practice there are always discrepancies between the geometric data entered by the user and the tracked screen points. The points being tracked are not necessarily the endpoints of the measured distances. The user is encouraged to use this method if possible!

The fixed camera position method (FCPM) (new in version 2, release 7)

In practice you will sometimes handle sequences, for which the essential condition of the DCFM is not fulfilled: the camera does not change its position during the shot and there are no reference frames available. For instance, the camera may be attached to a tripod and rotate during the shot. Another situation is a hand-held camera, slightly moving through three-dimensional space, but all the tracking points (and also the CG-content to be inserted) are very far away from the camera location. In this case the FCPM should be used. The workflow is exactly the same as in the DCFM. However, the resulting point positions have to be interpreted in a different way: instead of calculating the precise point positions, the FCPM calculates the “directions” of the points with respect to the camera position. Since the camera position is fixed, these directions are sufficient for inserting the CG-content as far as the proper perspective is concerned. If you need the precise point positions as well in order to locate your CG-models, you should use the DCFM with reference frames.

The user-defined-positions method (UDPM) (introduced in version 1)

This method requires the knowledge of the positions of the points in three-dimensional space. Suppose you are working in a blue box environment which has several markers attached to its walls at very well-defined positions in (x,y,z)-notation. In this method these positions can be communicated to 3DE and will be employed for the perspective adaptation. This mode of operation can be useful in sequences with few perspective information. In contrast to the DCFM the geometric model of the points is entered directly by the user. This may be considered as an advantage in comparison to the DCFM when the perfect agreement of the geometric point model with the corresponding real geometry is required.

The distance constraint method (DCM) (version 1)

This method requires to know the distances ("distance constraints") of at least some of the points designated in the real scene. 3DE builds a geometric model from these measurements which is then used for the perspective adaptation. This method has been used successfully by many users. However, when the DCFM asserts itself, the DCM will probably become obsolete, since the distance measurements can be replaced by appropriate use of reference frames in the DCFM.

In this manual we will concentrate on the distance constraint free method. Except for the constraints / user-defined positions the work flow is the same for all three methods. In the following the typical work flow for 3D-Equalizer projects is given. As you may see below, the program 3D-Equalizer has a clearly defined input and output.

Preparations and prerequisites:

- The real sequence, digitized, in some common image format.
- Points designated in the real scenery. These can be markers or striking points.
- In addition to the real sequence frames you can supply the so-called reference frames, which facilitate the reconstruction of the camera motion path and the points.
- (Possibly constraints, i.e. measured distances between points or three-dimensional positions of the points.)

Within 3D-Equalizer:

1. Create a new project.
    - The sequence frame data such as filename, imagetype, startframe, endframe, display rate are entered.
    - Reference frame data such filename and imagetype are entered, if available.

2. The points designated in the real scene and the constraints (if available) of the points are entered. By doing this, the user creates a list of points in the project. For each point the tracking properties are specified.
3. The points are tracked on the screen for each frame according to the tracking settings mentioned above. This is done by positioning the screen points for some frames (keyframes) and specifying further tracking parameters, namely the search pattern borders and the search area borders.
4. At this point the field of view is specified and the camera geometry (focal length, filmback,...) is reconstructed. The well-known camera parameters are entered by the user. Unknown camera parameters are adjusted by the program.
5. It is now possible to generate a preview movie in order to find out, if the perspective adaptation has been performed successfully.
6. A simple test scene is edited using Open Inventor objects. An object is loaded, its material properties and the illumination are specified. The camera motion path in relation to the real scenery is reconstructed and the preview movie is generated by composing the Open Inventor objects perspectively correct into the real scene. It should be emphasized that the preview movie is not thought of as the final result. The only aim is to check the perspective relation between the real environment and some sample objects.
7. Apart from the preview movie, the quality of the perspective adaptation is indicated for each frame in the so-called Status Window. There it is displayed, if the adaptation was not successful for some of the frames. The user examines the preview and the numerical values in the Status Window which indicate the quality of the adaptation. If it turns out to be necessary for some of the frames the screen points are corrected, i.e. go back to step 3.
8. If the adaptation for the entire sequence turns out to be problematical, e.g. because the screen points could not be set or tracked with sufficient precision, the postfilter functionality is activated/modified.
9. You may wish to designate further points in the real scene. In this case enter further points and set their screen points for a sufficient number of frames. These points will appear in your rendered scene.
10. When the camera motion path in relation to the real scene is reconstructed at a satisfying precision, the 3D-Equalizer project data are exported to the animation package. The postfilter is taken into account. This completes the work flow as far as 3D-Equalizer is concerned.

Within the animation package:

1. Load/retrieve the 3D-Equalizer export data.
2. Either render your animation and compose animated and real sequence externally, or render your animation with backdrop images.

Tutorial

In the following chapter the main features of 3D-Equalizer are presented by means of several examples. Furthermore, a few additional demonstration projects can be found in the directory “/usr/3dequalizer/tutorial/projects”.

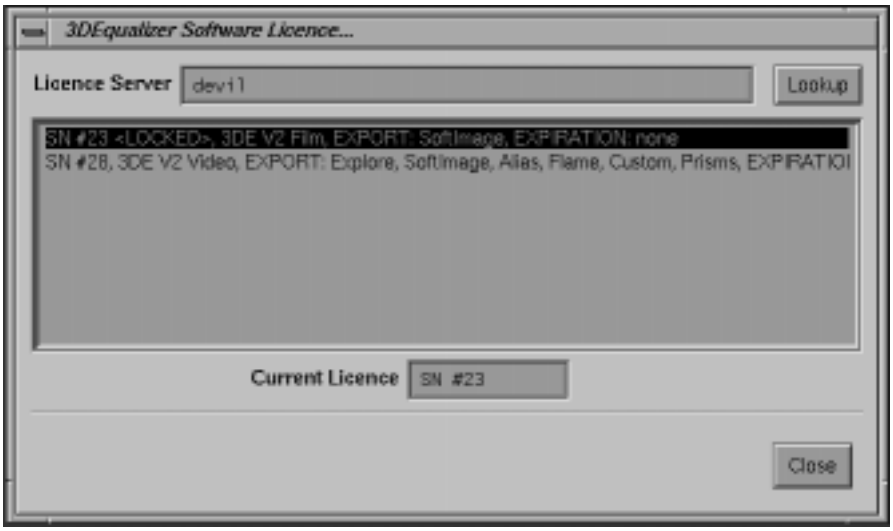
Tutorial 1: Introductory project “Evahead”

The process of adaptation of the scene can be summed up as follows. In section “Creating a Project” we describe how to set up a project, including the acquisition of the sequence frames. Section “Entering Points” describes how to enter points which have been declared in the real scenery by the user. Section “Creating Screen Points” describes the various methods of tracking the points on the screen. Afterwards, in section “Adjusting the Camera”, the camera geometry and motion path are reconstructed. This enables us to take a first look at the preview movie, which is generated as described in section “Generating a Preview Movie”. In order to get into contact with the user’s preferred animation package the reconstructed points and the reconstructed camera are exported, which is mainly described in the “Reference Manual”. This completes the basic procedure of 3D-Equalizer.

Getting started

Please start 3D-Equalizer by double-clicking the icon or by entering 3dequalizer in the Unix shell. Generally you can do this in any account. However, if you intend to generate export data for SoftImage 3D, you have to run 3D-Equalizer in the respective SoftImage user account. When this is done the Requester 3DEqualizer Software Licence opens. Enter the name or IP address of the Flc server workstation (see installation) in the text field Licence Server, in order to get a list of the currently available licences. Choose one of them by double-clicking or by

selecting and pressing the button Close. Afterwards the Main Window opens. It contains a display for the real sequence and all ramificating menues.



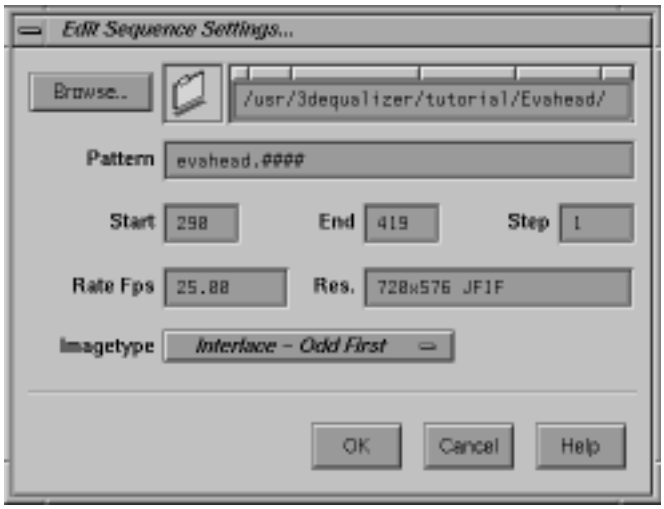
Requester: 3DEqualizer Software Licence...

Creating a Project

Now please select the menu item Options::3DEqualizer Preferences. The upper text field contains the default directory for 3D-Equalizer projects. The button on the left opens a standard file requester in which you can specify the default directory.

Important note: In order to enable a fluid working, 3D-Equalizer employs several graphics functions. Surprisingly, it turned out, that in connection with graphics hardware such as XZ graphics, Elan and Extreme, some of these functions do not work at a satisfying speed. Therefore, if you are using this type of equipment, the first thing you should do is to activate the toggle Integer Zooming. If no such graphics equipment is used both settings of this toggle are possible, but the toggle should be deactivated. In the course of the tutorial you can see the effect of this toggle e.g. in the Zoom Window when you use the zoom functionality.

First, we have to tell the system about our sequence data. This is done in the requester Edit Sequence Settings, which can be opened by selecting the menu item Options::Sequence Settings.



Requester: Edit Sequence Settings...

The sequence frame filenames are:

evahead.0290, ... , evahead.0419

You will find them in the directory “/usr/3dequalizer/tutorial/Evahead”. In the text field Pattern you should enter a filename pattern which matches all sequence frame filenames you wish to include. In our case a good choice is evahead.####. We wish to include all frames from 290 to 419, and therefore please enter these numbers in the text fields Start and End. The default value in the text field Step is 1, and we leave it as it stands.

At this moment the resolution and the image type of the frames should appear in the text field Resolution. When the current image type supports the subload property, this is also indicated. If this does not happen, please check the permission modes of the frame files and change them, if necessary, by applying the Unix shell command chmod. The image types SGI, TIFF, Softimage, etc. support the subload property, i.e. that only the needed part of the image is loaded into the memory. This is especially useful, when high resolution images are processed. The subload functions are only available in the filmversion.

If you have installed the tutorial sequences from the CD-ROM, you can try out the subload feature. The CD-ROM contains the sequence evahead in the SGI image format, which supports the subload function.

If you have downloaded the tutorial sequences from the web, the images are provided in JPEG format. The JPEG format is more suitable for the internet transfer, however it does not support the subload functions.

The tutorial sequence is an interlaced video at a frame rate of 25 (enter this number in the field Rate Fps) frames per second. Each interlaced frame contains two so-called fields, time-displaced by 1/50 second. There are two possible settings for interlaced frames: Interlace - Even First and Interlace - Odd First. You may specify here which of the two fields will be used as sequence frame. For the tutorial sequence please set this to Interlace - Odd First.

If you close the requester now, the first sequence frame is loaded and displayed in the Main Window. The frame filename is displayed in the text field above the Main Window display. In order to get familiar with the Main Window's interaction components you may try e.g. to move the frame slider, use the buttons -1, +1, End or Begin.

Main Window

The sequence shows an actress who moves her head back and forth and turns it around. On the right side of her face there are five dark markers. These will be tracked in the course of this tutorial. A situation like this appears in practice when a cg mask is attached to a real actor.

In the menu Project there are items Save and Save As. Selecting the item Save causes the program to save the project under its current name. Selecting the item Save As enables the user to enter the project's name. In the current state the project has not yet been given a name, and therefore selecting the item Save demands the specification of a project name as well. We would suggest to save the current project under the name „evahead". The default suffix .3de for 3D-Equalizer projects will be appended by the program.

In order to get an impression of the sequence you can create a preview movie (although nothing interesting has happened up to now). Click the item Preview in the menu Windows. Now the Preview Window opens, but the display is empty and the keyword OBSOLETE is shown. You may press now the button Play for generating and playing the movie and Stop for interrupting it. 3D-Equalizer displays a warning, which can be ignored by pressing ok. While generating the preview movie the Preview Window must be open and should not be overlapped by other windows, because the preview is generated and composed directly on the screen.

Entering Points

We will handle the tutorial sequence with the so-called *Distance Constraint Free Method*. In this method the minimum requirements for reconstructing the movement of the camera/object are as follows:

- There must be at least six points.
- In two of the sequence frames (or reference frames) these six points must be placed on the screen.

When this information is supplied the relative camera position and orientation between these two frames can be determined by the system. These two frames are called „root frames“. The positions of the six points are calculated as well, so that they can be considered as well-known to 3DE.

Starting from the root frames 3DE will afterwards try to calculate the position and orientation of the cameras of the remaining frames. This leads us to the next minimum requirement:

- A frame can (in general) be calculated only if it contains at least four points which have been calculated before.

In the simplest case this means that there are four common points in all remaining frames and that these four points also appear in the root frames.

In practice it often happens that four points are not enough. In fact, there can be very complicated situations containing points that wander into the scenery at a certain point and leave it a few frames later. A situation of this type is described in the “Tutorial 4: Reference Frames”.

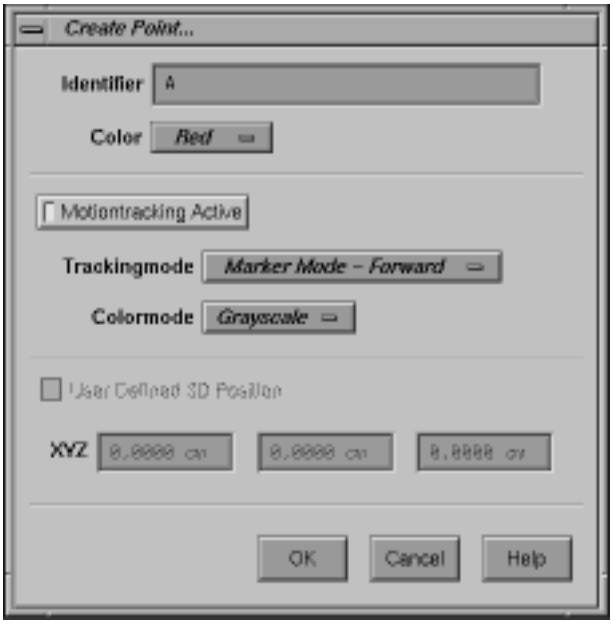
In this tutorial example we will slightly go beyond the minimum requirements, since here five points can easily be tracked in most of the frames.

The tutorial scene shows the head of an actress with five small markers in her face (read more about markers in the chapter “Selected Topics”, section “Tracking”). We will use these

markers as points because it is very easy to track them in the course of the scene. As mentioned above we need a sixth point. This could be e.g. the small earing or the right tip of the mouth. However, you should not use points on the dress or the neck because these points would not be at the same distance to the other points during the scene.

Let us now define and name the six points. For this purpose we open the Points Window by selecting the item Windows::Points... . The Points Window will later display the list of points (which is now empty) and some additional information resulting from the calculation procedure.

In order to add a point press Add. A requester entitled Create Point... opens. The text field Identifier enables you to enter a name for the point. The points may be given names like A, B, C, D, E and F, or 1 to 6. You can also use more complicated names like „near_to_hair“, „eyebrow“, „near_to_nose“ and so on. Please try to avoid blanks in the names. When you use meaningful long names it will be easier to identify them in more complicated projects. When you do not enter a name, 3DE will use numbers by default.



Requester: Create Point...

Below the identifier field you see a selector Color. This represents the color in which the point will be represented on the screen. You should choose this color according to the contents of the scene in order to achieve greater contrast. In our case red is quite good. If you like green better feel free to set the selector to green.

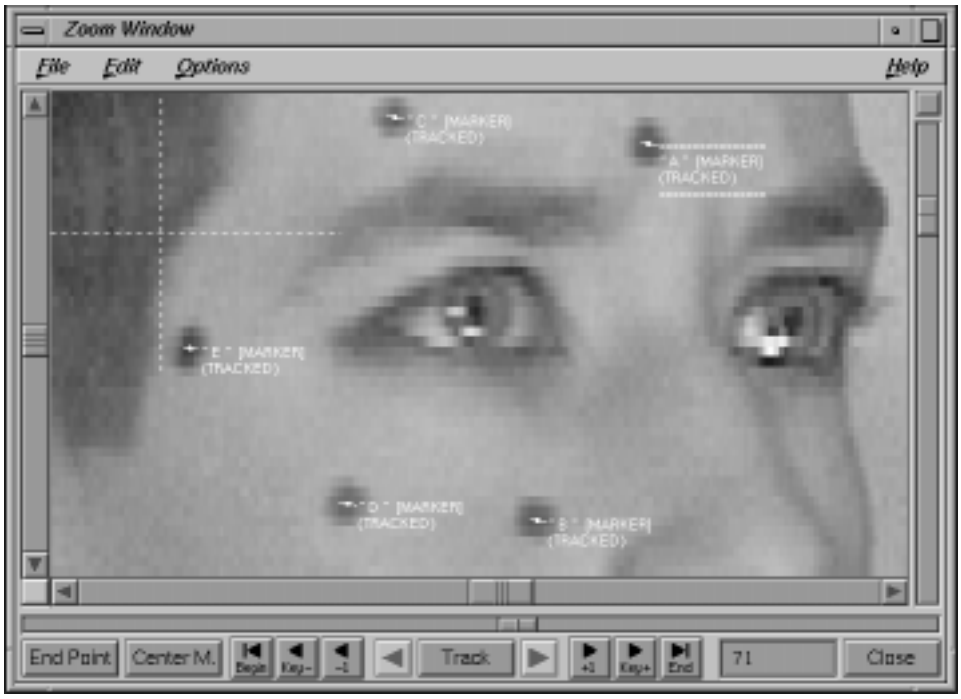
The other interaction components (Motiontracking Active, Trackingmode, Colormode) of this requester will be explained later, since they are related to motiontracking.

When you have specified the identifier and the representation color press OK to confirm your entry. The point name appears then in the Points Window. Please enter now the remaining five points.

If you wish to change the attributes of a point select it in the Points Window (MB1) and press Modify. A requester similar to the requester Add Point appears.

Creating Screen Points

The next task is to track the five markers on the screen. For this purpose please open the Zoom Window by selecting the menu item Main Window::Windows::Zoom.



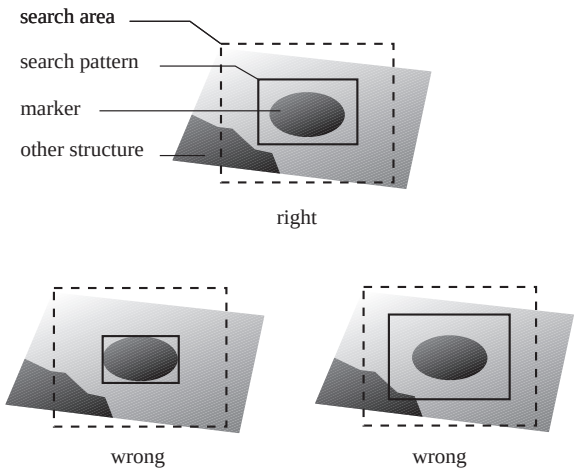
Zoom Window

Before positioning the screen points it is useful to get familiar with the functionality of this window. In the display you see the sequence frame currently displayed in the Main Window, or at least a cut-out part of the frame. By using MB2 and moving the mouse in the display the

cutout area can be moved. The mouse button MB3 is used for zooming in and out. The position of the mouse pointer in the display at the moment when MB3 is pressed specifies the point of interest, i.e. the point in the frame of which the position is unchanged while zooming. Pressing MB3 in the display and moving down, will cause a zoom in, while moving up will lead to a zoom out. Positioning the cut-out part and zooming can also be achieved using the sliders left, right and underneath the display.
We shall now track the points on the screen, thus creating screen points for each frame and each point. As an example consider the point A. Please select it in the Points Window. As mentioned, we associated it to the marker near the eyebrow as shown in the figure above. 3D-Equalizer provides essentially two different methods of tracking points on the screen, namely motiontracking and markertracking. In the chapter “Selected Topics”, section “Tracking” these methods are discussed in detail. For the moment it suffices to know that motiontracking is used for tracking any generic structure on the screen and that markertracking is specialized to markers (unicoloured spots). The five points we are going to treat in the following are associated to markers. Please open now the requester Modify Point... by pressing Modify... in the Points Window. Set now the selector Trackingmode to Marker Mode - Forward.

You may now place the screen point by clicking MB1 in the Zoom Window display. Use the zoom functionality for doing this precisely. In order to visualize the tracking areas select the menu item Options::Show Tracking Area. Now two squares appear around the screen point: the inner one is solid and the image cut-out within this square is called search pattern. The outer square is dotted and the area marked by this square is called search area. The borders of search pattern and search area can be moved by holding CTRL and dragging the border with MB1 pressed. The search pattern can be moved by holding CTRL and dragging the interior of the area or the pattern. When the search pattern is modified, the size of the search area changes appropriately. In order to perform markertracking for point A we will do the following steps:

1. Jump to frame 1.
2. Place the screen point approximately in the center of the marker.
3. Adjust the search pattern in a way that the marker is entirely contained in the solid square and that only the marker and the unicoloured surface lie within the solid square (see figure below). Leave a small border of about two pixel between the marker and the inner tracking box.
4. Adjust the search area, say, twice or thrice as big as the search pattern.
5. Press the button Center M. underneath the Zoom Window display once or twice. The screen point will find the center of the marker.



Tracking a marker

By performing steps 2 to 5 you have defined a keyframe for point A. Since the actress' head moves rapidly and the markers change their size (see preview movie again!), you will have to set further keyframes.

It is useful to select the menu item Options::Auto Center. This causes the program to place the cut-out in a way that the screen point of the currently selected point appears in the center of the Zoom Window display.

As a first step we will explain the tracking process in general. When you work with the filmversion, please activate the Options::ShowImage::All toggle. Now the whole image is loaded into the memory during the tracking.

Before starting the automatic tracking procedure, we should markertrack one single frame. Please go to frame 1. Underneath the Zoom Window display you see the buttons Track backward and Track forward (the left and right arrow). They are located next to the Track button. Pressing Track backward does not make sense, since we are already at frame 1. Now please press the button Track forward. After a few seconds frame 2 appears, and if you have set the search pattern and the search area as described above, the screen point will again appear in the center of the marker. To visualize the motion curve of the tracked screen points you can activate the toggle Options:: Show Motion Curve. You can now proceed tracking the point frame by frame or press the button Track underneath the display, causing the program to perform the automatic tracking procedure. It may happen that the program loses the marker, e.g. when the search area is to small or the luminosity contrast of the image is insufficient. In this case you should interrupt the automatic procedure and go back to the last frame that has been tracked correctly. Adjust the search pattern and search area again, press the button Center M. and restart the automatic tracking procedure.

You will see that the marker cannot be identified clearly in frame 57 and some of the following frames. Therefore, from frame 57 to frame 63 the screen points should be declared to be invalid (i.e. they will not be used for any calculation). To do this go to frame 56 and press the button End Point. In all further frames the point is invalid unless a new keyframe is defined. Now go to frame 64, define a new keyframe by placing point A on the marker and go on tracking as described above.

You can convince yourself that point A is tracked from frame 1 to 56 and from frame 64 to 130 by selecting Options::Show Motion Curve. The valid parts of the motion curve are drawn as solid lines whereas the invalid part is drawn as a dotted line.

To speed up the workflow, we will now use the subload functions for tracking point B. Remember, that the subload functions work only in connection with certain image formats. Please select point B in the points window and go back to frame 1. Place the screen point on the marker beside the nose and adjust the search pattern box. Press the button Center M. and then start the automatic tracking procedure (Track button). After a few frames, interrupt the tracking. Now choose the Options::Show Image::Zoom Area Only function and start the tracking again. As you notice, the tracking is performed much faster now. The Main Windows display shows a red rectangle box, which frames the cutout area of the Zoom Window, the part which is loaded into the memory. After tracking some more frames, stop the process again. The functionality of the zoom window is not restricted by the subload functions. To load the whole image again choose the function Frame::Show Entire Frame in the Main Window. The cutout area can be localiced by pressing MB2 and moving the mouse within the Main Window display.

In order to speed up the procedure even more, activate the Options::Show Image::Tracking Areas Only subload function and start the tracking process again. Now only the cutout area of the outer tracking box is loaded into the Memory.

Please repeat the same procedure now for the points C, D and E. You can also track them simultaneously and insert keyframes as described above. Points B, C and D can be recognized clearly during the entire sequence, and do not need to be declared invalid at all. Point E can be tracked from frame 45 to frame 114 using several keyframes. Remember to save the project from time to time.

Important note: As already mentioned, 3D-Equalizer needs at least two frames (“rootframes”) with at least six common screen points. In these two frames the object should be recorded from as different points of view as possible.

In the tutorial sequence frames 56 and 111 are a good choice for placing the sixth point. If you want to specify the sixth point in just two single frames, then the screen points must be declared as endpoints. If you are working on a project and you cannot figure out which of the frames could be appropriate as rootframes you can also track six or even more points, and the system will search for an appropriate pair of rootframes.

Adjusting the Camera

Now we have entered all data, that are necessary for the perspective adaptation. The next two tasks are the reconstruction of the camera geometry and the camera motion path. In practice, these two procedures are closely related: on one hand the camera motion path cannot be calculated precisely without a correctly adjusted camera, and on the other hand the motion path turns out to be a by-product of the camera adjustment procedure. The camera geometry is related to the field of view. Our next steps will be:

- Adjusting the field of view,
- Adjusting the camera geometry.

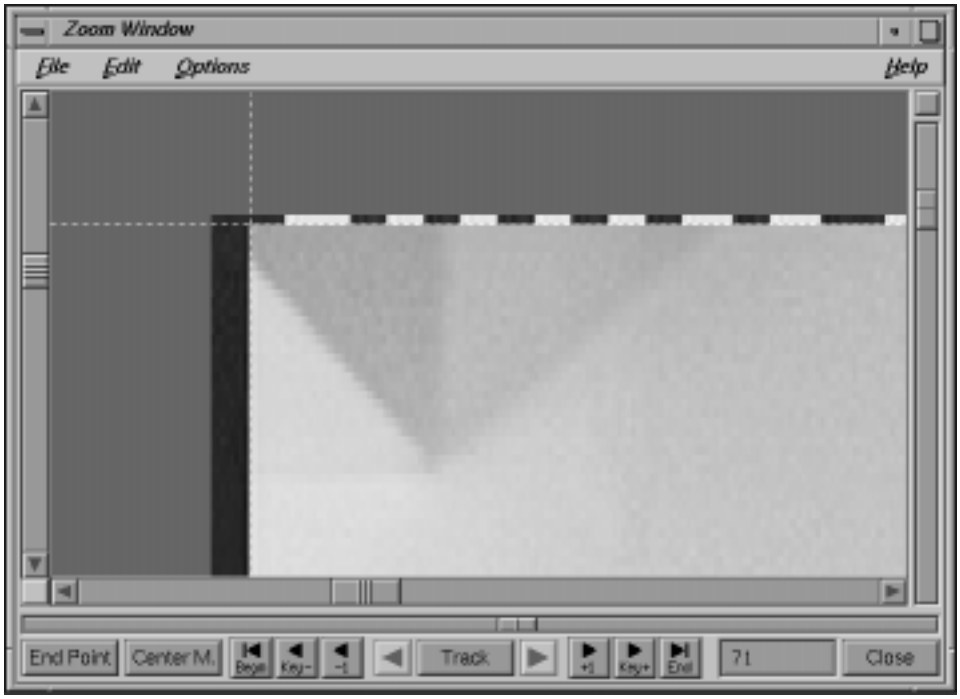
In the tutorial sequence the field of view can easily be recognized, and some of the camera parameters are known. Some other parameters will be adjusted by the program. In chapter “Selected Topics”, section “Camera Adjustment” the various parameters are illustrated and the adjustment procedure is discussed in detail.

Field of View

As you see, the frames of the tutorial sequence contain black areas on the left and on the right, which do not belong to the image itself. In general, in the process of digitizing there can appear black areas above and below the image as well. The rectangular area of the image without the black parts is called the field of view.

In the menu Options of the Zoom Window you see a toggle Show FOV. If you activate it the field of view borders are represented as dotted white lines in the Zoom Window display. The center of the field of view is represented by a cross of dotted lines.

You should now shift the white lines in a way so that they form the field of view as precise as possible. The lines can be moved by holding CTRL and dragging them with MB1.
The zoom functionality (dragging with MB3 pressed or the slider on the right of the display) should be used for working precisely. Having adjusted the field of view we may now close the Zoom Window.



Adjusting the field of view

Camera Adjustment

Please open now the Camera Adjustment Window and drag it to the maximum size. You see several text fields containing some predefined camera parameters. Next to the fields there are selectors that can assume the values Fixed, Fine Adjust, Unknown and <dependent>. The selector of Lens Distortion can assume the values Fixed, Fine Adjust and Unknown.

In the fields Fov Width and Fov Height the size of the field of view as you adjusted it in the previous section, is displayed. In this tutorial sequence we are given an interlaced video sequence (as you specified in the requester Edit Sequence Settings...). Each frame consists of two „half frames“ (fields) shifted by one pixel, i.e. half of the vertical resolution is not displayed. Please keep in mind that the value of Fov Height refers to the height of the entire frame, not of the half frame.

The interaction components of this window are described in detail in the chapter “Selected Topics”, section “Camera Adjustment”. For this tutorial we restrict ourselves to the most important functions. The general principle of handling this window is the following:

Camera Adjustment Window

A camera, as we understand it in the context of 3DE, is determined by four parameters. These are the parameters of which the fields are displayed in pink. All other parameters (grey) depend mathematically on the pink ones. You can choose which of the parameters are employed by 3DE for determining the camera. When you play around with the selectors you will notice that only few of all imaginable combinations of settings are possible. This is because 3DE will take care that the camera parameters are always consistent. You cannot set a selector to *<dependent>* because 3DE will do this when necessary.

If a parameter is unknown set its selector to Unknown. In this case you cannot enter a value in the corresponding text field, since you already signalled to 3D-Equalizer that you do not know the value. When you know one of the parameters approximately set its selector to Fine Adjust and enter the value. If you are very sure about a parameter set its selector to Fixed and enter the value.

The sequence has been recorded with a focal length of 5.9 mm. Please set the selector on the r.h.s of the field Focal Length to Fixed and enter the value 5.9 mm in the text field. Since the shot was taken with a videocamera, you know the value of the Film Aspect. The Film Aspect is the ratio between the width and the hight of the recorded images. Most PAL/SECAM video cameras have a “film” aspect of 4/3=1.333333. When you enter the Film Aspect, the Pixel Aspect is a <dependent> variable and therefore calculated by 3D-Equalizer. However, we have no idea about the Filmback Width/Height, the Horizontal/Vertical Angle and the Lens Distorion. Typical values of the lens distortion for a handy camera are 0.00 to 0.08. Good film cameras will often exhibit no visible lens distortion at all, so that the value may be set to zero. In this tutorial project you should set the selector to Fine Adjust and the value to 0.0. We will let 3DE calculate the Horizontal Angle, therefore set the corresponding selector to Unknown. To sum up, the parameters (approximately) and their selectors are now:

Filmback Width	0.48877 cm	<dependent>
Filmback Height	0.36658 cm	<dependent>
Focal Length	5.90000 mm	Fixed
Film Aspect	1.333333	Fixed
Horizontal Angle	45.00000 °	Unknown
Vertical Angle	34.51588 °	<dependent>
Pixel Aspect	1.09356	<dependent>
Fov Width	699.76 pixel	
Fov Height	573.92 pixel	
Lens Distortion	0.00000	Fine Adjust

The Precision slider specifies , how many of the frames are taken into account for adjusting the camera. If it is set to the right, all frames are used. If it is set to the left, 3DE chooses a minimum of frames for the adjustment procedure. You may use the leftmost position for rough estimations of the camera parameters. When your project is going to be finished the slider should be set to the right in order to gain the maximum precision.

If you now press Adjust several messages will appear on the screen, indicating the current status of the calculation. 3DE will try to calculate the parameters declared to be Unknown, and afterwards the parameters with setting Fine Adjust. You can terminate each level of calculation by pressing Stop in the progress requester. The parameters yielding the best value up to that moment will then be used.

Important note: All parameters are valid for the entire sequence. The current release of 3D-Equalizer does not support zooming during the shot.

After the adjustment procedure you will probably get the following values:

Filmback Width	0.38323 cm	<dependent>
Filmback Height	0.28742 cm	<dependent>
Focal Length	5.90000 mm	Fixed
Film Aspect	1.333333	Fixed
Horizontal Angle	35.98448 °	Fixed
Vertical Angle	27.37884 °	<dependent>
Pixel Aspect	1.09356	<dependent>
Fov Width	699.76 pixel	
Fov Height	573.92 pixel	
Lens Distortion	0.07774	Fixed

The values you obtain may slightly differ from ours. Maybe your interpretation of the field of view is different, or the tracking curves of the points deviate slightly. These things can influence the camera adjustment. If your values are different from ours this does not necessarily mean that you made some mistake. It means that you have now calculated a camera geometry which is compatible to the settings and tracking curves of your individual project.

However, after the adjustment procedure the values should approximately coincide with ours. If this is the case, the Camera Adjustment Window may be closed.

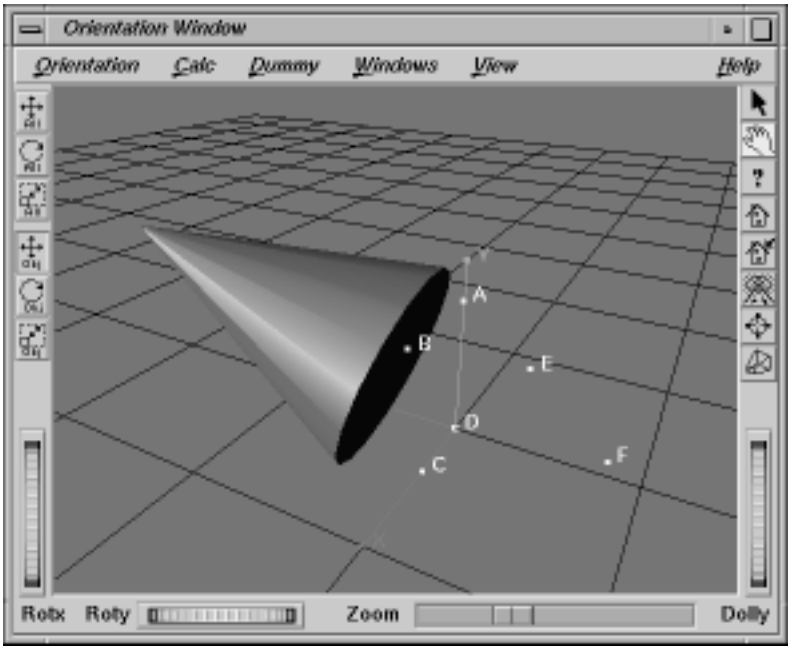
Generating a Preview Movie

Having adjusted the camera, we can now generate a preview movie in order to see, if the camera has been reconstructed successfully. We have to perform the following steps:

- Let 3D-Equalizer calculate the points in three-dimensional space.
- Edit a test scene in the Orientation Window, consisting of Open Inventor test objects (dummies).
- Compose (in a very simple way) the test scene and the real sequence, thus generating the preview movie.

Editing a Test Scene

Please open the Orientation Window. You see a black grid on a grey background and a coordinate frame with a red, a green and a blue axis. The camera motion path is reconstructed by selecting the menu item Calc Points & Path in the menu Calc. If you do this, several messages appear on the screen, indicating the current status of the calculation.
Afterwards the points A, B, C, D, E and F appear in the Orientation Window display. You should convince yourself, that the relative position of the reconstructed points is the same as in the real sequence.



Orientation Window

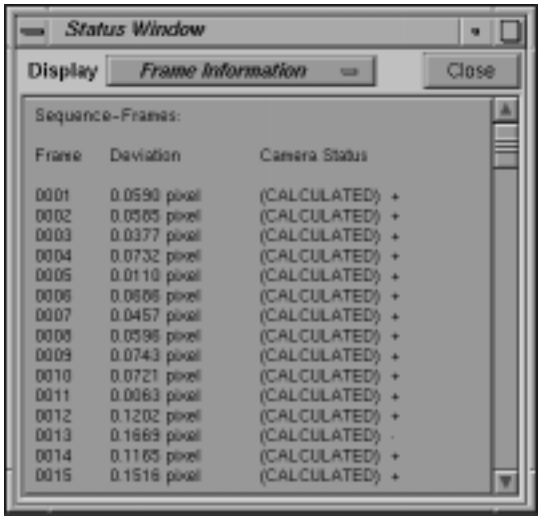
The Status Window

At this point it is useful to have a look in the Status Window. You can open it by pressing Main Window::Windows::Status....

When the selector Display is set to Frame Information you see three coloumns. The first one contains the frame number, the second one contains a value (error in pixel) which expresses the „inconsistency“ of the perspective adaptation. Generally these values depend on how

precise the points are tracked on the screen and how precise the camera geometry has been reconstructed. The values displayed in the figure below are those we obtained while preparing the tutorial sequence. Your results for each single frame will be different. However, all in all they should not be much worse. The third coloumn (status) specifies whether the camera position of the respective frame has been calculated successfully. In the tutorial sequence all frames can be treated and will carry the status CALCULATED. When a frame cannot be treated its status is UNDEFINED. Next to the status you see some characters that can be either “+”, “•”, “-”, “--” or “---”. This indicates whether the respective frame has been calculated good, normal, not so good or even bad.

If you notice that for some of the frames the error value deviates considerably from those of the neighbouring frames, you should take a closer look at this frame by means of the Zoom Window and check if the screen points are placed precisely. If you are convinced that all frames have been calculated at a satisfying precision you can go on creating a test scene in the Orientation Window.



Typical status values of the tutorial sequence

The Orientation Window is essentially an Open Inventor ExaminerViewer. We shall omit here the details of its usage and discuss only some of the interaction components which are specific for 3D-Equalizer. In the reference part of this manual some of the functions of the ExaminerViewer are outlined.

We consider now the positions of the points with respect to the coordinate frame. The alignment of the points is the same as it will be when the 3D-Equalizer data are exported to the animation package. One aim of this window is therefore to provide the functionality for aligning the points appropriately before exporting. In your own 3D-Equalizer projects it may

occur that some of the points are designated for instance at a wall. In such a case it is natural to align the points in the xy- or in the yz-plane rather than in the xz-plane. Animation systems are usually provided with a preferred plane. When your project data are exported, the points should appear in the animation system in the same relation to this preferred plane as they do in the Orientation Window.

Usually 3DE presents the points in a quite unintuitive manner so that it is difficult to draw the connection between the real scene and the reconstructed points. In order to get a more reasonable alignment of the points, you can simply perform the following steps, and the principle of the menu Orientation will certainly become clear.

1. Switch from the perspective view to the front view by selecting the View::Front function in the Orientation Window or by pressing Shift+F10.
2. You can see that some of the points are located unterneath the ground plane. Select the Translate All Button and translate the scenery in Y direction until all points lay over the ground plane.
3. The points still do not line up with the screen points in the Zoom Window. The points are placed the wrong way round. The whole scene should be rotated 180 degree around the Y-axis. Activate the Rotate All Button and rotate the scenery by pressing the middle mouse button and moving the mouse.
4. Now have a look at the calculated camera path. Please activate the View::Show Camera Path toggle. If you cannot see the calculated camera path use the dolly slider and the view function (the hand icon) to change the position of the Open Inventor Camera, until you see the calculated camera path. If it turnes out that the set of points and the camera path cover a very small or very large region of the ground plane, then you can use the Scale All function to scale the entire scenery.

As you see, the Orientation Window provides the functionality for modifying the entire scenery.

A simple test scene can be edited using Open Inventor objects, the so-called dummies. Please select the menu item Dummy::Create::Cone. A cone-shaped dummy apears near to the origin. When the object is created, its orientation is generally not well-adjusted in relation to the points. The Orientation Window provides the functionality for selecting, translating and rotating the object.

Click on the arrow button on the right, to activate the Pick-Mode. To select the cone hold down the Ctrl.-Key and pick the object with the left mouse button. The red bounding box indicates that the object is now selected. To manipulate the cone object you can use the Translate Object, Rotate Object and Scale Object buttons on the left side of the Orientation Window. (When the button Translate Object is selected, then you can translate the cone in X-direction by pressing MB1 and moving the mouse. Using MB2 translates in Y whereas MB3 translates in Z-direction.) While the Pick-Mode is active, the user can easily switch to the View-

Mode by holding down the Alt-Key. As long as the View-Mode is active the direction of the Open Inventor Camera can be changed using the left mouse button. The middle mouse button can be used for translating the camera. For more details see the chapter: Orientation Window in the “Reference Maual”.

The windows Material Editor and Light Editor, to be selected in the menu Windows, provide the functionality for associating surface properties to the object and for specifying a light source direction for the scene. It is very useful to select Main Window::View::Show Dummies. The dummy will then appear in the Main Window, so that material properties and the light source can easily be adjusted. Furthermore, you will see tiny green points near the screen points. They represent the points reconstructed in three-dimensional space, but their representation does not take into account the nonlinear distortion of the camera. Therefore, since we have a significant nonlinear distortion, they cannot coincide precisely with the tracking points. You can get a first impression of the perspective adaptation using the frame slider in the Main Window.

Preview Movie

In order to generate the preview movie please open the Preview Window by selecting Main Window::Windows::Preview and set the selector Playback to Loop. If you press Play, the preview will be generated and played unless you press Stop. Take care that, when the preview is being generated, no other window overlaps the Preview Window, because for reasons of performance the movie is rendered directly on the screen. If you have worked precisely the dummy will be aligned with respect to the actress’ right eye for the entire sequence. The other functions of this window are quite easy to understand, and we shall omit the details here. In the chapter “Reference Manual”, section “Preview Window” of the reference manual these functions are explained.

Preview Window

Generating Export Data

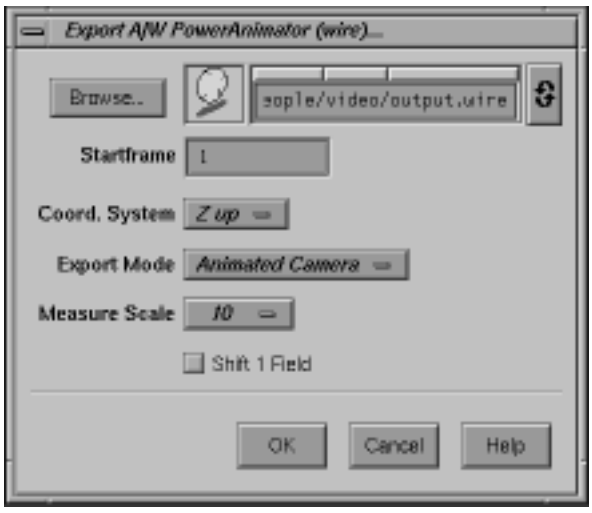
The reconstructed camera geometry and motion path are now going to be exported to the animation package. In the current release of 3D-Equalizer the packages A|W PowerAnimator, SoftImage 3D, A|W Explore, Discreet Logic Flint/Flame/Inferno and SideFX Prisms/Houdini are supported.

Please open the corresponding export requester for your preferred animation package by selecting Main Window::Project::Export. In the tutorial sequence the object (actress' head) moves and the camera is fixed. Therefore the selector Export Mode should be set to Animated Points. When the exported points and the camera path have the wrong scale in the animation software, then you can change the scale of the scenery with the Scale All Button and export the data anew.

Apart from the pixel aspect (PowerAnimator), the image ratio (Explore) and the vertical aperture angle (SoftImage) the camera geometry will be exported.

The mode of operation of the respective export requester is described in the chapter "Reference Manual", section "Main Window".

Important note: The wire frame representation of your models in the respective animation package does not take into account the pixel aspect, and therefore in general the real and the reconstructed points will not coincide in this representation mode.



Requester: Export A|W PowerAnimator (wire)...

Tutorial 2: Tracking Points on the Screen

The purpose of this section is to present several situations which can occur in connection with motion- and markertracking. In the first section the so-called markertracking (tracking of simple, symmetric, unicoloured objects) is treated. The use of the Image Controls Window is illustrated in the second section by means of a realistic example. In the third section the common motiontracking and the difference to markertracking are explained.

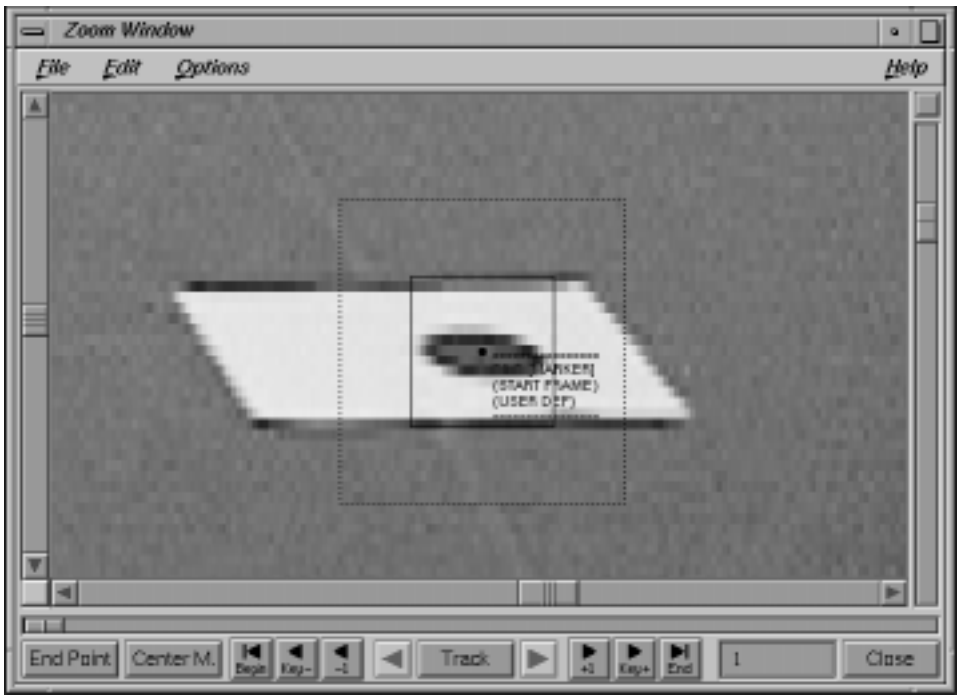
Markertracking

Please start 3D-Equalizer as described in the section “Getting started” and open the project “tracking1.3de” in the directory “/usr/3dequalizer/tutorial/projects”. On the floor you see two markers and three little balls. In the course of the animation, the camera moves around these objects. If you wish to get an impression of the sequence you can open the Preview Window and press Play. In the following it is useful to keep the Zoom Window opened.

First of all you need a point object, and therefore please open the Points Window and press the button Add. The requester “Create Point...” opens. Please change the selector Trackingmode from Forward Only to Marker Mode - Forward. This activates the markertracking mode for this point. All other settings can be left as they are, and therefore you can confirm the entries by pressing the button Ok.

In the first example we shall see what happens, if the two tracking areas of the screen point are not adjusted properly. Place the screen point over the right marker in the Zoom Window (without modifying the motiontracking areas), as shown in the figure below. By doing this you specify a keyframe for this point. As already mentioned in the first tutorial 3DE expects you to press the button Center M. in order to find the center of the marker.

If you do this now several times you see that the screen point does not identify the center, but jumps around in some strange manner. Finally it might be located at the upper or lower edge of the marker. The fact that the screen point does not find the marker indicates that something is wrong. In general there can be several reasons, e.g. low contrast. In this case, however, it is very clear: the search pattern (i.e. the inner rectangle) is to big, so that parts of the dark background lie within the rectangle. Now the markertracking system cannot properly tell apart the background and the marker itself, and therefore it cannot focus on the marker. The conditions for an “ideal” markertracking (which in practice are usually not fulfilled) are explained in chapter “Selected Topics”, section “Markertracking”.

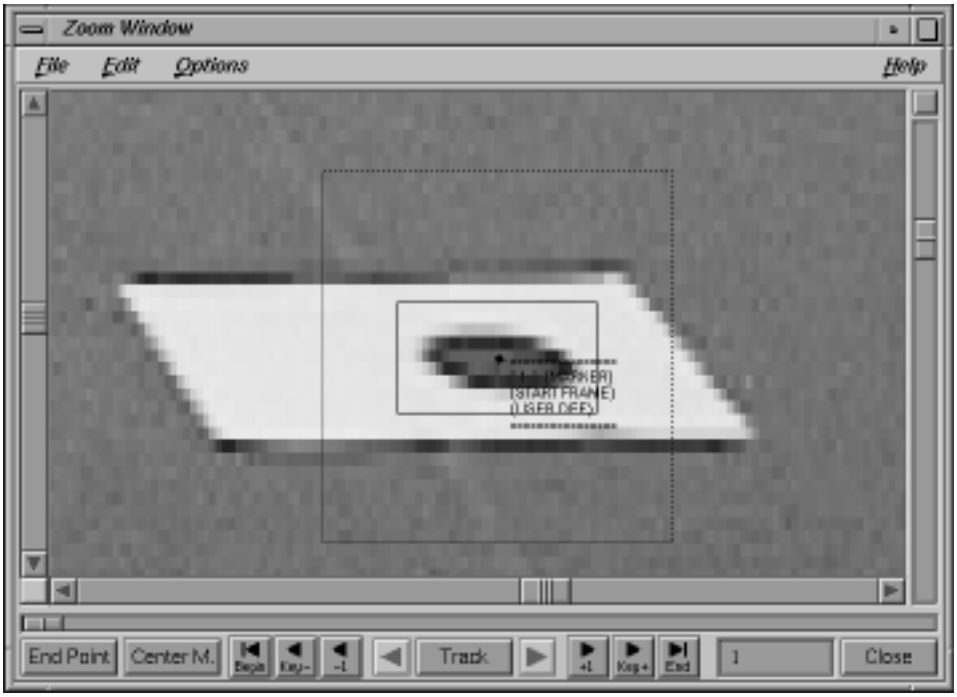


Search pattern too big

Please place the screen point by hand on the marker center again. Adjust the height of the search pattern, so that it covers only the bright background and the marker, as shown in the figure below.

If you press the button Center M. now, the system will be able to locate the screen point in the center of the marker correctly. For the following observations it is useful to activate the toggle Zoom Window::Options::Auto Center. Please press the button Track Forward a few times and convince yourself that the tracking system finds the marker center in the following frames as well.

You may procceed step by step or press the button Track in order to track the marker until the end of the sequence in order to see what happens. At frame 22 approximately, the system will not be able to find the center of the marker correctly. The reason is, that the size of the marker is constantly growing from frame to frame. At a certain point the marker does not fit in the search pattern any longer, and the markertracking fails again (see also chapter “Selected Topics”, section “Markertracking”).



Correct search pattern

We shall see now, how such a behaviour can be handled. Delete the entire motion curve by pressing Zoom Window::Edit::Delete Curve::All. Place the screen point on the marker center and adjust the search pattern as described above. Press the button Track to start the tracking. Whenever there are less than 2 pixels of the bright background between the marker and the edge of the search pattern (see figure below), interrupt the tracking procedure and adjust the search pattern in a way so that it covers the marker, and so that the bright background surrounds the marker within the search pattern, and continue the tracking by pressing the button Track.

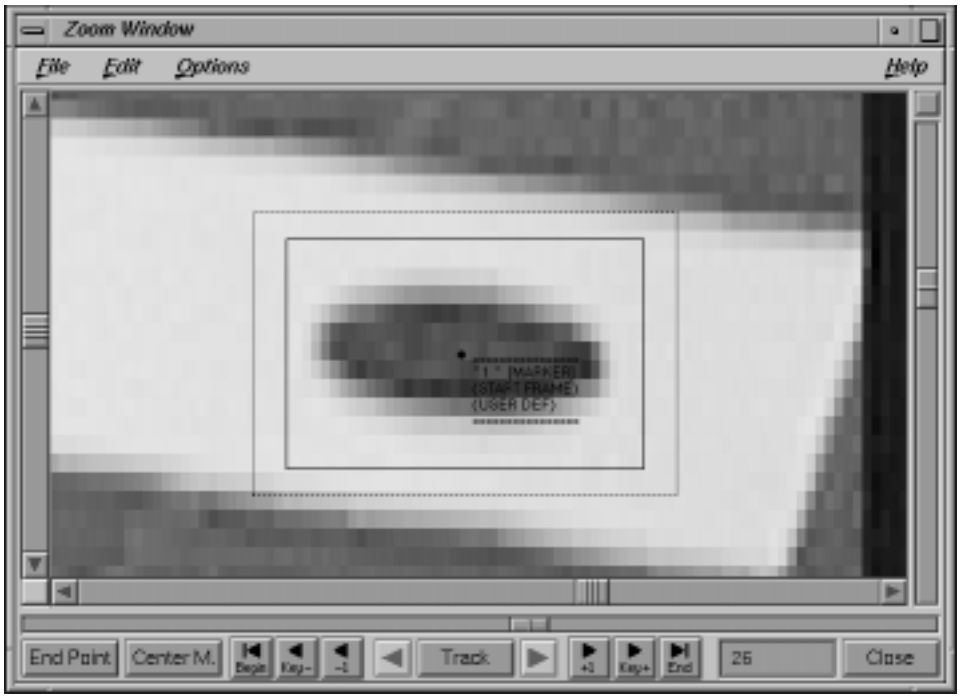
Important note: The best way to get a precise motion curve is to visually supervise the tracking process. If the point of interest is not tracked correctly, the process should be interrupted immediately so that the tracking areas can be adjusted. This technique saves time and guarantees the highest tracking quality!

Search pattern too small

We have seen now the effect of resizing the search pattern appropriately. In the next example you will see what happens if the search area is too small. Please choose the function Zoom Window::Edit::Delete Curve::All in order to delete the motion curve. Let us start now at frame 26. Adjust the search pattern correctly as described above, but adjust the search area to its minimum size as shown in the figure below.

Press the button Center M. several times, to ensure that the system identifies the center of the marker correctly. Please deactivate the Auto Center mode in the menu Options. If the button Track Forward is pressed, the following frame is not tracked correctly. The reason is that from frame 26 to frame 27 the marker moves very fast. The tracking system tries to find the marker in frame 27 within the search area specified in frame 26. The search area is too small and the marker is not contained in the search area and hence the tracking procedure fails.

In order to avoid this behaviour please go back to the previous frame 26 and enlarge the search area slightly. Now press the button Track Forward again: now the marker can be tracked correctly in the following frame. You see that - depending on the type of camera movement - a certain minimum size of the search area is required, but please keep in mind that the processing time increases if the search area is too big.



Search area too small

Image Controls Window

As we have seen in the last section, if the markermode is used for tracking, there have to be well-defined markers on a contrasting uniform background. In practice these conditions are not always fulfilled. In the following example a technique for improving the tracking quality is presented. The sequence for this tutorial has been placed at our disposal by Trix, Belgium.

Start 3D-Equalizer as described in the section “Getting started”. Please open the project “tracking2.3de” in the directory “/usr/3dequalizer/tutorial/projects”. You see a big studio with several yellow tennisball markers on the floor. If you wish to get an impression of the sequence you can generate a preview movie (open the Preview Window and press Play).

As in the previous example it is necessary to create a point object. For this purpose open the Points Window, and press the button Add. A requester “Create Point...” opens. Please change the selector Trackingmode from Forward Only to Marker Mode - Forward. This activates the markertracking mode for this point. All other settings can be left as they are, and therefore you can confirm the entries by pressing the button Ok.

Open the Zoom Window now, and activate the autocenter mode by choosing the menu function Zoom Window::Options::Auto Center. Jump to the first frame and place the screen point on the tennisball marker which is located in the middle of the frame (see figure below).

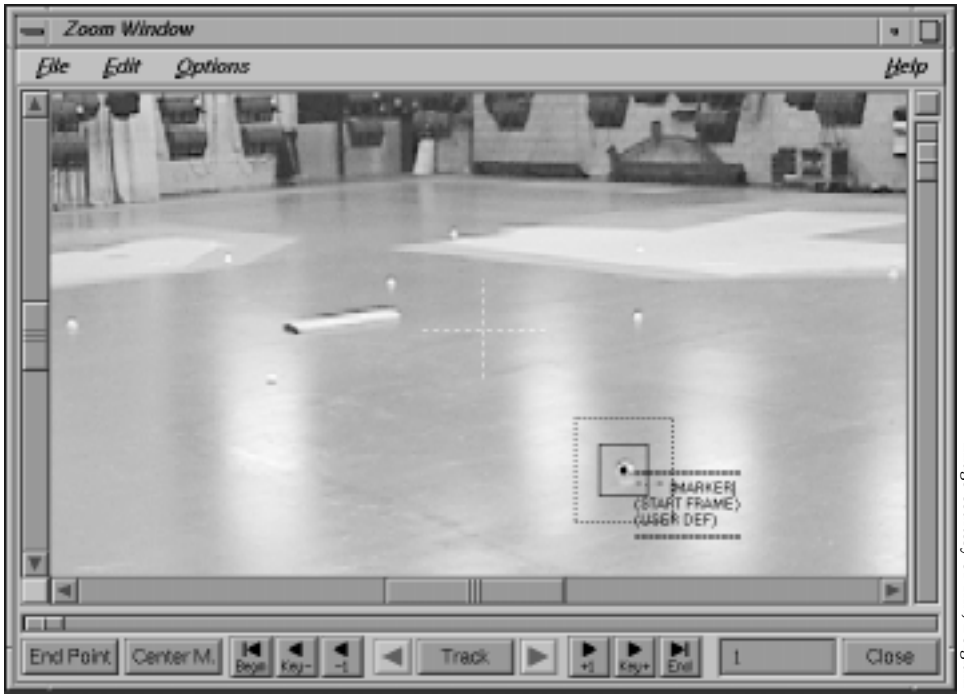


Image courtesy of Trix, Belgium

Studiofloor with several tennisball markers

Please press the button Center M. several times, to ensure that the tracking system identifies the center of the marker correctly. Activate the automatic tracking by pressing the button Track, and watch the tracking procedure until the last frame. You will note that from frame 8 to frame 19 in the area around the marker there is a reflection from one of the light sources. During this period the tracking system does not focus on the marker itself, but on the dark shadow of the tennis ball! However, by means of the Image Controls Window this misbehaviour can be avoided. Please jump to the frame 1 and choose the function Zoom Window::Edit::Delete Curve::All in order to delete the motion curve. Open the Image Controls Window. In principle you can try to use this panel in order to manipulate the images appropriately, but for the first it might be better to select the menu function Image Controls::File::Load Curves.... Please load the curve “Trix1.crv” in the directory “/usr/3dequalizer/tutorial/projects”.

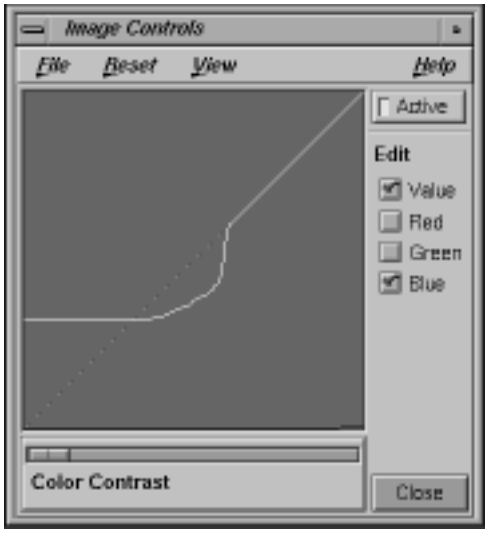


Image Controls Window

When you activate the toggle button Active, 3D-Equalizer modifies the image according to the loaded curves. As you can see the colored image has become greyscaled. Furthermore, if you jump e.g. to frame 14 there will be no dark shadow. Jump to frame 1 and place the screen point on the tennisball marker. Afterwards press the button Center M. a few times, to ensure that 3D-Equalizer identifies the center of the marker correctly. Please start the automatic tracking procedure again, and examine the result. Since the disturbing parts of the images are removed by the image controls the tracking will be performed successfully.

Motiontracking: Forward only vs. Forward & Backward

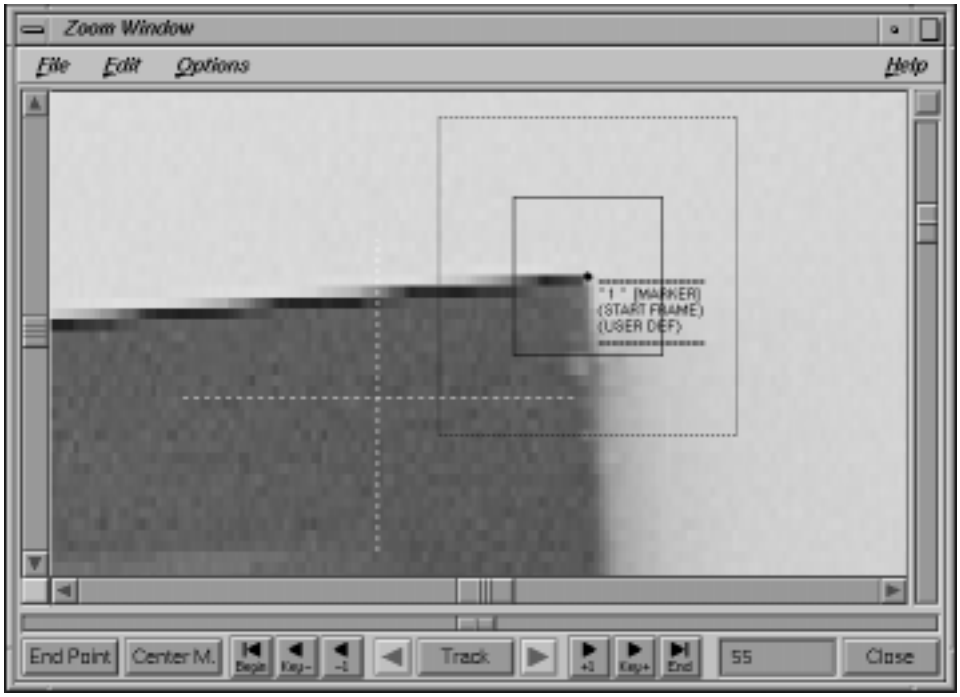
Up to now, during all tutorials the markertracking mode has been used without exception. In practice it often happens that markers are not available. In these situations points can be tracked by using motiontracking (in contrast to markertracking).

Start 3D-Equalizer as described in the section “Getting started”. Please open the project “tracking3.3de” in the directory “/usr/3dequalizer/tutorial/projects”. You see a red painting. If you wish to get an impression of the sequence you can generate a preview movie (open the Preview Window and press Play)

First we shall see what happens if the markertracking is applied in situations in which it should not be applied at all. As on the previous tutorials we start by creating a point object. For this purpose please open the Points Window, and press the button Add. A requester “Create

Point...” opens. Please change the selector Trackingmode from Forward Only to Marker Mode - Forward. This activates the markertracking mode for this point (which will soon turn out to be the wrong mode). Please confirm by pressing the button Ok.

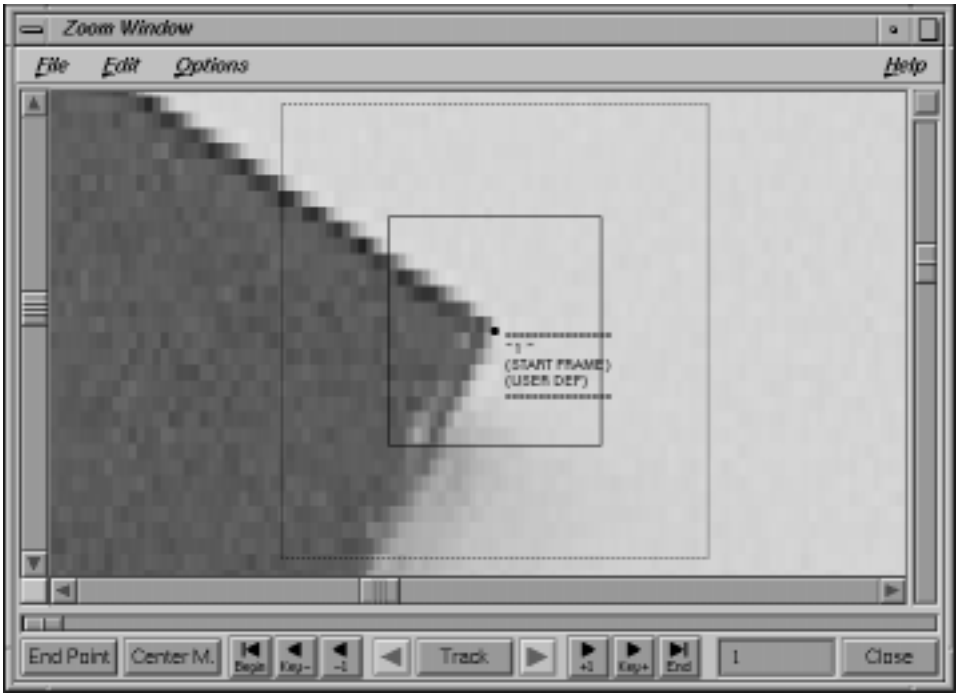
Now open the Zoom Window and jump to frame 55. Please place the screen point on the right corner of the painting as shown in the figure below.



Misuse of markertracking mode

Press the button Center M. several times. The screen point is jumping around and finally stays inside the painting. As described in the last tutorials the situation found here does not fulfill the conditions required for markertracking (see also chapter “Selected Topics”, section “Markertracking”). Therefore we have to use one of the non-marker modes. Press the button Modify in the Points Window. The requester “Modify Point” opens. Change the Trackingmode setting from Marker Mode - Forward to Forward only. The common motiontracking mode is now activated for this point. Close the requester by pressing the button Ok. Since you have changed the Motiontracking Settings, 3D-Equalizer asks you if the existing Motion Curve should be set to obsolete. Please confirm by pressing the button Set Obsolete.

Please jump to frame 1 and choose the function Zoom Window::Edit::Delete Curve::All in order to delete the motion curve and activate the Auto Center mode, by selecting Zoom Window::Options::Auto Center. Place the screen point on the upper right corner of the painting, as shown in the figure below.

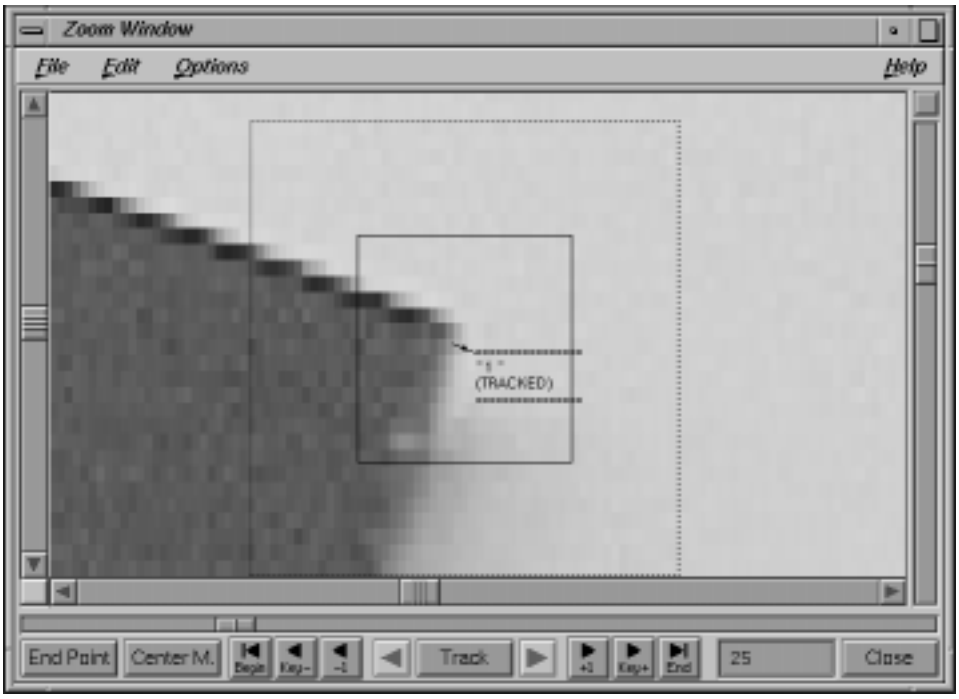


Point object with motiontracking mode active

If you try to press the button Center M. you will here a sound signal, because this function does only make sense in connection with markertracking. Start the tracking procedure by pressing the button Track and watch the screen point during this process. At approximately frame 25, the tracked screen point deviates by about 2 pixels from the corner of the painting. Please interrupt the tracking at this point.

What is going on? The motiontracking in the context of 3D-Equalizer always tries to track a point in a frame by evaluating the previous frame, i.e. in each step the deviation of the tracked point from its real position becomes bigger and bigger due to numerical inaccuracies and the lack of information in pixeloriented images. We shall refer to this phenomenon as “error accumulation”.

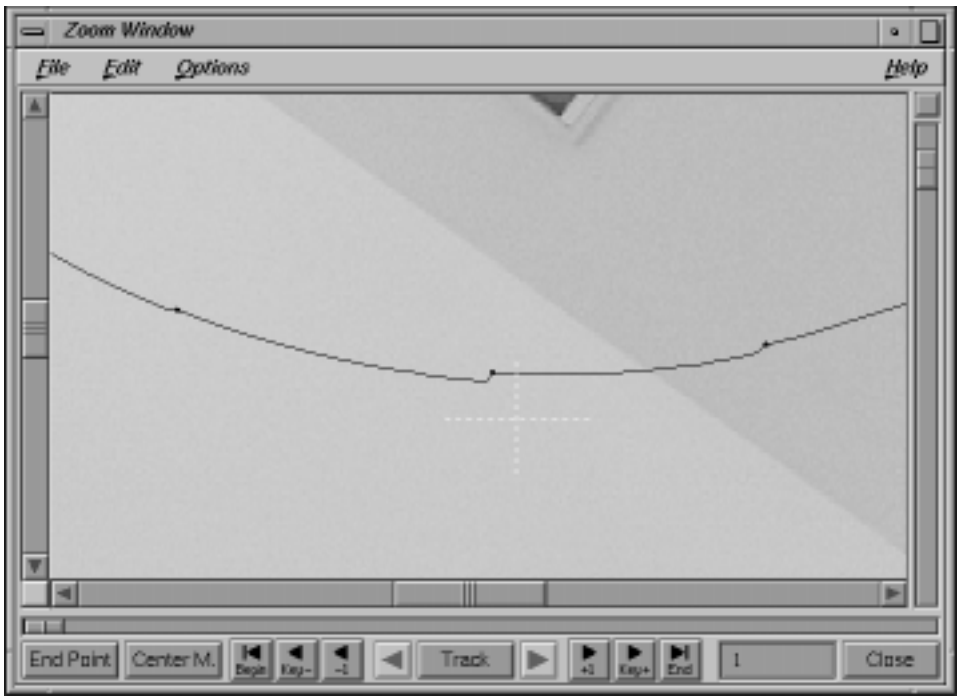
Important note: The advantage of the motiontracking mode is that all possible kind of patterns can be tracked. The disadvantage is a certain kind of error accumulation, that means the tracked position deviates more and more from the “reel” position during the tracking procedure. In comparison to that, the markertracking has the advantage of no error accumulation, but can only be applied to those situations where markers are found.



Screen point tracked with accumulated error

In order to “work around” the error accumulation, reposition the screen point at the corner of the painting, thus producing another keyframe (see also chapter “Selected Topics”, section “Tracking”). Please continue the tracking until the end. After approximately every 25 frames, the tracking should be stopped for repositioning.

Make 3DE display the motion curve by selecting the menu function Zoom Window::Options::Show Motion Curve. Zoom out so that you can examine the entire curve (see figure below)



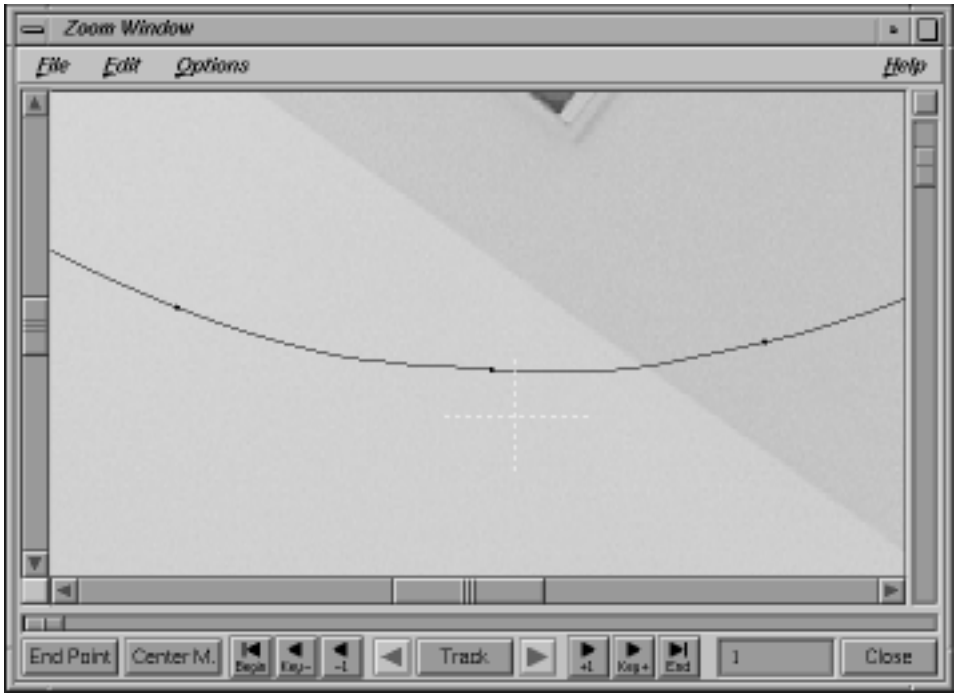
Motion curve with “jaggies” due to error accumulation

You will note that the motion curve exhibits little “jaggies” at the intermediate keyframes. For 3D-Equalizer’s reconstruction procedures it is quite important to avoid these jaggies, because all properties of the motion tracking curves will be transferred to the three-dimensional camera motion path. We shall see now how this inaccuracy can be avoided.

Press the button Modify in the Points Window. The requester Modify Point opens. Change the Trackingmode setting from Forward only to Forward & Backward. Close the requester by pressing the button Ok. A requester opens, which asks you to decide whether the motion curve should be set to obsolete or not. Since you wish to replace the failed tracking curve by a better one press the button Set Obsolete in this requester.

In the trackingmode Forward & Backward it is recommended to declare at least the first frame and the last frame of the tracking curve as keyframes. You start the tracking process as usual, by defining a start frame and pressing the track button. In the first pass 3D-Equalizer tracks the corner from the beginning until the end of the sequence, producing exactly the same motion curve as before. Having arrived at the last frame, a requester opens which tells you to define the last keyframe. Press cancel to interruppt the tracking process and set the last keyframe by hand. Please start the tracking again. Now the corner is tracked backwards from

the end to the beginning. During this pass the curve is smoothed out and the jaggies are eliminated (see figure below).
What has happened? In the backward tracking procedure 3D-Equalizer produces another motion curve. This is combined with the first jagged motion curve by some splining prescription so that the resulting curve is smooth.



Motion curve smoothed out by "Forward & Backward" motiontracking

Tutorial 3: Camera Adjustment

The following tutorial demonstrates how to use the functions of the Camera Adjustment Window, in order to minimize the calculation time for a camera adjustment procedure.

In general the pre-conditions for using the camera adjustment feature are: precise motiontracking curves and a noticeable amount of camera movement, i.e. the camera position must considerably change during the course of the sequence. If this is not the case, reference frames can be used. (see also Tutorial Reference Frames).

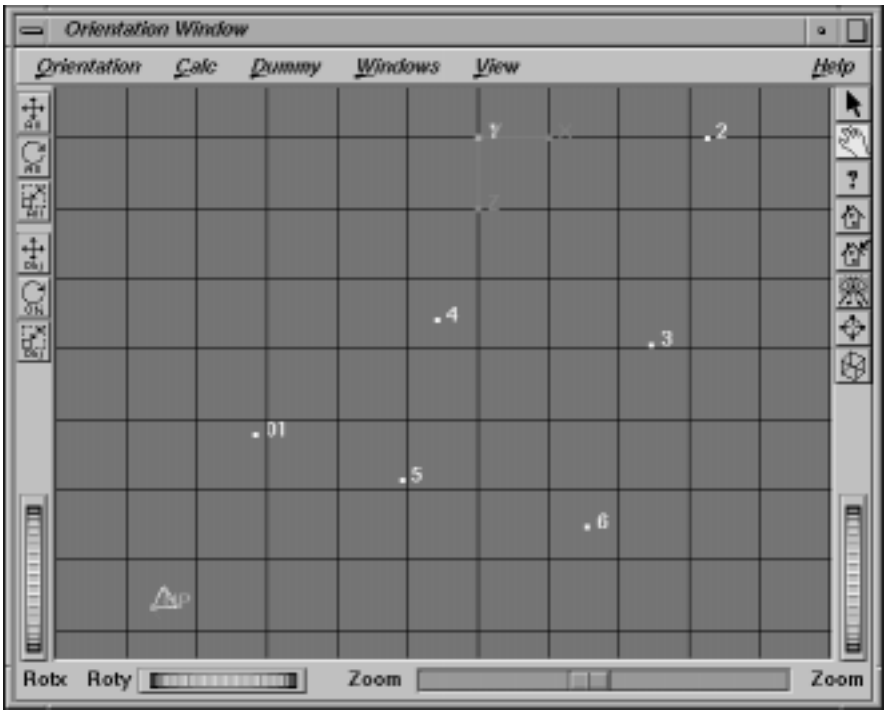
Start 3D-Equalizer as described in the section “Getting started”. Please open the project “cam_adjust.3de” in the directory “/usr/3dequalizer/tutorial/projects”. You see a studio with several yellow tennisball markers on the floor (see figure below).

Image courtesy of Trix, Belgium

Studio floor with several tennisball markers

Please take a look at the sequence by clicking a few times on the left hand side of the Main Window frame slider. The camera is highly moving around the tennisball markers. There is already a sufficient number of tracked points, so that we can concentrate on the camera adjustment procedure only.

Please open the Camera Adjustment Window. You will find standard values for the camera parameters. First of all, let us try to calculate a camera motion path and points using these standard values. Please open now the Orientation Window and press Calc::Calc Points & Path. After a few seconds the 3D point positions are displayed. As we can easily see from the image sequence, the tennisball markers form squares on the floor. However, when we examine the calculated point positions we notice that they do not form squares. The points are distorted (see figure below) due to wrong camera parameters!



Distorted point model due to wrong camera parameters

Please open now the Status Window and take a look at the Frame Information values. The average deviation is about 2 pixel, which is also too high, when you take into account that the tracking of this project is quite precise!

Let us assume, that we have no idea about the camera parameters. Of course, we could set every possible selector to Unknown and start the adjustment procedure, but this would probably take about 1 or 2 hours to compute.

Although we do not know any of our camera parameters, it is possible to aquire some useful information. In a first step, we will try to get a rough idea about our camera parameters, and afterwards we will tune the result.

When we examine the image sequence, we realize no “special” distortion, that means, as in almost every production, the lens distortion will probably be between 0.0 and 0.1. Because this amount of lens distortion has only a minor effect on the camera path calculation, we can enter “0.0” into the lens distortion field and set the selector to Fixed.

Please open the requester Edit Sequence Settings by selecting the menu item Main Window::Options::Sequence Settings. The selector Imagetype is set to Interlace - Odd First. That means, the image sequence has been filmed with a video camera. The film aspect of video material is always 4:3 (1.3333)! Please press the Cancel button to close the requester Edit Sequence Settings, set the selector Film Aspect of the Camera Adjustment Window to Fixed and enter “1.3333” in the respective field. As you might have noticed, the Pixel Aspect has been automatically changed to <dependent> and “1.06667” (which is a well-known value for PAL video).

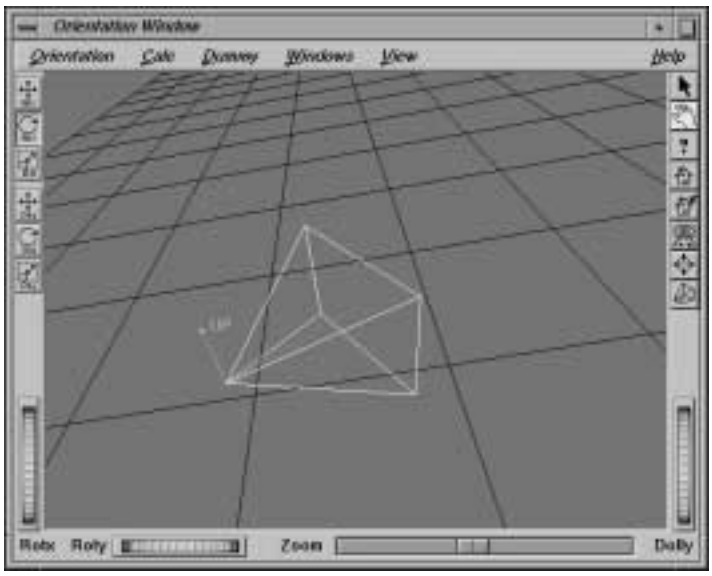
Important note: To guarantee a consistent camera, either the pixel aspect or the film aspect is <dependent>. As long as you do not have any other information, you fit in with the following rules. If you work with Video or Telecined material, adjust the FOV and set the Film Aspect selector to Fixed and the respective field to “1.3333”. If you work with scanned (film) images, set the Pixel Aspect to Fixed and the respective field to “1.0”.

Now please open the Orientation Window and activate the toggle button View::Show Camera. Use the navigation functions of the Orientation Window in a way, so that the camera object becomes visible (see figure below).

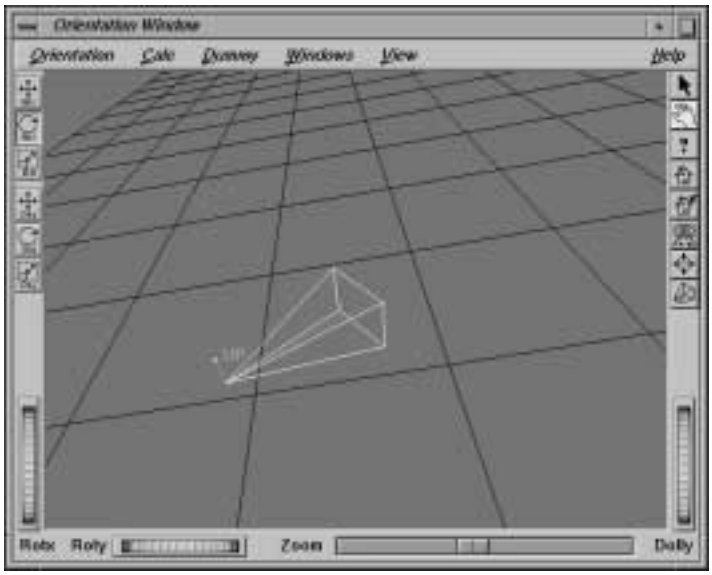
Please modify the Horizontal Angle value in the respective field of the Camera Adjustment window to “30.0”. When you examine the camera object again, you will notice that the shape of the camera pyramid has changed (see figure below). Please enter the original value of “60.0” into the Horizontal Angle field of the Camera Adjustment Window.
Now please modify the Focal Length value to “5.0”. This time only the size of the camera pyramid has changed (see figure below)!

In general, there are always three non-dependent camera parameters in the Camera Adjustment Window (and in addition the Lens Distortion parameter). In almost every case, one of them specifies only the size of the camera pyramid, while the two remaining ones specify its shape. However, for calculating the camera motion path, only the shape of the camera pyramid is important. Modifying its size has no effect! Therefore, we can set the Focal Length field to any value and the respective selector to Fixed.

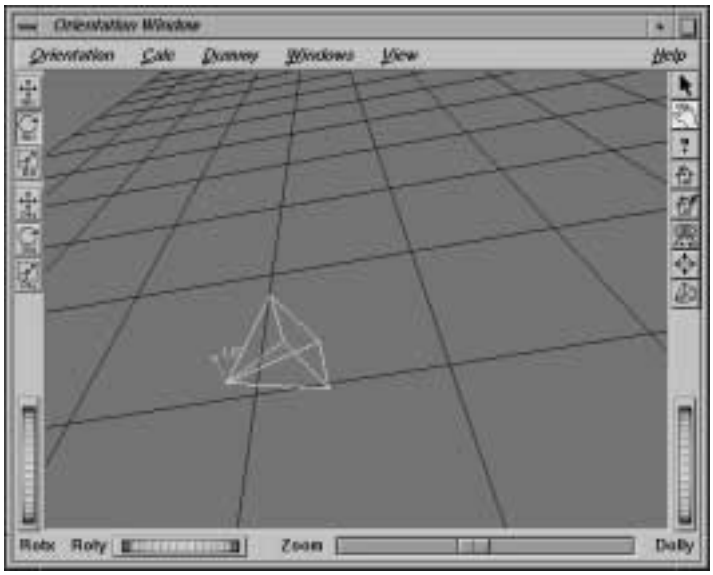
Please set the remaining selector “Horizontal Angle” to Unknown and press the Adjust button to start the camera adjustment procedure. After about 20 attempts, 3D-Equalizer has calculated a horizontal angle of 43.05. If you open the Status window, you will find an average deviation of 0.24 pixel, which is already an acceptable value.



Default camera



Camera shape changed



Camera size changed

Please increase the size of the Main Window to its maximum, activate the toggle Options::View::Show Distortion Grid and go to frame 135. The edge of the floor and the wall seems to be curved in comparison to the distortion grid. This is probably a lens distortion effect. Please set the Lens Distortion selector of the Camera Adjustment Window to Fine Adjust and press the Adjust button. After 5 attempts, 3D-Equalizer has calculated a new lens distortion of 0.009. The average deviation of the Status Window has changed to 0.22 pixel. However, if you take a look at frame 135 again, you will notice that there is still a mismatch between the curvature of the floor-wall edge and the lens distortion grid.

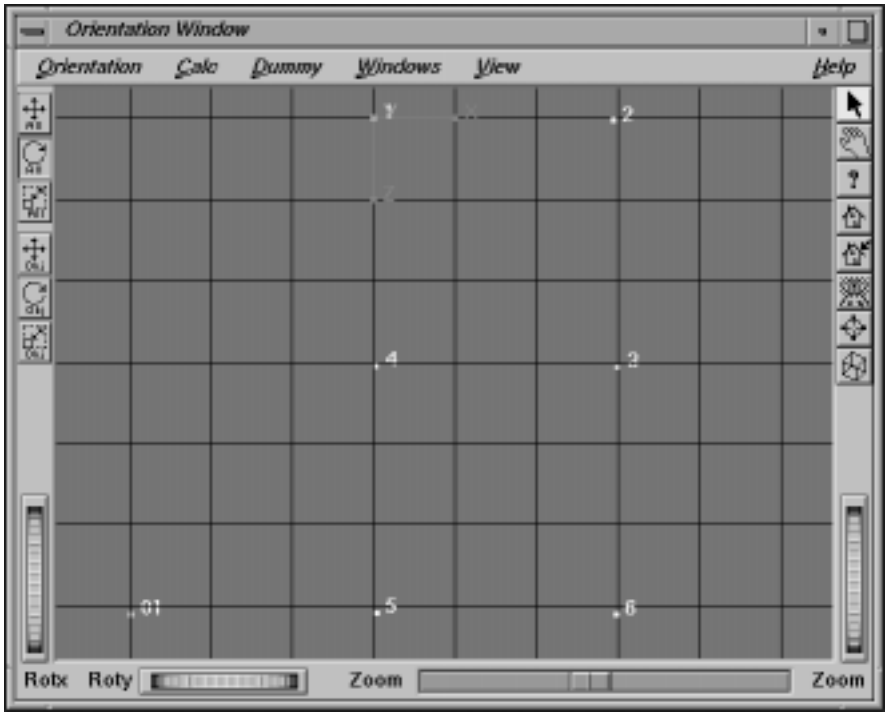
The lens distortion and the “shape” of the camera are closely related to each other. That means, if one of them is modified the other has to be modified too! So, please set the Horizontal Angle and the Lens Distortion selectors to Fine Adjust, and press the Adjust button. After about 50 attempts, 3D-Equalizer has calculated a Lens Distortion of 0.05 and a Horizontal Angle of about 47.4. The average deviation has been reduced to 0.12 pixel!

Please take a last look at frame 135. As you see, the curvature of the floor-wall edge and the lens distortion grid are matching quite good now (see figure below).

Image courtesy of Trix, Belgium

Matching lens distortion

Please open the Orientation Window and examine the 3D point positions again. They form squares now, because the camera parameters are much more precise (see figure below).



Well calculated points due to correct camera parameters

Tutorial 4: Stabilizing

The purpose of this tutorial is to point out several techniques for improving the quality of the camera reconstruction. The situation presented below represents one of the most problematical types of 3DE-projects. The camera motion path is improved by the technique of stabilizing points and by using the postfilter functionality.

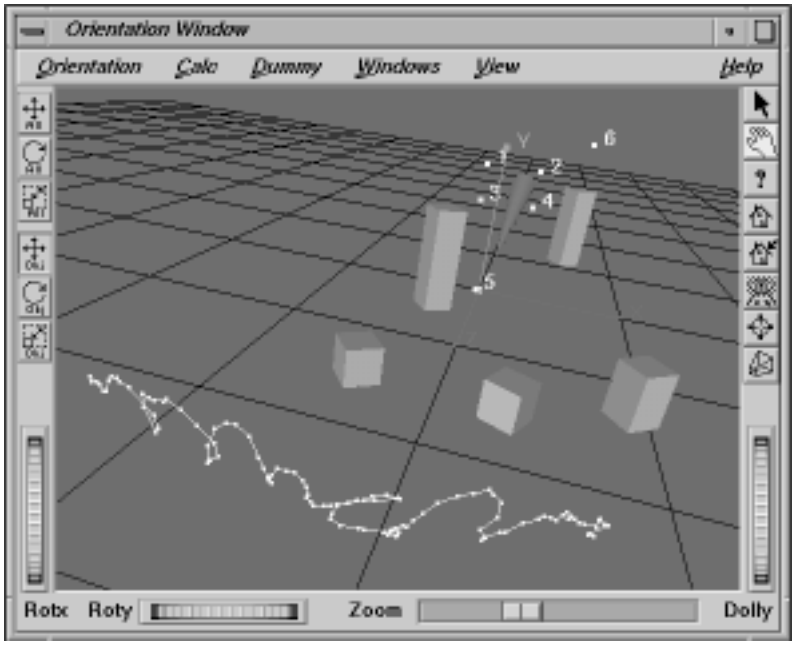
Stabilizing Points

Start 3D-Equalizer as described in the section “Getting started”. Please open the project “dolly.3de” in the directory “/usr/3dequalizer/tutorial/projects”. You see a black wall with four markers attached to it. The project is already prepared, the four points on the wall are tracked. The fifth and the sixth point are defined in the first and the last frame, the camera geometry is correct, so that in principle the camera motion path can be calculated.

Please open now the Orientation Window and press Calc::Calc Points & Path. After one or two minutes the calculation is over and the points appear in the Orientation Window display. Now open the Status Window and have a look at the error values. The average deviation is about 0.15 pixel. From the first tutorial you know that this value is quite good, therefore it seems that the camera motion path is consistent with the screen points.

Please open now the Preview Window, press Play, and do not be shocked too much. As you see, the preview looks absolutely terrible, the objects are fluctuating in a strange manner, although the recorded sequence looks very smooth and uniform. Interrupt the preview playing and activate the toggle Orientation Window::View::Show Camera Path. Use the facilities of the Examiner View in order to examine the path (see also figure below).

In this sequence the camera has been moved in a smooth way by means of a dolly, but the reconstructed camera performs strange curly movements. What is going on? In this project the optical axis of the camera is almost perpendicular to the plane in which the markers lie which have been used for tracking, i.e. there is not enough perspective information available. From a mathematical point of view this case is extremely sensible to slightest fluctuations in the motiontracking curves. In other words, it is impossible to work precisely enough for achieving a reasonable camera motion path! In the following we shall see how the camera motion path can be stabilized. The basic principle is to supply more perspective information, e.g. by adding points which do not lie within the perpendicular plane.

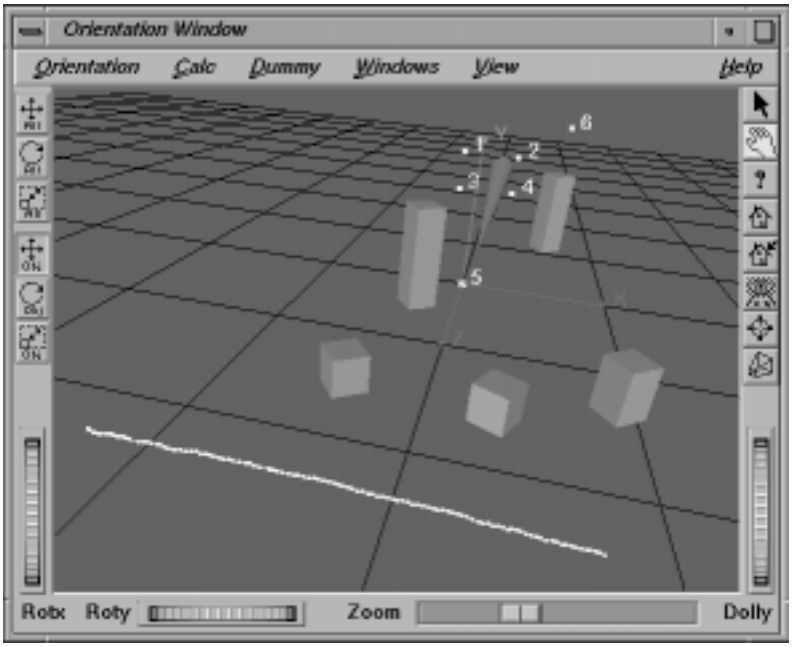


Curly camera motion path

Please open the Zoom Window and the Points Window. Select point 5 and jump to the first frame. Activate Zoom Window::Options::Auto Center and Show Motion Curve. The dotted line indicates that point 5 is invalid between the first and the last frame. We wish to track this point for the entire sequence, and therefore please press the button End Point. This toggles the point's status from endframe to startframe. The search area and the search pattern are already adjusted correctly and therefore you may simply press the button Track in order to track the point until the last frame (the object on the floor is tracked as a marker).

Now select Orientation Window::Calc::Calc Points & Path again. After a minute the points and the reconstructed camera motion path appear. The curly camera path has now become an almost straight line (see figure below).

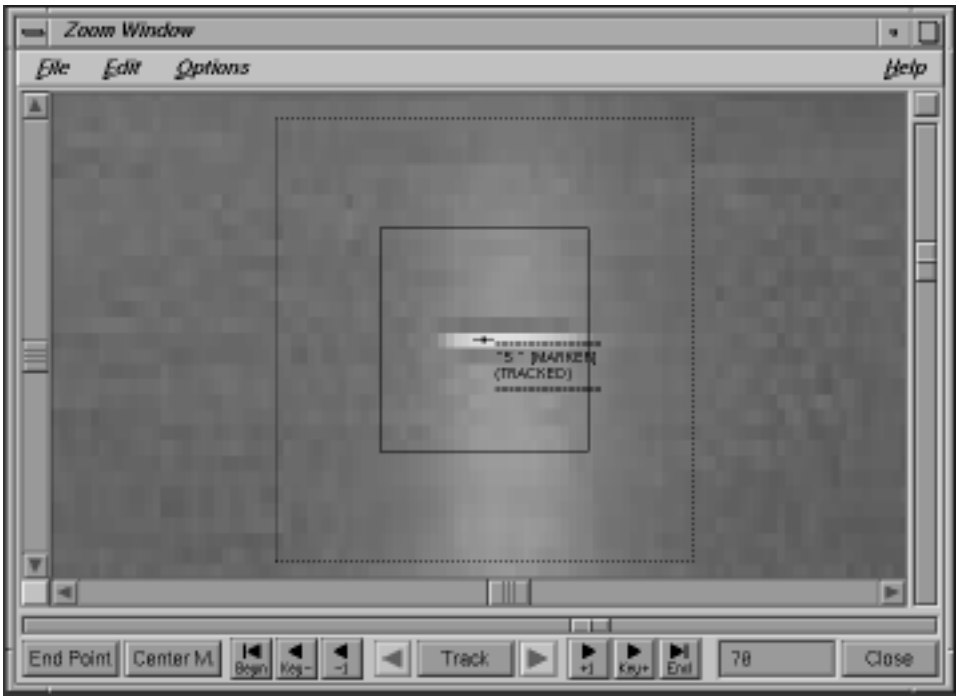
Please open the Preview Window and let 3DE generate a preview movie. Since the camera path has been stabilized by the fifth point the movie looks much better now. However the cone and in particular the cube in the foreground still perform some trembling movements. Obviously there is still some precision problem.



Straight camera motion path

Important note: Since the preview movie has a lower resolution than the original images, it is useful to place the dummies in a way so that inaccuracies in the reconstructed camera motion path are amplified. This can be done as demonstrated in this tutorial, i.e. by placing some of the dummies close to the camera and remote from the markers.

The next step is to check whether the motion tracking of point 5 has been performed correctly. You can do this by means of the Preview Window. Set the playback range to 60 and 80 and the selector Playback to Swing. As you see in the middle of this range there is some jaggy movement of the objects. In order to find out precisely which one of the frames causes this behaviour set the slider Current Frame to 60 and click on the right hand side of the knob in order to examine the sequence frame by frame. From frame 69 to 70 the dummies move in some strange manner. Please examine the Zoom Window and go to frame 70. As you see, point 5 has not been tracked correctly in this frame (see figure below).

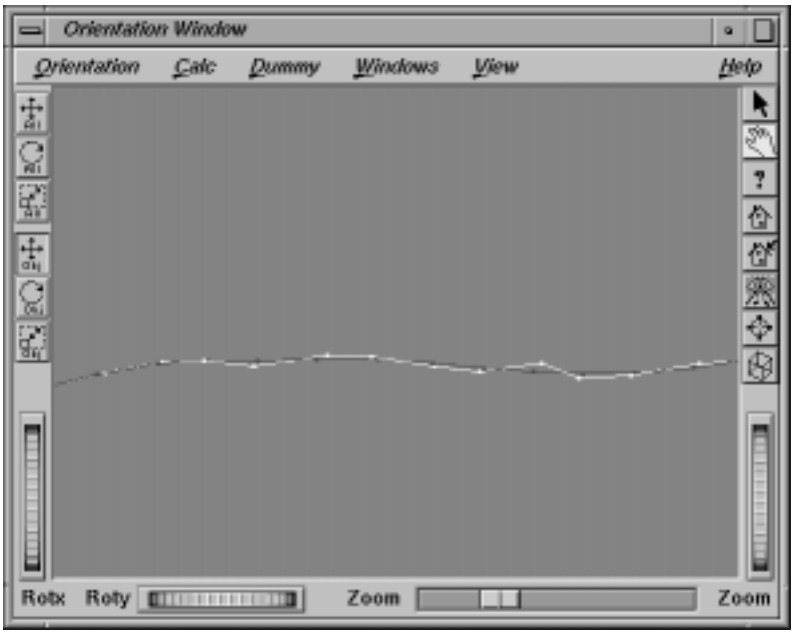


Screen point tracked not correctly

You can simply correct the screen point position by hand and press Play in the Preview Window afterwards. After some processing time the preview movie is generated between frame 60 and frame 80 as you specified by means of the sliders Playback Range. At least the jaggy movement at frame 70 has gone. As you see, this technique can be used for improving the quality of single bad frames. However, the entire sequence is still a little bit jaggy. In the following we shall see how this effect can be minimized.

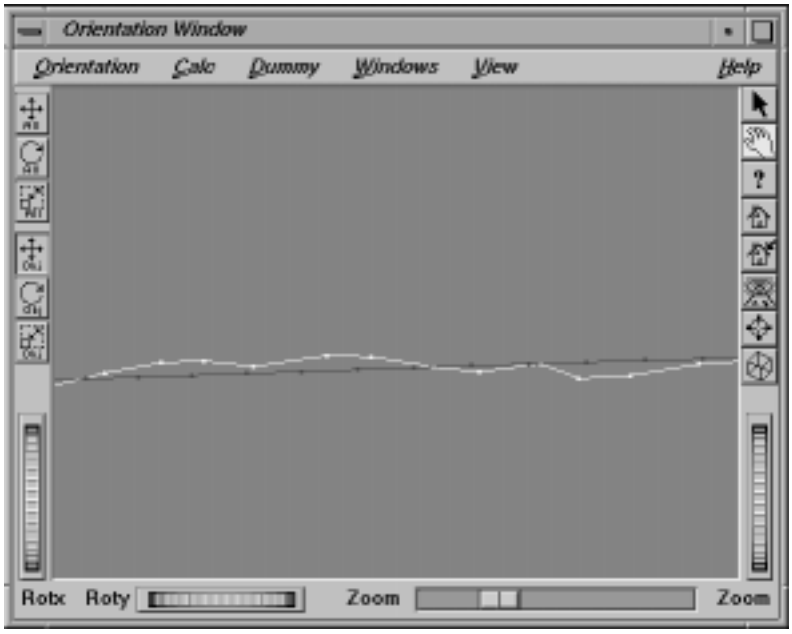
Applying the Postfilter

Please select Main Window::Options::Postfilter Settings. The requester Edit Postfilter Settings... opens. Activate the toggle Camera Filter Active. In the following you can investigate the relationship between the strength and resulting filtered camera motion path. For the first we shall use the setting 2.0 for the slider Strength Position. After confirming the entry by pressing OK press Calc Points & Path in the Orientation Window again. 3DE calculates now a filtered camera motion path. When you activate the toggle View::Show Filtered Path a red motion path appears near the white one. You should have a closer look at the two paths: the red one is a little bit smoother than the white one (see figure).



Filtered camera path using Strength Position 2.0

Please generate a preview movie again. As you see some of the fluctuations are removed, others are still visible. That means, the postfilter is too weak for this case. Now change the postfilter strength position to some value, say, from 10 to 15, and look at the resulting camera paths. You will note that the filtered path has become much smoother (see figure below). The preview will also look very smooth with this setting.



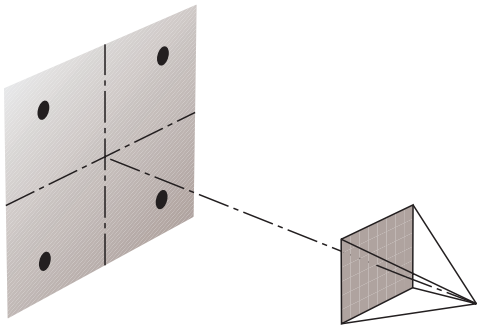
Filtered camera path using Strength Position 15.0

Important note: The strength of the postfilter to be used depends on the type of camera equipment. When the real camera motion path is smooth, e.g. because a dolly or a crane has been used you can set the strength to some higher value. However, the motion paths should always be checked in the Orientation Window and the Preview Window. When the sequence is recorded by a handy cam, the strength of the postfilter should not be too high so that the reconstructed camera motion path is not falsified too much.

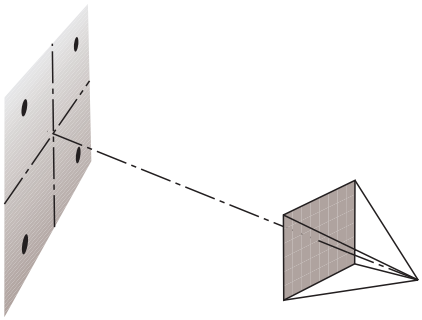
In addition to the position filter there is also a filter function for the orientation. Filtering the orientation means, that the 2D tracking curves are smoothed out collectively. You can use it in order to compensate 2D tracking errors. The effect of filtering the orientation is much lower than the effect of filtering the position. Therefore, when you apply postfiltering, adjust the filter Strength Position first and the filter Strength Orientation afterwards. You can provoke a situation, which enables you to study the various filter effects, by misplacing a tracking point in one single frame (e.g. in the sequence “Evahead”, Tutorial 1) by, say, 10 pixels and playing around with the filter settings.

General remarks

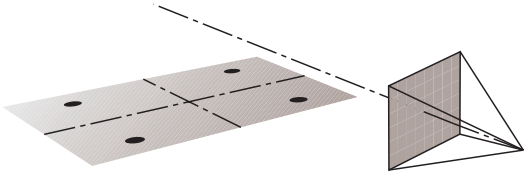
You have seen that the situation in which the optical axis is perpendicular the plane with markers can bear some problems, and how these problems can be eliminated step by step. In practice you may try to avoid these situations: rearrange the wall and the markers or place the markers in a completely different way as illustrated in the figures below.



Problematic: optical axis perpendicular to markers on a wall



Not problematic: optical axis not perpendicular to markers on a wall



Not problematic: optical axis not perpendicular to markers on the floor

Tutorial 5: Fixed Camera Position

Frequently there are projects, in which the camera position does not change over time, e.g. when the camera is attached to a tripod. In these cases the camera is only rotating around a fixed point.

These quite “simple” matchmoving projects can become quite difficult using the standard Distance Constraint Free (DCFM) calculation method, because the key condition, a varying camera position during the shot, is not fulfilled! Using reference frames is one possibility to solve the problem (see section Tutorial Reference Frames). In this section however, we will learn another technique to handle this type of projects: the calculation method “Fixed Camera Position”.

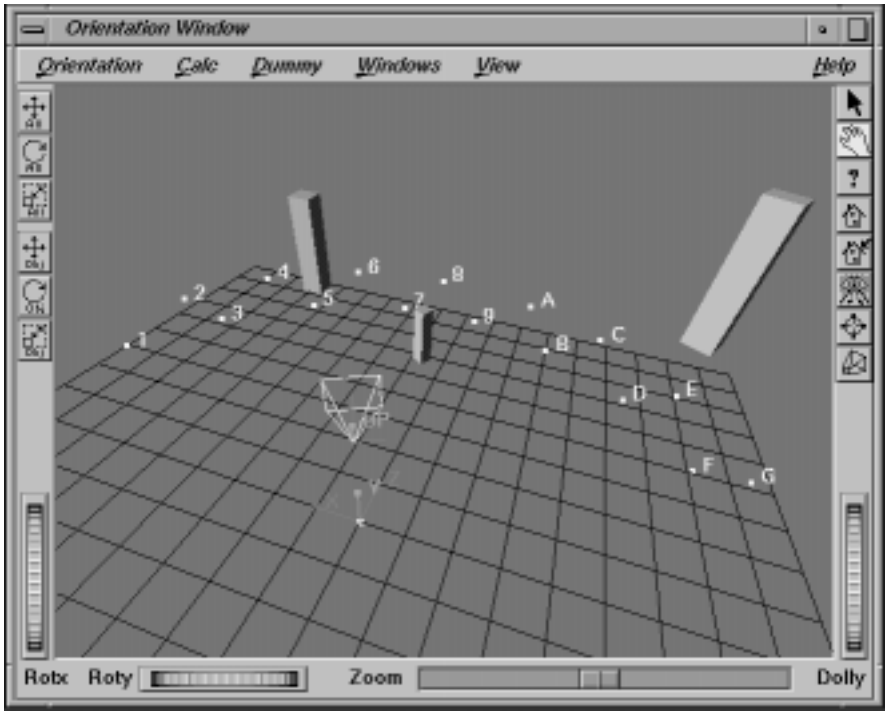
Please open the project file “fixed_cam_position.3de”. You see a TV studio with sixteen markers on the floor. The camera is attached to a tripod. In the course of the sequence it turns around by an angle of about 120°. The camera position remains unchanged, or at least almost unchanged. Sixteen points have already been tracked.

To change the mode of calculation, please open the Project Settings requester by selecting the menu item Main Window::Options::Project Settings and set the selector Calculation to Fixed Camera Position Method. An info requester opens and displays the minimum requirements for this method. Press the Ok button to close this requester. In order to confirm your changes and close the Project Settings requester press its Ok button, please.

Like every calculation method, also the Fixed Camera Position Method allows camera adjustments. So, please open the Camera Adjustment window, set the selector Horizontal Angle to Unknown and press the Adjust button. After about 25 attempts 3D-Equalizer has calculated a horizontal angle of 45.6.

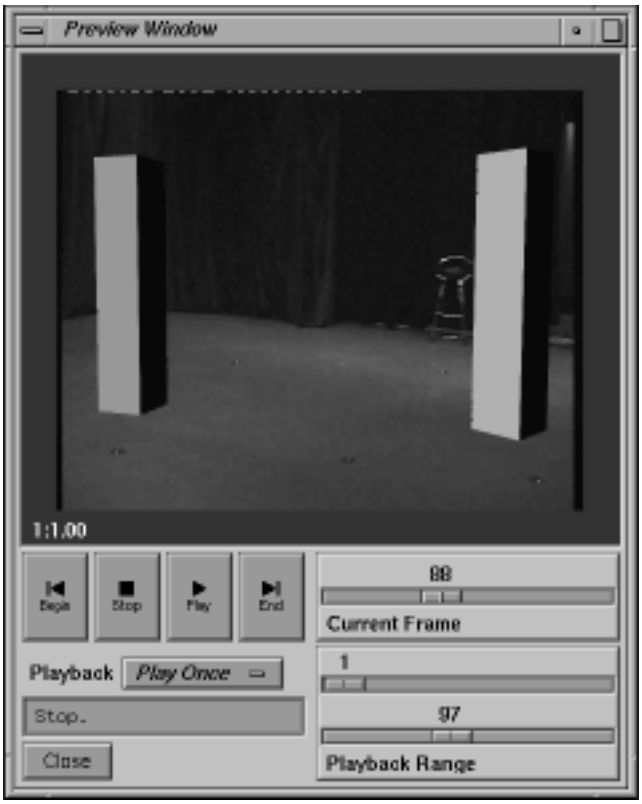
To examine the calculation result, open the Orientation window and activate the menu item View::Show Camera. You will notice that something strange is going on. Although all markers are placed on the studio floor and thus lie in the same plane, the reconstructed points are distributed in space. More precise, they lie on the surface of a virtual sphere. The Fixed Camera Position Method does not allow to calculate “real” 3D point positions, because the real scenery is only filmed out of one single point of view. The distance information between the camera position and each point is missing and cannot be recovered.

Fortunately, this lack of depth information does not cause any problem. Due to the fact that the camera position does not change over time, the distance between the cg objects and the camera does not affect the representation as far as the perspective is concerned. In our example, the dummy objects are placed at different distances (see figure below).



Points projected on a virtual sphere due to fixed camera position method

To prove this, please open the Preview Window, set the Playback selector to Loop and press the button Play. After a short period of time, the sequence will be played back in realtime. Although the three dummy objects are located at different distances from the camera the preview looks correct (see figure below).



Preview window

So, the missing accuracy in the point positions is no problem, since the dummy objects (or the models in the final animation package) can be placed “by hand”. If, for some reason, it is absolutely necessary to know the accurate point positions, the distance constraint free calculation method in connection with reference frames must be used (see section Tutorial Reference Frames).

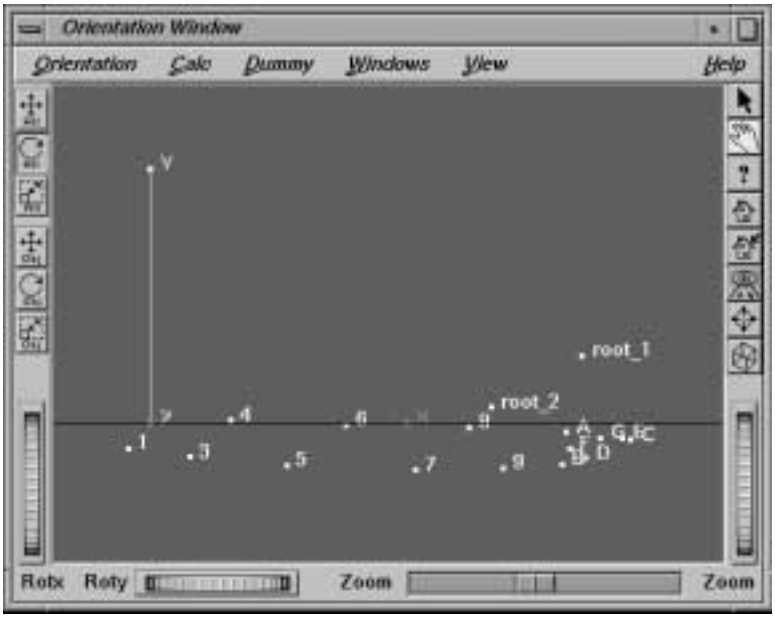
Tutorial 6: Reference Frames

As mentioned before, 3DE can reconstruct the camera movements and the point positions (or the movements of the recorded object) only if the camera position varies during the sequence. In the following we take up again the previous example. However, this time we will provide more information to the system, in order to obtain accurate point positions in 3D space. We achieve this by introducing the concept of reference frames.

In the second part of this section, we will present a sequence that contains enough camera movement to obtain a reasonable camera motion path, but no precise point positions. By using reference frames the quality of the point model is considerably enhanced.

Insufficient perspective information

Please open the project file “turn1.3de” in the directory “/usr/3dequalizer/tutorial/projects”. You see a TV studio with sixteen markers on the floor. The camera is attached to a tripod. In the course of the sequence it turns around by an angle of about 120°. The camera position remains unchanged, or at least almost unchanged. Sixteen points have been tracked and in the frames 101 and 118 there are two further points (“root_1” and “root_2”) designated in the environment. The camera parameters are already well-adjusted.



Misplaced points due to insufficient perspective information

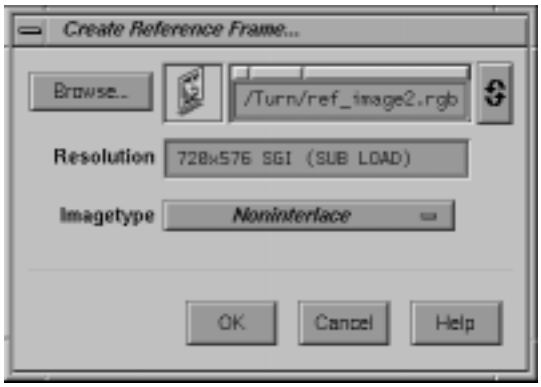
Please open the Orientation Window and press Calc::Calc Points & Path. After a few seconds the calculation is complete and the points appear in the Orientation Window display.

If you play around with the Examiner Viewer you will note, that the points which correspond to the markers do not lie in a plane, neither in the xz-plane nor in any other plane. The points “root_1” and “root_2” are misplaced as well. The reason is that since there is a lack of perspective information due to insufficient camera movement the points cannot be calculated precisely but exhibit a huge numerical error.

There are two possibilities to go on in this tutorial. In the following section we will add reference frames and define their screen points step by step. If you are not interested in these details at the moment you may simply read this section without following each single step and open the project “turn3.3de” instead.

Defining reference frames

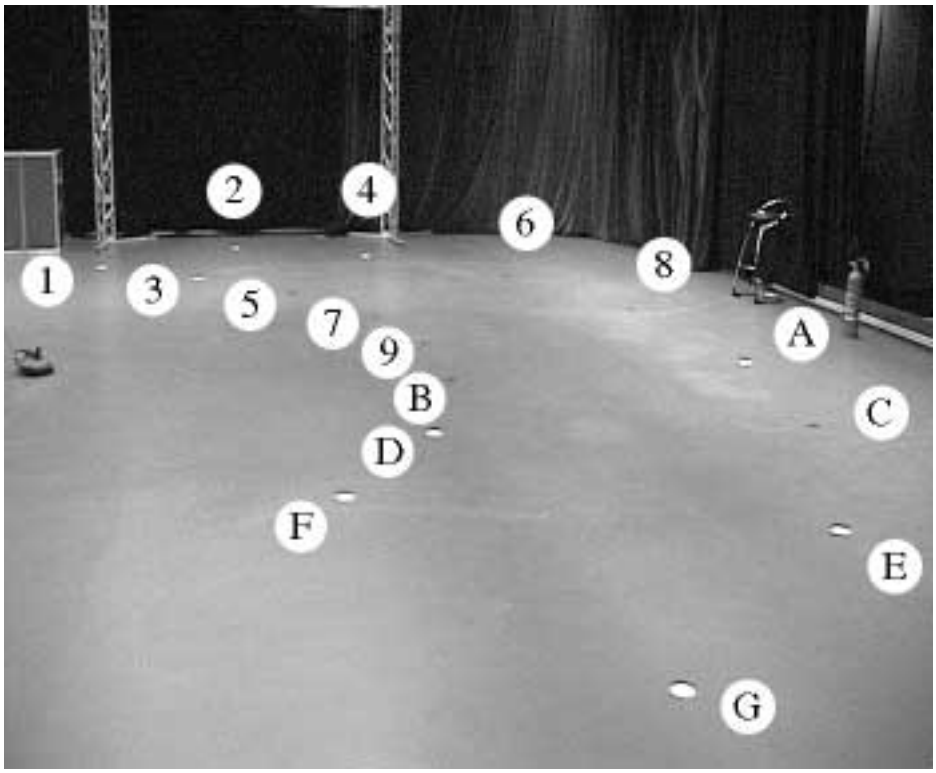
Please open the project “turn2.3de” in the directory “/usr/3dequalizer/tutorial/projects”. This project is similar to the project “turn1.3de” from the previous section. However, the points “root_1” and “root_2” are removed, since they are not needed in the following. Above the Main Window display you see a selector Sequence/Reference. Now set this to Reference. The display of the Main Window turns black, i.e. no reference frames are specified yet. You can add reference frames as follows: select Frames::Insert Reference... in order to open the requester Create Reference Frames... and press Browse. The reference frames of this tutorial are located in the directory “/usr/3dequalizer/tutorial/Turn”. Please select the image file “ref_image2.rgb”. The images named “ref_image#.rgb” have been recorded with the same camera, but they are non-interlaced. Therefore the selector Image Type should be left to Noninterlace. When you press OK the image is loaded and displayed in the Main Window.



Requester: Create Reference Frame...

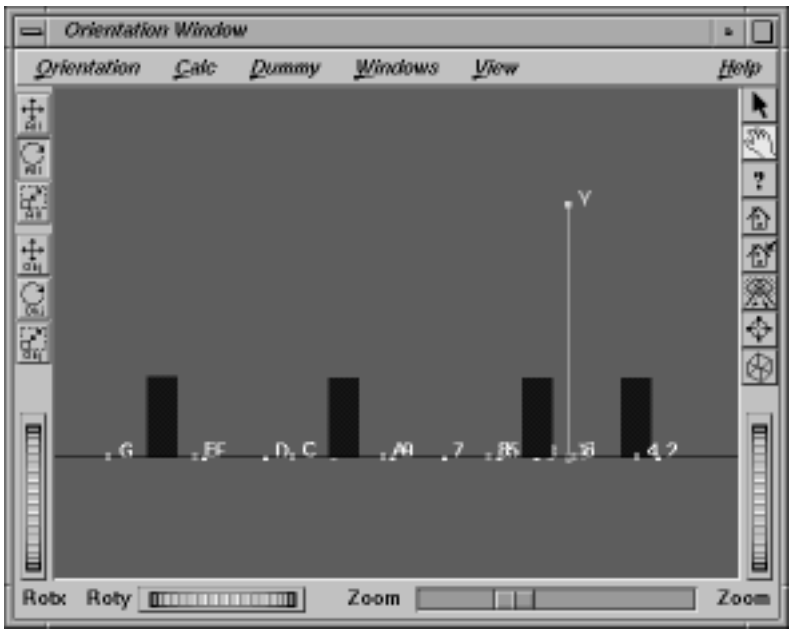
In order to benefit from the concept of reference frames you need at least two of them, otherwise there will not be any effect on the calculation process. Therefore you should follow the procedure given above and add the image file “ref_image7.rgb” to the set of reference frames. You can examine the reference frames by using the frame slider of the Main Window. The two frames are recorded from different points of view. In order to include all markers on the floor the second frame was recorded with a roll angle. A general principle in the concept of reference frames is, that one should try to include as many points as possible in each of the frames, so that more information is provided to the system.

Now place the points on the markers for both of the reference frames. The points cannot be tracked as in the sequence frames, because reference frame do not represent a “continuous” succession in time. Therefore all points must be placed by hand. Take care that the same points are associated to the same markers in both reference frames and sequence frames, as shown in the figure below.



Point object - marker assignment

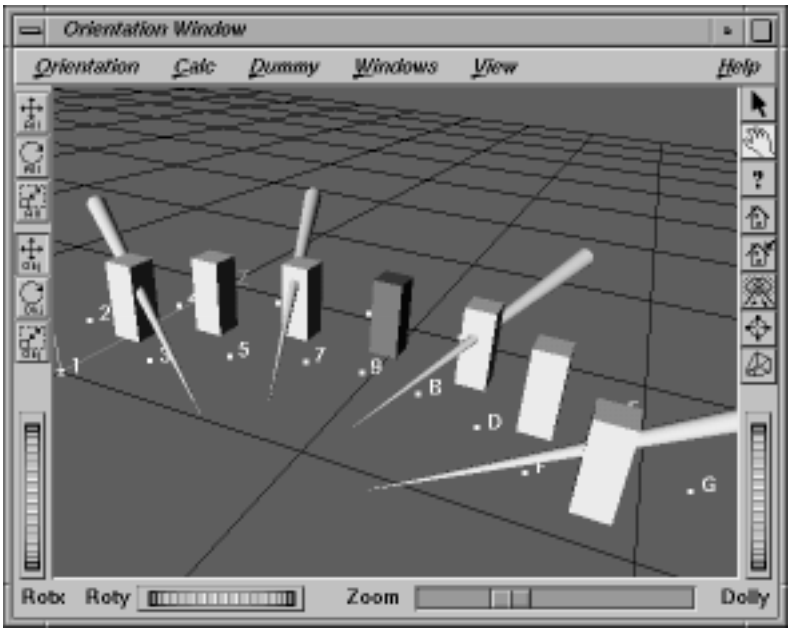
Now you should have a project with two reference frames containing sixteen points. Press Calc::Calc Points & Path in the Orientation Window. After a few minutes the points appear in the display. In contrast to the project “turn1.3de” they now almost lie in a plane because 3DE was able to calculate them by means of the reference frames.



Well-calculated 3D point positions due to reference frames

Now please open the Preview Window and press Play. After some time the preview movie is complete and you can examine it. If you have placed the points in the reference frames precisely enough the movement of the boxes should be smooth and uniform.

Please open the Status Window. As you see the average deviation is about 0.56 pixel. In comparison to other projects this value seems to be a little bit high. The reason is that the points still have some error, although they have been reconstructed from reference frames. If you supply more reference frames from more different points of view, the points will be calculated more precisely, and the frame average error is reduced. In the directory “/usr/3dequalizer/tutorial/projects” you will find the last project of this tutorial, “turn4.3de”. It contains eight reference frames and the average error in the Status Window is about 0.18. The cones are placed in a way so that slightest errors of the camera position can be visualized. You may try out how the system reacts when you remove one or more of the reference frames or if you change the camera parameters by hand. You may also turn on the postfilter and see what happens.



Project "turn4.3de"

Extra reference camera

In practice it often happens that the camera used for recording the sequence is heavy, unwieldy or even part of some big installation. In this case it cannot be moved to different points of view without problems. However, the reference frames can also be taken with a completely different camera. If you want to provide such a kind of reference frames, turn on the toggle Extra Reference Camera in Main Window::Options::Project Settings. In the Camera Adjustment Window there is a selector Camera that can assume the values Sequence/Reference. When you set this to Reference you can specify (or let 3DE calculate) the camera of the reference frames (see also next section). Note, that the calculation of many parameters requires more reference frames.

Important note: An adjustment of the sequence camera can only be successful if the reference camera is already calculated, i.e. you should carefully adjust the reference camera *before* adjusting the sequence camera.

Improving the quality of the point model

We will now investigate a project which, at first sight, contains enough camera movement for doing matchmoving, but which turns out to yield badly calculated point positions (and bad camera parameters). By providing reference frames this fault is removed.

Please open the project file “vicky1.3de” in the directory “/usr/3dequalizer/tutorial/projects”. Three actors are standing in front of a bluebox environment (see also figure below).

Image courtesy of Silicon Studio L.A.

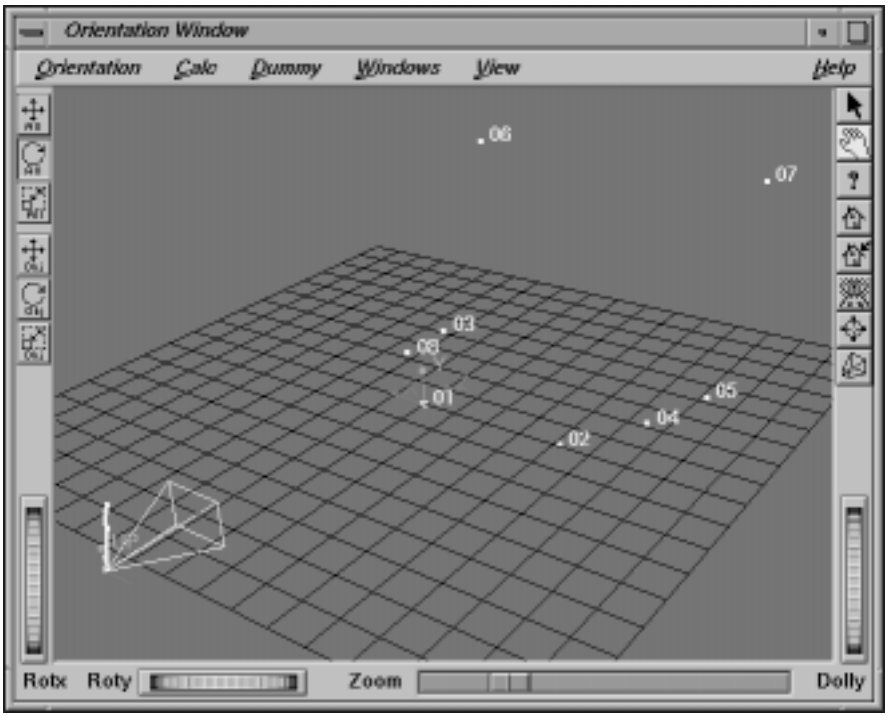
Main Window

Please take a look at the sequence by clicking a few times on the right hand side of the Main Window frame slider. As you might see, the camera moves slightly upwards.

Please open the Camera Adjustment Window, set the Horizontal Angle selector to Unknown and press the Adjust button. After about 20 attempts, 3D-Equalizer has calculated a horizontal angle of 35.0. If you open the Status window, you will find an average deviation of 0.1 pixel, which is a rather good value.

Now please open the Orientation Window and activate the toggle View::Show Camera Path. The points seem to be well calculated in 3D space (see figure below) when you compare then only to the image sequence. However, after the next step we will notice that they are not

calculated so good! The point model is distorted because of insufficient camera movement and wrong camera parameters.



Orientation Window

In the following section of this tutorial we will insert 3 reference frames, which have been taken with a different camera than the sequence. If you are not interested in the details, you can skip the following section and load the project “vicky2.3de” instead.

Adding Reference Frames

To add a new reference frame to the current project, please select the menu item Main Window::Frames::Insert Reference. The requester Create Reference Frame is opened. Please press the button Browse and choose the file “/usr/3dequalizer/tutorial/vicky/ref_vicky1.jpg” from the file requester. Confirm your selection and close the requester Create Reference Frame by pressing Ok.

Please add the two additional reference frames “ref_vicky2.jpg” and “ref_vicky3.jpg” to the project in the same way.

As already mentioned above, these reference frames have been taken with a camera different from the one used for taking the image sequence, namely a photo camera. We have to tell 3D-Equalizer about this, and therefore please open the Projects Settings requester by selecting Main Window::Options::Project Settings and activate the toggle Extra Reference Camera.

Now please open the Zoom Window and set the screen points of point 03, 05, 01 and 02 on the respective markers in each of the reference frames (see figure below).

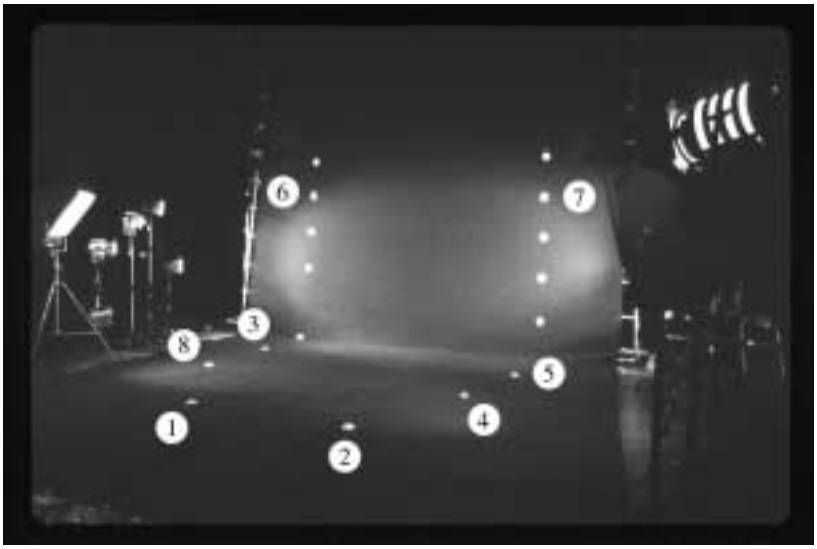


Image courtesy of Silicon Studio L.A.

Markers 1-8

Specify the FOV for the reference frames using the MB1 while holding down the Ctrl key.

Finally, we have to specify the reference camera parameters. For this purpose, please open the Camera Adjustment Window and set the selector Camera to Reference. The filmback width for a photo camera is 3.6 cm and a focal length of 25 mm was used to take the pictures. Furthermore, set the film aspect to “1.5” and the lens distortion to “0.0”. These settings should give us good results.

Adjusting Reference and Sequence Camera

Now please select the menu item Main Window::Calc:Force Calc to let the system re-compute the 3D camera motion path along with the point positions again. Please increase the size of the Main Window to its maximum, activate the toggle Options::View::Show Dummies and go to the last reference frame “ref_vicky3.jpg”. When you examine the image, you will notice small green dots near the tracked markers. These green dots represent the reconstructed point

positions in 3D space. It's easy to see, that they hardly match the respective markers (see figure below). The reason for this mismatch is a distorted poin model!

Image courtesy of Silicon Studio L.A.

Distorted point positions

Please open the Zoom Window and set the screen points of the remaining points 04, 08, 06 and 07 on the respective markers for each of the reference frames or simply open the project "vicky3.3de".

Re-compute the 3D camera motion path and point positions by selecting the menu item Main Window::Calc:Force Calc. Go back to the last reference frame "ref_vicky3.jpg" and take a look at the "green dots" again. They match better now, but not yet good enough.

Please open now the Status Window. The average pixel deviation of the image sequence is about 0.7 pixel and the deviation of the reference frames ranges from 2.5 to 8.0 pixels.

Let us try to improve our camera data, so please open the Camera Adjustment Window and set the selector Camera to Reference. Choose Fine Adjust for the Focal Length selector and press the Adjust button. 3D-Equalizer will try to improve the reference camera. After 9

attempts, 3D-Equalizer has calculated a new Focal Length of 25.5, which is nearly the same value.

If you check the “green dots” and the Status values again, you will find no improvement. So, please go back to the Camera Adjustment Window and set the Camera selector to Sequence. Choose Unknown for the Horizontal Angle selector and press the Adjust button. 3D-Equalizer now will try to improve the sequence camera. After 24 attempts, the horizontal angle has been corrected to 26.4.

Please open the Status Window. The average deviation of the image sequence is now 0.13 pixel and the deviation of the reference frames now ranges from 0.57 to 1.43 pixel. These value are quite good.

When you examine the “green dots” in the reference frames and also in the image sequence, you will find that the points now match the markers. As you see, the point positions are much more precise now, due to the use of reference frames!

Image courtesy of Silicon Studio L.A.

Accurate point positions

Selected Topics

Tracking

A point which has been designated in three-dimensional space and which has been entered in the Points Window should be represented on the screen by screen points for as many frames as possible. This is usually done by setting the screen points for a sufficient number of frames (keyframes) and using tracking techniques in order to determine their position on the screen for the intermediate frames as well. In the current release 3D-Equalizer provides two methods for doing this, namely motiontracking and markertracking. The modes of operation for these methods are similar, but the application is different. Before pointing out the differences and the limits of applicability we shall discuss in detail the mode of operation.

Search pattern and search area

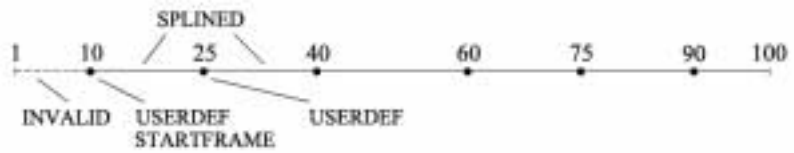
The basic principle of tracking a point can be described as follows. The user fixes the position of a screen point in a given frame, say frame j, by clicking the left mouse button in the Zoom Window. If the toggle Zoom Window::Options::Show Tracking Area is activated, the search pattern (solid line) and the search area (dotted line) are displayed in the Zoom Window display. The areas can be modified as decribed in the chapter “Tutorial 1”, section “Creating Screen Points”.

The program tries to localize the search pattern specified in frame j by scanning the search area around the pre-determined point in frame j+1 with the search pattern. In the requester Modify Point... (opened by pressing Points Window::Modify...) the selector Trackingmode specifies whether marker- or motiontracking is going to be performed. When the selector Colormode is set to Grayscale, the search pattern and search area are transformed into black-

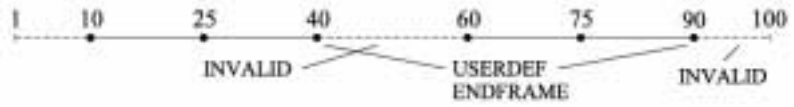
and-white images before being matched. In general this mode is sufficient. Otherwise the selector can be set to Truecolor. In this case all three colour channels are used for matching the patterns, and the results are combined appropriately. In this mode tracking takes more time.
The tracking procedure can be supported by the functionality of the Image Control Window (opened by activating Main Window::Windows::Image Controls). The preconditions for markertracking are described in the section “Markertracking”.

Valid and invalid screen points

Assume you are given a sequence of 100 frames and you want to track a point of a moving object. For some frames the point may be covered by any obstacle, so that it cannot be tracked. The point may be visible from frames 10 to 40 and from 60 to 90, and invisible for frames 1 to 9, 41 to 59, 91 to 100, for what reason ever. Now you set keyframes for instance at frames 10, 25, 40, 60, 75, 90. The first keyframe of the point is automatically defined as startframe. The situation may be visualized by the following diagram:



Since in the intermediate frames no information about the screen point is available, 3D-Equalizer uses some interpolation procedure in order to generate a screen point position, thus setting the screen point motion curve to a well-defined state. Since we do not have any information at all about frames 41 to 59 and 91 to 100, the screen points for these frames should be defined as invalid. This can be done by transforming the screen points of frames 40 and 90 into endpoints (see also End Point, Zoom Window). Frame 60 is now a startframe of the point, and the situation is now:



When the point is tracked, the setting of the parameter Trackingmode (requester Create Point..., Modify Point...) is taken into account. We shall consider the case that it is set to Forward & Backward, since all other cases are logically contained therein. When the automatic tracking procedure is started (see also Track, Zoom Window), 3D-Equalizer begins at frame 11, and an intermediate situation of the screen point key-states is:

The screen points which are tracked carry now the key-status forward. Having tracked frame 89, the same procedure is done in the reverse direction.

The screen points which carried the key-status forward are now transformed into tracked. The results from tracking forward and tracking backward are combined appropriately. The final situation is

According to our experience the mode Forward & Backward (!) is the most appropriate one for motiontracking, since in this mode any discontinuities of the screen point motion curve resulting from error accumulation in stepping from a tracked frame to a keyframe can be avoided.

It may occur that you wish to correct the screen point position for any frame by hand or insert another keyframe, because in the tracking procedure, the program has lost the track. If you insert a keyframe for instance at frame 30 the situation becomes

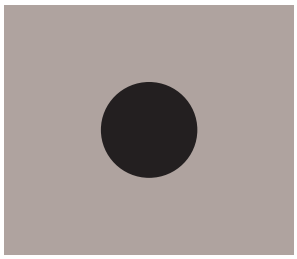
When the automatic tracking procedure is started, 3D-Equalizer will handle frames 26 to 29 and 31 to 39 once more, running again into the final situation mentioned above. A similar behaviour occurs when a userdefined screen point is modified or removed.

Markertracking

In the following, the peculiarities of the markertracking procedure are described. In order to do this, we have to clarify what we understand by a marker in the framework of 3D-Equalizer.

Let us consider a surface with a spot on it. We call this spot a marker if

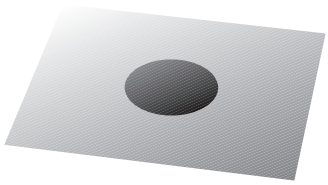
- the spot is unicoloured and point-symmetric,
- the spot is point-symmetric (only for calculation mode *Distance Constraint Method*)
- the surface is unicoloured and non-curved (i.e. flat).



Example of a marker

If you use a marker in the real scenery for designating a point, it is important to know the center (physically speaking, the center of mass) of the marker. When a marker is going to be used as a designated point, its distance to other points must be measured in order to specify the distance constraint. A distance of two markers must be measured from center to center. For point-symmetric spots this center can easily be found.

The surface may be illuminated, so that it does not appear to be unicolored or to have a uniform luminosity, as shown in the figure below. Nevertheless markertracking can be applied, since 3D-Equalizer is able to compensate non-uniformities of this type within certain limits.

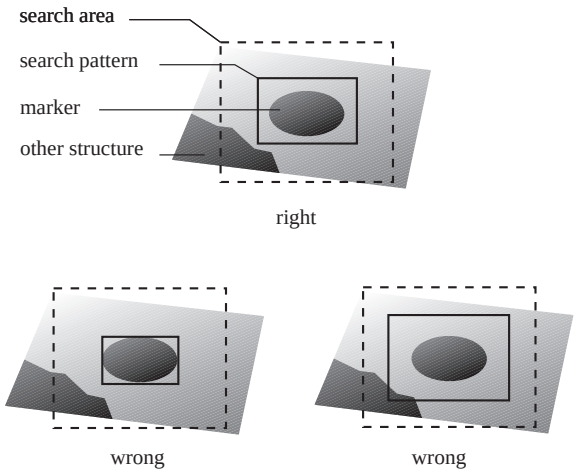


A non-uniformly illuminated marker

When you specify the search pattern for tracking a marker, you should do this as shown in the following figure. The two conditions which must be fulfilled, are:

- The marker must be entirely contained in the search pattern and should not touch the search area borders.
- In the search pattern there should be nothing else but the marker and the surface to which the marker is attached.

The search area is specified as in motiontracking.



Tracking a marker

Now the procedure is clear: 3D-Equalizer tries to recognize the search pattern of one frame within the search area of the frame currently being tracked. When the area (which contains the marker) is found, 3D-Equalizer calculates the center of the marker, thus completing the tracking procedure of this frame.

Applicability

As you have seen, markertracking is applied in very special situations, namely in presence of unicoloured markers on unicoloured surfaces, whereas motiontracking can be applied to each structured image. So, why should markertracking be used at all?
The advantage of markertracking is the greater precision in contrast to motiontracking. In a motiontracking procedure sooner or later the deviation of the screen point from its „true“ position becomes too big due to error accumulation. The position of the tracked screen point

in the current frame extremely depends on the position of the screen point in the previous frame.

The markertracking procedure is based on template matching of neighbouring frames as well. However, in each frame the center of the marker can be found without recourse to the previous frame. Thus, the position of the screen point in the current frame does not change when the screen point of the previous frame is placed at a slightly different position. One could say markertracking is more stable as time elapses (if the conditions of markertracking are fulfilled, of course).

The tracking procedure may fail under the conditions given in the following. Motiontracking does not work at a satisfying precision under the following circumstances:

- The luminosity contrast of the search pattern is too weak.
- The image within the search pattern is subject to extreme deformations. This can occur, when the camera or the object at which the point is designated perform rapid rotations around the direction-of-view axis.

Markertracking fails to work at a satisfying precision if:

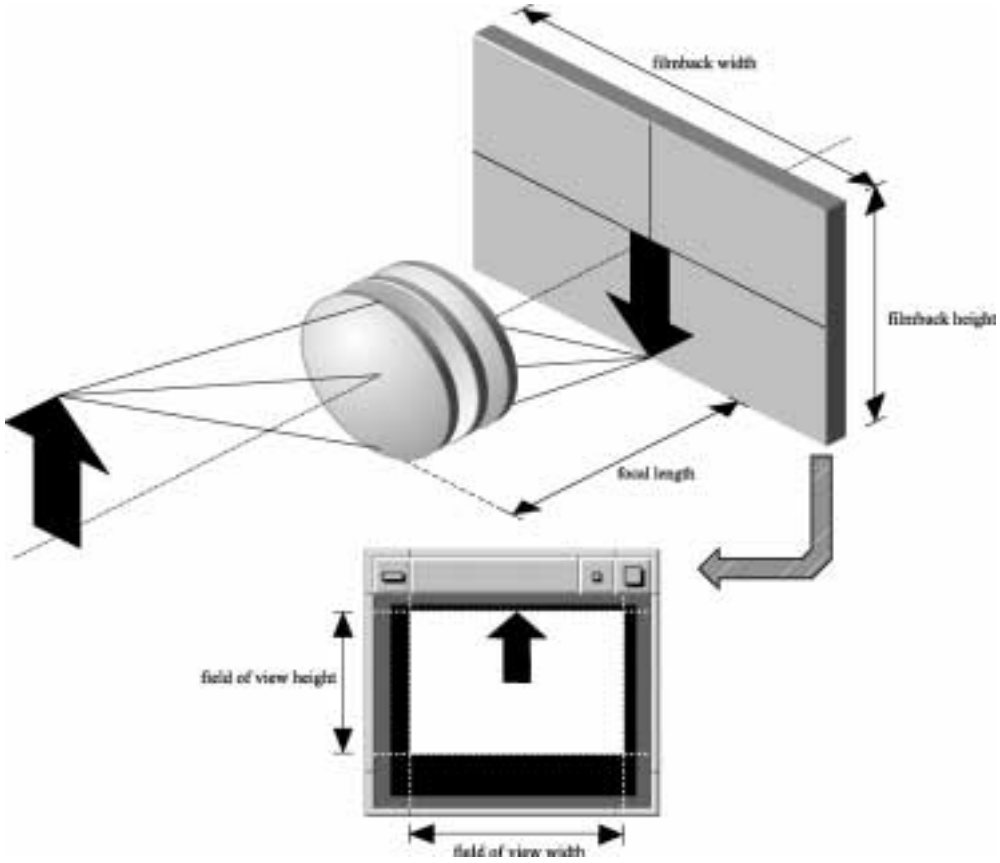
- the marker does not fulfil the conditions specified in the section “Markertracking”.
- if the luminosity contrast of the marker on the surface is too weak.

Camera Adjustment

In the following the terms *focal length, filmback width, filmback height, field of view width, field of view height* which arise in connection with 3D-Equalizer, camera optics and digitizing are illustrated.

Camera models

A highly simplified model of a realistic camera is shown in the figure below. It essentially consists of a lens turret and the filmback.



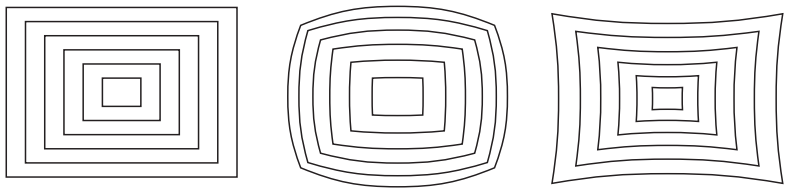
Real camera geometry

In terms of the ray model of light, each point of the recorded object is the origin of a bundle of light rays, which pass the lens turret. If the rays meet in one point on the filmback the turret is well-focused with respect to the object. In the case of a film camera the filmback is a piece of celluloid. In the case of a modern video camera it might be a CCD chip. Abstractly speaking, we visualize the filmback as a rectangular shape in the focal plane of the camera, to which the recorded image is projected. It has a width and a height, measurable in common length units (not in pixel). We do not need to consider here the details of digitizing and data compression and storage.

In connection with 3D-Equalizer's reconstruction procedures it is very important to maintain this one-to-one correspondence, and therefore the field of view should be specified with great care, as well as the filmback should be carefully specified by the user or calculated in 3D-Equalizer's automatic camera adjustment procedure.

A realistic lens system can exhibit several optical errors such as chromatic error, vignette, nonlinear distortion. Among these only the nonlinear distortion is significant for our purposes. More precisely, it is only important to know, that 3D-Equalizer is able to compensate this kind of error within certain limits. The barrel-type distortion usually appears when a panorama lens is used. There are slight distortions in almost each lens turret. Usually, the higher the quality of the lens turret is, the smaller is the distortion (maybe except for special effects lenses). The figure "Nonlinear distortion" shows - slightly exaggerating - the influence of nonlinear distortions on a square-shaped object.

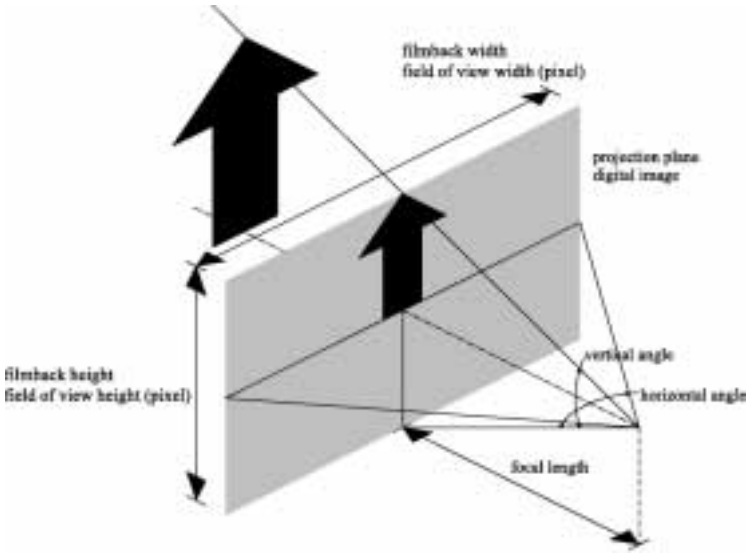
The next point of interest is the output device (namely the display field of the 3D-Equalizer Main Window) used for displaying the recorded images. We shall assume here, that the entire image has survived the process of digitizing, i.e. there is not cropping at the borders of the image. On the filmback one can associate a width and a height in length units to the image. The representation on the screen leads us immediately to the term field of view. The field of view is the rectangular area on the screen, which defines precisely the borders of the images. It is measured in pixel by pixel. The parameters filmback width and height are closely related to the parameters field of view width and height. The field of view, i.e. the image displayed in the Main Window display must correspond to the image on the filmback. In other words, the field of view is the representation in pixel by pixel of the filmback in length unit by length unit.



Original image *barrel-type distortion* *pillow-type distortion*

In connection with 3D-Equalizer the realistic camera can be replaced by a simple model as shown in the figure below, which contains the parameters filmback width, filmback height, focal length (the nonlinear distortion is taken into account as well, but it is not visualized in the figure). In the case of well-adjusted field of view and filmback you can think of the image plane as the filmback in length units on one hand and the field of view in pixel on the other hand. Thus, if you sit exactly in front of the computer monitor your eye corresponds precisely to the camera.

An important parameter arising in connection with the filmback and the field of view is called the pixel aspect. In the section “Examples of pixel aspect” you will find some details about this quantity.



Simplified camera geometry

Adjustment procedure

One of the most important points in camera tracking is to know the precise geometry of the camera. As you know, there are two different types of frames in 3D-Equalizer, namely sequance frames and reference frames. In the current version both groups of frames can either be recorded with the same camera or with different cameras. The Camera Adjustment Window provides the functionality to adjust both of them, if there is enough perspective information in the respective set of frames. The interaction components are the same for sequence and reference frames, and therefore in the following we shall consider the adjustment procedure for sequence frames in detail.

In the Camera Adjustment Window you see a list of ten parameters that describe the camera model (if you cannot see them all magnify the window or use the slider on the right to become aware of the full splendour of this window). Some of these parameters are related to others by mathematical equations. At first sight the large amount of parameters might be shocking because usually you will at most know a few of them. However, among all these parameters only four (or three as you will see) are significant.

You may have noticed, that some of the parameter text fields are pink while others are grey. According to the guidelines used in the entire user interface of 3D-Equalizer you can only enter values in the pink fields. In the Camera Adjustment Window the colours are used to tell apart the camera parameters which determine the camera and those that are dependent of them.

The basic technique to find an appropriate camera the following: try to find out as much information as possible about the camera and about the digitizing equipment. Set the selectors of the parameters that you do not know to UNKNOWN. The text fields turn into some ugly muddy pink. You may try to enter values in these fields. Since you signalled to 3DE that you do not know the corresponding parameter 3DE will immediately set this field to a value which the software developers found most reasonable.

The Camera Adjustment Window will only allow certain combinations of pink and grey fields, therefore it is not possible to get them all pink. This guarantees that the values in the fields always represent a consistent camera geometry, even if it does not yet necessarily represent the one you used for recording the scene.

Set the selectors right to the parameters that you know precisely to FIXED. You will notice that the corresponding text fields turns into some more friendly pink. You should enter the values in the text field.

Set the selectors of the parameters you are not quite sure about to FINE ADJUST and enter what you think might be the correct value.

By fixing the selectors you specified the parameters on which the camera is based. All remaining grey fields are dependent of the pink ones. For example you will never see that film aspect and pixel aspect are pink (or muddy pink) at the same time: specifying one of them automatically determines the value of the other one.

Here is another example: focal length, filmback height and vertical angle cannot be pink at the same time because each two of them determine the third one. The same is valid for focal length, filmback width and horizontal angle.

You may be tempted to set as many selectors as possible to UNKNOWN. However, this increases the processing time dramatically. A better strategy is to think about the parameters and follow the above procedure.

The grey text field underneath the camera parameters displays information about what is going to happen when you press the button Adjust. You may read it or ignore it, as you like. If you want to know more about the parameters and their selectors you can try out a few settings of the selectors and see what message appears in the text field.

Let us consider the following example. Set the selector Horizontal Angle to „FINE ADJUST“, the selector Vertical Angle to „UNKNOWN“, the selector Focal Length to „FINE ADJUST“ and the selector Lens Distortion to „UNKNOWN“. Then in the text field the following messages appear:

Calculation level „Unknown“ (large search interval):
filmback width vertical angle lens distortion

focal length will be fixed by definition.

Calculation level „Fine Adjust“ (small search interval):
filmback width vertical angle lens distortion

When you press the adjust button, filmback width and vertical angle will be determined roughly, thereafter the lens distortion will be calculated roughly as well. Afterwards the focal length will be fixed by definition (10mm), and finally filmback width, vertical angle and lens distortion will be determined as precise as possible.

The actual adjustment procedure can be described as follows: First you have to decide how precise you want to determine the camera. There are two parameters which determine the level of precision, namely the precision slider in the Camera Adjustment Window and the parameter „Point Finetuning“ in the requester „Edit Project Settings...“.

The meaning of the precision slider is quite easy to understand: it simply determines how many frames are taken into account for adjusting the camera. When it is set to the right most position all frames are taken into account. When it is set to the left 3DE chooses a set of frames for the adjustment. As soon as your production comes to an end you should choose the highest precision and perform a fine adjustment.

In order to understand the parameter „Point Finetuning“ imagine the following situation: your sequence consists of many frames, and many points come in and out of the screen. While 3DE calculates the positions of the points it performs some kind of „over all finetuning“ from time to time. The „Point Finetuning“ specifies how many of these finetuning cycles are performed during the procedure. Therefore, if your sequence looks as described above, the number of point finetuning cycles should be increased. For sequences with a minimum of points (six) the value 5 is a quite good default value.

When you press Adjust a requester that displays the current status of the calculation appears. The form of the message depends on the „calculation level“, whether if the system is trying to determine parameters with „FINE ADJUST“ or „UNKNOWN“ setting. As you can see in the grey text field the „UNKNOWN“ parameters are always treated before the „FINE ADJUST“ parameters.

Calculation level „Unknown“

Let us consider the case that one or more selectors are set to „UNKNOWN“. The requester contains a line

Attempt: x/y Deviation a.aaaa pixel (Best: b.bbbb)

That means, 3DE has done its x-th attempt out of a total number of y attempts in order to determine the parameters roughly. The result was a pixel deviation of a.aaaa pixel and the best value up to now was b.bbbb pixel. A calculation of two or three unknown parameters can take a long time. However, after 30-50 % of the total number of attempts, 3DE will usually have found a quite acceptable result. If this is the case you can decide if you want the system to go on searching or if you terminate this calculation level and go on with the fine adjustment.

Calculation level „Fine Adjust“

The message for the case of fine adjustment is similar:

Attempt: x Deviation a.aaaa pixel (Best: b.bbbb)

Again, x indicates howmany attempts have been done. However the overall number of attempts is not yet known to the system. There is a maximum number of attempts in order to keep the processing time finite, but when the system reaches the limit of calculation precision earlier the procedure may also terminate. As soon as you notice that the pixel deviation only changes slightly (e.g. 0.001 or less) you may terminate the procedure by hand. As general rules for the processing time simply keep in mind:

- three parameters take more time than two parameters take more time than one parameter,
- „UNKNOWN“ parameters take more time than „FINE ADJUST“ parameters,

Examples of pixel aspect

In many cases in which you do not know the pixel aspect there are ways to find it out by „guessing“.

Let us assume your images have a size of 720x576 pixel and come from a PAL/SECAM video camera. In this case your pixel aspect is usually 1.06667. This is the case when you have done the digitizing e.g. with Flint/Flame/Inferno. Or maybe the images have a size of 768x576 pixel. This might be a PAL/SECAM image with a pixel aspect of 1.0.
As a third example we consider the case of a size of 720x486 and you are working on NTSC images. Then the pixel aspect will probably be 0.9.

Finally, if your images come from a film scanner, the pixel aspect will often be 1.0, although other pixel aspects may occur as well.

Again, if you are not quite sure, try to adjust the camera by setting the selector to „FINE ADJUST“ and press adjust.

If you do not have any idea for the pixel aspect, maybe you know the film aspect. Most PAL/SECAM video cameras have a „film“ aspect of 4/3 = 1.333333. Many cameras for taking photographs have a film aspect of 3/2 = 1.5. This could be an important information if you are using digitized photographs as reference frames. When you enter the film aspect the pixel aspect is a <dependent> variable and therefore calculated by 3D-Equalizer.

How to guess the lens distortion

What do we know about the lens distortion? First of all there are „tricky“ lenses that use lens distortion as a means of artistic expression. This case is difficult. If your lenses are made for such recordings you should carefully set up test projects (good markers, high contrast, smooth camera movements, a lot of perspective information) and let 3DE find it out.

In most of the sequences you are going to handle with 3DE the lens distortion will be small, between 0.00 (excellent camera) and 0.08 (custom handy cam with short focal length). Rarely, the lens distortion will be slightly negative (pillow type distortion). There are general rules for the lens distortion (except for special effects lenses):

1. The shorter the focal length is, the bigger will be the lens distortion,
2. The more expensive the lenses are, the smaller is the lens distortion,
3. The more expensive the lenses are, the more angry get the lens manufacturers when you ask them: „Do your lenses have a nonlinear distortion?“. Independent of the price, the answer will be „No!“

When 3DE finds that the lens distortion is non-zero this does not necessarily mean that it is actually non-zero. It only means that for this particular sequence the tracking data are more compatible to a non-zero distortion camera. If this is contradictory to your experience (e.g. because the lens was incredibly expensive) set the value to zero and the selector to „FIXED“.

Adjustment of the reference camera

In practice it is useful to take reference frames with a camera different from the one used for recording the sequence frames. This might be the case when the sequence camera is unwieldy or part of a bigger mechanical installation, so that it would be difficult to move it to another point of view.

Photographs as reference frames

The reference frames can be provided e.g. by means of high resolution digitized photographs. In this case usually you will know many of the parameters of the camera.

Although it is possible to have different sequence and reference cameras please take into account that 3DE expects all reference frames to be taken with the same camera (more precise: with the same camera geometry). It is necessary to impose this condition in order to obtain the required precision when the calculation of the points is based on reference frames.

The rules for estimating parameters of the sequence camera can be applied to the reference camera as well. The reference camera can be adjusted by 3DE as well as the sequence camera described above. Since usually there are much less reference frames than sequence frames there are limits which and how many of the parameters can be calculated. The general rules are

1. The more reference frames are used, the more precise the reference camera and the points can be calculated by 3DE.
2. The more common points ar contained in the reference frames, the more precise the reference camera and the points can be calculated by 3DE.

Minimum requirements

To use the concept of reference frames you will need at least two of them containing at least six common points. When these minimum requirements are fulfilled the points can be calculated. If you want 3DE to calculate the parameters of the reference camera you should take into account that it is almost impossible to calculate more than one parameter if only the above minimum requirements are fulfilled.

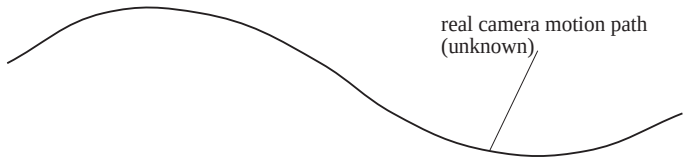
Generally it is problematical (ore even impossible) to let 3DE calculate the focal length for the minimum requirements, although we have examples for which this works as well. We have done tests with one of the tutorial sequences. 3DE was able to calculate the following parameters (in case the others are fixed and correct):

- horizontal angle
- vertical angle (very unprecise)

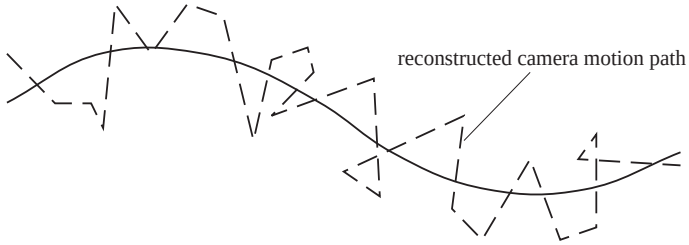
Important note: If you are using different cameras for the reference and sequence frames you should determine the reference camera first and the sequence camera afterwards.

The Concept of Postfiltering

The purpose of this section is to outline some aspects of 3DE's postfilter functionality. Let us consider the following situation: assume you are recording a real sequence. The camera motion (position) path will be a more or less smooth curve in three-dimensional space. We visualize this path by a solid line as follows:

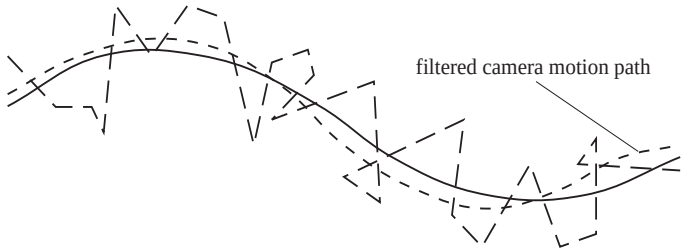


When 3DE reconstructs this motion path by evaluating the tracking curves of the points, the result could look like this:

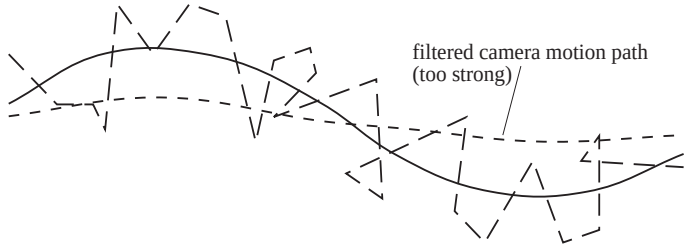


The magnitude of the fluctuations of the reconstructed path depends on the quality of the tracking curves and on the relative alignment of the points in three-dimensional space with respect to the camera. In the tutorial "Stabilizing" you may have seen this dependency in detail. Now the idea of postfiltering is the following: In the reconstruction procedure the information of "smoothness" of the real camera motion path obviously gets lost. The task of a postfilter is to restore this information without falsifying the reconstructed motion path too much. 3D-Equalizer does this by means of a Fourier analysis and synthesis: the camera motion path is considered as a superposition of periodic movements of many different frequencies. When the motion path is jittered, there are a lot of high frequency movements which contribute to the path in an uncontrollable manner. Fourier analysis means to find out the strength (amplitude) of each frequency. Filtering by means of Fourier synthesis means to recombine many of the frequencies, but to leave out the high, disturbing ones. The more higher frequencies are left out, the smoother becomes the filtered motion path. The highest frequency to be taken into account is called the "cut-off"-frequency (because all higher ones are cut off). In the requester Edit Postfilter Settings... the cut-off frequency is represented by the slider Strength.

The following figure shows an example of a good filtered motion path. However, in practice one cannot know whether the real motion path and the filtered motion path are so close together. This fact represents the difficulty of finding the optimal value for the slider Strength.



The next figure shows a filtered motion path that could have been created with a value for the slider Strength which was too high. The filtered motion path is smooth, but its coincidence with the real camera motion path is even worse than the one of the reconstructed motion path.



Rules for points and constraints

The aim of this section is to give a detailed description of the rules, which must be fulfilled by the set of points and constraints in order to do a perspective adaptation using the calculation mode *Distance Constraint Method* (see also: Edit Project Settings...). The most fundamental rule is: no two points may be at the same position in three-dimensional space, i.e. no distance constraint must be zero. The more complicated rules can be separated into three levels. Each level is contained logically in the next higher one. In the following description calculating a frame means reconstructing camera position and orientation for this frame.

Remarks

If a point is calculated, i.e. its position reconstructed in three-dimensional space, the status CALCULATED appears in the Points Window and in the Status Window. If a point is primary (as explained below) the status PRIMARY appears in the Points Window and in the Status Window. If a point is secondary (as explained below) the status SECONDARY appears in the Points Window and in the Status Window.
If a frame is calculated the status CALCULATED appears in the Status Window.

Level 1 rules: four points

The level 1 rules are those already used in the tutorial sequence. There have to be four points and six distance constraints connecting all the points. The points must have screen point representations in each frame. No three points should lie on a line. The four points should either lie in a plane so that a plane constraint can (and should) be defined, or they should be well-extended in three-dimensional space.

If the above conditions are fulfilled, each of the four points can be calculated and is defined as primary point. Each frame can be calculated as well.

Level 2 rules: four or more primary points

In some cases it may be difficult to designate four points, which are visible during the entire sequence. In principle such a case could be handled by splitting the sequence into subsequences and handling each subsequence according to the level 1 rules. However it is possible to handle the entire sequence by designating more than four points if the rules described hereunder are payed attention to.

We now assume that there are four or more points. Furthermore, there is one frame in which four points have screen point representations and all these four points are connected by six

distance constraints. 3D-Equalizer will find such a frame. We call these four points and six constraints the root tetraeder and the corresponding frame the root frame. When the root frame is found, the points of the root tetraeder are calculated. The root frame is calculated as well, i.e. its camera is reconstructed.

Starting from the root frame (in both directions, forward and backward in time) 3D-Equalizer tries to calculate the remaining points. The following two rules are then applied alternately by the program.

- A point X can be calculated, if there is a calculated frame containing four calculated points and point X as well, and if X has at least three distance constraints with calculated points in this frame. These three constraints should be well-extended in space, or they should lie within a plane. In this latter case a plane constraint should be declared for point X.
- A frame can be calculated, if there are at least four calculated points.

After the two passes starting at the root tetraeder (forward and backward), all points, which have been calculated in this way, are called primary points.

Level 3 rules: primary and secondary points

A root tetraeder may be given as described in the previous section. The points which cannot be calculated as described in the level 2 rules are called secondary points.
The following two rules are applied alternately by the program after applying the level 2 rules.

- A secondary point can be calculated, if there are at least two calculated frames, in which the secondary point has a screen point representation. In order to calculate the secondary point at a satisfying precision, it is recommended to choose frames with different directions of view. If this is not possible, then reference frames (see section “Reference Frames”) should be used.
- A frame can be calculated, if there are at least four screen points of calculated points (primary or secondary).

The level 3 rules describe the most general case of points and constraints which can be handled by the current release of 3D-Equalizer.

Plane constraints

A plane constraint will be taken into account in 3D-Equalizer’s reconstruction procedures, if it contains at least four calculated points (primary or secondary). In the current release of 3D-Equalizer each point can be involved in at most one plane constraint. The rules for points and constraints are not affected by the plane constraints.

Reference Manual

The purpose of this chapter is to give a complete description of 3D-Equalizer's features, listed window by window. A menu is opened by pressing ALT-shortcut. A menu item is selected by pressing the shortcut without the ALT-key.

Main Window

Provides all menus and functions for handling sequence frames and reference frames.

Miscellaneous

Sequence Frames and Reference Frames

The basic task for which 3D-Equalizer has been created is the perspective adaptation to real sequences. The real sequence consists of sequence frames. However, in some cases the information about the three-dimensional arrangement of the real environment encoded in the sequence frames may not be sufficient for reconstructing the camera motion path, the camera geometry or the secondary points. In order to handle these cases the developers introduced the concept of reference frames. Reference frames are additional frames which are employed by 3D-Equalizer for reconstruction procedures. In order to profit from this feature, the reference frames should view the scene of interest from various points of view, containing as many of the points as possible.

It is possible to record the reference frames with a different camera than the sequence frames (see also Project Settings).

Functions for adding and removing reference frames are provided in the menu Frames. The sequence frames are handled under the menu item Sequence Settings of the menu Options.

The display

The Main Window display field displays the sequence and the reference frames depending on the setting of the switch Sequence/Reference. The field of view borders are displayed depending on the setting of Show FOV. Furthermore the screen points are shown. If Show Point Names is active the point names and information text are displayed as well. If Show Dummies is active the dummies created and arranged in the Orientation Window are displayed in case the camera position and orientation for the current frame have been reconstructed. When the Zoom Window is open, the cutout area displayed there can be localized by holding the middle mouse button and moving the mouse in the Main Window display.

Main Window

Keys

CURSOR-LEFT and CURSOR-RIGHT are used for jumping forth and back in the sequence according to the setting of Frame Keyboard Grid. CTRL-CURSOR-LEFT and CTRL-CURSOR-RIGHT are used for going forth and back by one frame. CURSOR-UP and CURSOR-DOWN are used for selecting points. PAGE-UP/PAGE-DOWN jumps to

the previous/next keyframe of the currently selected point. HOME/END jumps to the first/last sequence or reference frame.

Status line „Frame:...“
Contains the filename of the current frame.

Sequence/Reference
Switches the display between reference and sequence frames.

Begin
Jumps to the first sequence or reference frame.
shortcut: HOME

End
Jumps to the last sequence or reference frame.
shortcut: END

Frame -1,Frame +1
Steps back/forth by one frame in the sequence or in the list of reference frames.
shortcuts: CTRL-CURSOR-LEFT, CTRL-CURSOR-RIGHT
see also: Sequence/Reference

Frame slider
Used for moving within the sequence or reference frame list. While moving the slider, the screen points are displayed. The frame is displayed as soon as the slider is released. The number of the current frame is displayed above the knob. It always ranges from 1 to number of frames, regardless of the numberation of the sequence frame filenames. In the requester Edit Sequence Settings the sequence may be specified by Start = 50, End = 250, Step = 2, corresponding to the filenames myimage.0050, ..., myimage.0250. Then there are 101 frames, and frame nr. 1 corresponds to frame filename myimage.0050, and frame nr. 101 corresponds to myimage.0250.

Menu: Project

Project handling and export functionality.
shortcut: ALT-p

New
Sets up a new project. The window configuration is set to its default.
shortcuts: n, CTRL-n
see also: Set Default Window Configuration

Open

Opens a standard file requester Open New Project. The default directory can be specified in Option::3DE Preferences::Projects.
shortcuts: o, CTRL-o

Save

Saves the current project. The default directory can be specified in Options::3DE Preferences::Projects.
shortcuts: s, CTRL-s

Save As

Opens a standard file requester Save Current Project As. In case of existing preview or cache movie(s), the system asks the user to copy the movie files too. The default directory can be specified in Options::3DE Preferences::Projects.
shortcut: a

Export

Several export functions.
shortcut: e

A|W PowerAnimator...

Opens a requester Export A|W PowerAnimator...
shortcut: p

SoftImage 3D..

Opens a requester Export SoftImage 3D...
shortcut: s

A|W Explore...

Opens a requester Export A|W Explore...
shortcut: e

Flame, Flint...

Opens a requester Export Discreet Logic Flame, Flint...
shortcut: f

Prisms, Houdini...

Opens a requester Export Prisms/Houdini...
shortcut: h

3D Studio Max 2...

Opens a requester Export Kinetix 3D Studio Max 2...
shortcut: m

A|W Maya...

Opens a requester Export A|W Maya...
shortcut: y

Custom...

Opens a requester Export Custom Filter...
shortcut: c

Delete Movies...

If the preview and/or the cache movie are not longer needed, they can be deleted by the use of this function. A requester is displayed, asking for the movie to be deleted.
shortcut: d

Exit

Leave the program.
shortcuts: x, CTRL-q

Menu: Frames

Handling sequence and reference frames.
shortcut: ALT-f

Jump...

Opens a requester Jump To Frame.
shortcuts: j, CTRL-j

Jump To Rootframe

Functions that jump to one of the two rootframes.
shortcut: r

Frame A

Jumps to the first rootframe.
shortcut: a

Frame B

Jumps to the second rootframe.
shortcut: b

Begin, End

Jumps to the beginning/end of the sequence/reference frame list.
shortcuts: b, CTRL-a, e, CTRL-z

Insert Reference

Opens a requester Create Reference Frame...
shortcut: i

Copy to Reference

The current sequence frame is copied and inserted as an additional reference frame. All point tracking information are copied as well.
shortcut: c

Modify Reference

Opens a requester Modify Reference Frame...
shortcut: m

Delete Reference

Removes the current reference frame from the project. The selector Sequence/Reference in the Main Window must be set to Reference.
shortcut: d

Set Rootframe

The user can specify the rootframes by hand, if the option “Determine Rootframes Automatically” in the requester “Edit Project Settings” Panel is disabled.
shortcut: e

Frame A

Define the current frame as the first rootframe.
shortcut: a

Frame B

Define the current frame as the second rootframe.
shortcut: b

Show Entire Frame

When the subload functions of the film version are activated, only the needed subarea of the image is loaded into the memory (see also Zoom Window). The function “Show Entire Frame” displays the entire frame in the Main Window.
shortcut: CTRL-x

Menu: Windows

Provides functions for opening/raising several windows.
shortcut: ALT-w

Zoom

Opens the Zoom Window.
shortcut: z

Points

Opens the Points Window.
shortcut: p

Constraints

Opens the Constraints Window.
shortcut: c

Camera Adjust
: Opens the Camera Adjustment Window.
shortcut: a

Image Controls
: Opens the Image Control Window.
shortcut: i

Orientation
: Opens the Orientation Window.
shortcut: o

Status
: Opens the Status Window.
shortcut: s

Preview
: Opens the Preview Window.
shortcut: v

Restore Windows
: Rearranges all windows to their default position, size and visibility.
shortcut: r
see also: Edit 3DEqualizer Preferences...

Menu: Options

Settings for project, sequence, preview, postfilter, motion blurring, keyboard, 3D-Equalizer preferences, software license and the Main Window display.
shortcut: ALT-o

Project Settings...
: Opens a requester Edit Project Settings...
shortcut: r

Sequence Settings
: Opens a requester Edit Sequence Settings...
shortcut: s

Preview Settings
: Opens a requester Edit Preview Settings...
shortcut: v

Postfilter Settings

Opens a requester Edit Postfilter Settings...
shortcut: f

Motion Blur Settings...

Open a requester Edit Motion Blur Correction Settings...
shortcut: b

Frame Keyboard Grid

Choose among off, 2, 3, 4, 5, 10, 15, 20, 25. The frame keyboard grid is taken into account, when the CURSOR-keys are pressed for jumping forth and back within the sequence.
shortcut: g

3DE Preferences

Opens a requester Edit 3DEqualizer Preferences...
shortcut: p

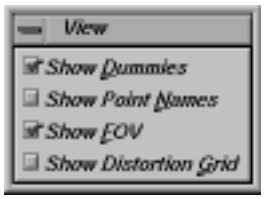
Software License

Opens a requester 3DEqualizer Software License...
shortcut: l

Camera Types

Opens a requester Edit Camera Types...
shortcut: c

View



Several toggles concerning the Main Window display.
shortcut: w

Show Dummies

If activated, the dummies are displayed in the Main Window display. The dummies can only be displayed, if for the current frame the camera position and orientation have been calculated successfully.
shortcut: d
see also: Orientation Window, Status Window

Show Point Names

If activated, the point names and the accompanying information text are displayed in the Main Window display besides the screen points.
shortcut: n

Show FOV

If activated, the field of view borders are represented in the Main Window display by dotted lines.
shortcut: f

Show Distortion Grid

If activated, the lens distortion of the calculated camera (depending on the selector Sequence/Reference) is visualized in the Main Window.
shortcut: g

Menu: Calc

shortcut: ALT-c

Force Calc

Start the main procedure of 3D-Equalizer. The reference and sequence frames are used in order to reconstruct the points positions in space and to determine the camera position and orientation with respect to the points. The calculation is performed every time the function is activated, regardless of the calculation status.
shortcuts: c, SHIFT-c

Requester: Export A|W PowerAnimator...

Exporting the reconstructed camera and points to Alias|Wavefront's PowerAnimator. A wire file is generated that can be easily retrieved starting with PowerAnimator V6 or higher. It may happen, that the retrieved points are not visible. In this case the far clipping plane must be increased (can be found in the camera editor).

Browse...

Opens a file requester. The filename of the wirefile to be generated must be specified.

Startframe

This number indicates at which frame the animation begins when it is loaded into PowerAnimator.

Coord. System

Choose among *Y up* and *Z up*. Should be set to the same setting as specified in A|W PowerAnimator.

Export Mode

Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Shift 1 Field

If interlaced frames are used there may be a time discrepancy of one field due to some misunderstanding of terms like even and odd fields or mixing up the different video standards used in Europe, Northern America or elsewhere. This toggle can be used in order to correct a mistake of this type a posteriori immediately before exporting to the animation package.

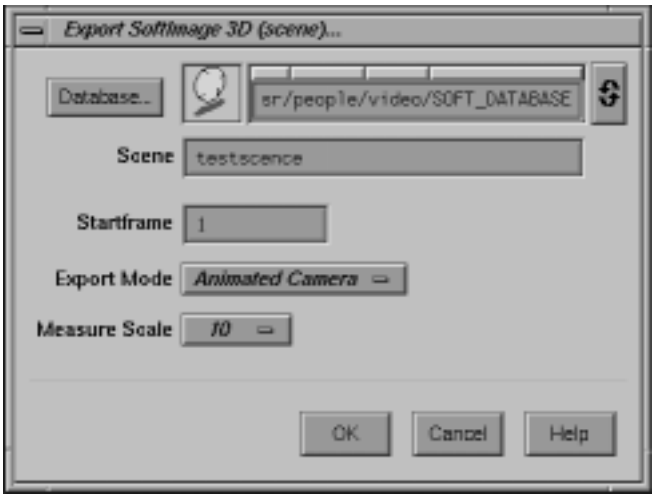
Ok

Causes the system to generate the wire file according to the settings of this requester.

Requester: Export A|W PowerAnimator...

Requester: Export SoftImage 3D...

Exporting the reconstructed camera and points to Microsoft's SoftImage 3D. A complete scene is generated that can be easily loaded starting with SoftImage 3D 3.7 or higher.



Requester: Export SoftImage 3D...

Database...
: Opens a file requester. The path to the database in which the scene should be generated, must be specified.

Scene
: Name of the scene.

Startframe
: This number indicates at which frame the animation begins when it is loaded into SoftImage.

Export Mode
: Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

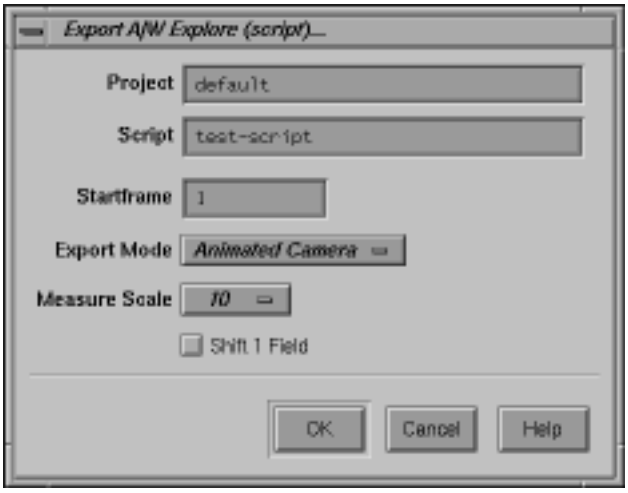
This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok

Causes the system to generate the scene according to the settings of this requester.

Requester: Export A|W Explore...

Exporting the reconstructed camera and points to Alias|Wavefront's Explore. A script file (with trajectory file) is generated that can be easily opened within the anim module.



Requester: Export A|W Explore (script)

Project

The name of the project into which the script file should be generated must be specified.

Script

The name of the script file.

Startframe

This number indicates at which frame the animation begins when it is loaded into Explore.

Export Mode

Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Shift 1 Field

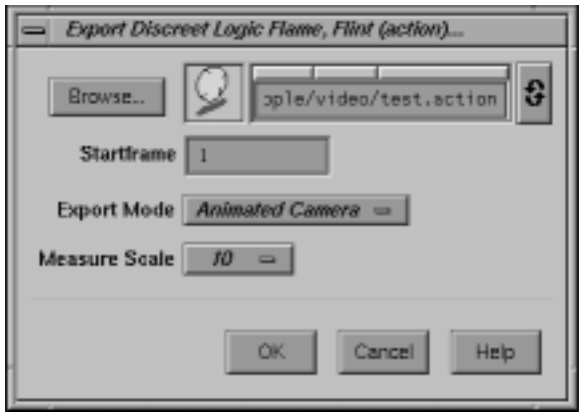
If interlaced frames are used there may be a time discrepancy of one field due to some misunderstanding of terms like even and odd fields or mixing up the different video standards used in Europe, Northern America or elsewhere. This toggle can be used in order to correct a mistake of this type a posteriori immediately before exporting to the animation package.

Ok

Causes the system to generate the script and the trajectory file according to the settings of this requester.

Requester: Export Discreet Logic Flame, Flint...

Exporting the reconstructed camera and points to Discreet Logic's Flame or Flint. An action file is generated that can be easily opened from the action module.



Requester: Export Discreet Logic Flame, Flint...

Browse...

Opens a file requester. The filename of the action file that should be generated must be specified.

Startframe

This number indicates at which frame the animation begins when it is loaded into the action module.

Export Mode

Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

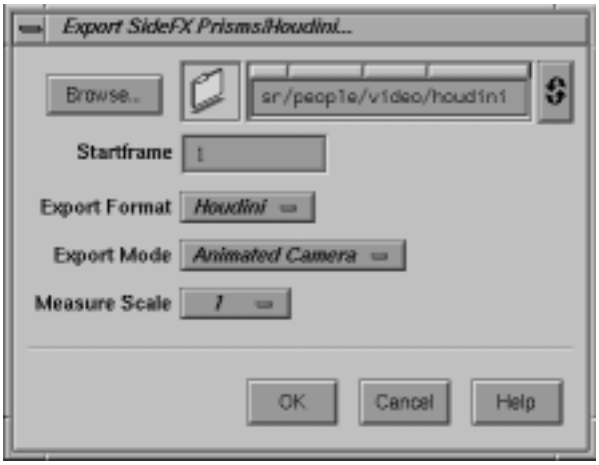
This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok

Causes the system to generate the action file according to the settings of this requester.

Requester: Export SideFX Prisms/Houdini...

Exporting the reconstructed camera and points to SideFX Prisms or Houdini.



Requester: Export Prisms, Houdini

Browse...

Opens a file requester. The filename of the action file that should be generated must be specified.

Startframe

This number indicates at which frame the animation begins when it is loaded into the respective animation package.

Export Format:

This toggle enables you to choose between the Prisms and Houdini export.

Prisms: An action command file and a channel file are generated. The action command file simply carries the name you enter in the text field (i.e. the standard suffix ".rc" is not added by 3DE). It is an ASCII file containing a sequence of commands. The channel file contains translation and rotation data of the camera/the points. It has the suffix ".chan". The files can be opened in Prisms as follows: First you should specify the parameters Start (frame), End (frame) and Length (of the sequence) in a way, so that the camera motion path from 3DE lies completely within this range. Enter the command "`rcread <mypath>/<myfile>`" in the shell "Side Effects Software Action". Prisms will then open the file (in this case "<`myfile`>") and add the channel data from the file "<`myfile`>`.chan`". Probably a lot of information will be printed out, something like:

```
no channels or objects match the current scope <camera_3DE/t*,r*>
...
added 6 channels
rows (frames) = 226  columns (channels) = 6
frame range = ...
... clipping input frames to fit selected range
column 0 to channel camera_3DE/tx
...
modified 6 expression channels
added 1 channels
...
```

After loading the data there will be three new objects named "geometry_3DE", "camera_3DE" and "points_3DE". The object "geometry_3DE" is parent to the other OPs, and you can use this OP in order to scale, rotate and translate the scene imported from 3DE. Depending on the setting of the selector Export Mode (see below), either the OP "camera_3DE" or the OP "points_3DE" is animated. When you set the viewer to "camera_3DE", you should see the points from your 3DE project represented by small crosses. When you open another action command file from 3DE all new OPs mentioned above will be deleted, therefore you should rename them in case you want to keep them.

Houdini: A command file and a channel file are generated. The command file simply carries the name you enter in the text field. No suffix is added by 3DE. The file contains a list of commands according to Houdini's scripting language. The channel file contains translation and rotation data of the camera/the points. It has the suffix ".chan". The format is the same as for Prisms. The files can be opened in Houdini as follows: First, you should set the frame range in the Requester "Global Animation Parameters" to appropriate values, so that the camera motion path from 3DE lies completely within this range. Open the Houdini textport and type "`cmdread <mypath>/<myfile>`". Houdini will then open the file (in this case "`<myfile>`") and add the channel data from the file "`<myfile>`.chan" and print out the number of data elements read from the channel file. In Houdini's Layout Area you will see three new OPs named "3DE_geometry", "3DE_camera" and "3DE_pointgroup". Since "3DE_geometry" is parent of the other OPs, you can use this OP in order to scale, rotate and translate the scene imported from 3DE. Depending on the setting of the selector Export Mode (see below), either the OP "3DE_camera" or the OP "3DE_pointgroup" is provided with channels and animated. When you switch Houdini's viewer to "3DE_camera" you should see the points from your 3DE project represented by small crosses. If this is not the case, adjust the Viewing parameters "Near" and "Far" of the OP "3DE_camera" accordingly. When you open another command file from 3DE all OPs named "3DE..." will be deleted, therefore you should rename them in case you want to keep them.

Export Mode

Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

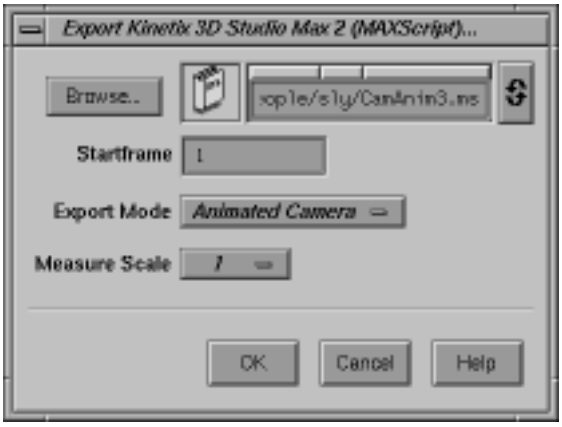
This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok

Causes the system to generate the action file according to the settings of this requester.

Requester: Export Kinetix 3D Studio Max 2...

Exporting the reconstructed camera and points to Kinetix 3D Studio Max 2. A MAXScript (ascii) file is generated, that can be executed within 3D Studio Max 2 using the function Utilities::MAXScript::Run Script.



Requester: Export Kinetix 3D Studio Max 2...

Browse...

Opens a file requester. The filename of the MAXScript file that should be generated must be specified.

Startframe

This number indicates at which frame the animation begins when it is loaded into 3D Studio Max 2.

Export Mode

Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale

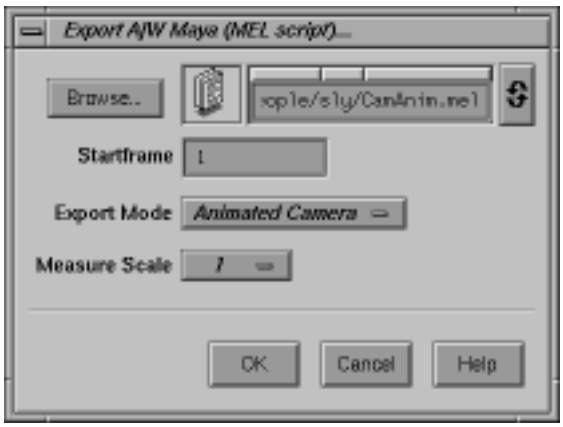
This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok

Causes the system to generate the MAXScript file according to the settings of this requester.

Requester: Export A|W Maya...

Exporting the reconstructed camera and points to Alias|Wavefront's Maya. A Mel script file is generated, that can be easily opened/imported into Maya.



Requester: Export A|W Maya...

Browse...
: Opens a file requester. The filename of the Mel script file that should be generated must be specified.

Startframe
: This number indicates at which frame the animation begins when it is loaded into Maya.

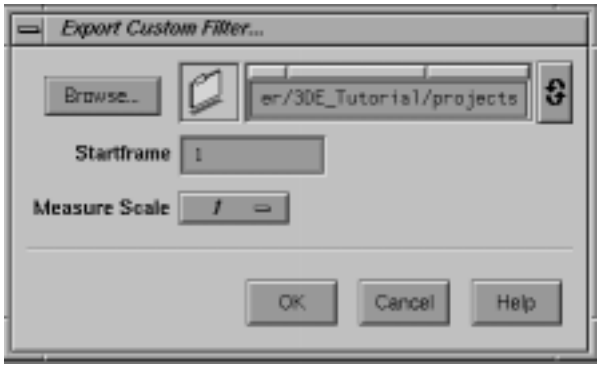
Export Mode
: Choose between Animated Camera and Animated Points. At this point the user communicates to the export module, how the camera motion path and the points are going to be exported: a fixed camera and moving points, or a moving camera and fixed points?

Measure Scale
: This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok
: Causes the system to generate the Mel script file according to the settings of this requester.

Requester: Export Custom Filter...

Exporting the reconstructed 3D data using a special custom exportfilter. A custom exportfilter is a software that has been developed by Science.D.Visions to satisfy the customer's special requirements. If you need a custom exportfilter, please contact us !



Requester: Export Custom Filter...

Browse...
: Opens a file requester. The filename of the custom exportfile that should be generated must be specified.

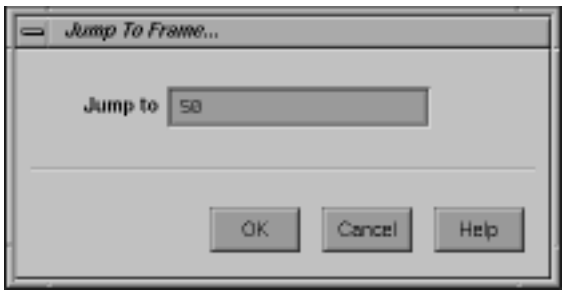
Startframe
: This number indicates at which frame the animation begins when it is loaded into your software.

Measure Scale
: This selector can be used to rescale the position of the points and the camera when these are exported to the animation package.

Ok
: Causes the system to generate the exportfile according to the settings of this requester.

Requester: Jump To Frame

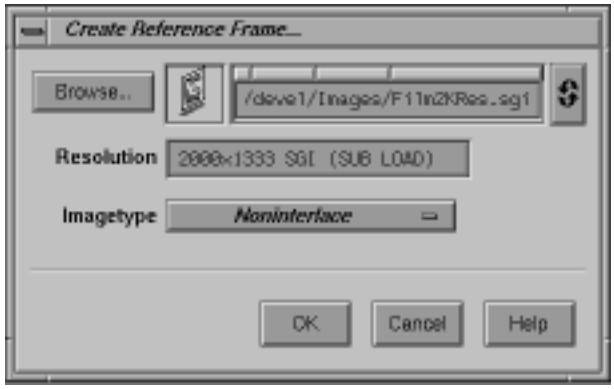
Jumps to the frame specified by the number in the text field.



Requester: Jump To Frame...

Requester: Create Reference Frame...

The standard interaction components are used for opening a reference frame file. If this has been done successfully, its resolution and the image type are displayed in the corresponding text field. When the image format supports the subload property, this will be indicated. The selector Imagetype specifies if the reference frame file is interpreted as one frame or as two fields, if it is recorded with an field aspect ratio of 1:2, or if it has been recorded using an anamorphic camera.
see also: Edit Sequence Settings...



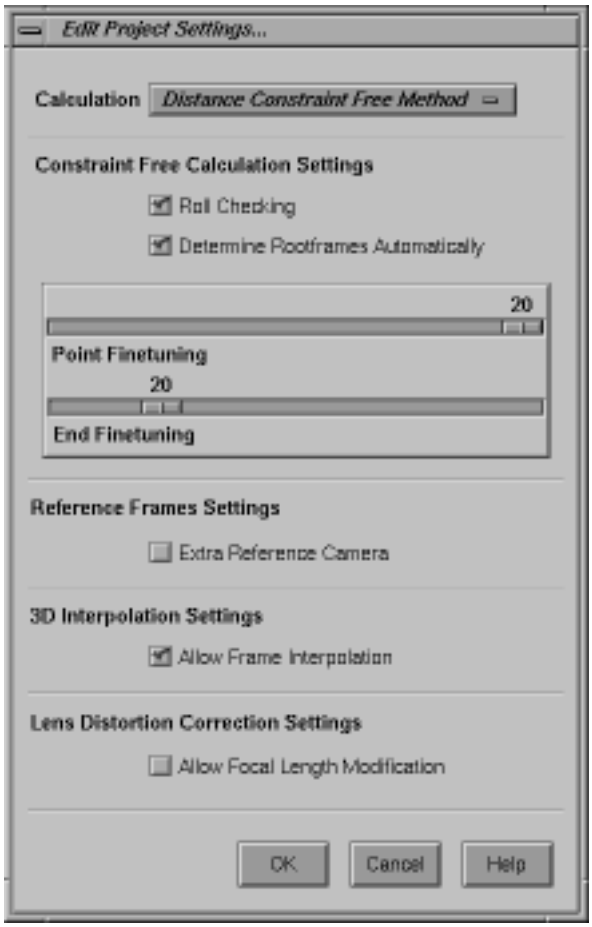
Requester: Create Reference Frame

Requester: Modify Reference Frame...

The currently displayed reference frame can be modified with regard to filename and imagetype. The lay-out of this requester is the same as in the requester Create Reference Frame....

Requester: Edit Project Settings...

Global settings concerning the calculation methods, reference frames and frame interpolation.



Requester: Edit Project Settings...

Calculation

Choose among *User Defined 3D Positions, Distance Constraint Method, Distance Constraint Free Method* and *Fixed Camera Position Method.*

User Defined 3D Positions means, the user enters for every primary point a certain 3D position in space. 3D-Equalizer uses this information to calculate for the position and orientation of each camera.

Distance Constraint Method means, the user takes at least six measurements between the primary points in the real world and enters them as the so-called distance constraints to the system. During the calculation procedure, the 3D position of each point is determined out of these constraints.

Distance Constraint Free Method means, 3D-Equalizer calculates the 3D position and orientation of each camera, without any additional real world information. This is the preferred calculation method. In general it produces the best results.

Fixed Camera Position Method is used, if the camera does not change its position during the shot. Its time-dependent rotation is calculated by 3D-Equalizer. The points are not calculated completely; only their direction relative to the constant camera position is determined.

Constraint Free Calculation Settings

Configuration settings for the Distance Constraint Free calculation method.

see also: Calculation

Roll Checking

If the camera roll angles of the two rootframes are very different, this toggle should be activated; otherwise the calculation process might fail. The toggle is activated by default. If the roll angles of the two root frames do not differ too much, the toggle can be switched off. In this case the calculation process will take less time.

Determine Rootframes Automatically

If this toggle is activated, 3D-Equalizer tries to find the two best rootframes for the calculation. This toggle is activated by default. When it is disabled, you have to specify the two rootframes by yourself.

see also: Set Rootframes

Point Finetuning

Number of finetuning passes after each added point. If many points come in and out of frame, this value should be increased.

End Finetuning

Number of final finetuning passes. Increasing this value can yield better calculation results.

Reference Frames Settings

If the reference frames have been taken using a diffenrent camera than the sequence frames, the toggle Extra Reference Camera should be activated.

3D Interpolation Settings

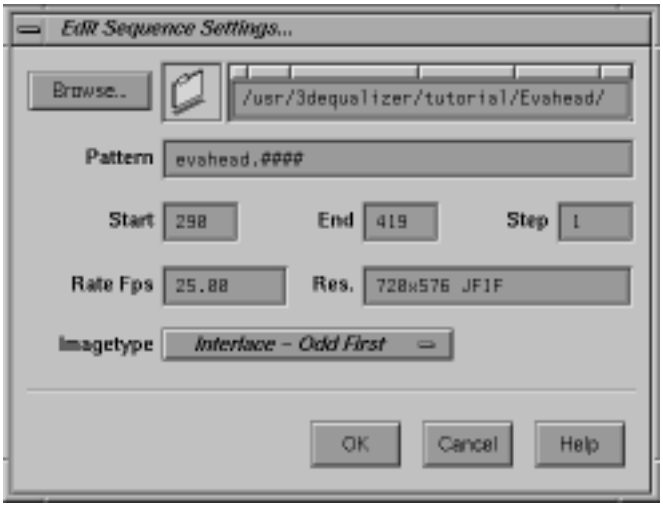
If activated, 3D-Equalizer calculates cameras for frames with less than 4 visible points. Usually you should always have at least four points in each frame. If this is not possible, 3DE can bridge small parts of the sequence, which contain only two or three points.

Lens Distortion Correction Settings

Most of the render packages are not able to render through distorted camera optics. When this toggle is activated, the focal length is slightly modified (internally; you cannot see this in the Camera Adjustment Window) in order to compensate as good as possible the discrepancy between the distorted tracking points of the real sequence and the undistorted points calculated by 3DE. You can see the effect in the Main Window, in the Preview Window and of course in your animation package.

Requester: Edit Sequence Settings...

Settings concerning the sequence data: sequence frame filenames, image type and resolution.



Requester: Edit Sequence Settings...

Pattern

Enter here a file name pattern which matches the names of the sequence frames. For example, if the frame filenames are myimage.0100 ... myimage.0300 the pattern may be myimage.####.

Start, End, Step

Specify the first and the last frame file and the step size between the frames. If the parameter is set to 1 each frame is used. Example: assume the frame filenames are myimage.0100 ... myimage.0300. If the parameter Step is set to 10, only the frames myimage.0100, my image.0110, myimage.0120, ... are used.

Rate Fps

In this text field the number of frames per second of the sequence frames should be entered. It is required by the export function and for generating a preview movie.
see also: Export 3DE Data, Preview Window

Image Type

Choose the image type used in the sequence: Noninterlace, Interlace-Even First, Interlace-Odd First, Field-Aspect 1:2, Anamorphic 2:1. Interlaced frames at a rate of 25 frames per second contain two fields displaced by 1/50 second. For the case of interlaced frames this selector specifies which of the fields (even or odd) is used for representing the sequence frame within the 3D-Equalizer project.
see also: Shift 1 Field

Resolution

Displays the resolution and image type of the project's sequence frames. When the subload property is supported, this is also indicated.

Requester: Edit Preview Settings...

Preview configuration settings.

Requester: Edit Preview Settings...

Preview Active
: Enables the preview feature.

Preview Size (%)
: This slider is used for specifying the frame size of the preview movie in percent with respect to the original input sequence frames.
see also: Resolution

Resolution
: Shows the resolution of the frames of the preview movie as specified in the slider Preview Size (%).

Preview
: File format of the preview movie. Choose among Uncompressed, MVC1, MVC2, RLE24, JPEG.

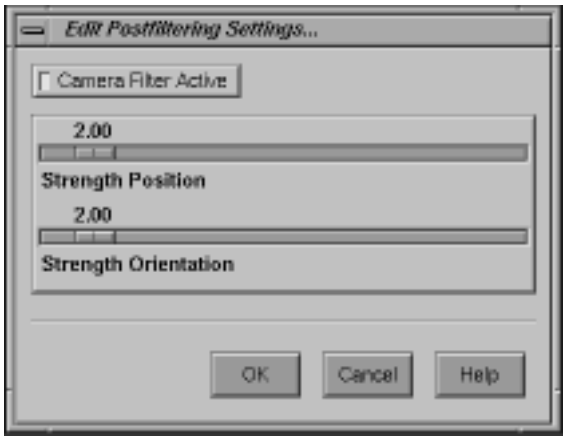
Cache
: File format of the cache movie. Choose among Uncompressed, MVC1, MVC2, RLE24, JPEG.

Cache Active
: If activated, the previewer generates a cache movie, composing all sequence frames to one movie file. Next time when the preview movie is built, the procedure will take less time because the images taken from the cache are already in an appropriate format.

Antialiasing
: If activated, the dummies are composed into the preview movie using antialiasing techniques.

Requester: Edit Postfilter Settings...

Provides a functionality for smoothing out the camera (or points) motion path being exported to the animation package (see also Export) or being used for rendering the preview.
see also: Preview Window.



Requester: Edit Postfiltering Settings...

Camera Filter Active
: If activated, the program uses the postfilter settings when the project data are exported and when the preview is generated.

Strength Position
: This value specifies the strength of the position postfilter. The camera positions are

filtered, the camera orientation is corrected accordingly. The value 1 means there is no filter effect at all.
see also: Strength Orientation

Strength Orientation

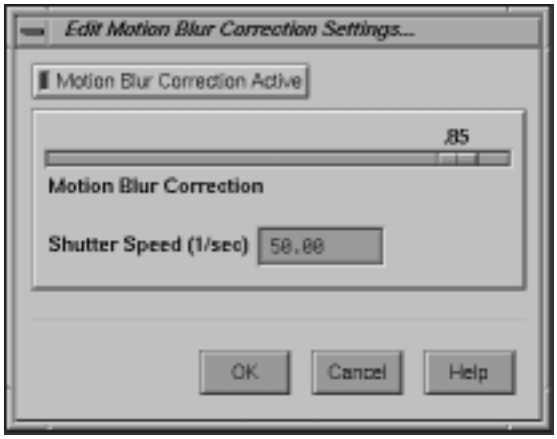
This value specifies the strength of the orientation postfilter. This filter can be used for correcting errors of the motiontracking curves. The value 1 means there is no filter effect at all. When you are using the postfilter facility, the best strategy is the following:

1. Adjust the position postfilter first and leave the orientation postfilter at value 1.
2. Adjust the orientation postfilter afterwards.

see also: Strength Position

Requester: Edit Motion Blur Correction Settings...

Settings for the timebase correction of motionblured sequences. The Motion Blur Correction should be activated, when it is intended to render the cgi sequence in the respective animation package using a motionblurring feature.



Requester: Edit Motion Blur Correction Settings...

Motion Blur Correction Active

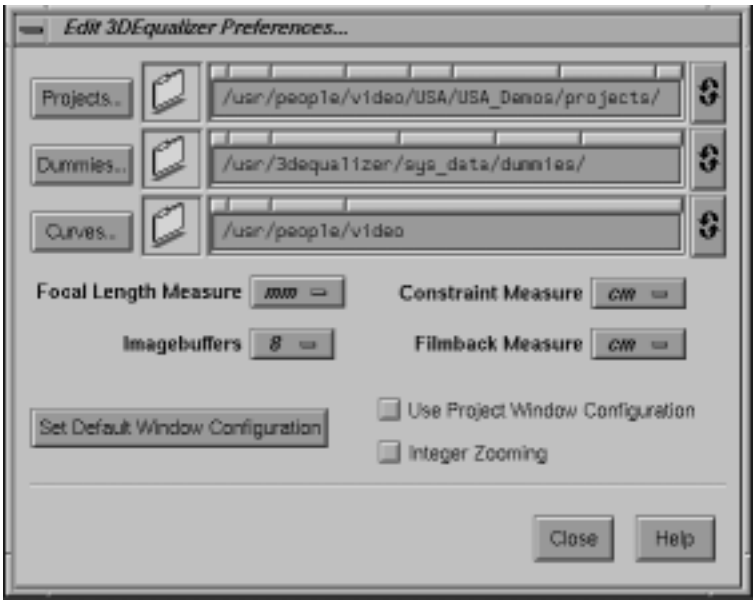
If activated, the screen points are shifted according the motionblur correction settings. The corrected screen points are displayed as dots in the Main Window and the Zoom Window.

Motion Blur Correction
Specifies the amount of correction. A value of 0.85 to 0.9 is a good choice.

Shutter Speed (1/sec)
Enter here the shutter speed that has been used to record the filmed sequence.

Requester: Edit 3DEqualizer Preferences...

Default directories, default length units, default window configurations.



Requester: Edit 3DEqualizer Preferences...

Projects
The default directory for 3D-Equalizer projects.
see also: Open, Main Window

Dummies
The default directory for dummies.
see also: Orientation Window

Curves

The default directory for image control curves
see also: Image Control Window

Zoom Measure

The default length unit for representing the focal width.
see also: Camera Adjustment Window

Constraint Measure

The default length unit for representing distance constraints.
see also: Constraint Window

Filmback Measure

The default length unit for representing filmback width and height.
see also: Camera Adjustment Window

Imagebuffers

The number of image buffers. Set this as high as possible in order to work fluidly, but take care of not running out of memory.
see also: Camera Adjustment Window

Set Default Window Configuration

Define the current window configuration as the default.
see also: Use Project Window Configuration

Use Project Window Configuration

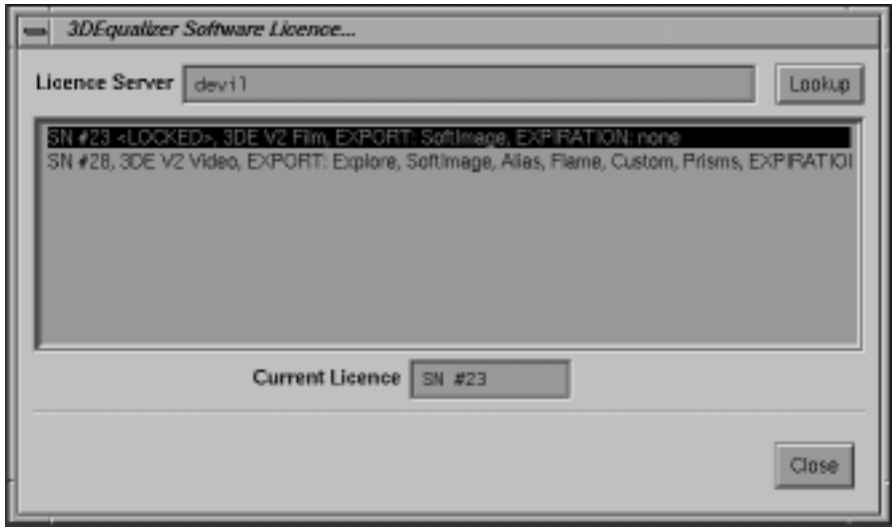
If activated, the default window configuration is used when 3D-Equalizer is started, and the program tries to use the respective project window configuration, when a project is opened. If not activated, the current window configuration does not change, when a project is opened.
see also: Set Default Window Configuration

Integer Zoom

If you are using a XZ-, Elan- or Extreme-graphics board this toggle must be activated. In this case the zoom functionality of the Zoom Window works graded, not continuously. Otherwise this toggle should be deactivated.

Requester: 3DEqualizer Software Licence...

All available floating licences and the floating licence currently used by the system are displayed. By double clicking a licence entry, the user can grab another licence. The licence in use is automatically unlocked, and can be grabbed by another user on another host.



Requester: 3DEqualizer Software License...

Licence Server
: Enter the name (or IP address) of a Flc server workstation here. All available licences are immediately displayed in the list below the text field.

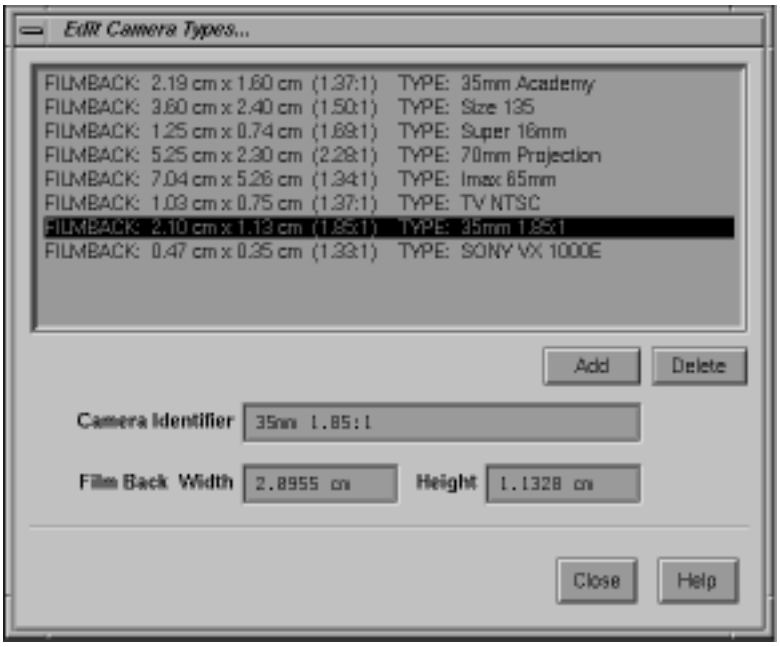
Lookup
: Update the list of available licences.

Current Licence
: Displays the Serial Nr. of the currently used licence. If <none> is displayed, no licence has been grabbed.

Close
: The system tries to grab the currently selected licence. The requester is closed.

Requester: Edit Camera Types...

3D-Equalizer maintains a project-independent list of camera geometries. This requester provides functions for adding a camera geometry to this list and for removing it. The geometries consist of filmback width and height. The focal width is not specified, since for any given camera it depends on the lens turret used and should be adjusted in the Camera Adjustment Window.



Requester: Edit Camera Types...

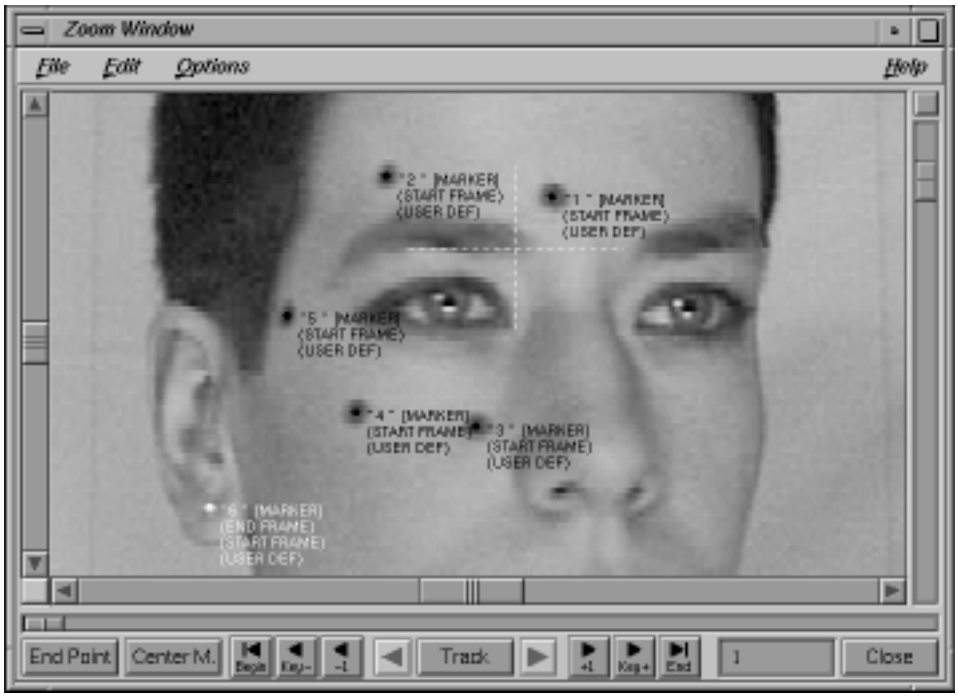
Camera Identifier
: User-defined name of the camera.

Filmback Width, Filmback Height
: Enter filmback width and height here. If no length unit is supplied, the default will be used.
see also: Filmback Measure

Add, Delete
: Add/remove the camera to/from 3D-Equalizer's project-independent list of camera geometries.

Zoom Window

This window provides the functionality for creating screen points and tracking them within the real scene. In the following, the various functions of the window and its display are explained.



Zoom Window

Miscellaneous

The display

The Zoom Window display represents a rectangular cut-out part of the frame currently displayed in the Main Window. The location of this cut-out can be selected by either holding the middle mouse button and moving the mouse or by using the slider underneath the display for horizontal movement and the slider on the left hand side for vertical movement. The zoom-in-out functionality is accessed by holding the right mouse button and mouse movement or by using the slider on the right hand side of the display. The cut-out part is represented in the Main Window display by a dotted rectangle.

Keys

CURSOR-LEFT and CURSOR-RIGHT are used for jumping forth and back in the sequence according to the setting of Frame Keyboard Grid. CTRL-CURSOR-LEFT and CTRL-CURSOR-RIGHT are used for going forth and back by one frame. CURSOR-UP and CURSOR-DOWN are used for selecting points. PAGE-UP/PAGE-DOWN jumps to the previous/next keyframe of the currently selected point. HOME/END jumps to the first/last sequence or reference frame.

Field of View

The field of view can be adjusted as follows: hold CTRL, drag the field of view border with the left mouse button. The entire field of view can be moved by holding CTRL, clicking inside the field of view and moving the mouse.

Screen Points

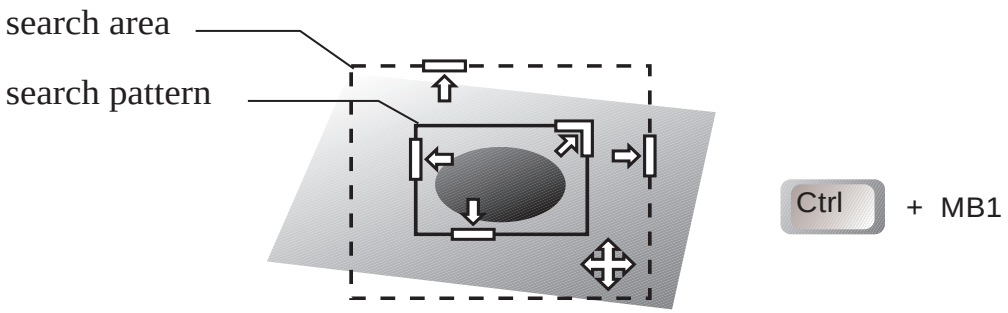
A screen point is a representation of a point (in three-dimensional space) on the screen for a specific frame.

A screen point can be positioned in different ways. The most fundamental one is to place the Zoom Window display at the intented location within the frame and to place the screen point at the intended position using the left mouse button. The screen point is accompanied by some text providing various information. This screen point information text consists of the following components: identifier, selection-status, key-status.

The identifier is simply the identifier of the point represented by the screen point.

Tracking area

If the currently selected point is going to be motion- or markertracked, it is necessary to specify the search pattern size and the search area size. For this purpose the boxes must be visible (see also Show Tracking Area). The borders of these areas can be moved by pressing CTRL and touching the respective border (hold left mouse button) and dragging them around. The entire search pattern can be moved by pressing CTRL, clicking the left mouse button within the borders and moving the mouse. The window Image Controls can be used for improving the luminosity contrast of the images involved in the tracking procedure.



selection-status

If the point is currently selected, the double dotted lines appears above and underneath the text information. If the point is not selected, the double dotted lines do not appear. CURSOR-UP and CURSOR-DOWN are used for selecting points.

key-status

The key-status of a screen point in a given frame assumes the following values: *userdef, userdef endframe, userdef startframe, splined, forward, backward, tracked, obsolete, invalid*.

userdef means, the screen point has been placed by the user, or the user has modified some parameters of the screen point e.g. size of the tracking area. In this way the current frame is made a keyframe for the tracking procedure of the currently selected point.

userdef endframe indicates, that the motion curve of the point ends in the current frame.

userdef startframe indicates, that the motion curve of the point begins in the current frame. The subsequent screen points are valid unless an endframe occurs.

splined means, the screen point is valid, but has not been placed by the user. Its position results from one of the previous frames and eventually from one of the following frames where the screen point has been userdefined or tracked.

forward means, the screen point has undergone a tracking procedure based on the previous frame, and its position will be modified in a backward tracking procedure, if such a procedure is started.

backward means, the screen point has undergone a tracking procedure based on the following frame, and its position will be modified in a forward tracking procedure, if such a procedure is started.

tracked means, the screen point has undergone its complete tracking procedure as specified in the points Trackingmode.

obsolete means, the screen point has been tracked, but in some of the frames, on which this tracking procedure was based, the screen points have changed. The current screen point may be placed well in the current frame, but if tracking is applied again its position will be calculated anew.

invalid means, the screen point is not valid, i.e. does not exist in the current frame, hence does not contribute to any reconstruction procedure.

Buttons and sliders

End Point
: Defines/undefines the current screen point as endpoint. The key-status userdef endframe indicates, that the motion curve of the point ends in the current frame.

Center M.
: The user chooses a frame and defines the screen point. If the point is going to be markertracked, by pressing Center M. the user can place the screen point in the center of the marker. The search pattern should be well-adjusted.

Begin
: Jumps to the first sequence or reference frame.
shortcut: HOME

End
: Jumps to the last sequence or reference frame.,
shortcut: END

Key -
: Jumps to the previous userdef (sequence) frame of the currently selected point.
shortcut: PAGE UP

Key +
: Jumps to the next userdef (sequence) frame of the currently selected point.
shortcut: PAGE DOWN

Frame - 1
: Jumps to the previous frame.

Frame + 1
: Jumps to the next frame.

Frame Text field
: Displays the current frame number.

Track backward
: The display jumps to the previous frame. The screen points of the previous frame are tracked if necessary.

Track forward
: The display jumps to the following frame. The screen points of the following frame are tracked if necessary.

Track

Starts the automatic motion- and markertracking procedure due to the settings of the points tracking areas and tracking parameters. Tracking means that the search pattern of a point in a given frame is searched and localized in the neighbouring frame. When the patterns are being compared, the settings of the Image Control Window are taken into account and can be used for improving the contrast of the patterns.

Sliders

The slider on the right hand side of the display is used for zooming, the sliders on the left and underneath are used for moving the cut-out of the Main Window display represented in the Zoom Window display. Pressing the button above the zoom slider moves the knob to the upmost position, so that the entire image is displayed. The small horizontal slider right above the button row is a frame slider. Moving the knob changes the current frame.

Menu: File

Contains functions for saving and loading 2D motion (tracking) curves.
shortcut: ALT-f

Import Curve

Functions for loading 2D motion curves.
shortcut: i

Raw

Opens a file requester. The motion curve of the currently selected point is replaced by the data found in the specified file. It must be of the type 3D-Equalizer raw motion curve format.
shortcut: r
see also: Export Curve

Flame

Opens a file requester. The motion curve of the currently selected point is replaced by the data found in the specified file. It must be of the type Discreet Logic Flame Raw (Track) format.
shortcut: f

Cineon

Opens a file requester. The motion curve of the currently selected point is replaced by the data found in the specified file. It must be of the type Kodak Cineon Raw format.
shortcut: c

Export Curve

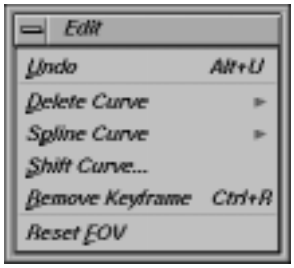
Functions for saving 2D motion curves.
shortcut: e

Raw
Opens a file requester. The data of the motion curve of the currently selected point is saved into the specified file, using the type 3D-Equalizer raw motion curve format. This function can be used to share motion curves between different projects.
shortcut: r
see also: Import Curve

Ascii
Opens a file requester. The data of the motion curve of the currently selected point is saved into the specified textfile.
shortcut: a

Close
Closes the Zoom Window.
shortcut: c

Menu: Edit



Contains functions for editing motion curves and the field of view.
shortcut: ALT-e

Undo
Undo the previous point editing action.
shortcut: u, ALT-u

Delete Curve
Contains functions for deleting parts of motion curves.
shortcut: d

All
Deletes the entire motion curve of the currently selected point.
shortcut: a

Range...
Opens the requester Delete Motion Curve Range.
shortcut: r

Until End
Deletes all screen points after the current frame until the end of the sequence and defines the current frame as the end-frame for this motion curve.
shortcut: e

Spline Curve
Contains functions for splining parts of the motion curve of the currently selected point.
shortcut: p

All
Splines the screen point positions for all frames of the motion curve, except for userdef frames.
shortcut: a

Range...
Opens the requester Spline Motion Curve Range.
shortcut: r

Shift Curve...
Opens the requester Shift Motion Curve.
shortcut: s

Remove Keyframe
Removes the key-status userdef from a screen point. The screen point becomes invalid or splined.
shortcut: r, CTRL-r

Reset FOV
Resets the field of view to the default settings. The field of view is located at the borders of the frame.
shortcut: f

Menu: Options

Contains toggles for the Zoom Window display.
shortcut: ALT-o

Auto Center
If activated, the screen point of the currently selected point is centered in the Zoom Window display whenever the display is re-built.
shortcut: c

Show Motion Curve
If activated, the two-dimensional motion curve of the screen point for the entire sequence is displayed, depending on the setting of the menu item Show Invalid Points.

Show FOV

If activated, the field of view is displayed in the Zoom Window display.
shortcut: f

Show Invalid Points

If activated, the screen points which are declared invalid in the current frame are displayed.
shortcut: i

Show Tracking Areas

Contains toggles for the display of the motiontracking areas of the points.
shortcut: a

All

If activated, the search patterns and the search areas of all visible points are displayed.
shortcut: a

Selected

If activated, only the search pattern and the search area of the currently selected point are displayed.
shortcut: s

None

If activated, no motiontracking areas are displayed at all.
shortcut: n

Show Points

Contains toggles for hiding and showing points.
shortcut: p

All

If activated, all points are displayed.
shortcut: a
see also: Show Invalid Points

Selected

If activated, only the currently selected point is displayed.
shortcut: s
see also: Show Invalid Points

Show Image

Contains toggles for the image subload. The subload functions are especially useful, when high resolution images are processed, since the working speed is increased considerably. These functions are only available in the filmversion.
shortcut: m

All

If activated, the entire image is loaded into the memory.
shortcut: a

Zoom Area Only

If activated, only the part of the image that corresponds to the zoom area (the area displayed in the Zoom Window) is loaded into the memory.
shortcut: z

Tracking Area Only

If activated, only the tracking area (the dotted tracking box) is loaded in the memory. This increases the working speed.
shortcut: t

Image Controls

Contains toggles in order to choose if the Image Control functions should be applied to the whole image or to a subregion only. These functions are useful, when high resolution pictures are being processed. When the Image Control is applied to a subregion, this will speed up the workflow.
shortcut: t

All

Applies the Image Control functions to the entire image.
shortcut: a

Zoom Area only

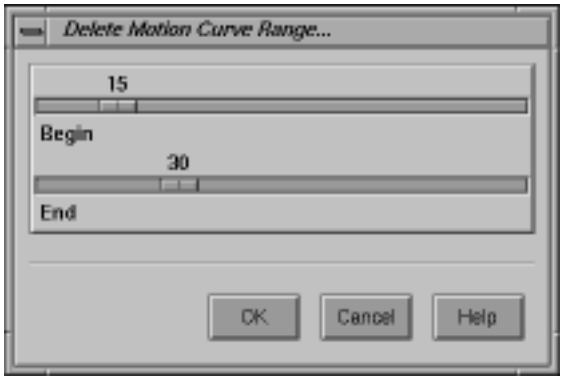
Applies the Image Control functions to the zoom area only. The zoom area is the region of the image displayed in the Zoom Window.
shortcut: z

Tracking Area Only

Applies the Image Control functions to the tracking area only. The tracking area is the subregion of the image that is contained in the dotted tracking box.
shortcut: t

Requester: Delete Motion Curve Range...

Deletes a part of the motion curve of the currently selected point (see figure below).

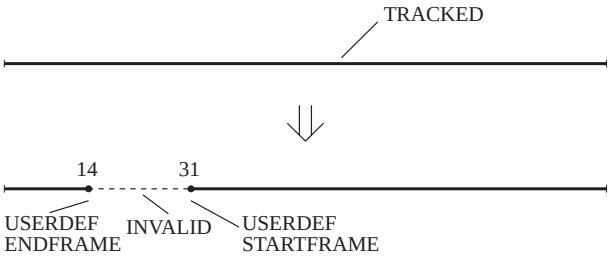


Requester: Delete Motion Curve Range...

Begin
: This slider specifies the first frame of the range to be deleted.

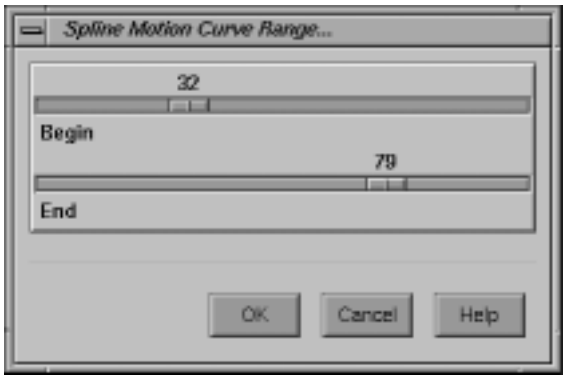
End
: This slider specifies the last frame of the range to be deleted.

Ok
: Deletes the specified frame range of the motion curve, all frames within this range are declared *invalid*.



Requester: Spline Motion Curve Range...

Splines a part of the motion curve of the currently selected point (see figure below).

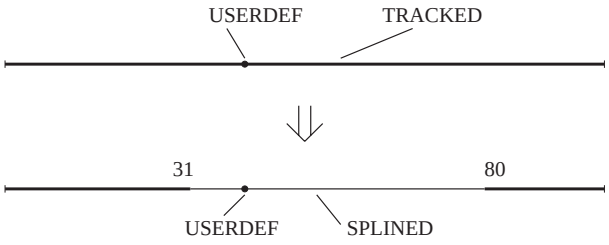


Requester: Spline Motion Curve Range...

Begin
: This slider specifies the first frame of the range to be splined.

End
: This slider specifies the last frame of the range to be splined.

Ok
: Splines the specified part of the motion curve.



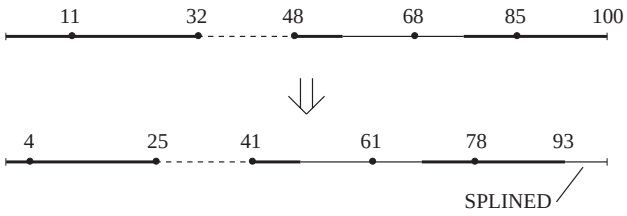
Requester: Shift Motion Curve...

Shifting the motion curve of the currently selected point forth and back the timeline (see figure below).

Requester: Shift Motion Curve...

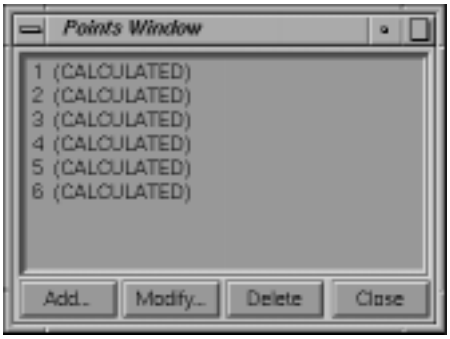
FrameShift

Contains the current shift value in frames.



Points Window

Provides functions for creating, modifying and deleting points, including their motiontracking properties and screen point representation properties. The points can be selected using the left mouse button. The list of points is sorted alphabetically. Double-clicking a point opens the requester Modify Point... for this point.



Points Window

Buttons

Add...
: Opens a requester Create Point...

Modify...
: Opens a requester Modify Point...

Delete...
: Remove the selected point from the point list and delete all its constraints.

Requester: Create Point...

Create a new point and enter its settings.
see also: Modify Point...

Identifier
: The points must be given distinct names, in order to identify them uniquely. If the user does not specify a name, the program will create it automatically.

Color
: Allows to select the color for the screen point representation in the Zoom Window and the Main Window. Choose among *Red, Green, Blue, Yellow, Black, White, Gray*.

Motiontracking Active
: If activated, this point is tracked next time the 3D-Equalizer motiontracking functions are applied. If a point should be prevented from (automatic) motiontracking, this toggle should be deactivated.
see also: Zoom Window

Trackingmode
: There are two different types of tracking, and for both different directions in time can be specified. The two methods are referred to as motiontracking and markertracking. For details see section „Tracking“ in chapter „Selected Topics“. Choose among *Forward only, Backward only, Forward & Backward, Marker Forward, Marker Backward*.

Colormode
: Colormode for motion- and markertracking. Choose among *Grayscale* and *Truecolor.*

  Grayscale
  : Tracking is performed by recognizing the search pattern within the search area. When the colormode is set to *Grayscale*, only the luminosity contrast is taken into account, but no color information. Usually, this mode is sufficient for tracking.

  Truecolor
  : When the colormode is set to *Truecolor*, all three color channels are employed for pattern recognition, and the three results are combined appropriately.

User Defined 3D Position
: If activated, the user must specify the 3D position of the point in the XYZ text fields. The mode of calculation must be set to *User Defined 3D Positions* in order to be able to change the state of this toggle.
see also: Project Settings...

XYZ
: Displays the 3D position of the point. This 3D position is unaffected by the alignment of the points in the Orientation Window.

Requester: Modify Point...

Enables to modify the settings of the currently selected point. The functions are the same as in the requester Create Point...

Requester: Modify Point...

Constraints Window

Provides functions for entering, modifying and removing distance constraints and plane constraints. The data entered in this window are only used in connection with the calculation modes *User Defined 3D Positions* and *Distance Constraint Method*.
see also: Edit Project Settings...

Constraints Window

Miscellaneous

Distance Constraints/Plane Constraints
: Switches the window's functionality between displaying/editing distance constraints and plane constraints.

Distance Constraints
: The display shows the list of distance constraints. The identifiers of the points involved and their distance are displayed. Double-clicking a distance constraint opens the requester Edit Distance Constraints...

Edit...
: Opens the requester Edit Distance Constraints...

Delete...
: Removes the currently selected distance constraint from the list.

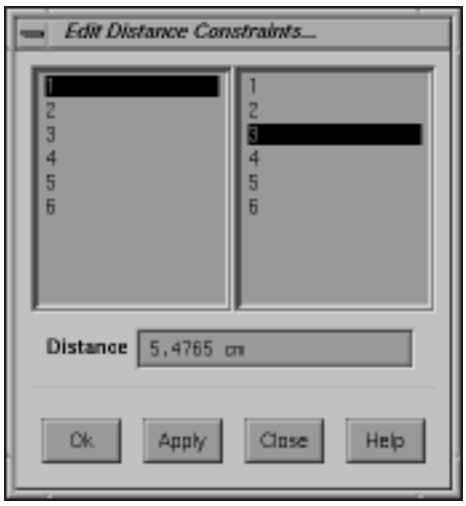
Plane Constraints
: The display shows the list of plane constraints. The plane constraint's identifier and the identifiers of the points involved are displayed. Double-clicking a plane constraint opens a requester Edit Plane Constraints...

Edit...
: Opens the requester Edit Plane Constraints...

Delete...
: Removes the currently selected plane constraint from the list.

Requester: Edit Distance Constraints

In each of the display fields one point can be selected.



Requester: Edit Distance Constraints...

Distance
: Enter here the measured distance of the two currently selected points.

Requester: Edit Plane Constraints

This requester is meaningful only in the distance constraint method. In the display field one or more points can be selected. Use left mouse button for selecting and SHIFT for multi-selecting. Use CTRL and left mouse button for multi-selection toggling.

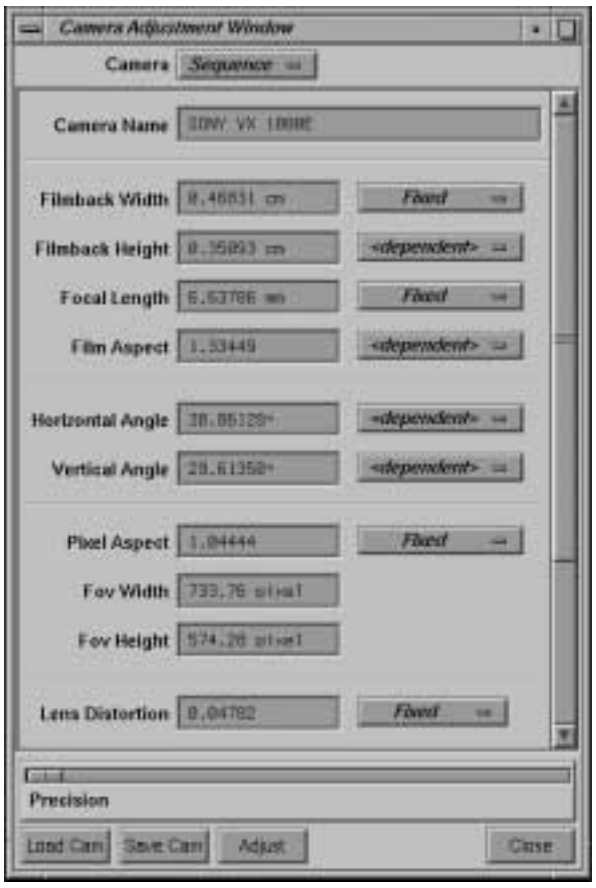
Edit Plane Constraints...

Identifier
: Enter here the name of the plane constraint (optional).

New
: Prepares the window for creating a new plane constraint.

Camera Adjustment Window

Provides the functionality for reconstructing and modelling the camera(s) used for recording the sequence and reference frames. There are several text fields representing the various parameters of the camera and the field of view. They are listed below. On the right hand side of some of the parameters there is a selector which can assume the values *Fixed, Fine Adjust, Unknown* and <*dependent*>. They specify whether the respective parameter is known, approximately known, unknown or if the parameter should be calculated out of other parameters automatically.



Camera Adjustment Window

When the selector of a parameter is set to *Fixed*, the text field color changes to pink and the user is able to enter a value. The parameter itself will not be modified when the system adjusts the camera geometry.

When a selector is set to *Fine Adjust*, the text field color changes to pink and it is possible to enter a value. The corresponding parameter is modified in the adjustment procedure, where the system assumes, that the entered value is approximately correct.

When a selector is set to *Unknown*, the text field color changes to pink-grey, a default value is automatically displayed with respect to the parameter type. The text field cannot be modifed by the user, and during the adjustment procedure a large parameter range is scanned.

All camera parameters (except Lens Distortion) are always kept to be consistent against each other. There are always three parameters set to *Fixed, Fine Adjust* or *Unknown*. All other parameters are automatically set to <*dependent*>. The color of a <*dependent*> text field is set to grey, and it is not possible to enter a value. The value of a <*dependent*> parameter is immediately calculated by the system due to the three non-<*dependent*> parameters.

Miscellaneous

Camera

Choose between Sequence and Reference. It is possible to record the reference frames using the same or a different camera as the sequence frames. This selector switches between both cameras.
see also: Project Settings...

Camera Name

The identifier of the camera currently used.

Filmback Width, Filmback Height

Fields for displaying and modifying the current filmback width and height. The selector on the right of the fields is used in order to specify if or how precise the values are known. The default length unit can be specified in Filmback Measure.

Focal Length

Field for displaying and modifying the current focal length. The selector on the right of the field is used in order to specify if or how precise the value is known. The default length unit can be specified in Zoom Measure.

Film Aspect

Field for displaying and modifying the current film aspect. The selector on the right of the field is used in order to specify if or how precise the value is known.

Horizontal Angle, Vertical Angle

Fields for displaying the horizontal and the vertical camera angle. The selector on the right of the field is used in order to specify if or how precise the value is known.

Pixel Aspect

Field for displaying and modifying the pixel aspect. The selector on the right of the field is used in order to specify if or how precise the value is known.

Fov Width, Fov Height

Fields for displaying the field of view width and height. These quantities can only be modified by hand in the Zoom Window.

Lens Distortion

Field for displaying and modifying the parameter which describes the nonlinear distortion of the real camera. The selector on the right of the field is used in order to specify if or how precise the value is known. Positive values compensate a barrel-type distortion, negative values compensate a pillow-type distortion.

Precision Slider

Enables to specify the number of frames being taken into account for adjusting the camera. In order to reconstruct the camera geometry many frames are required. Setting the quality slider to the right causes the program to take into account each frame, setting it to the left causes the program to use a minimal amount of 20 frames (if available) for adjusting the camera. When using the calculation mode *Distance Constraint Free Method* it is recomended to set the slider to the middle position at least.

Load Cam

Opens a requester for loading a predefined camera geometry.
see also: Edit Camera Types...

Save Cam

Adds the current camera to the list of predefined camera geometries.
see also: Edit Camera Types...

Adjust

Starts the process of adjusting the camera according to the settings of the selectors on the right of the fields containing the camera parameters. During the process a requester containing a Stop button, a current and a best avarage pixel deviation value, are displayed. If the user hits the Stop button, the adjustment procedure is terminated, and the camera parameters of the best attempt are displayed in the text fields. If the user does not hit the Stop button, 3D-Equalizer calculates the best possible camera parameter values. This process may take a few minutes up to one or two hours. After the adjustment procedure, all non-<dependent> selectors are automatically set to Fixed.

Image Controls Window

This window allows you to modify the color representation of the sequence and reference frames in the Main Window and the Zoom Window. It does not influence the preview movie and the representation of the dummies is not affected. The settings are taken into account when screen points are motiontracked. The features may be used for enlarging contrast, for cutting out irrelevant or disturbing areas around the screen point being tracked. There are two different methods applied to the image, namely image control curves and color contrast. If both are employed, the software applies the image control curves first and color contrast afterwards as shown in the figure below.

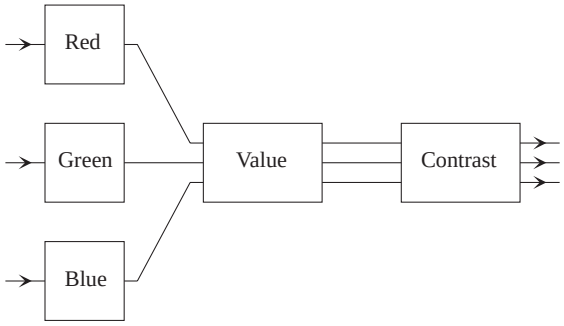


Image control diagram

Image Control Curves

There are 4 different types of curves available, namely Value (which means brightness), Red, Green and Blue. The image control curves field allows to modify each set of pixels of an image with a specific brightness and color. The horizontal axis specifies the brightness of the pixel being modified, the vertical axis specifies the resulting luminosity. Shifting a point to the upper bound of the field causes the part of the image specified by the choice on the horizontal axis to appear in white, shifting it to the lower bound causes the part to appear in black. Intermediate settings conserve the color tone as far as possible and modify the contrast. The curves Red, Green and Blue work as follows: the horizontal axis specifies the brightness of the respective color channels. The vertical axis specifies the resulting brightness of the color channel after applying the curve.

Active

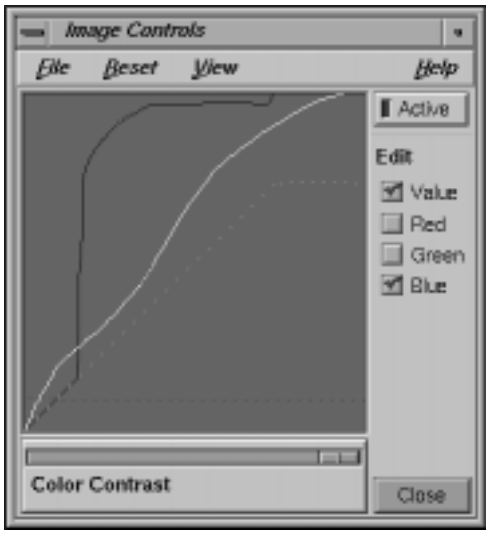
If activated, the settings of the window are applied to the Main Window display and to the Zoom Window display. In this case the image control settings are taken into account when motion- or markertracking is being performed.

Edit

To be able to modify one or more control curve(s), the respective edit toggle(s) must be turned on. All editable control curves are drawn using a solid line.

Color Contrast

This slider ranges from full color contrast (default setting, right position) to a black-and-white representation (left position). In calculating the luminosity all color channels - red, green, blue - are weighted equally.



Window: Image Controls

Menu: File

Contains functions for saving and loading image control curves.
shortcut: ALT-f

Load Curves...

Load an image control curves and a color contrast setting from a file. Selecting it opens a standard file requester Load Image Control Curve...
shortcut: l
see also: Curves, Edit 3DEqualizer Preferences...

Save Curves...

Save an image control curves and a color contrast setting to a file. Selecting it opens a standard file requester Save Image Control Curve...
shortcut: s
see also: Curves, Edit 3DEqualizer Preferences...

Close

Closes the Image Control Window.
shortcut: c

Menu: Reset

Contains functions for reseting control curves to their default state.
shortcut: ALT-r

Value

Resets the Value control curve to its default state.
shortcut: v

Red

Resets the Red control curve to its default state.
shortcut: r

Green

Resets the Green control curve to its default state.
shortcut: g

Blue

Resets the Blue control curve to its default state.
shortcut: b

All

All settings are reset to their default values, i.e. the image is not changed, even if image control is active.
shortcut: a

Menu: View

Contains toggles for showing/hiding control curves.
shortcut: ALT-v

Show Value
: If activated, the Value control curve is displayed.
shortcut: v

Show Red
: If activated, the Red control curve is displayed.
shortcut: r

Show Green
: If activated, the Green control curve is displayed.
shortcut: g

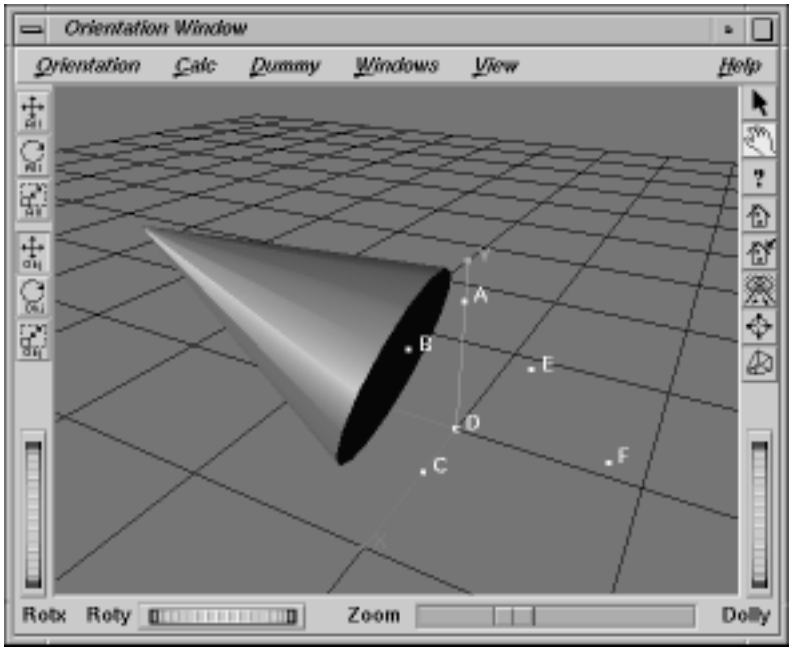
Show Blue
: If activated, the Blue control curve is displayed.
shortcut: b

Orientation Window

The two main purposes of this window are to provide the user with features for fixing the coordinate frame and for positioning 3D Open Inventor objects (dummies) for the preview movie.

In order to clarify the profit of this window, we shall assume in the following that the real sequence consists of a fixed environment, and that it has been recorded with a moving camera. When the item Calc::Calc Points & Paths is selected, the points are reconstructed in three-dimensional space. The animation packages for which 3D-Equalizer generates export data supply some kind of base plane. When the export data are loaded into the animation package the points will appear in the same relation to this base plane as they do in the Orientation Window. In many cases the points designated in the real environment by the user span a plane parallel or orthogonal to the base plane. This window provides a few basic operations to align the points in this way.

see also: Menu: Orientation



Orientation Window

Miscellaneous

The display

The Orientation Window display contains the following elements: a coordinate frame consisting of x-axis (red), y-axis (green) and z-axis (blue), a black grid representing the xz-plane. When 3D-Equalizer reconstructs the camera motion path the points are reconstructed in three-dimensional space as well. All points which have been reconstructed successfully are displayed. Furthermore, the dummies created by the user for preview purposes are displayed. The scene is viewed by a camera which is referred to as the internal Open Inventor camera in the following. Finally, the postfiltered and unfiltered camera motion path as well as the camera of the current frame are displayed.

Zoom

A slider which allows to modify the focal width of the internal camera. If parallel perspective representation is chosen this has no effect.

Selecting a dummy object

For selecting a dummy object, you have to be in the pick mode (see overview: Open Inventor ExaminerViewer: Pick button). A dummy object can then be selected by holding down the Ctrl-Key and picking the dummy with the left mouse button. A previously selected dummy becomes unselected. The selected dummy is framed by a red bounding box.

Modifying a dummy object

On the left hand side of the Orientation Window there are some buttons for modifying the dummy object and the whole scenery. The currently selected dummy object can be translated, rotated and scaled using the following functions.

Translate Object

This function enables the user to translate the currently selected dummy object in 3D space. By pressing (and holding) the left mouse button and moving the mouse, the dummy is translated in x-direction. Using the middle mouse button translates in y, while the right mouse button translates in z-direction.

Rotate Object

This function enables the user to rotate the currently selected object around one of the coordinate frame axis. By pressing (and holding) the left mouse button while moving the mouse, the dummy is rotated around the x-axis. Using the middle mouse button rotates around the y, while the right mouse button rotates around the z-axis.

Scale Object

This function enables the user to scale the currently selected dummy. By pressing (and holding) the left mouse button while moving the mouse, the dummy is scaled in the x-dimension. Using the middle mouse button scales in the y, while the right mouse button scales in the z-dimension. Pressing all three mouse buttons together, causes the dummy to be scaled uniformly.

Modifying the entire scenery

The following functions enable you to translate, rotate and scale the entire scenery.

Translate All

Translates the entire scenery, depending on which mouse button is pressed. By pressing the left mouse button and moving the mouse, the scenery is translated in x-direction. Using the middle mouse button translates in y, while the right mouse button translates in z-direction.

Rotate All

Rotates the entire scenery, depending on which mouse button is pressed. The left mouse button rotates the scenery on its x-axis; the middle mouse button rotates it on its y-axis; and the right mouse button rotates it on its z-axis.

Scale All

Scales the entire scenery, depending on which mouse button is pressed. The left mouse button scales the scenery along its x-axis, the middle mouse button scales it along its y-axis and the right mouse button scales it along its z-axis. While holding down all three mouse buttons it is possible to scale the scenery uniformly.

Overview: Open Inventor ExaminerViewer

Pick button

As long as the Pick button is active, an Open Inventor object can be selected and modified. In order to select a dummy object hold down the Ctrl-Key and pick the object with the left mouse button. While the pick mode is active, the user can temporarily switch to the View-Mode by holding down the Alt-Key.

View button

As long as the View button is active, the direction of view of the Open Inventor camera can be changed using the left mouse button. The middle mouse button can be used for translating the camera.

Help button

If the Open Inventor online help is installed, a help window on the ExaminerViewer opens.

Home button

Resets the camera to its home position.
see also: Set Home button

Set Home button

Defines the current camera position as the home position.
see also: Home button

View All button

Sets the camera to a position which enables to view the entire scene.
see also: Menu: Scale

Seek button

When this mode is active, you can click an object. The camera is then animated to a position where this object lies in the center of the image.

Perspective/Orthogonal camera toggle

Switches the camera between perspective and orthogonal optics.

Dolly/Zoom

When the Perspective/Orthogonal camera toggle is set to perspective camera, this thumb whell moves the camera forth and back with respect to the direction of view. When the Perspective/Orthogonal camera toggle is set to orthogonal camera, a zoom function is mimicked.

Rotx, Roty

Rotates the camera around its x-axis and y-axis, respectively.

Menu: Orientation

Provides functions for aligning the preview scene with respect to the coordinate frame. Example: assume you have three points A, B and C. You wish point A to coincide with the origin, points B and C to be parallel to the y-axis and points A, B and C to lie in the yz-plane. The simplest way to achieve this is to select points A, B and C in the window Point List and to align them within the yz-plane. Afterwards points B and C are selected and aligned with respect to the y-axis. Finally, point A is selected and moved into the origin of the coordinate frame.
shortcut: ALT-o

Reset

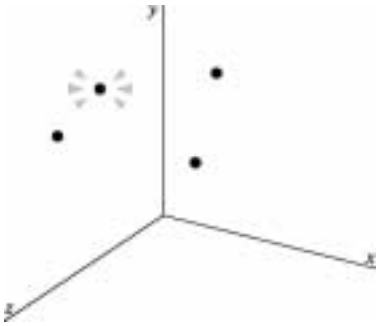
Resets the position and orientation of the calculated scenery. The scaling of the scenery is adjusted in a way, so that the set of points has the same order of magnitude as the ground plane. The camera path is aligned in a way, so that the average camera up-vector points along the y-axis.
*shortcut*s: r, CTRL-r

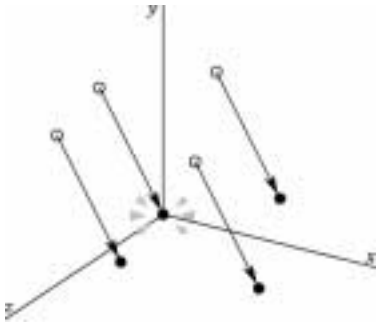
Move 1 Point

When the functions of this item are employed, it is assumed that one point is selected.
shortcut: 1
see also: Point List

Origin

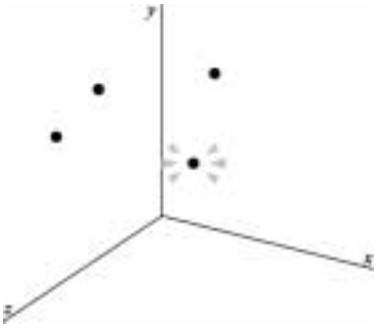
The entire scene is translated so that the currently selected point (see also Point List) is located in the origin.
shortcut: o

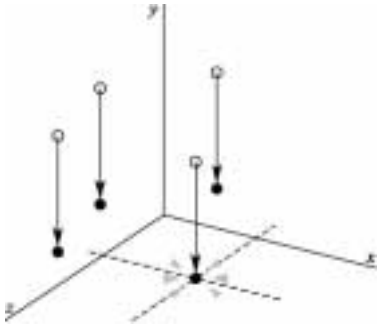




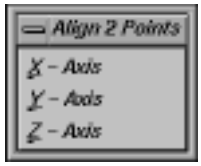
XY-, XZ-, YZ-Plane

The entire scene is translated so that the currently selected point (see also Point List) is projected orthogonally into the xy-, xz- or yz-plane.
shortcuts: x, z, y





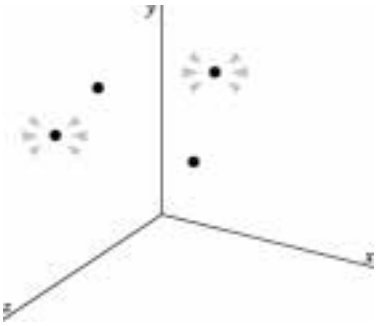
Align 2 Points

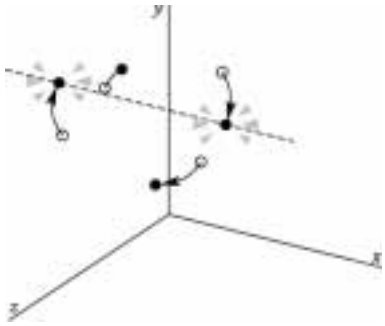


When the functions of this item are employed, it is assumed that two points are selected.
shortcut: 2
see also: Point List

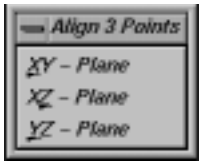
X-, Y-, Z-Axis

The entire scene is rotated so that the two currently selected points (see also Point List) are aligned parallel to the x-, y- or z-axis.
shortcuts: x, y, z





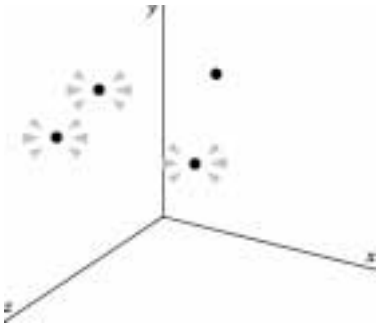
Align 3 Points

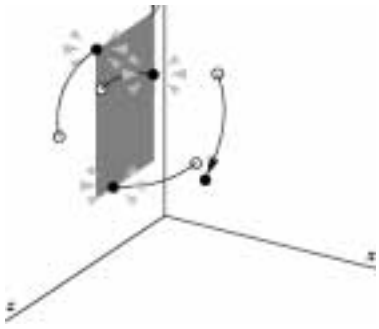


When the functions of this item are employed, it is assumed that three points are selected.
shortcut: 3
see also: Point List

XY-, XZ-, YZ-Plane

The entire scene is rotated so that the three currently selected points (see also Point List) are aligned in the xy-, xz- or yz-plane.
shortcuts: x, z, y



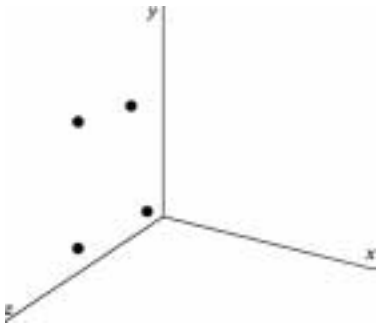


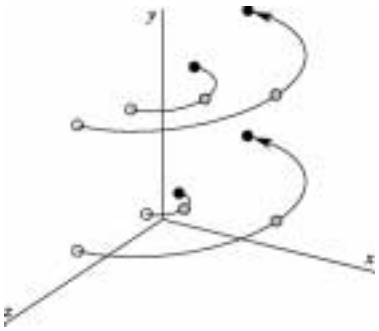
Rotate 90

Turn over the entire scene by 90 degree.
shortcut: o

X-, Y-, Z-Axis

The entire scene is rotated around the x-, y- or z-axis by an angle of 90 degree.
shortcuts: x, y, z





Menu: Calc

shortcut: ALT-p

Calc Points & Path
: Start the main procedure of 3D-Equalizer (only if necessary). The reference and sequence frames are used in order to reconstruct the points positions in space and to determine the camera position and orientation with respect to the points. Afterwards all points which have been calculated successfully are displayed in the Orientation Window display. If activated, the postfiltered and the unfiltered camera motion paths are displayed as well.
shortcuts: c, SHIFT-c
see also: Menu: View

Menu: Dummy

Menu providing elementary functions for creating and deleting dummies. The dummies can be selected as explained in Dummy Editing Selector or in Dummy List.
shortcut: ALT-d

Create
: Functions for creating dummies.
shortcut: c

Load...
: Opens a standard file requester for loading a dummy. The default directory for dummies can be specified in Options::3DE Preferences::Dummies.
shortcut: l

Cube
: Creates a cube-shaped dummy.
shortcuts: c, ALT-1

Cone
: Creates a cone-shaped dummy.
shortcuts: o, ALT-2

Cylinder
: Creates a cylinder-shaped dummy.
shortcuts: y, ALT-3

Sphere
: Creates a sphere-shaped dummy.
shortcuts: s, ALT-4

Delete...

Removes the currently selected dummy from the scene, i.e. from the Orientation Window display.
shortcuts: d, DELETE

Copy

Creates a further instance of the currently selected dummy with same size and material properties and places it in the dummys neighbourhood.
shortcuts: c, CTRL-c

Align to Point

Positions the tip of a selected Cone Object exactly onto the currently selected Point. You have to select the point in the Point List (Orientation Window::Windows::Point List). This function is recommended to be used in connection with Cone Objects. It also works with the other dummy objects, but in this case the origin of the selected object is aligned to the point.
shortcuts: SHIFT-a

Reset

Functions for reseting the attributes of the currently selected dummy.
shortcut: r

All

Resets the position, orientation and size of the currently selected dummy.
shortcut: a

Position

Resets the position of the currently selected dummy to the default state.
shortcut: p

Rotation

Resets the orientation of the currently selected dummy to the default state.
shortcut: r

Size

Resets the size of the currently selected dummy to the default state.
shortcut: s

Menu: Windows

Provides menu items for opening the windows Dummy List, Point List, Material Editor and Light Editor.
shortcut: ALT-w

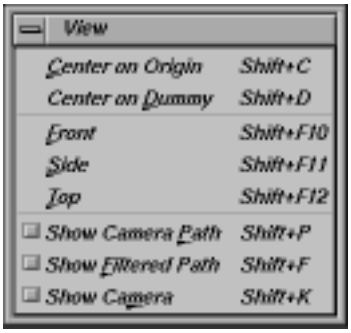
Dummy List...
Opens the window Dummy List.
shortcut: d

Point List...
Opens the window Point List.
shortcut: p

Material Editor
Opens an Open Inventor window Material Editor.
shortcut: m

Light Editor
Opens an Open Inventor window Dir Light Editor.
shortcut: l

Menu: View



Modify the direction of view of the internal Open Inventor camera. Hide or show the reconstructed camera and its motion paths.
shortcut: ALT-v

Center on Origin
Points the internal Open Inventor camera of the Orientation Window at the origin of the coordinate frame.
shortcuts: c, SHIFT-c

Center on Dummy
Points the internal Open Inventor camera of the Orientation Window at the center of the currently selected dummy.
shortcuts: d, SHIFT-d

Front, Side, Top
Sets the internal Open Inventor camera of the Orientation Window to front, right side or top of the scene, respective to the displayed coordinate frame.
shortcuts: f, SHIFT-F10, s, SHIFT-F11, t, SHIFT-F12

Show Camera Path

If activated, the unfiltered camera motion path is displayed in white.
shortcuts: p, SHIFT-p
see also: Calc Points & Path

Show Filtered Path

If this toggle and the toggle Edit Postfiltering Settings::Active are activated, the postfiltered camera motion path is displayed in red.
shortcuts: f, SHIFT-f
see also: Calc Points & Path

Show Camera

If activated, the camera of the current frame is displayed. If Edit Postfiltering Settings::Active is activated the camera appears at the filtered position.
shortcuts: m, SHIFT-k
see also: Calc Points & Path

Window: Dummy List

Displays a list of all dummies used in the current scene. Dummies can be selected in this window by left mouse button clicking. Around the selected dummy a red bounding box is drawn.

Window: Dummy List

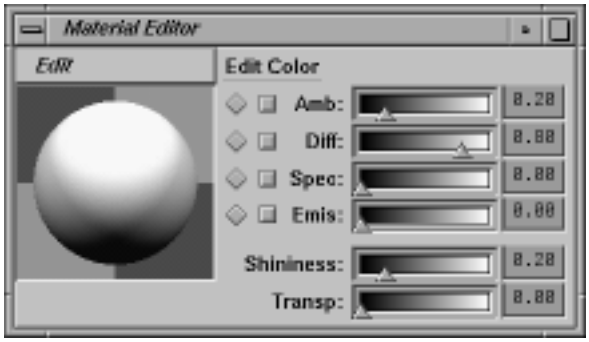
Window: Point List

Displays all points which have been reconstructed successfully in three-dimensional space. A point can be selected by a left button mouse click. Multiple selection is achieved holding SHIFT or CTRL and left button mouse clicking.

Window: Point List

Window: Material Editor

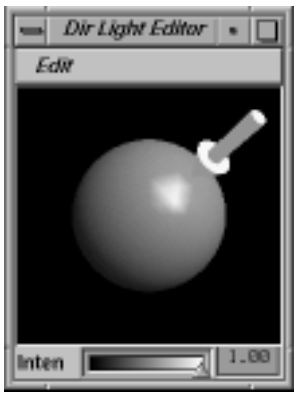
This is an Open Inventor interaction component. It enables the user to modify the material/surface properties of the currently selected dummy.



Window: Material Editor

Window: Dir Light Editor

This is an Open Inventor interaction component. It provides the functionality for editing a light source (direction) which illuminates the dummies.



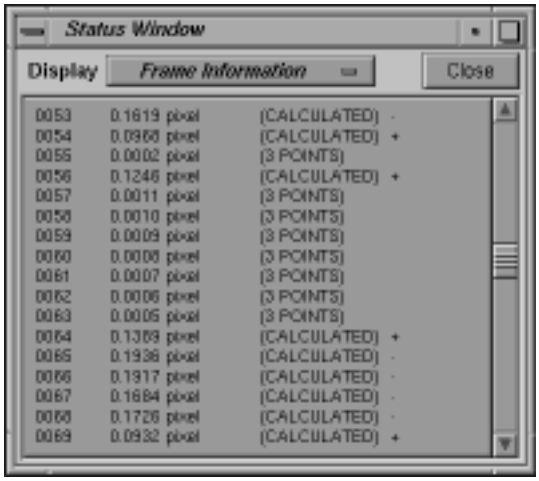
Window: Dir Light Editor

Status Window

A multi-purpose window for displaying various information concerning the current project.

Display

Enables to choose one of the following representation modes: frame information, point information, constraint information, project information.



Status Window displaying frame information

Display Frame Information

Three coloumns are displayed. The first one contains the number of the frame, the second one contains a value named deviation. The third one is the so-called camera status.

When the camera position and orientation are reconstructed 3D-Equalizer determines if the screen points (and their constraints) are consistent. The degree of inconsistence is called deviationand can be expressed in pixel. It may be considered as the error of the reconstruction. Nevertheless, the user should not rely on this value too much, but rather judge the quality of the camera reconstruction for the entire sequence by his/her own eyes.

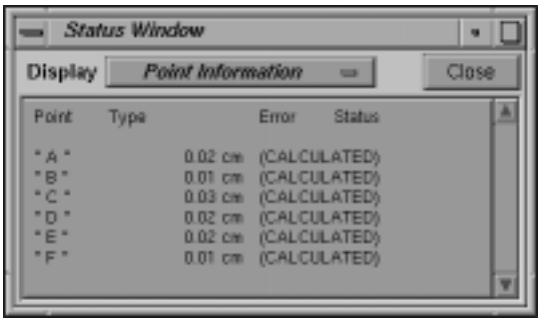
The camera status can assume the values UNDEFINED, CALCULATED, 3 POINTS and SPLINED.

UNDEFINED means that 3D-Equalizer was not able to reconstruct the camera for the respective frame, because there are not enough screen points whose point status is CALCULATED.

The status CALCULATED means that 3D-Equalizer has calculated the position and orientation of the camera using the specified calculation method (see also Project Settings).

3 POINTS means that 3D-Equalizer has calculated the position and orientation of the camera using a special calculation method. It is applied automatically to frames with only three visible screen points. Typically the deviation of these frames is nearly zero. Since for mathematical reasons the camera position and orientation cannot be determined uniquely it is recommended to use this feature only in short parts of the sequence.

SPLINED means that 3D-Equalizer splines the position and orientation of the camera out of the information of the surrounding CALCULATED and 3 POINTS frames. This status is associated to a frame, if less than 3 visible screen points are found. This feature can be deactivated (see also Project Settings). It is also recommended to use this feature only in short parts of the sequence.



Status Window displaying point information

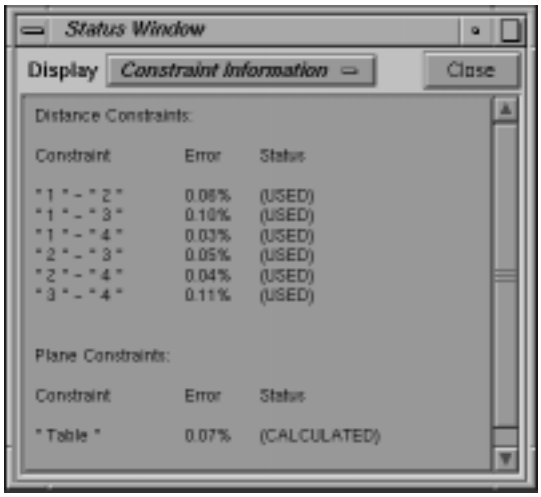
Display Point Information

Four coloumns are displayed. The first one contains the identifier of the point. The second one contains the so-called point type. The third one contains an error value, and the fourth one contains the so-called point status.

For the calculation methods *Distance Contraint Method* (see also Project Settings) the point type can assume the values PRIMARY and SECONDARY. A primary point is a point with a sufficient number of constraints to other points. A point is secondary if it is not primary. The position of a secondary point is reconstructed optically by 3D-Equalizer by using all frames in which the point has a screen point representation.

The error has different interpretations for primary and secondary points. For primary points it contains information about the consistency of its constraints in percent. For secondary points the error (in length units) represents the standard deviation of the point's reconstructed position from its real (unknown) position.

The point status can assume the values CALCULATED and UNDEFINED. CALCULATED means, that the position of the point (primary or secondary) has been determined by 3D-Equalizer. Otherwise the status is UNDEFINED.
see also: Calc Points



Status Window displaying constraint information

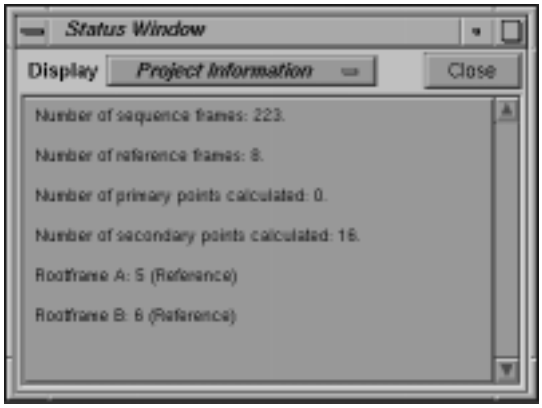
Display Constraint Information

There are two sections, one for the distance constraints and one for the plane constraints. For the distance constraints there are three coloumns. The first one contains the identifiers of the points which form the respective constraint. The second one contains an error value, and the third one contains the so-called constraint status. The error (in percent) represents the relative deviation of the reconstructed points' distance from the constraint's user-entered distance. The constraint status can assume the values USED and UNUSED. The constraint is USED, if both of its points are primary. Otherwise the constraint is UNUSED.

For the plane constraints there are three coloumns. The first one contains the identifier of the plane constraint. The second one contains an error value, and the third one contains the so-called status.

The error is the average error of the constraints of the points involved in the plane constraint.

The status can assume the values CALCULATED and UNDEFINED. The plane constraint is CALCULATED, if 3D-Equalizer has been able to reconstruct and to use the plane spanned by the points of the plane constraint.



Status Window displaying project information

Display Project Information

Displays information about the current project.

Preview Window

Provides functions for generating, playing and examining the preview movie.

Preview Window

The display
: Displays the frames of the preview movie. If a frame is obsolete the word OBSOLETE appears in the display.

Status line
: Displays the status of the Preview Window, e.g. frame rate (frames per second).

Begin
: Jump to the first/last sequence frame.

End

Jump to the first/last sequence frame.

Play

Plays the preview movie of the current project. If necessary the camera motion path is reconstructed. If any of the frames is obsolete for what reason ever it is updated.
A preview frame is generated by taking a sequence frame (eventually from the cache) and composing it with the dummies. The Preview Settings are taken into account.

Important note: the Preview Window must be open while generating the preview, and must not be overlaid by other windows, because the sequence and the dummies are composed directly on the screen.

Stop

Interrupt the preview movie playing.

Playback

Sets the playback mode. Choose among Play Once, Loop, Swing. Play Once causes the program to play the movie once within the limits given by Playback Range. Loop causes the program to play the movie again and again forward in time within the limits given by Playback Range, until being interrupted. Swing causes the program to play the movie forth and back within the playback range until it is interrupted.

Current Frame

Selects a frame.

Playback Range

Set the first and the last frame for Playback. You can use these sliders e.g. if you wish to examine a specific part of the preview movie in order to check the quality of the perspective adaptation.