# MOVIAS Pro
MOTION ANALYSIS SYSTEM

## User Manual

**Version 1.5**
**Final Draft Edition**

**NAC Image Technology Inc**

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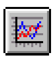
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# 3. System Requirements

### *3.1. Minimum*

Pentium II Processor or equivalent
Windows® NT4/2000/XP
10Gb Hard Disk
128MB Memory
CD-ROM
16bit colour display Adapter capable of 1024x768 resolution

### *3.2. Recommended*

500Mhz or better processor/s
Windows® NT4/2000/XP
256+ MB RAM
20Gb + Hard Disk
32 bit colour display adapter @ 1280 x 1024 (or higher) resolution

## 4. Installing Movias Pro

You must exit all Windows programs before attempting to run the Setup program to begin the installation of Movias Pro.

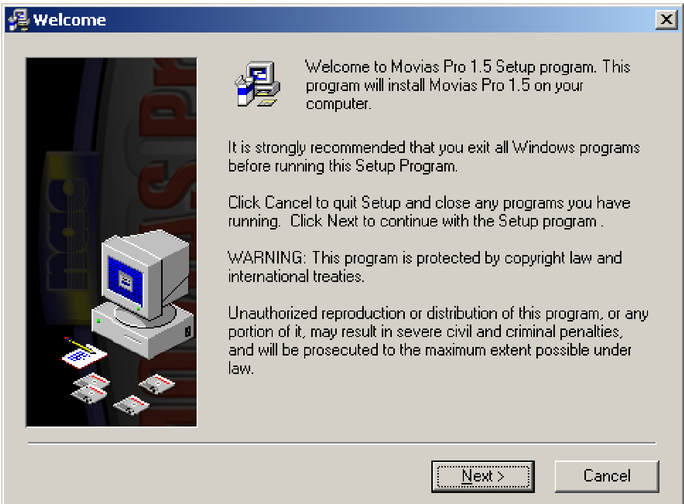
During installation, the Setup program checks the display settings of your system for the following:

| | |
|---|---|
| Minimum screen resolution | 1024 x 768 (1280 x 1024 recommended) |
| Screen colour depth Screen | 16 bit |

To install Movias Pro:

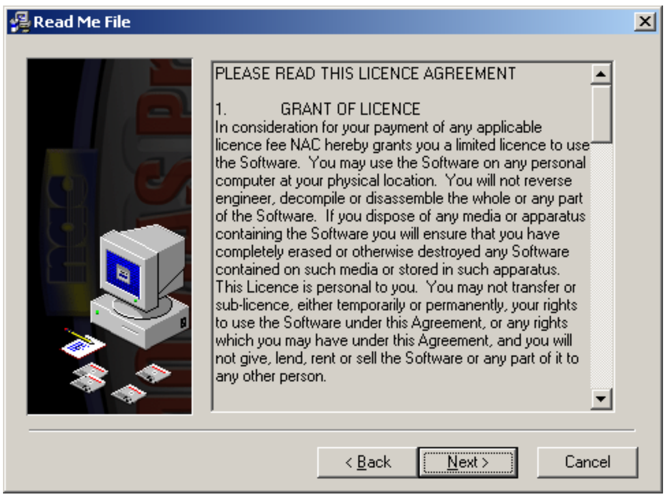
1. Locate and run the Setup program file **install.exe** from the Movias Pro installation CD or the appropriate network folder if installing from a network location.

   The installation program's **Welcome** dialogue box appears:



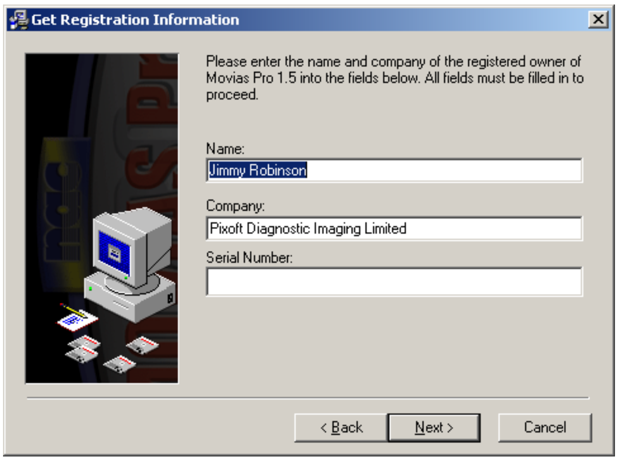

   Click the **Next** button to continue onto the **Licence Agreement** dialogue box.

2. Read the Licence Agreement.




Click the **Next** button to indicate that you accept the conditions set out in the Licence Agreement.

3. Enter your registration details in the **Get Registration Information** dialogue box

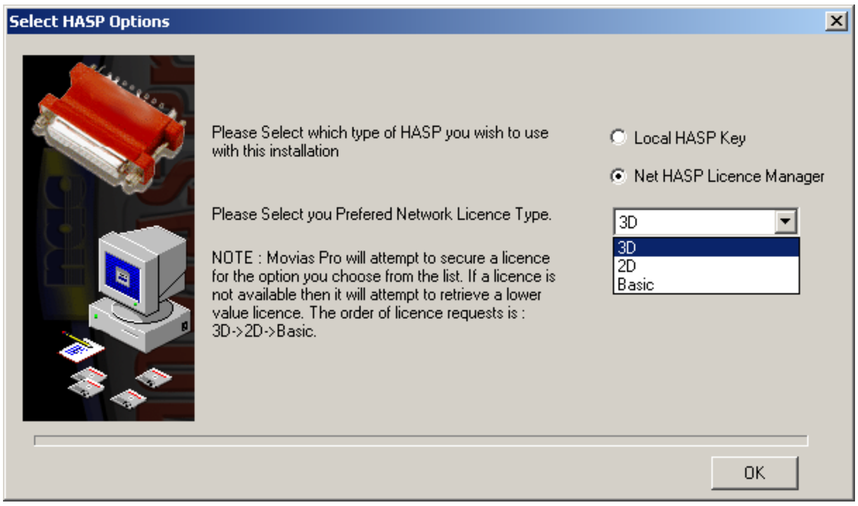



The **Name**, **Company** and **Serial Number** fields are compulsory. The serial number will have been provided with the Movias Pro media.

Click the **Next** button to continue.

4. In the **Select Installation Options** dialogue box, select which type of HASP you wish to use with this installation:

- Local HASP key
- Network HASP Licence Manager




If you choose a **Network HASP Licence Manager**, you must also select which version of the licence you require for the machine on which you are installing Movias.

There are three types of software licence available:

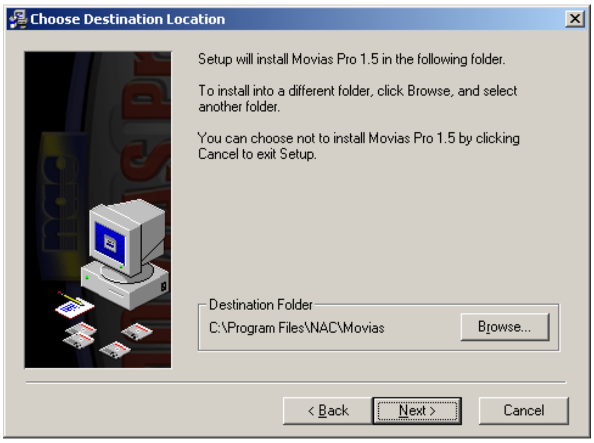
- Movias Pro 3D
- Movias Pro 2D
- Movias Pro Basic

If you are upgrading this version of Movias, you do not need to reinstall the software, you only need to upgrade the licence by choosing a different option from the Network HASP licence manager.

| | |
|---|---|
| **Note!** | You can only upgrade the licence if the Network HASP Licence manager has the requested licence available.<br><br>For example, if you request a licence for the 3D version and there are no more available, you may be issued with the licence for the 2D version. If there are no licences available for the 2D version, you may be issued with the licence for the Basic version. If there are no more licences available for the 3D, the 2D or the Basic version, you will not be able to use Movias Pro. |

Click the **OK** button to continue.

5. Select a destination location for the program.

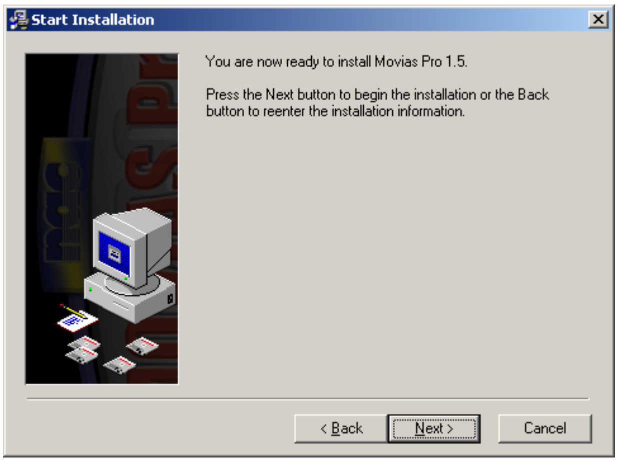



By default, the Setup program installs the program into the **c:\program files\NAC\movias** folder. If the **NAC** folder does not already exist, the Setup program will create it.

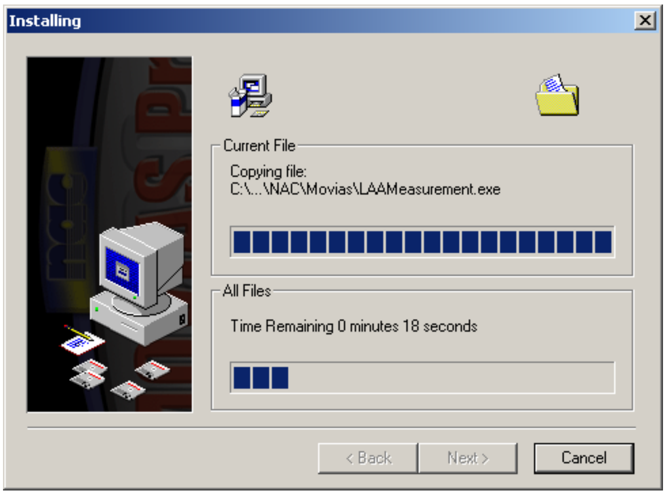
If you wish to install the program to a different location, click the **Browse** button to locate a different destination location.

6. Click the **Next** button to continue.

If you are performing an upgrade of the Movias program, the Setup program will create a backup of your files. The backup procedure defaults to the installation directory, so if you accepted the default destination location, the Setup program creates the following folder for your backup files: **c:\program files\NAC\movias\backup**.

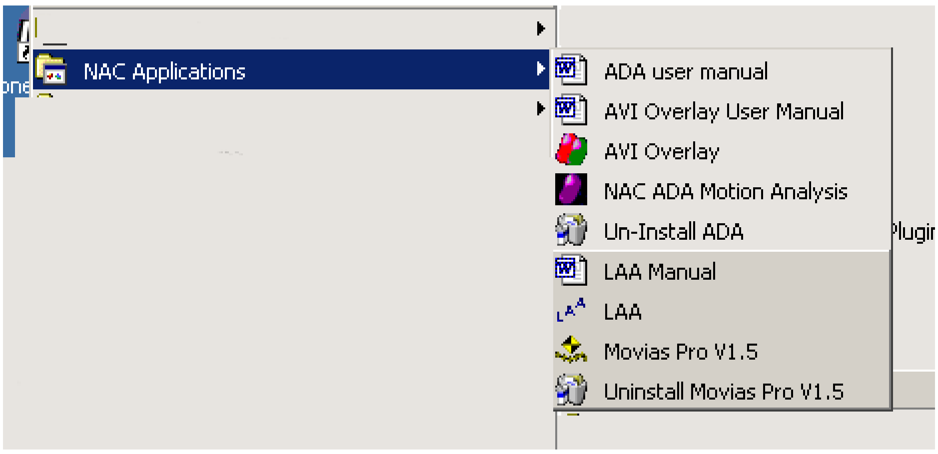



7. Click the **Next** button to begin the installation.




8. Click the **Finish** button when the installation is complete.

The Setup program creates a **NAC Applications** group.




The installation of Movias Pro is complete.

## 5. Introduction

To launch the program, select **Start/Programs/NAC Applications/Movias**

The main Movias Pro screen is divided into two main areas, the **Data Tree** area and the **Work** area. The menu and toolbars are located at the top of the screen.

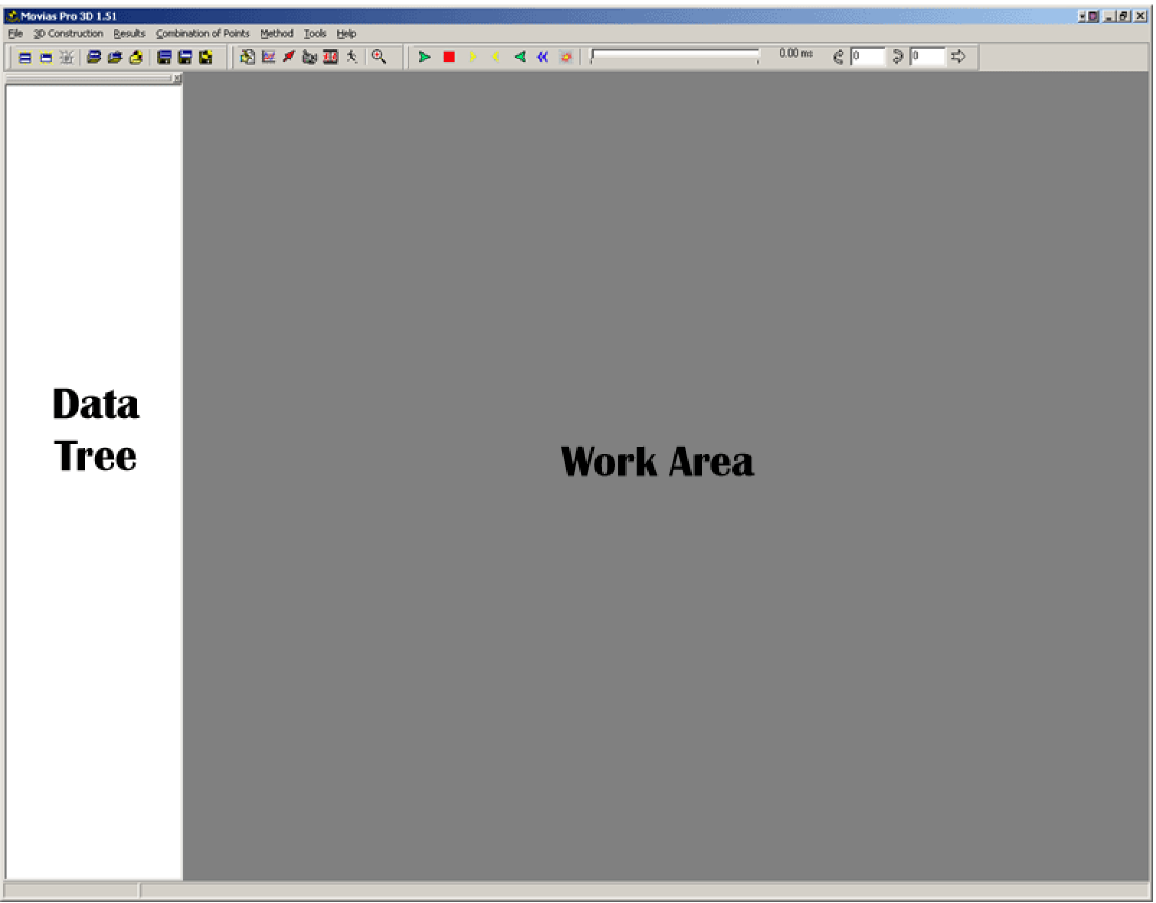



**Figure 1 - Main screen**

### *5.1. Data Tree*

The Data Tree is used to graphically represent the data within your Movias Pro analysis session.

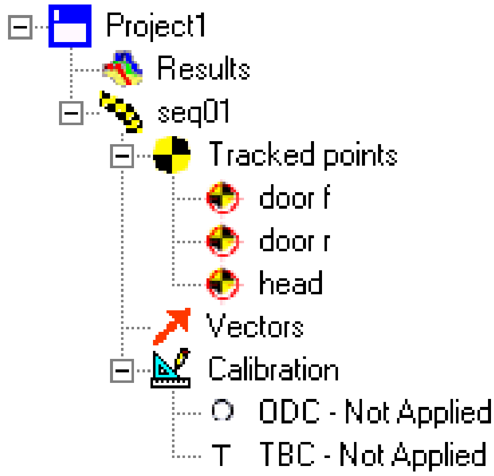
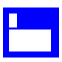



**Figure 2 - Example Data Tree**

The data is organised hierarchically as follows:

#### 5.1.1. Movias Pro Project



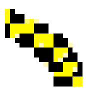
A **Project** is the base level for Movias Data. A Project is equivalent to an experiment, such as a vehicle crash test, a missile launch etc.

Movias Pro allows for multiple projects to be open at any time allowing the user to make back-to-back comparisons between experiments or tests.

#### 5.1.2. Movias Pro Results

The results from a Movias Pro analysis session can be accessed by clicking the **Results** icon.

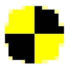
#### 5.1.3. Movias Pro Sequence



Each Movias Pro Project will contain one or more Sequences. A **Sequence** is equivalent to a camera view of the experiment. The camera image sequences should be provided as Windows ® AVI files.

A sequence must belong to a project because it is created from an existing project. However, a sequence can also be saved in isolation from a project and used in another project or shared between projects.

### 5.1.4. Movias Pro Tracked Points



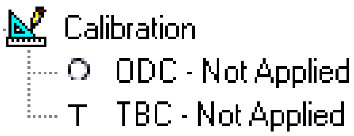
Each Movias Pro Sequence will contain one or more **Tracked Points**. Tracked Points will contain the X, Y and Z spatial coordinates of the point for each frame of the image sequence.

For 2D analysis, the Z value will be the distance of the point from the camera.

### 5.1.5. Movias Pro Vectors

During a Movias Pro analysis session you may generate **Vectors** from a combination of tracked points. These are placed in the data tree under the **Vectors** branch.

### 5.1.6. Movias Pro Calibration

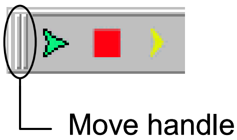



Calibration information relating to **Optical Distortion Correction** (lens correction) and **Time Base Correction** are stored under the **Calibration** branch.

### *5.2. Tool Bars*

There are four toolbars available. The toolbars can be re-arranged in the toolbars area, or floated anywhere on the Work area of the screen.

To reposition a toolbar, point to its **Move** handle and drag it to its new position. If you drag the toolbar onto the Work area of the screen, the toolbar will float. To dock the toolbar, drag it back onto the toolbar area.

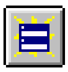
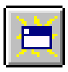
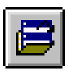
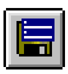
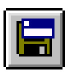



#### 5.2.1. Standard Toolbar

The Standard toolbar contains command buttons that allow you to manage Movias Pro Files. These commands are also available on the **File** menu.


**Figure 3 - Standard Toolbar**

**Standard Toolbar**

| Use this button… | | To do this… |
|---|---|---|
|  | New Session | Start a new Session |
|  | New Project | Create a new Project |
|  | New Sequence | Create a new Sequence |
|  | Open Session | Open an existing Session |
|  | Open Project | Open an existing Project |
|  | Open Sequence | Open an existing Sequence |
|  | Save Session | Save the current Session |
|  | Save Project | Save the current Project (and any sequences within it) |
|  | Save Sequence | Save the current Sequence. |

### 5.2.2. The Results Toolbar

The Results toolbar contains command buttons that allow you to select the results of the image analysis. These commands are also available on the **Results** menu.  To use any of these commands, first select a sequence from the data tree.

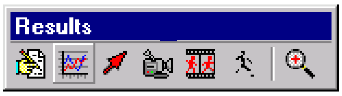



**Figure 4 - Results Toolbar**

**Results Toolbar**

| Use this button… | | To do this… |
|---|---|---|
| | List | To display the Data List window.  You must first select a data point |
| | Graph | To display the Graph Parameters dialogue box for the selected sequence |
| | Trajectory | To display the Trajectories window for the selected sequence |
| | AVI Overlay | To display the AVI Overlay window for the selected sequence |
| | Movie Strip | To Display the Movie Strip Output for the selected sequence |
| | 3D Stick | To display 3D Stick output for the selected (3D) sequence. |
| | Zoom In | Zoom into a graph or Video Sequence |

### 5.2.3. The Control Toolbar

The Control toolbar is used to replay and control video sequences.

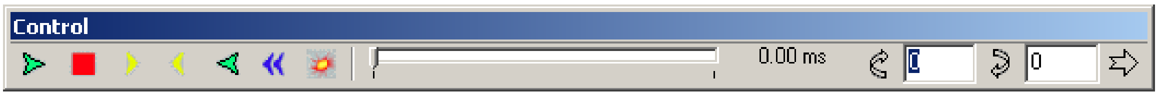



**Figure 5 - Control toolbar**

**Control Toolbar**

| Use this button… | To do this… |
|---|---|
| Play | Play the sequence forward |
| Stop | Stop the sequence |
| Step F | Step forward through the sequence a frame at a time |
| Step B | Step backward through the sequence a frame at a time |
| Play Backwards | Play the sequence backward |
| Rewind | Rewind the sequence to the first frame |
| Time Zero Frame | Goto the Time Zero frame |
| Mark In | Mark a frame as the starting frame in the sequence for "loop" playback |
| Mark Out | Mark a frame as the last frame in the sequence for "loop" playback |
| Clear Mark | Clear the Mark in and Mark out points |

By setting the mark in ad mark out, playback will loop around the marked frames.
You may also control the playback of video sequences by Dragging the Scroll Bar.

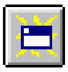
# 6. Common Icons and their Meanings

The following tables describes common Icons used throughout Movias Pro and their meanings.

| Use this button… | To do this… |
|---|---|

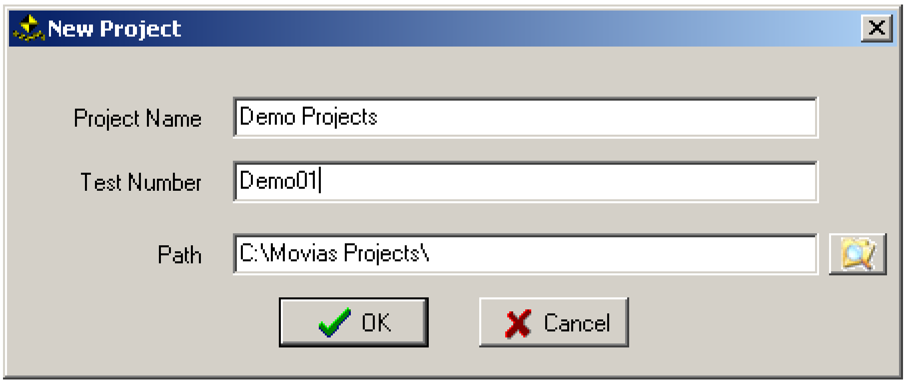
| | |
|---|---|
| Play | Play the sequence forward |
| Stop | Stop the sequence |
| Step F | Step forward through the sequence a frame at a time |
| Step B | Step backward through the sequence a frame at a time |
| Play Backwards | Play the sequence backward |
| Rewind | Rewind the sequence to the first frame |
| Time Zero Frame | Goto the Time Zero Reference frame |
| Set TZero | Set the T Zero reference frame of the Movie |
| Zoom in / out | Zoom the image in and out |
| Zoom Amount | Set the Current Zoom as a Percentage |
| Fit To Screen | Zoom the image to fit the screen |
| Reset Zoom | Undo Zoom and the show the whole image pixel for pixel |
| Mark In | Set the first frame Mark |
| Mark Out | Set the last Frame Mark |
| Clear Marks | Clear the Mark in and Out settings |

# 7. Creating a New Project

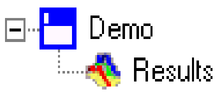


To create a new project:

1. Click the **New Project** button on the standard toolbar or select **File/New/Project**
2. Enter a name for the project in the **Project Name** field
3. Enter a **Test Number** (optional)
4. Change the path if necessary by clicking the ellipsis button and selecting a different directory
5. Click **OK**




The **Tree Area** of the window shows the new **Project's** name and a **Results** icon.




The program creates a directory structure as shown in Figure 6. A project file (***.map)** with the same name as the project (eg, demo.map) is created and stored in the project's main directory.

Empty sub directories are created as follows:

- **defs** directory to store defaults and definitions.
- **results** directory to store analysis results.
- **user** directory to store user specified files.
- **video** directory to store video files.
- **3D System** directory to store 3D calibration information.

You do not need to modify any of the files in these directories. You may use the user Directory to store information as required.

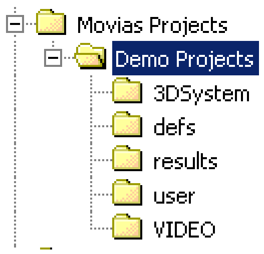
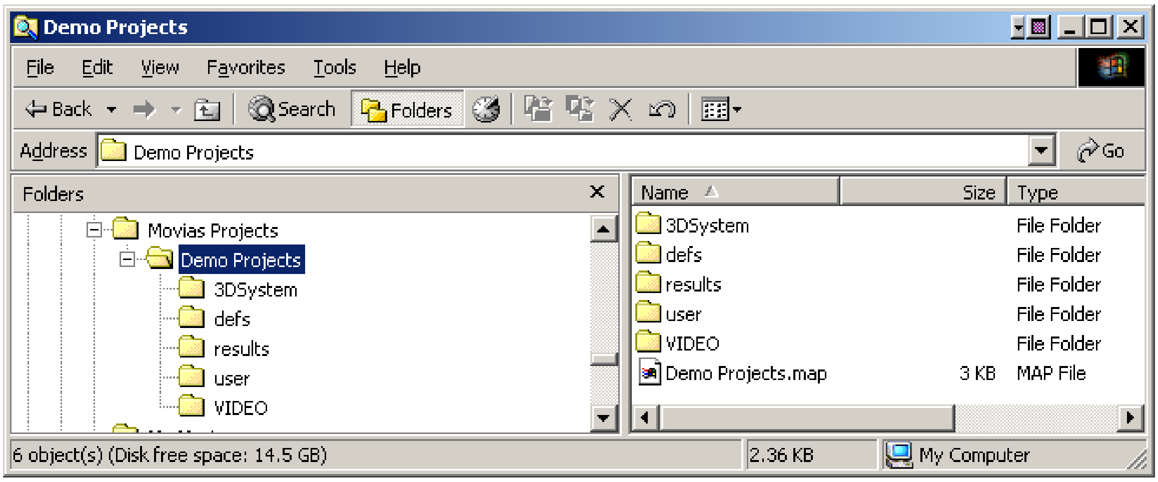
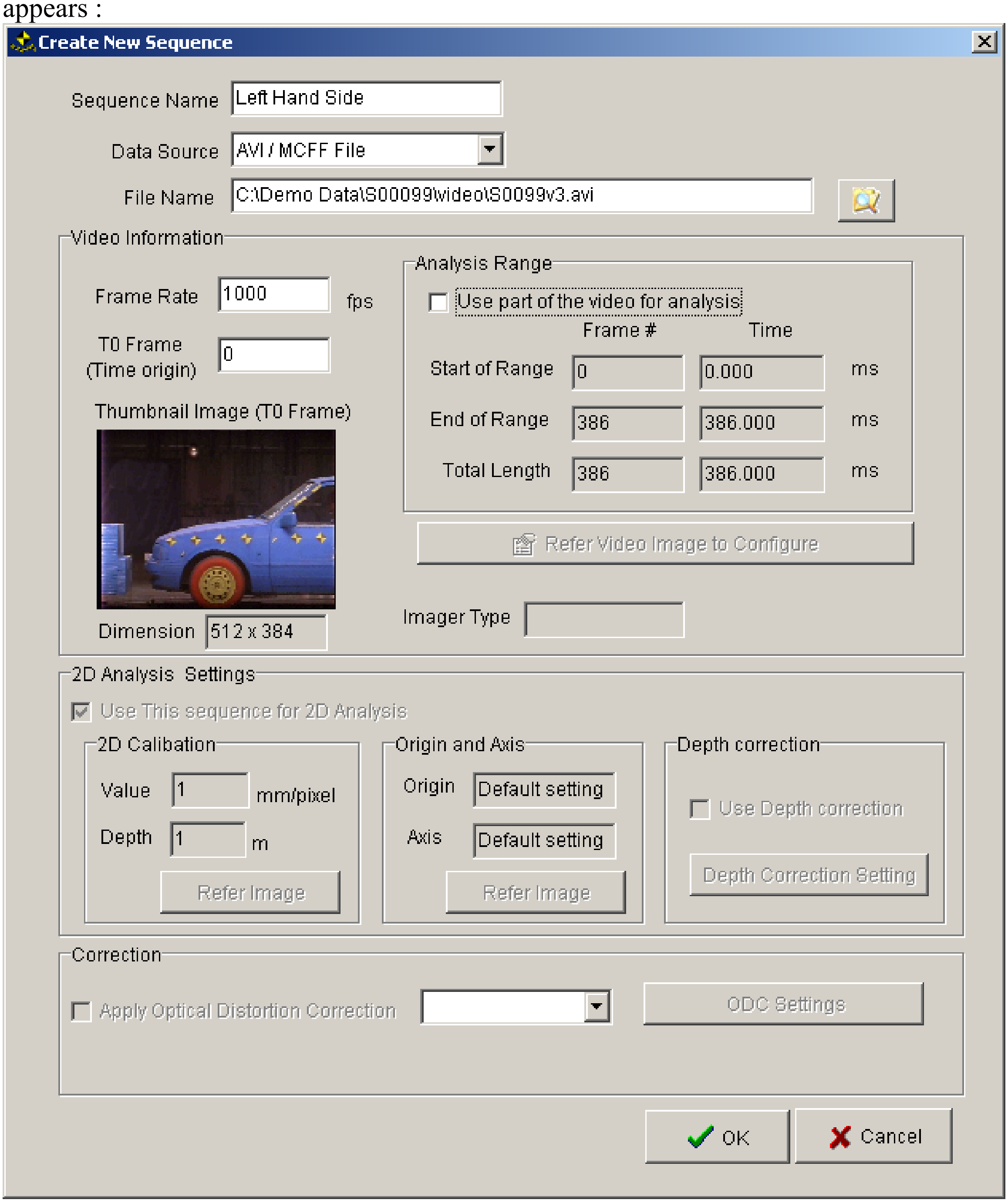



**Figure 6 - Project directory structure**



## 8. Creating a New Sequence

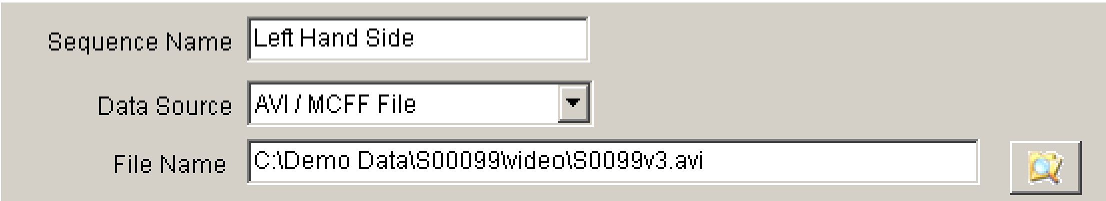
To create a new sequence Click the New Sequence Button. The Sequence information screen appears :



## *8.1. The Sequence Information Form*

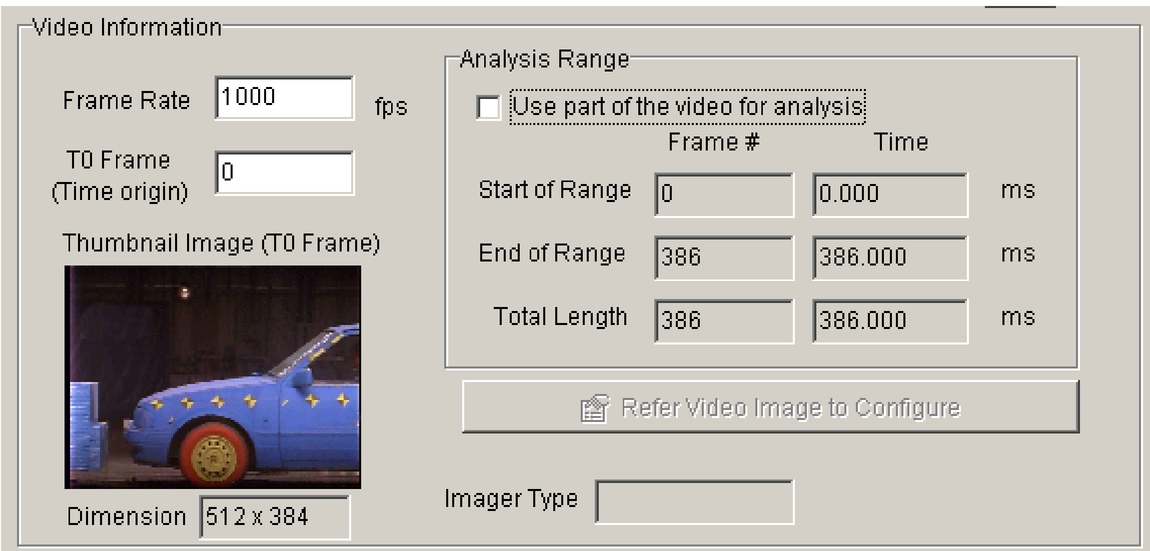
The sequence information form is separated into a number of sections. Some of these sections are only available once the Sequence has been created.

### 8.1.1. General Sequence Information




Enter the general Sequence information. This included : Sequence Name; Data Source and Filename. By default the data source will be “AVI / MCFF file”. You only need to select a different data source if you have legacy NAC tracking equipment such as AZ160F or X-Y Co-ordinator.

### 8.1.2. Video Information




In the video information section you should enter : Frame Rate of the camera used; Tzero Frame and the section of the movie to be analysed. In mast cases the whole of the Movie is to be analysed so you do not need to set an Analysis range.

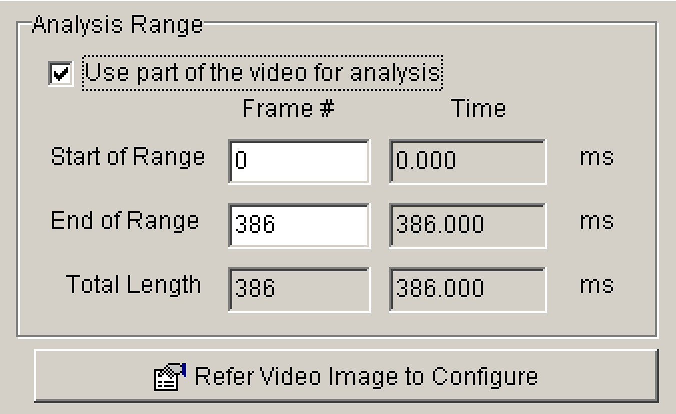
The TZero position can be entered at a later time.

The FPS MUST be correctly entered at this time.

If the FSP and Tzero information is available within the movie file or associated text file then these values are entered for you automatically.

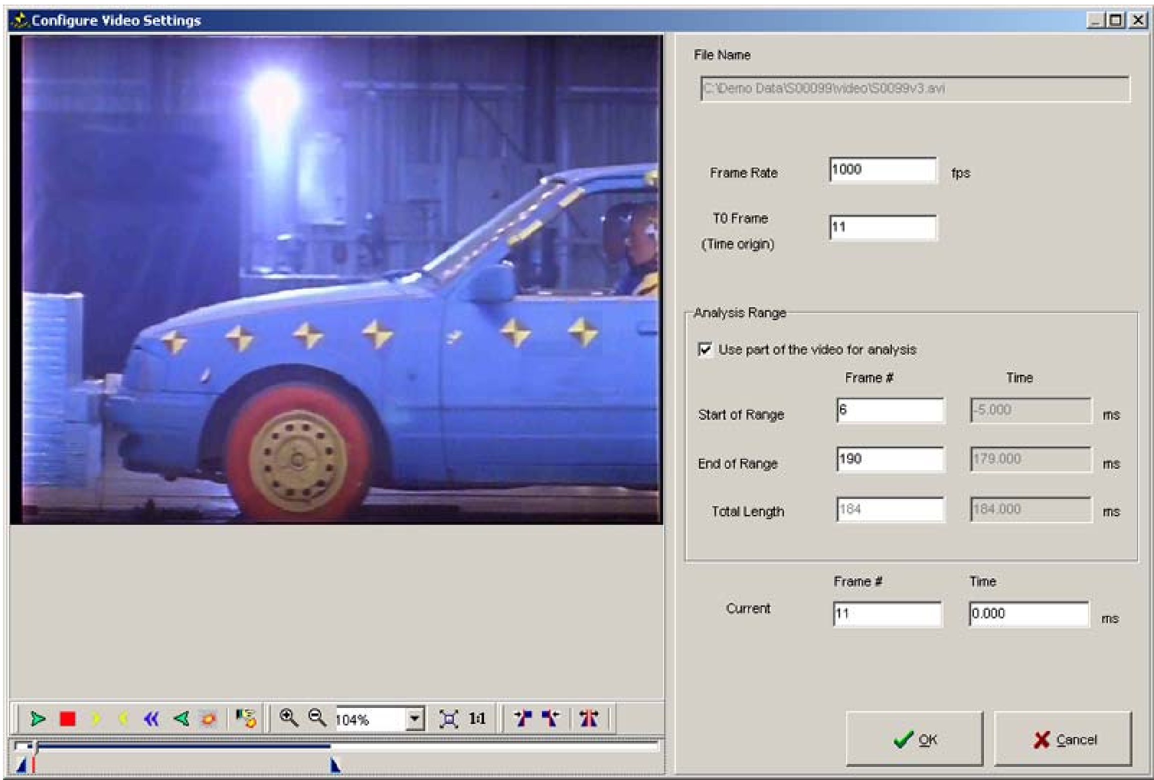
### *8.1.2.1.Analysis Range*

If you do not wish to analyse the entire range of the movie file you can, optionally set an analysis range at this point.




Check the "Use part of Video for analysis" check box.
You can either enter the frame range directly (if known) or press the "Refer Video Image to Configure" button. This will bring up the Configure Video Screen.

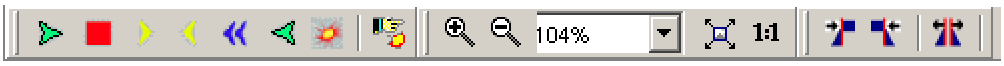
### *8.1.2.2.Configure Video*




Use the Configure Video Screen to :

1) Set the first Analysis Frame

2) Set the Last Analysis Frame
3) Set the Video FPS
4) Set the Video Tzero.




Refer to Chapter 6 for usage

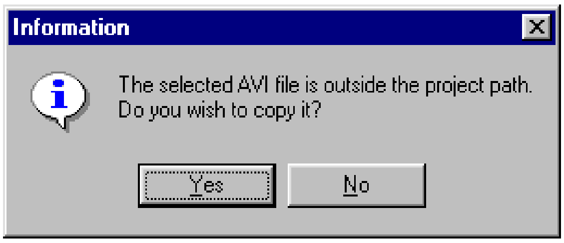
##### *8.1.2.3.2 2D Analysis Settings and Correction*

These are not available when a sequence is created. Refer to Chapter XXX for more information.

Confirming Sequence Creation

Once you have correctly chosen the Movie File and entered the Video Information Click the OK Button.

If the chosen file is outside the project path, Movias Pro prompts you to copy the file into the project's directory structure. You are advised to copy the sequence into the directory structure for the project in case the file is moved to another location.



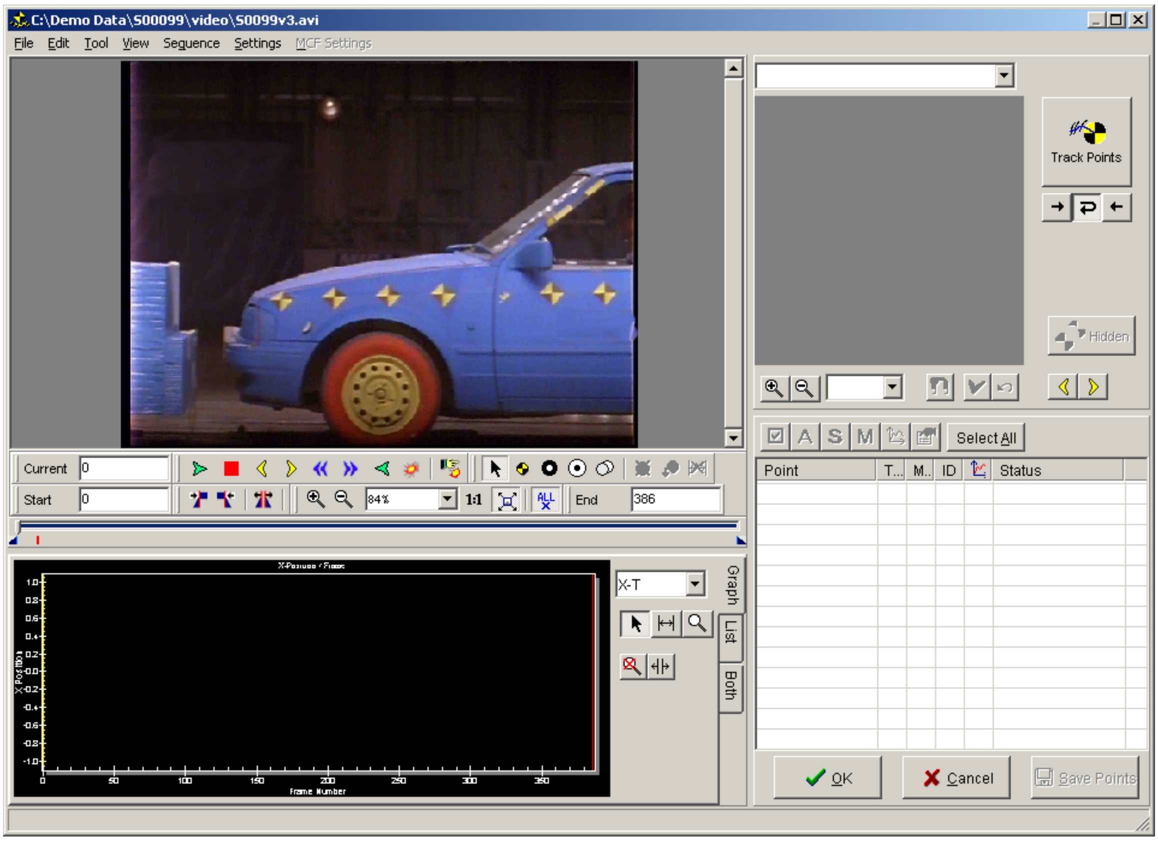

### *8.2. Non Movie File Data Source Types*

The **Data Source** drop-down list in the **New Sequence** dialogue box, gives you the following options:

- AVI / MCFF File
- AZ160F
- XY Co-ordinator
- 2D Results File
- 3D Results File

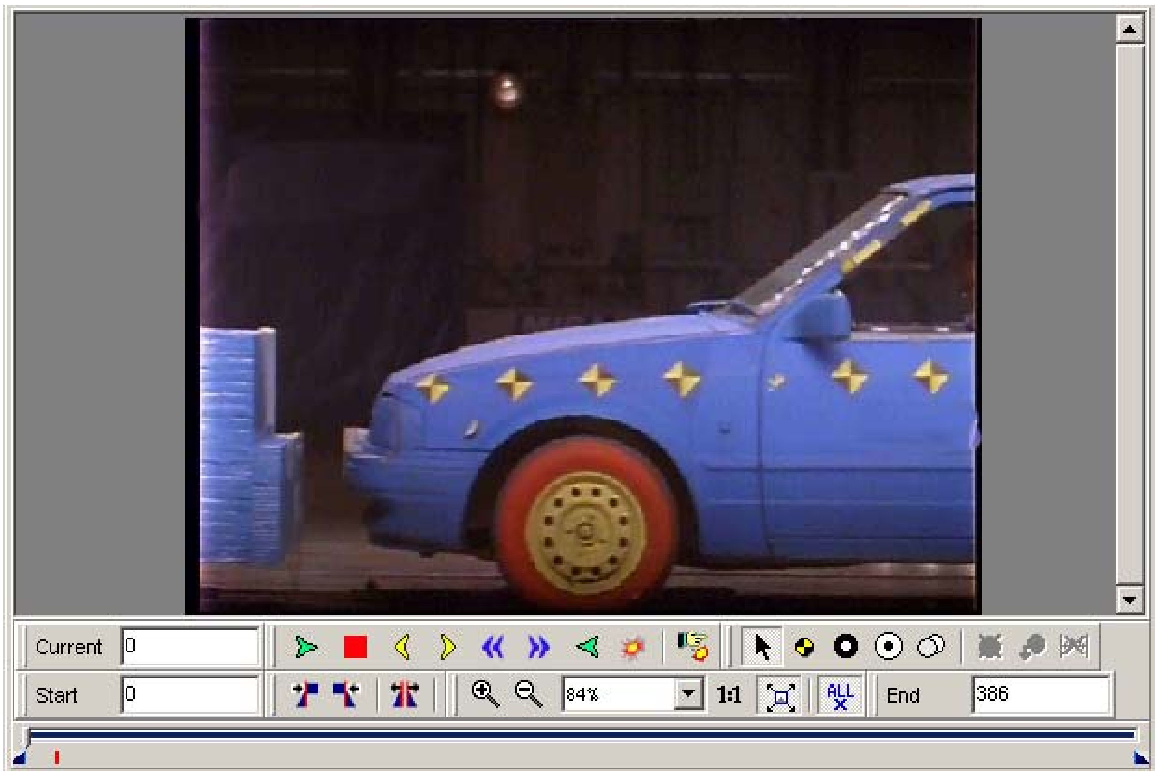
## 9. AVI / MCFF Tracking

Once A Movie Sequence has been create you are taken to the tracking Screen as shown below.



The Tracking screen is separated into FIVE sections.

### 9.1. Tracking – Tracking Area



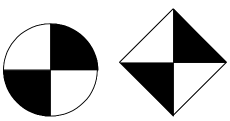
The Tracking Area shows the current Movie along with control Buttons (see Section 6).

In addition to the standard control buttons there are some additions buttons.

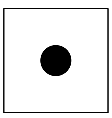
| Use this… | | To do this… |
|---|---|---|
| | Select Point | Select a Tracking Point |
| | Define Quadrant | Define a Quadrant Marker to track (see Marker Types) |
| | Define Light Spot | Define a Light Spot Marker to track (see Marker Types) |
| | Define Dark Spot | Define a Light Spot Marker to track (see Marker Types) |
| | Define Correlation | Define a Correlation to track (see Marker Types) |
| | Delete Target | Delete the selected Target/s |
| | Place Target | Locate / Re-locate the target |
| | Delete Range | Delete the tracked positions within the selected range for the selected Targets |
| ALL | Show All | Show all the targets. If NOT depressed then ONLY the selected targets will be displayed. |

### 9.1.1. Marker Types

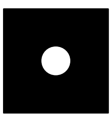
A marker is any 'area of interest' that you select for tracking on a video sequence. The area may be a pre-defined target or simply any other area of the image you are interested in.



*Quadrant targets*



*Dark Spot target*

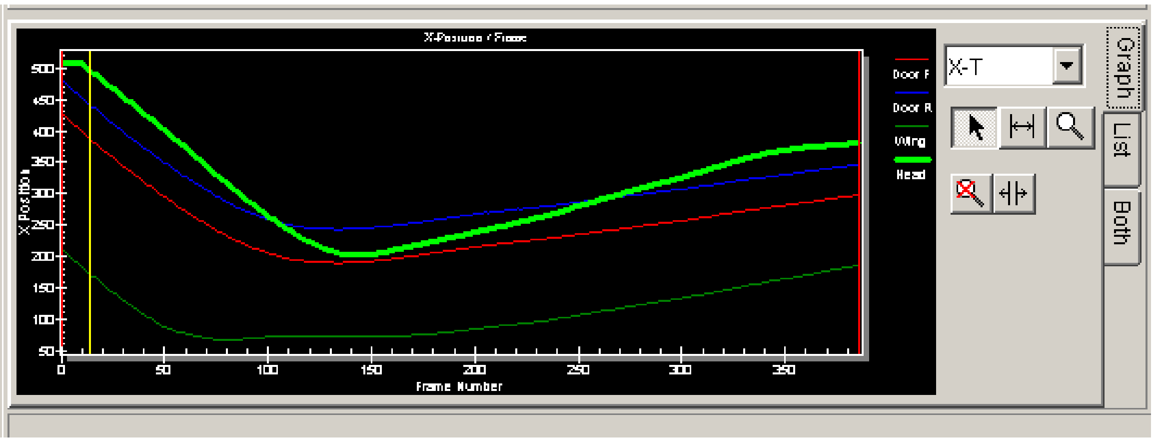


*Light Spot target*

There are four available target types: **Quadrant**, **Dark Spot**, **Light Spot** and **Correlation**. Use the **Correlation** target type if the target you are tracking is not a Quadrant, Dark Spot or Light Spot target.

### *9.2. Tracking - Tracking Results*

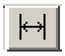
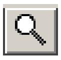
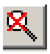
The results of the tracking are shown in the Tracking Results Area.




The results are dynamically updated as tracking proceeds. The results can be viewed as a Graph, a list or both.

#### 9.2.1. Navigating the Tracking Results Area

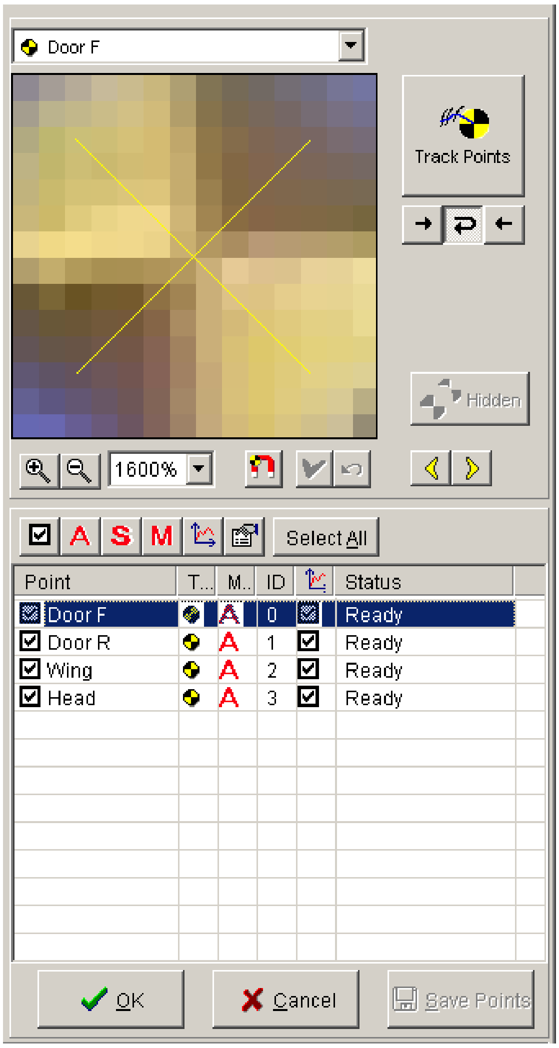
To “Move Time” in the tracking window you can click in the graph are while the “SELECT” tool is selected . 
Clicking on a tracked point’s curve will SELECT that point.

| **Use this…** | | **To do this…** |
|---|---|---|
|  | Select {default} | Select a Tracking Point by clicking the tracked curve<br>Select a time / Frame Number by clicking inside the graph |
|  | Select Range | Select Range : Drag over the graph range to select |
|  | Zoom | Zoom Into the Graph : Drag over graph to select ZOOM Area |
|  | Zoom Out | Zoom out of graph |
|  | De-Select Range | Deselect a frame range (select the entire range) |

| | | |
|---|---|---|
|  | Plot Mode | Choose the plot mode<br>(X-T) X position against Time<br>(Y-T) Y Position Against Time<br>(X-Y) X position against Y Position<br>(Tracked) Frames with Tracked Data<br>(Un-Tracked) Frames without Tracked Data |

### *9.3. Tracking Point Information*

The Point Information area is show in fig below



## 9.4. General Notes on Tracking Screen

### 9.4.1. Selecting Points

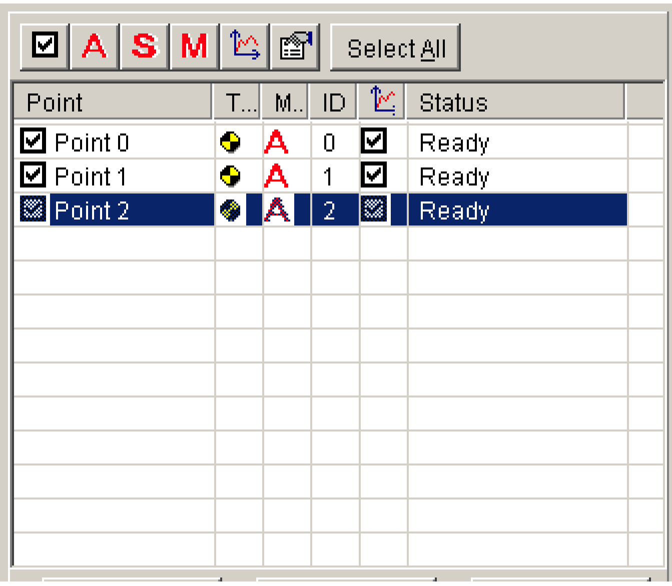
There are a variety of methods for selecting points.

i) Click the point name in the point list
ii) Click the point in the tracking area
iii) Click the point's graph line in the results area
iv) Select the point from the Point Combo
v) Push the Select ALL button.

To select MULTIPLE Points use the CTRL KEY
When multiple points are selected the Zoom Area will be GRAY,

## 9.5. Defining Points track

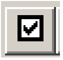
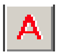
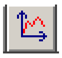
To define a point to track select the correct target type button and click in the image close to the centre of the point. If the target type allows, Movias Pro will auto-centre on the point. The point will be created and added to the point list. You can add more points by clicking futher points in the image. When all points are defined click the select button.




Points to track can be defined in ANY frame of the Movie Sequence.

### 9.5.1. Tracking Point Properties

Once the points have been defined you can set the properties of the point.
You can set properties of multiple points in one go by selecting the points to set by any of the select points methods described in 9.4.1.

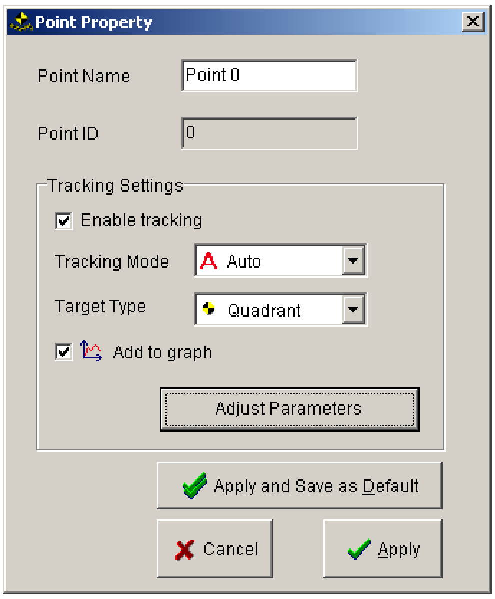
| Use this… | | To do this… |
|---|---|---|
|  | TRACK | Toggle if t he point is tracked or not |
|  | Automatic | Set the tracking mode to AUTOMATIC |
|  | Semi-Auto | Set the tracking mode to SEMI-AUTOMATIC |
|  | Manual | Set the tracking mode to MANUAL |
|  | Graph | Show the point tracking results on the Graph |
|  | Properties | Show the Advanced Point Property Dialog |

#### *9.5.1.1.Renaming a Point*

To rename a point you can either select the point and click the properties button, OR select the point and click in the “name area” of the list to rename it directly.

#### *9.5.1.2.Advanced Point properties*

To show the Advanced Point Properties form click the Properties button. If more than one point is selected then some of the properties (such as point name) will NOT be editable.




After setting the Advanced Point Properties you can Apply them (to all selected points) OR Apply and save as Default. If you save as default then ALL new targets created of this type will default to the settings made.

#### *9.5.1.3. Tracking point parameters*

The Tracking point parameters form has a different layout depending on what point type is selected.
Some of the setting are common while others relate to the target type.

**For Quadrant Targets**

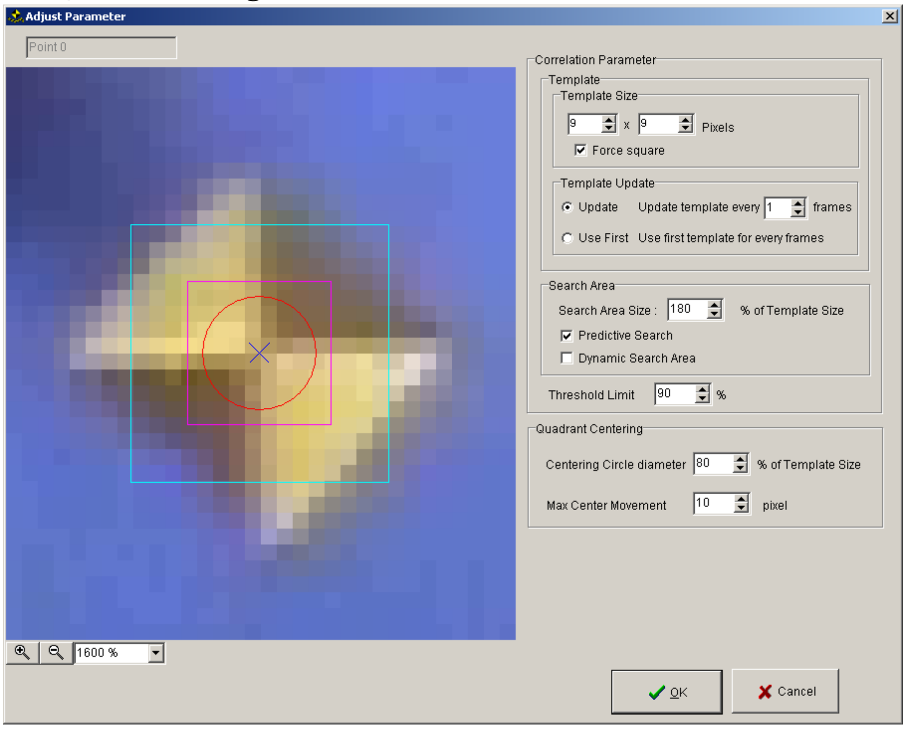



**Figure 7 Point Properties**

Template Size

The template size is the size of the pixel pattern Movias Pro will try to find. A smaller the template size is usually better and faster to track, but it depends on the image and image quality. The template size is show as the PINK square in Figure 7.

Force Square

This check box will force the template to be square

Template Update

During tracking, the template which Movias Pro looks for during the target search process can be updated. The default is that it updates every frame. This means tat in each frame Movias Pro will search for the target as it appeared in the previous frame. By doing this, Movias Pro can automatically adjust for small changes in the shape or orientation of the target.
In some special cases it may perform better of the template is updated less frequently or not at all. The template update settings allow you to set these parameters.

Search Area

The search area defines the size of the area in which Movias Pro will look for the target. The Size of the search areas should be set in relation to the distance moved by the target from frame to frame. The search areas is shown by the Cyan square in Figure 7. The smaller the search area, the faster the tracking process.
If Movias Pro consistently fails to find the target then it might be because the search area is too small.
Using **Predictive Search**, Movias Pro will first predict the position of the target before setting the Search Area. By default this is activated.
Using **Dynamic Search Area** will allow Movias Pro to automatically ***decrease*** the search area size if it is useful to do so.

### Threshold Limit

The Threshold Limit is the measure of "Pattern Match Accuracy". If during searching the pattern match accuracy drops below this level then Movias Pro will request user confirmation. The default is a 90% match. In some cases it may be helpful to reduce this. HOWEVER, the more the reduction, the more likely it will be that Movias Pro could start "drifting" in its tracking results.

### Quadrant Centring

When tracking a Quadrant Target, Movias Pro will perform Auto centering function. It does this by looking for edges around the Quadrant Centre Circle. This is shown as the red circle in Figure 7.
If Auto Centring continually fails you should adjust the diameter of the Quadrant Centering Circle.
As a further check, Movias Pro will limit the amount of movement allowed for the Centre of the target (similar to the search area). If the centre moved more than the value in **Max Centre Movement** then Movias Pro will stop for user confirmation.

**For Dark Spot / Light Spot Targets**

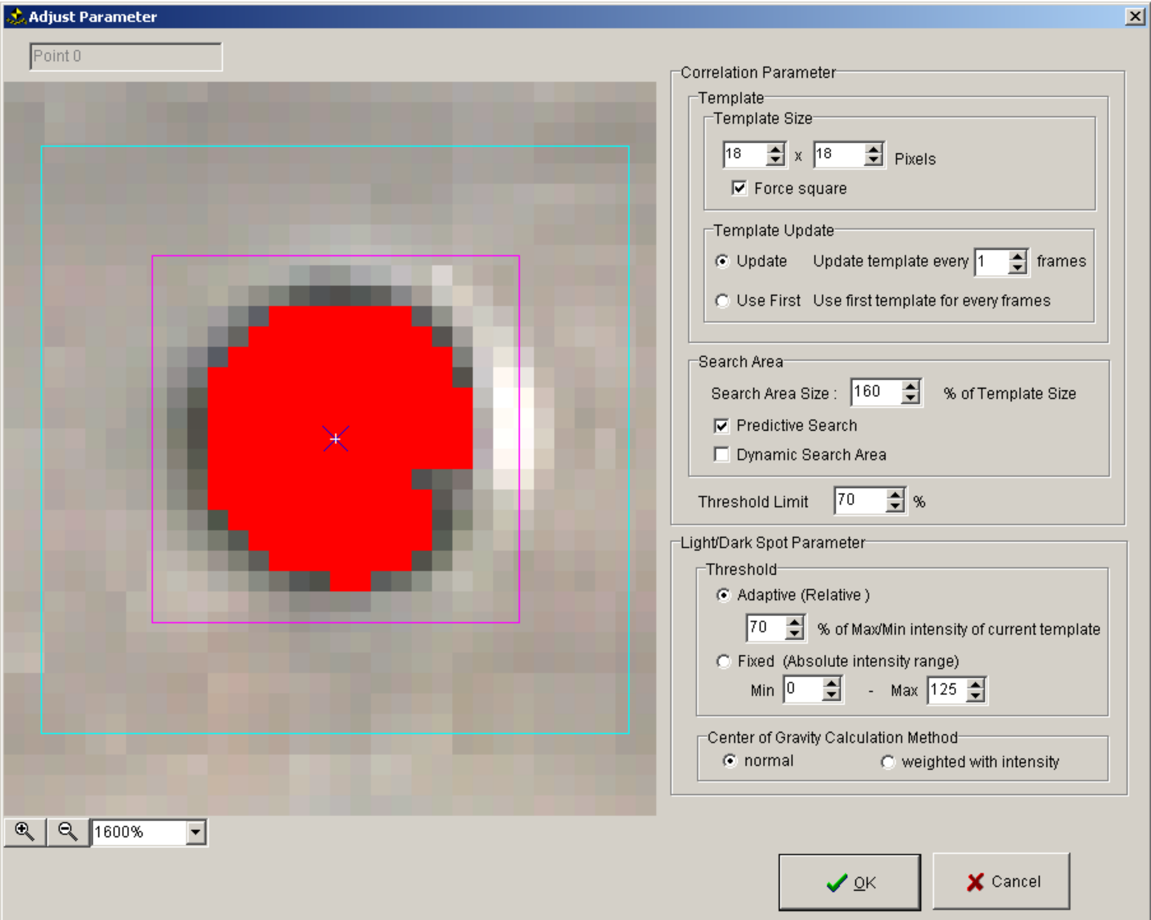



**Figure 8 Dark / Light Spot Parameters**

The point parameters form is different for light and dark spots as illustrated in Figure 8.

### Light/Dark Spot Threshold

The Light / Dark Spot threshold is used to determine what portions of the template are light / Dark. Movias Pro will look at all the pixels in the template area and judge their intensity. Pixels which are more than the set %age above the mean intensity will be considered part of the “spot” if Adaptive thresholding is used. If Fixed thresholding is used then the user can define the intensity range which is considered to be the “spot”.
For either usage, the pixel within the Threshold range are colour Red as shown in Figure 8.

### Centre Of Gravity Calculation

The centre of gravity calculation defines the method used to determine the centre of gravity (and thus the centre) of the “spot”.
**Normal** will treat all pixels within the threshold area as equal. **Weighted** will treat each pixel differently depending on it’s relative distance from the threshold value.

## 9.6. Tracking Modes

There are three tracking modes, automatic, semi-automatic and manual.

### 9.6.1. Automatic Tracking

Automatic Tracking will track the selected point with no user intervention subject the to the Tracking Preferences (see section 9.8).

### 9.6.2. Semi Automatic Tracking

Semi-Automatic Tracking will track all points BUT will require the user to confirm EACH point on EACH frame to be tracked.

### 9.6.3. Manual Tracking

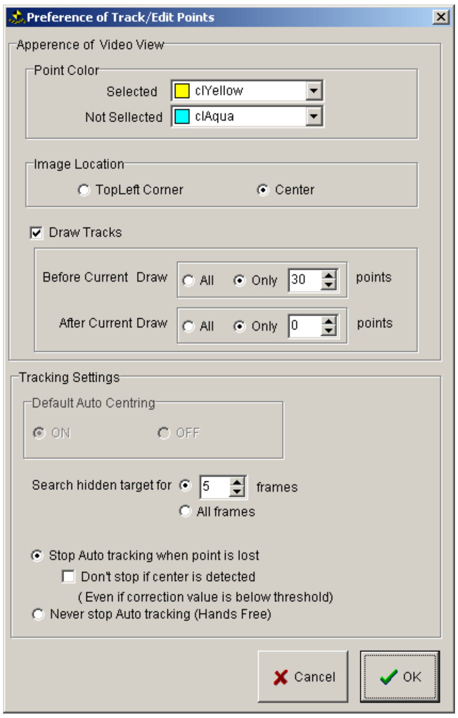
Manual Tracking required the user to position the tracked points for each frame.

You can switch between tracking modes for any point during the tracking process.

## 9.7. Tracking Direction

Movias Pro can track forward and backwards (and both).
For forwards tracking Movias pro will track each point from it's defined frame to the end of the sequence.
For Backwards Tracking Movias Pro will track all points from their defined frame to the beginning of the sequence.
Auto-Reverse tracking will track all points forwards from the defined frame to the end of the sequence and then backwards from the defined frame to the beginning of the sequence.

## 9.8. Tracking Preferences




The Tracking preferences screen is shown above.

| Use this… | To do this… |
|---|---|
| Point Colour | Set the display colour of the points during Tracking |
| Image Location | Set the position of the image in the image window |
| Draw Tracks | Toggle drawing the known position of the target on all frames |
| Search Hidden For | Set the number of frames to search for hidden (vanished) targets before requesting user intervention |

## *9.9. Tracking Form Menu*

### 9.9.1. File | Save Points

Saves the current tracking information

### 9.9.2. File | Close Window

Closes the Tracking Form and returns to the Main Movias Pro Window

### 9.9.3. Edit

The Edit Menus can be activated from the main Menu Bar OR by right Clicking in the following areas : Point List; Point Mark on the Tracking Window; Tracked Point Graph line

You can use the edit menu to :
- Select All Points
- Check Selected Points (activate for Tracking)
- Un-Check Selected Points (De-Activate for Tracking)
- Show the Point Property Form
- Change the Target Type
- Change The Tracking Mode
- Show / Not Show Graph
- Delete Point
- Delete Range data

#### 9.9.4. Tool

Use this to define / Select a target

#### 9.9.5. View

Change the viewing Style

#### 9.9.6. Sequence | Property

Show the Sequence Property Form

#### 9.9.7. Sequence | 2D Calibration

Define 2D Calibration Data (see 9.10)

#### 9.9.8. Setting | Preferences

Show the Tracking Preferences Form (see 9.8)

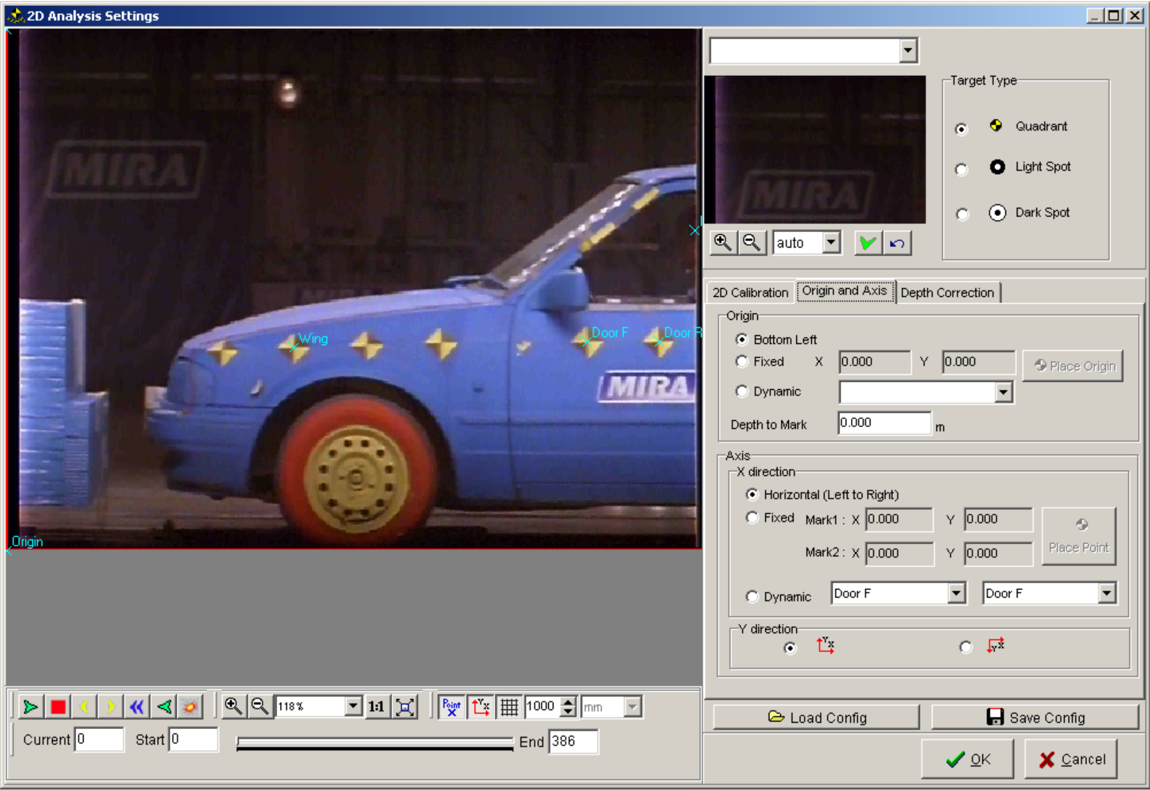
#### 9.9.9. MCF Settings

Set the display parameters for NAC MCFF Files

### *9.10. 2D Calibration*

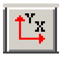
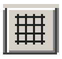
To perform 2D calibration select Sequence | 2D calibration from the menu.

The Calibration Screen has three input areas : 2D Calibration, Origin and Axis and Depth Correction.
The screen in split into the Data Area and the image Display area.



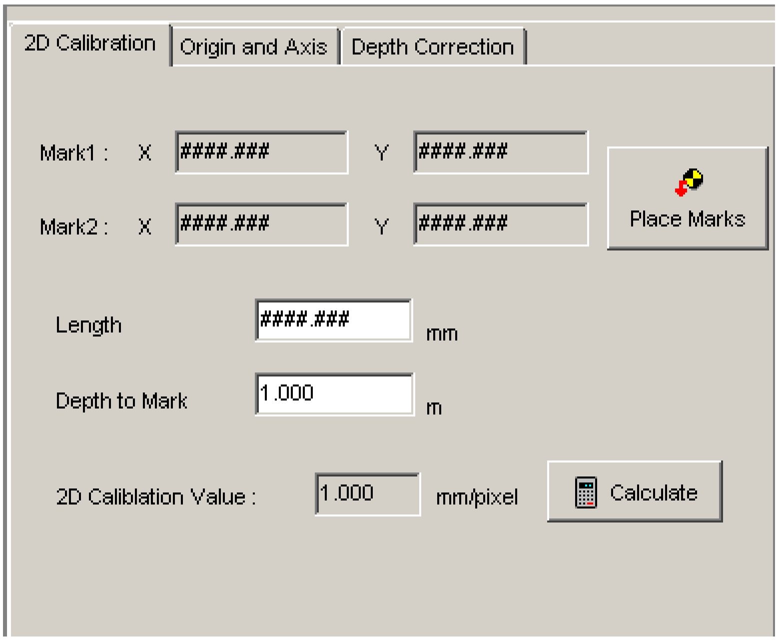

### 9.10.1. 2D Calibration Control Buttons

Along with the standard control buttons there are some further controls in the Image Display Area.

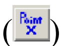
| Use this… | | To do this… |
|---|---|---|
|  | Show Points | Toggle the display of Tracked Points (if any) |
|  | Show Axis | Display the Axis |
|  | Show Grid | Overlay a Grid on the Image |
|  | Grid Frequency | Set the Frequency of the Grid Lines |

### 9.10.2. Defining the 2D Calibration

Use 2D Calibration to make a pixel size calculation. To do this you must know the (real) distance between two marks in the image.




Push the Place Marks Button

You must now click in the image on the first calibration mark. If the mark is a specific target type the n select the target type first. This will allow Auto Centring. If the mark is Also a tracked target, then you will need to TURN OFF the display of the tracked points in order to set it as a calibration mark ().
CONFIRM the mark by clicking the Confirm Button ().
Then place the second Calibration Mark and Confirm it's position.

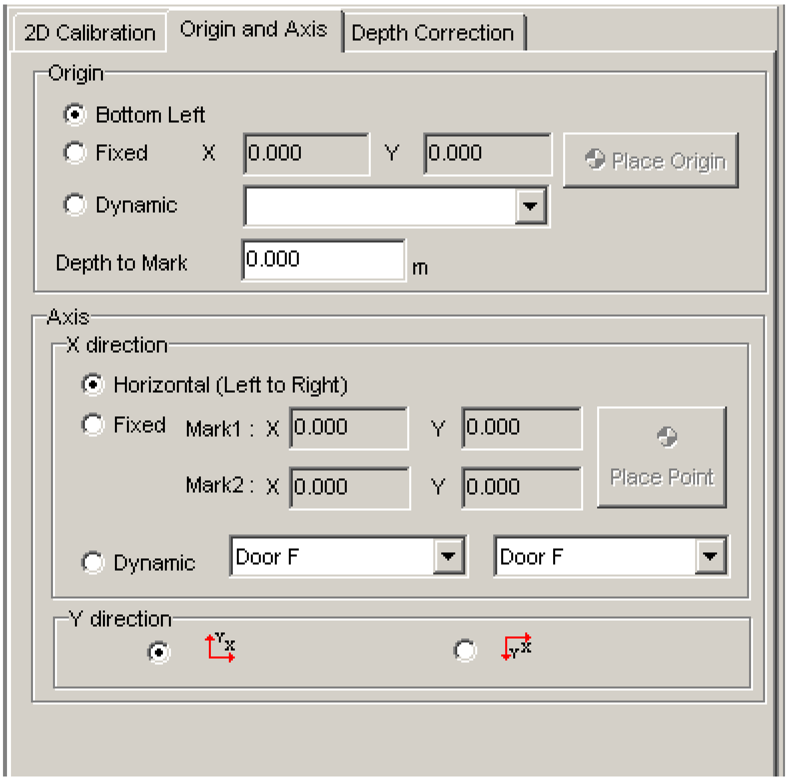
You must then enter the distance (in mm) between the calibration marks.
Enter the Distance from the Camera to the calibration marks (optional, ONLY required if depth correction is to be used).

Then Press the **Calculate** Button. This will generate a Pixels Per mm value.

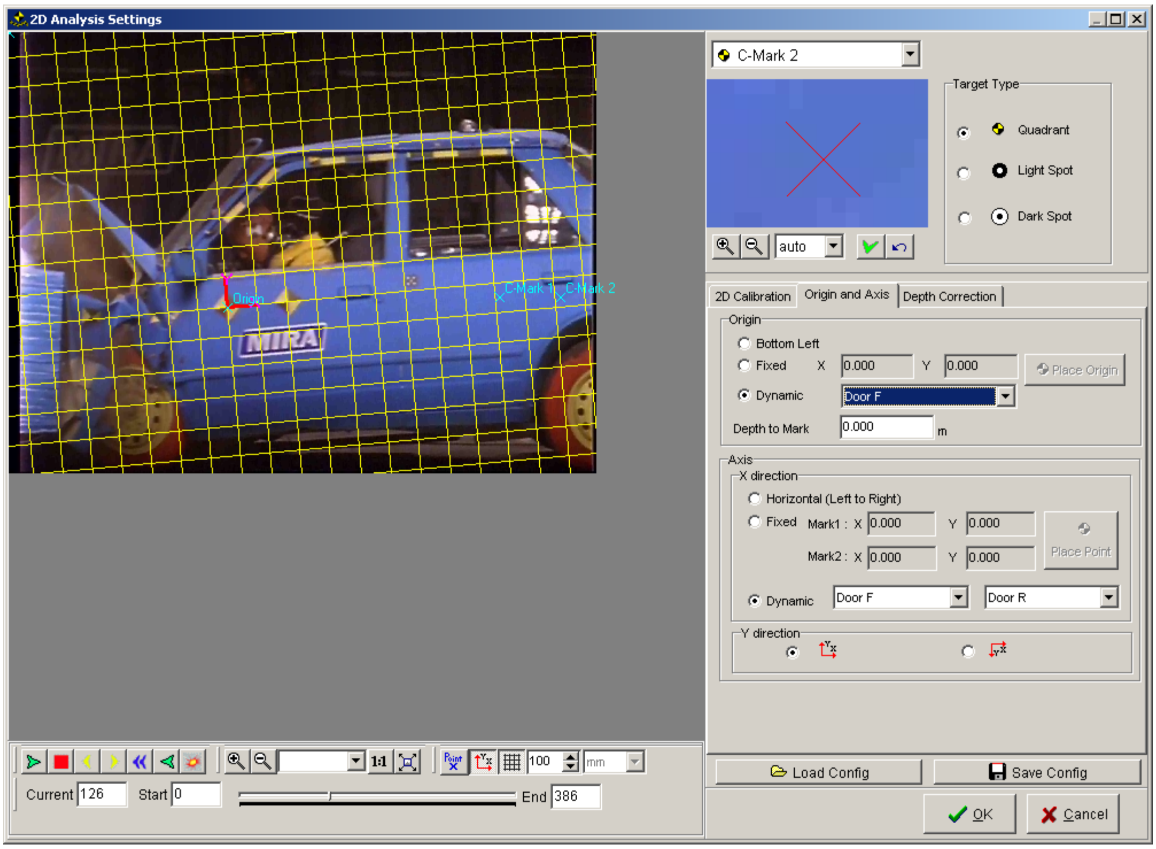
All results will then be calculated using this information.

### 9.10.3. Origin And Axis

By default Movias Pro used the Botton Left of the image as the ORIGIN. The Vertical Direction is "Y" and the Horizontal Direction is "X".
It is possible to alter these setting to define a fixed or even dynamic co-ordinate system. You can do this using the Origin And Axis definition page.




You can Define a fixed Origin and Axis in the same was that the Calibration points were set. To define a Dynamic Origin and Axis, the Points which make up the Origin and Axis MUST have already been defined and tracked.

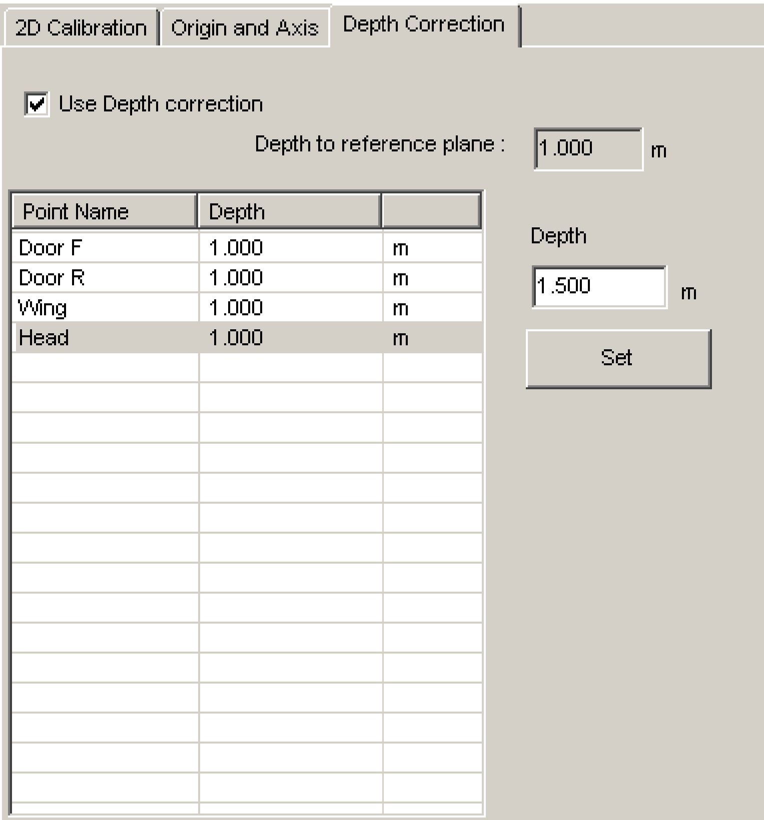


The above screen shot show a dynamic origin and Axis. The origin is set to the Front Door Target and he axis is defined as the front door target to the rear door target.

When a dynamic origin and axis are set, ALL calculation will be with reference to these locations.

#### 9.10.4. Depth Correction

If the tracked points are at different distances from the camera then the calibration information will need to be adjusted in order to correct for this “depth”. You can enter the distance information in the Depth Correction tab page.
The Calibration depth can be “nominal” so long as the depth of the points are in relation to the nominal depth.
If depth correction is used then it will be applied to all calculated results.




When all the calibration information has been input. You can click the OK button to return to the tracking window.

### *9.11. The Tracking Process*

To begin Tracking Press the TRACK button. To stop tracking press the STOP Button. Tracking will be done is one of the following ways :

**Forwards Tracking** : From the first frame in the range to the last frame in the range.
**Backwards Tracking** : From the last frame in the range to the first frame in the range.
**Auto-Reverse** : Forwards from first to last and then Backwards from Last to First.

The defined points will be tracked from the first frame on which Movias Pro has data (usually the frame on which it was defined).

#### 9.11.1. Confirming Point Positions

In some circumstances the user must CONFIRM point positions. This can be one by pressing the Confirm button[], pressing the <SPACEBAR> or pressing the <ENTER> Key.

#### 9.11.2. Automatic Tracking

With Automatic tracking, Movias Pro will search for each target on each frame in turn. It will auto-centre the target if it is a target type which allows. Once all targets are found on a frame it will progress automatically to the next frame.
Under some conditions Automatic Tracking will halt and request User confirmation. This will happen if :

The target match is below the user set threshold
The Centre of the target cannot be found
The target has moved more than the user set distance

In these circumstances the user must CONFIRM the point [] OR adjust the point and then Confirm the point.

#### 9.11.3. Semi-Automatic Tracking

In Semi Automatic Mode the process is the same as in automatic mode EXCEPT the user MUST confirm each point.

#### 9.11.4. Manual Tracking

In Manual Tracking mode the user MUST locate and Confirm each point during the tracking process.

#### 9.11.5. Hidden Points

On some occasions the points being tracked might become hidden (obscured) by other items in the image. If this happens during Automatic tracking then tracking will stop due to match below threshold error. You then have the option to push the HIDDEN button [Hidden]. This will make Movias Pro predict the position of the target. Prediction will continue until the target is found again OR the hidden number frames exceed the value set in the preferences (see 9.8).

### *9.12. Editing Tracked Points*

You can adjust tracked points manually at any time. To move a point select it and drag it in the main video view or the Zoom View. When correctly located click the Confirm

Button[ ]. TO revert back to its' original position click the revert button[ ]. NOTE : you cannot Revert once you have Confirmed a point position.

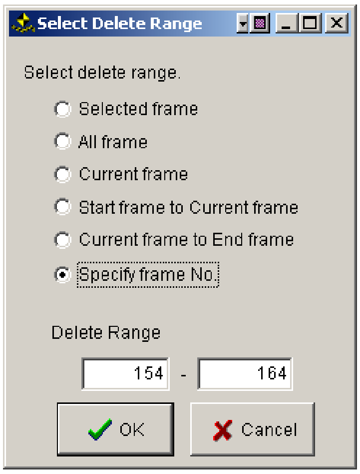
You can use the "centre" button [ ] at any time to let Movias Pro detect the centre of the target automatically.

#### 9.12.1. Deleting a point

To delete a tracked point completely select the point and click the delete target button [ ].

#### 9.12.2. Deleting tracking data

To delete the tracking results first select the range you wish to delete using the Mark in and Mark Out buttons. Then select the points for which you wish to delete the data for. Finally click the delete range button [ ].
You will be presented with the delete range dialog.




Select the required option and click OK. This will delete the data for the selected points over the selected range.

You can re-track this data again if required.

### *9.13. Completing the Tracking Process*

Once the tracking process is completed and the calibration information entered you can return to the main Movias Interface by clicking the OK button

### *9.14. Returning to Tracking*

You can return to the tracking window at any time by right clicking the "Sequence" icon on the Data Tree and select "Track/Edit Points".

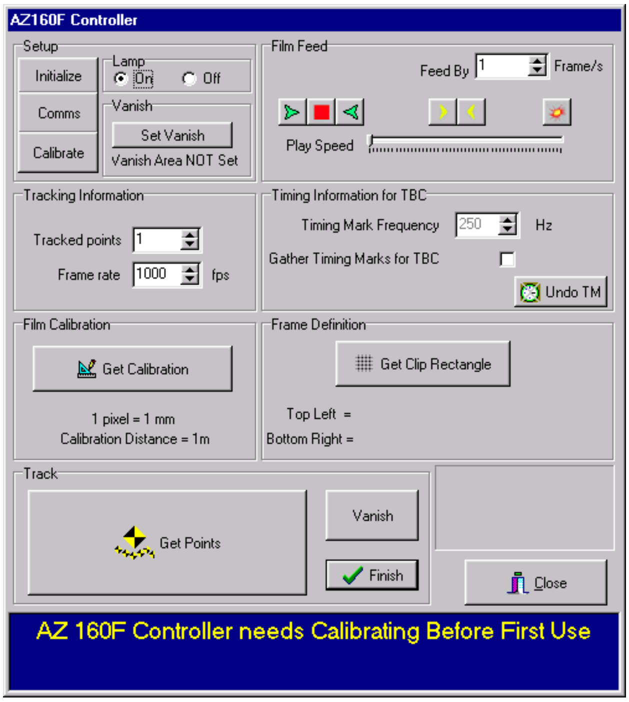
## 10. Manual Tracking

Manual Tracking is available using the AZ160F Motion Analyser or The NAC XYCo-ordinator.

### 10.1. AZ160F

Operation of the AZ160F hardware is described in the AZ160F user manual.

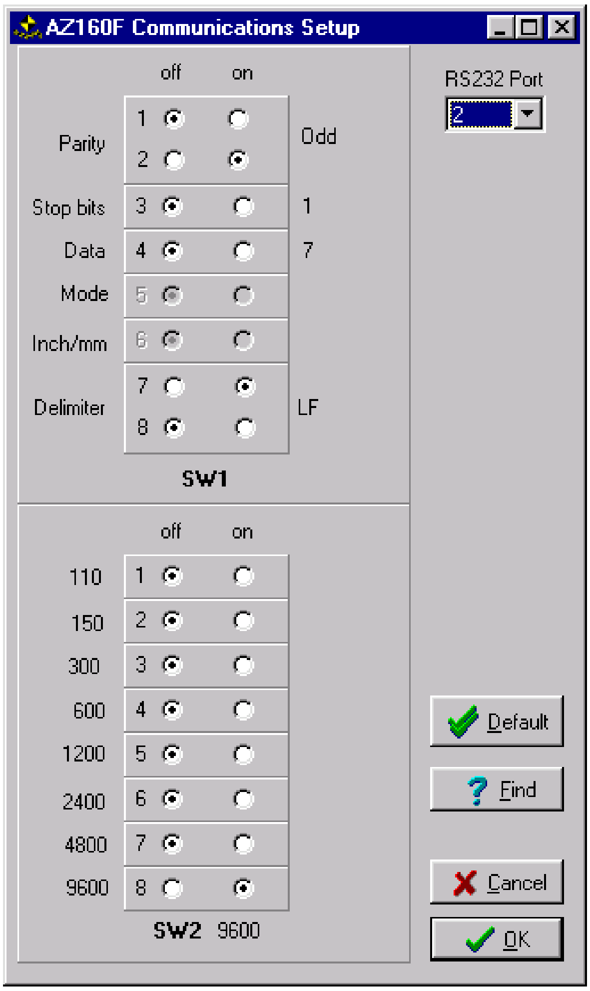
To use the AZ160F you should select AZ160F as the source for a new sequence. You will then see the AZ160F Control Panel as illustrated below :




Before using the 160F for the first time you should make sure that the communication channels between the 160F and the computer are enabled.

#### 10.1.1. Setting up the Communications

To set up the communications between the AZ160F and the computer you should push the "comms" button. This will show the Comms dialog as shown below:




The RS232 Port selector should be set to the COM port to which the AZ160F is attached. The Two Switch Banks should match the settings of SW1 and SW2 inside the AZ160F. To access these switches you should remove the panel cover on the left hand side of the AZ160F.

Once the setting in the dialog match the setting on the 160F you can OK this dialog.

To test weather the Communications are working you should switch on the 160F and Toggle the lamp on and off using the A160F controller form. IF the lamp does not work check that the com settings are correct.

### 10.1.2. Using the 160F for the first time

Once Communication with the 160F has been established you will need to perform a calibration task. Do this by clicking the Calibrate Button. You will be requested to click the topmost and the rightmost area of the 160F digitizer screen.

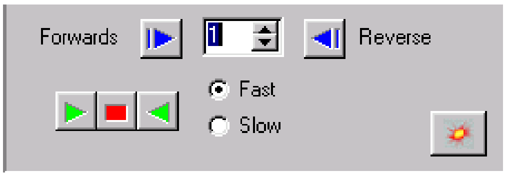
### 10.1.3. Setting a vanish area

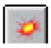
You may set a part of the 160F screen to be an area to click if you wish to "vanish" a point. To Do this click "Set Vanish". You will be asked to click the bottom Left and the top right of the vanish area.
The vanish area will be saved by Movias Pro and used until it is re-defined.

Clicking the Vanish area will vanish the current point for the current frame. You may also vanish the point by clicking the Vanish.

### 10.1.4. Tracking points using the 160F

First load a film into the 160F. User the Video controllers to find the frames of interest.




Use the  button to reset the counter of the AZ160F and set the Tzero from within Movias Pro. Use the VCR controller to rewind the film to the first frame on which you wish to start tracking.

Before tracking points you need to calibrate the film and set a region of interest.

#### *10.1.4.1. Calibration*

To calibrate the AZ160F click the "**GET CALIBRATION**" button. Follow the on screen instruction. You will select two calibration points and be prompted for the physical distance between then and their depth from the camera. Depth from the camera is used for depth correction.

#### *10.1.4.2. Region of interest*

To set the region of interest click the "**GET CLIP RECTANGLE**" button. Follow the on screen instructions. You will be prompted for the top left and the bottom right of a rectangle that specifies the region of interest. Be sure that all points to be tracked are within the region for the duration of the frames to be tracked.
If you are gathering Timing Marks then any point input which is outside of the Clip Rectangle will be assumed to be a timing mark.

#### *10.1.4.3. Selecting Points to track*

Enter the number of points per frame and the Frame rate of the camera.

Click "Get Points". Follow the onscreen instructions. You will be asked to click each point in turn. When all the points have been located the AZ160F will advance to the next frame and you will be asked to click the points in turn again.

To finish manual tracking you can push the "**STOP**" button. You can ONLY do this after you have completed all the points for a frame.

The data will then be loaded into the Main Movias Pro Data Tree for manipulation.

### *10.2. XY Co-ordinator*

Operation of the XY Co-ordinator hardware is described in the XY Co-ordinator user manual.

To use the XY Co-ordinator you should select XY Co-ordinator as the source for a new sequence. The XY Co-ordinator control panel and communications setup panel are identical in look and usage as for that of the AZ160F.

## 11. Results Files

Data can be imported into Movias Pro from older versions of Movias or other applications in the form of ASCII data files. The format of these files is described the File Formats section of this manual. Once data has been imported it can be used to generate results in the same way as all other data.

## 12. Outputting Data

To select Data Output method use the Results Toolbar or Results Menu.

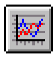
### *12.1. List (`Results|List`)* 

List output will list the pure pixel co-ordinate of the selected point for each frame. This information is raw data. No analysis or correction has been made to the values.

### *12.2. AVI Overlay (`Results|AVI Overlay`)* 

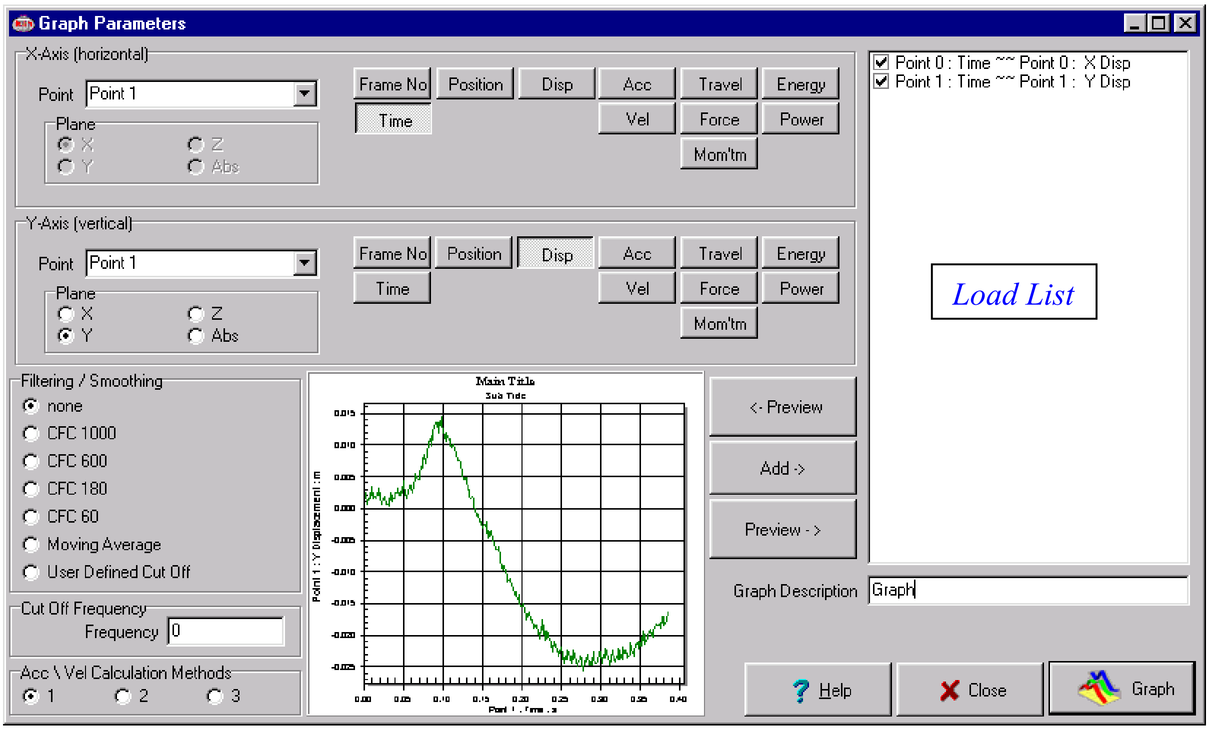
AVI Overlay display the image sequences for review.


| Use this… | | To do this… |
|---|---|---|
| | **POINT** | Toggle the tracked points visible and invisible |
| | **VIDEO** | Toggle the images visible and invisible |
| | **POINTS** | Toggle all point locations visible and invisible |
| | **LOCUS** | Toggle the tracked point locus' (trajectories) visible and invisible |
| | **STICK** | Toggle ***stick definitions*** visible and invisible |
| | **AXIS** | Toggle the angle definition visible and invisible |
| | **ZOOM IN** | Zoom in |
| | **NO ZOOM** | Undo zoom |
| | **DEFAULT SIZE** | Undo zoom and re-size the window to the original image size |
| | **ZOOM OUT** | Zoom out |
| | **COPY** | Copy frame to clipboard (including any annotation) |
| | **BACK COLOUR** | Select the background colour (visible when the images are invisible or not available) |

## *12.3. Graph and List (`Results|Graph`)* 

### 12.3.1. Graph Selection

The graph selection screen is as follows :

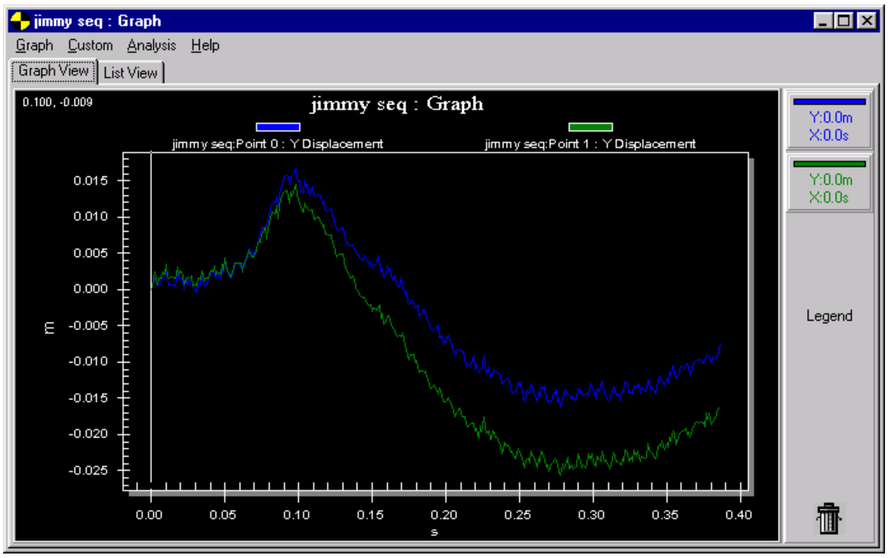



| **Use this…** | **To do this…** |
|---|---|
| **X-Axis** | Select the parameters of what is to be plotted on the X Axis |
| **Y-Axis** | Select the parameters of what is to be plotted on the Y Axis |
| **Filtering / Smoothing** | Specify what filtering to perform |
| **Acc \ Vel Calculation Methods** | Select the calculation method for Accelerations and Velocities. For definition see Section 0. |
| **Cut off Frequency** | Specify a cut off frequency (Hz) |
| **<- Preview** | Preview the Selection from the axis definitions |
| **Add ->** | Add the selection to the Load List |
| **Preview ->** | Preview the selection on the Load List |
| **Graph Description** | Describe the data to be graphed (used for identification) |
| **GRAPH** | Plot the items which are checked (☑) in the load list (on the same graph) |
| **CLOSE** | Close the graph selection screen |

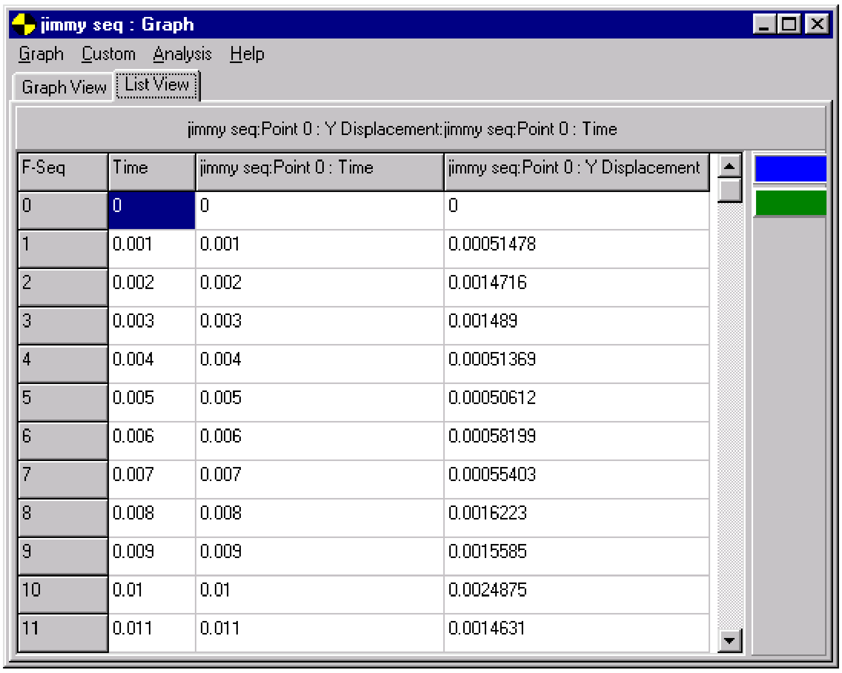
To plot all trajectories you can use the Trajectories Shortcut (**Results|Trajectories**) 

### 12.3.2. Graph Manipulation

Once you have plotted graphs there are two viewing options. As a graph or as a list. These are shown below :




The colour of each plot is defined by the colour of the point from which it originated (Y-Axis). You can change the colour of the plot by using the customization dialog (see Modifying the graph display settings).
The value of the plot at the cursor position is displayed in the legend.




| F-Seq | Time | jimmy seq:Point 0 : Time | jimmy seq:Point 0 : Y Displacement |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 0.001 | 0.001 | 0.00051478 |
| 2 | 0.002 | 0.002 | 0.0014716 |
| 3 | 0.003 | 0.003 | 0.001489 |
| 4 | 0.004 | 0.004 | 0.00051369 |
| 5 | 0.005 | 0.005 | 0.00050612 |
| 6 | 0.006 | 0.006 | 0.00058199 |
| 7 | 0.007 | 0.007 | 0.00055403 |
| 8 | 0.008 | 0.008 | 0.0016223 |
| 9 | 0.009 | 0.009 | 0.0015585 |
| 10 | 0.01 | 0.01 | 0.0024875 |
| 11 | 0.011 | 0.011 | 0.0014631 |

Use the `Graph View | List View` tab to select the desired view.

In graph view a cursor will scroll along the graphs showing the synchronisation point with `master time`. In list view the data table will scroll.

#### 12.3.2.1. Graph Menus

| Use this… | To do this… |
|---|---|
| `Graph|Info` | View information about the graphs |
| `Graph|Rename` | Rename the Graph (window and results icon) |
| `Graph|Copy` | Copy the graph image to the clipboard |
| `Graph|Print|Printer / File …` | Print the graph to a printer or file |
| `Graph|Print|Collated Print` | Set up a multiple graphs per page print (see section XXX) |
| `Graph|Save as…` | Save the graph in a Movias Pro format. Saved Graphs can be reloaded into a project (see section xxx) |
| `Graph|Export T/HIS…` | Save each plot on a graph as an ASCII Time History (compatible with MIRA Data Viewer) |
| `Graph|Unload` | Close the Graph Window. Depending on the Display Setting the graph definition may remain on the results list (see section XXX) |
| | |
| `Custom|Zoom Scrolling` | Place Scroll Bars on the graph when the graph is zoomed |
| `Custom|Cursor..` | Set the cursor type of the graph. The default cursor is a vertical line. Where the x-axis is not time, it is useful to change the cursor type. |
| `Custom|Undo Zoom` | Undo any zoom on the graph |
| `Custom|List Font..` | Set the font used in the List View |
| | |
| `Analysis|Invert` | Invert the selected channels (see selecting channels to manipulate) |
| `Analysis|Define` | Generate new channels by manipulation current data. (see defining analysis) |
| | |
| `Help` | Obtain On-Line Help |

#### 12.3.2.2. Selecting Channels to manipulate

Where there is more than one channel plotted on a graph you can select a channel using the legend on the right hand side of the graph. A RIGHT CLICK will select the channel. To select multiple channels use a LEFT CLICK. To deselect RIGHT CLICK again.

You need to select channels in order to do the following :

- **Analysis|Invert**
- Drag a channel into the Trash Can (deleting the channel)
- Drag and Drop a Channel between Graph Windows

In the List View you can select the channel to list by clicking the list view legend.

#### *12.3.2.3. DRAG & DROP*

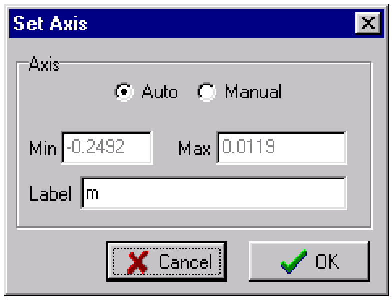
You can Drap & Drop channels between graph windows by doing the following :

- Select the channels to D&D from the Graph Legend.
- Right mouse down inside the graph image
- Hold down the mouse button and drag to another graph window
- Release the mouse button

#### *12.3.2.4. Setting the AXIS Bounds*

The graph axis are auto-scalled to fit the data. You can change the bounds in two ways.

1. Zooming the graph (see zooming the graph)
2. Manually setting the axis bounds
   To manually set the graph axis you must double click the axis to set. Where there are multiple Y axis be sure to click the correct one. This will display an axis dialog where you can enter the bounds to set.




#### *12.3.2.5. Modifying the graph display settings*

Right Click of the graph window will display a popup menu. This menu will ONLY operate if :

1. No Channels are selected
2. Graph Zoom button is INACTIVE

The function of these options are as follows :

| Use this… | To do this… |
|---|---|
| `Viewing Style` | Set the viewing style (colour / momochrome) |
| `Font Size` | Set the graph text font size |
| `Numeric Precision` | Set the number of decimal places to use. This value will change precision displayed in the legend. |
| `Plotting Method` | Change the plotting method. The default and most useful is Line. Other options include bar / area/ etc |
| `Data Shadows` | Draw Data Points with Shadows |
| `Grid Lines` | Show or Hide grid lines with the data |
| `Grid on top` | Set whether the grid is "in front of" or "behind" the data |
| `Include Data Labels` | Display the X and Y values at each data point |
| `Mark Data Points` | Mark each data point with a symbol |
| `Show Annotations` | Unused at present |
| `Undo Zoom` | Undo any zoom of the graph |
| `Maximize` | Create a full screen *copy* of the Graph |
| `Customization Dialog…` | Display a Dialog to allow full customization of the display properties of the graph |
| `Export Dialog…` | Display a dialog to allow printing and exporting data |
| `Help` | Display graphing Help |

#### *12.3.2.6. Synchronising with other data windows*

Clicking on a plot in a graph window will move master time to the time of the sample on which you click.

#### *12.3.2.7. Other*

See also chapter 14, Preferences.

## *12.4. Movie Strip*

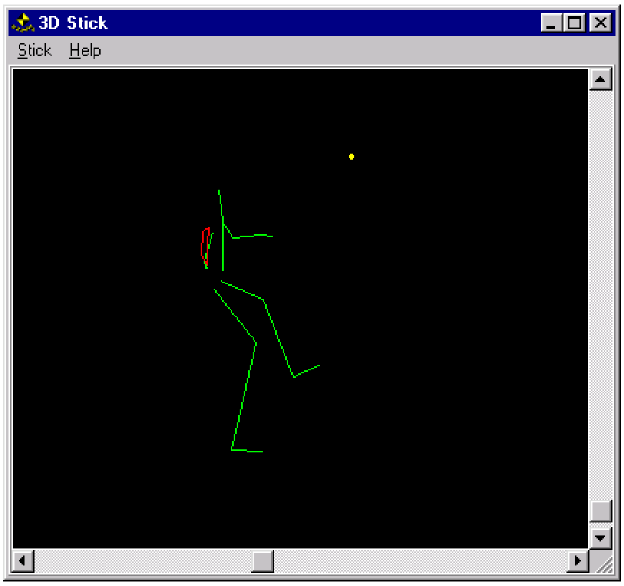
The Movie Strip output will show a number of image frames around the current master time. The number of frames to show is specified in Display Settings. The frame maked "0" is the current frame. Negative frames are frames BEFORE the current frame. Positive frames are frames AFTER the current frame.


| Use this… | | To do this… |
|---|---|---|
| | **POINT** | Toggle the tracked points visible and invisible |
| | **VIDEO** | Toggle the images visible and invisible |
| | **LOCUS** | Toggle the tracked point locus' (trajectories) visible and invisible |
| | **STICK** | Toggle ***stick definitions*** visible and invisible |
| | **BACK COLOUR** | Select the background colour (visible when the images are invisible or not available) |

### *12.5. 3D Stick Output*

Where you are working with 3D data, you may use the 3D stick output. Where Sticks have been defined these will be shown in 3 dimensions on the 3D Stick form. (Note : when generating 3D sequences, the sequence is automatically assigned the sticks of the composing 2D sequences). For more information on Defining Sticks see section 13.1.7.

The 3D Stick window is shown below :




Use the scrollbars to rotate the stick image to the required view.

# 13. Manipulation of Data

## *13.1. Derived Data from the Combination of Measured Point*

Movias can derive some data from the combination of measured point. Data that can be derived are as follows:

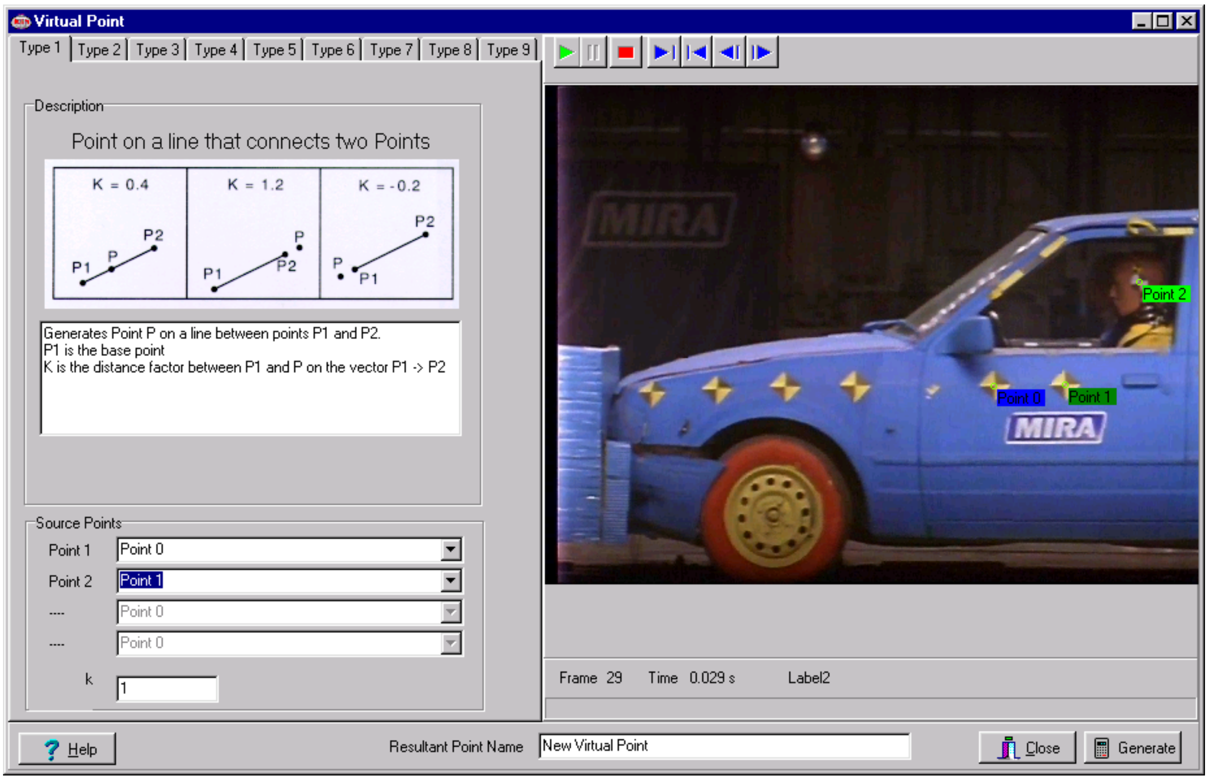
- Virtual Point
- Partial Gravity
- Length
- Area
- Angle
- Stick Figure

The contents of each data are as follows.

### 13.1.1. Virtual Point

A Virtual Point is a point or a vector derived from a point or vector that is already defined. To generate a Virtual Point use the menu option **Combination of Points | Virtual Point**.

The Virtual Point definition screen is as follows :




Virtual Point Options

| Use this… | To do this… |
|---|---|

| | |
|---|---|
|  | Control playback of the sequence images |
|  | Select the type of virtual point to generate |
| **Source Points** | Set the parameters of the Virtual Point |
| **Resultant Point Name** | Give a name to the Virtual Point |
| **Generate** | Generate the specified Virtual Point |
| **Close** | Close the Virtual Point Window |

*NOTE : You can select the source points using the Drop Down Combo's or by double clicking on the point in the Image.*

Virtual Points will be added to the Tracked Points of the sequence. You can use Virtual Points just like any other tracked point, including generating other Virtual Points. Where a Virtual Point is a Vector it will appear in the Sequence Vectors list.

There are nine types of Virtual Point.

#### *13.1.1.1. Type 1: Point on the Line that Connects P1 and P2*

This virtual point is a point on the line that connects P1 and P2. It needs two point numbers for P1 and P2 and coefficient. This coefficient means a distance from P1 to virtual point.

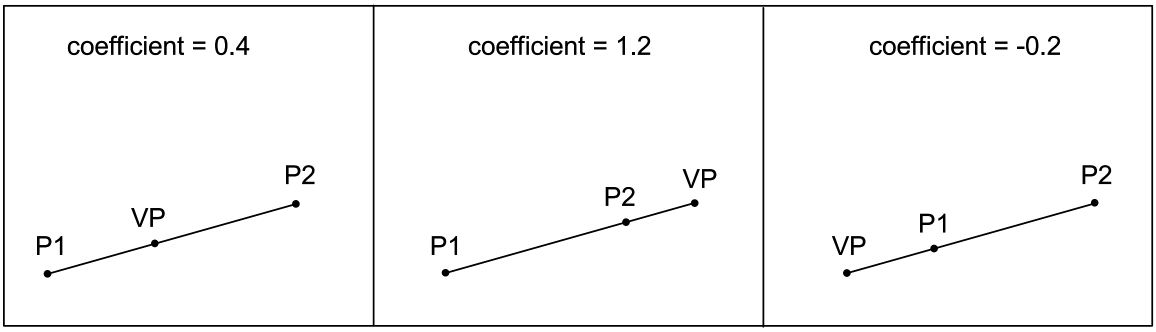



**Figure 9 - Virtual Point Type 1**

#### *13.1.1.2. Type 2: Rotation within a Plane No 1*

This is a point derived from a rotation of P2 around P1 within a plane determined from P1, P2, and P3. Direction of rotation is a direction from P2 to P3 around P1.

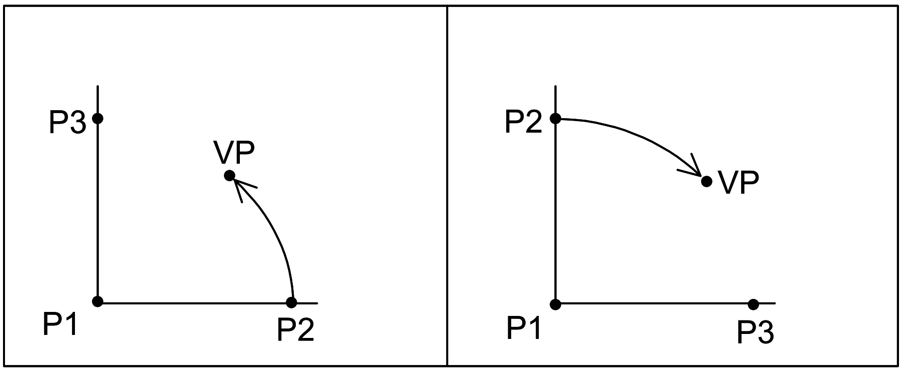
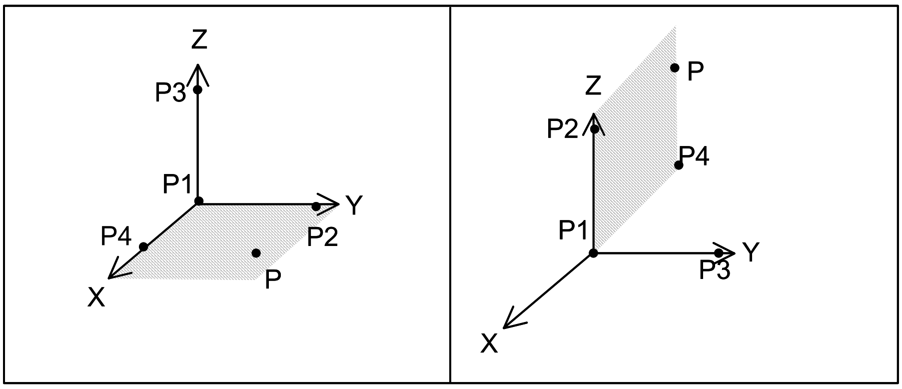



**Figure 10 - Virtual Point Type 2**

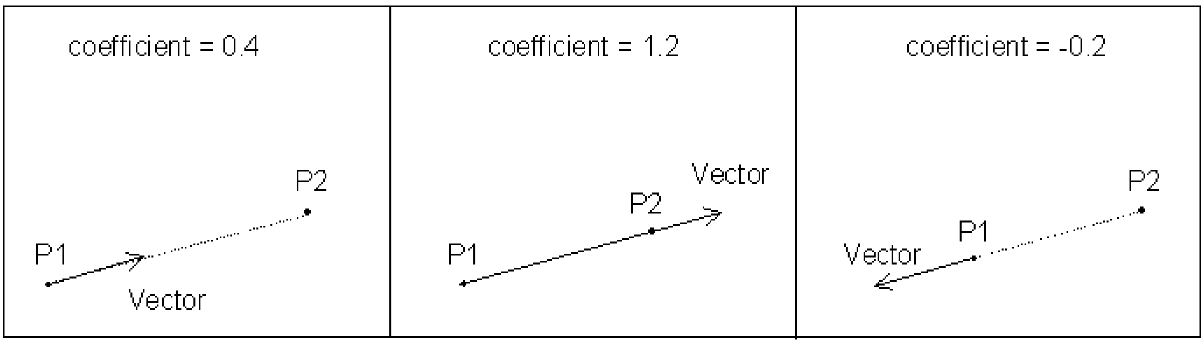
#### *13.1.1.3. Type 3: Rotation within a Plane No 2*

This is a point derived from a rotation of P2 around P1 within a plane determined from P1, P2 and P4. Direction of rotation is a direction from P2 to P4 around P1. P4 is a point on the line that passes through P1 and perpendicular to a plane determined from P1, P2 and P3. And P4 is derived on the side of right-handed screw when it is located at P1 and rotated from P2 to P3. Refer to figure below.



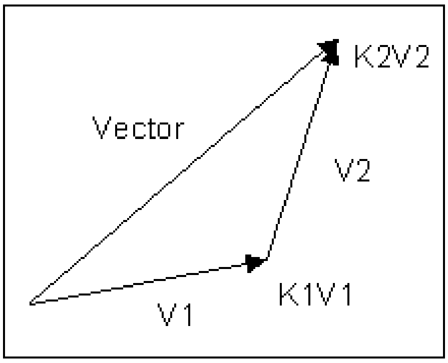

#### *13.1.1.4. Type 4: Vector derived from two points*

This virtual point is a vector that starts with P1 and ends with the virtual point just like Type 1



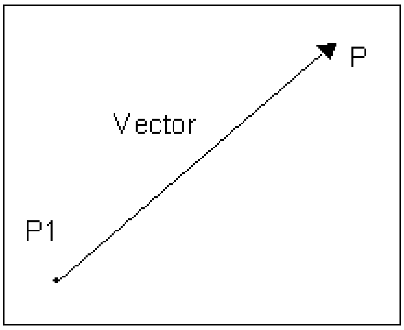
##### *13.1.1.5. Type 5: Addition of two vectors*

This is a vector that is made by addition of two vectors.



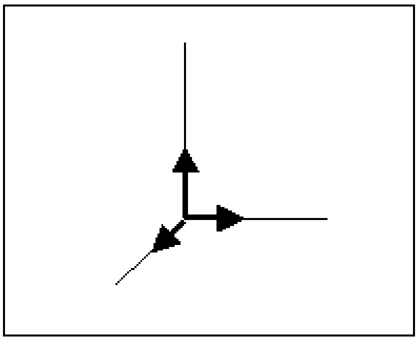

##### *13.1.1.6. Type 6: The point shifted by a specified vector from a specified point*

This is an end point of a specified vector whose start point is shifted to the specified point.



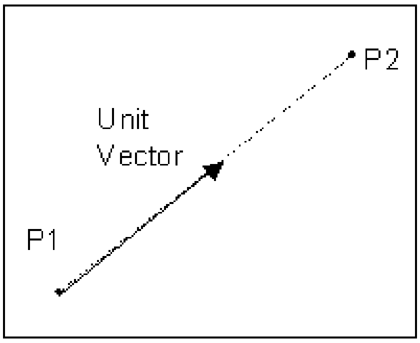

##### *13.1.1.7. Type 7: Unit Vector – 1*

This is a unit vector on each of three axes.



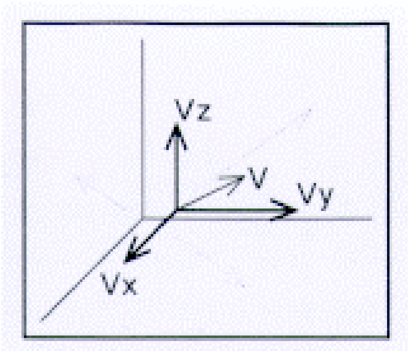
##### *13.1.1.8. Type 8: Unit Vector – 2*

This is a unit vector on the line that connects specified two points.



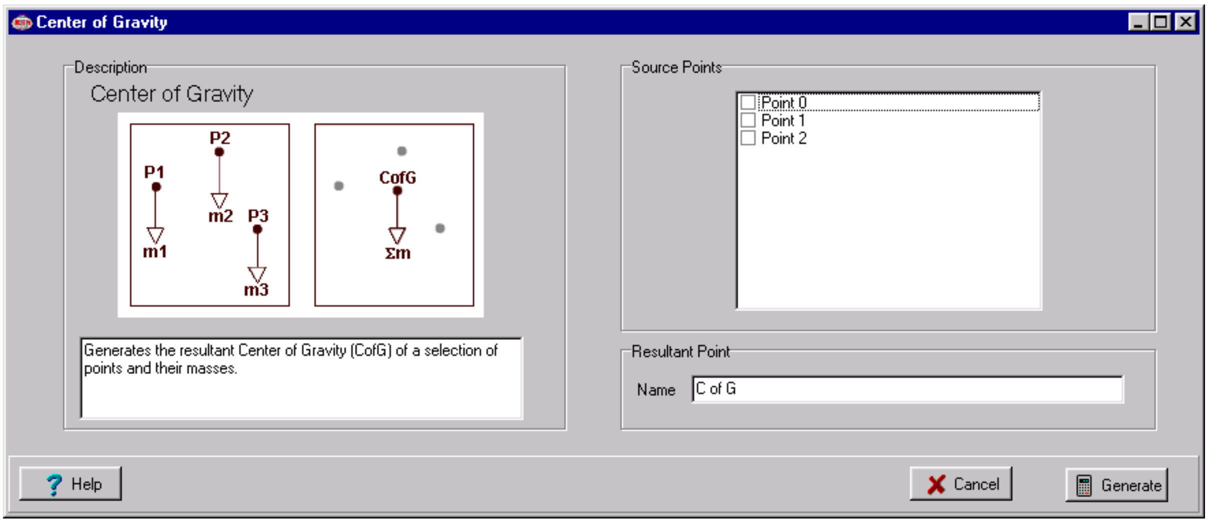

#### *13.1.1.9. Type 9: Component Vector*

This is a component vector of a specified vector.



### 13.1.2. Partial Gravity

This option computes the centre of gravity of a selected part enclosed by points, assuming that each part is a mass point.




For this job, you should specify measuring points that enclose a part whose centre of gravity you want to obtain.

For example, the centre of gravity of a part enclosed by points P1, P3, P6 and P7 is calculated by the following expressions.

$$G_X = \frac{m_1 \times P_{1X} + m_3 \times P_{3X} + m_6 \times P_{6X} + m_7 \times P_{7X}}{m_1 + m_3 + m_6 + m_7}$$

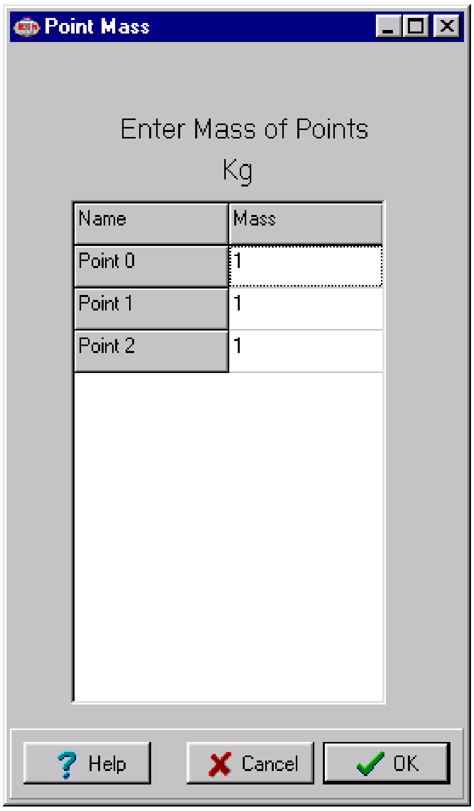
$$G_Y = \frac{m_1 \times P_{1Y} + m_3 \times P_{3Y} + m_6 \times P_{6Y} + m_7 \times P_{7Y}}{m_1 + m_3 + m_6 + m_7}$$

$$G_Z = \frac{m_1 \times P_{1Z} + m_3 \times P_{3Z} + m_6 \times P_{6Z} + m_7 \times P_{7Z}}{m_1 + m_3 + m_6 + m_7}$$

Where $m_1$, $m_3$, $m_6$ and $m_7$ are masses of points P1, P3, P6 and P7.

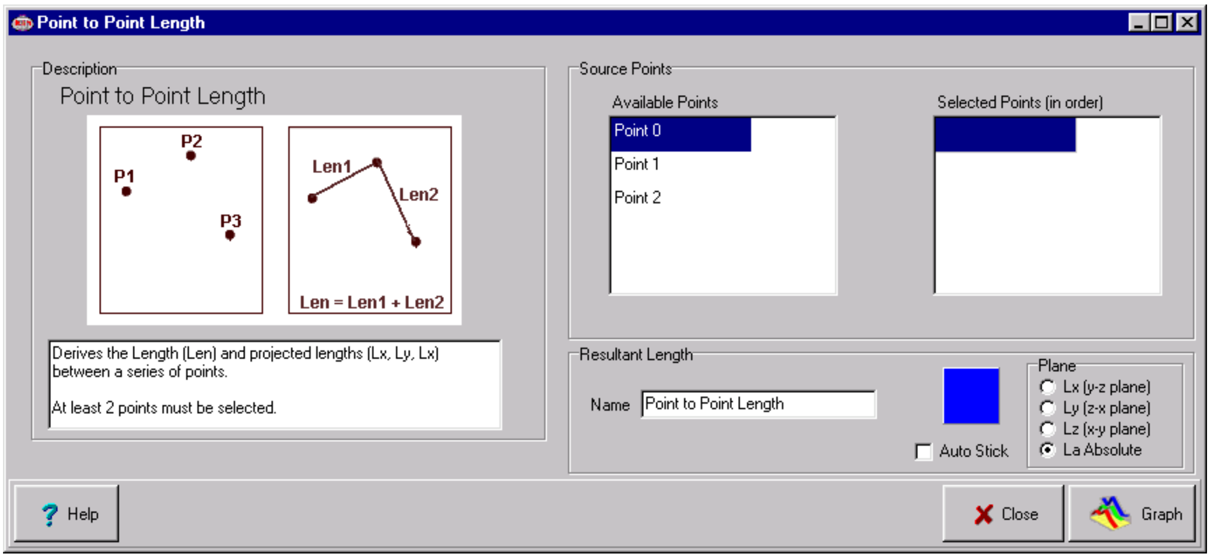
### 13.1.3. Mass of Point

This function sets the mass of each measuring point used for measurement of power, energy, and centre of gravity.




### 13.1.4. Length

This function defines the length of line segments connecting points that were entered in sequence. Substantially, enter the numbers of points constituting the line segments.



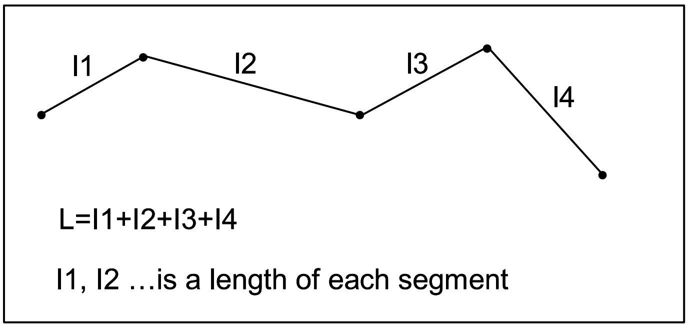
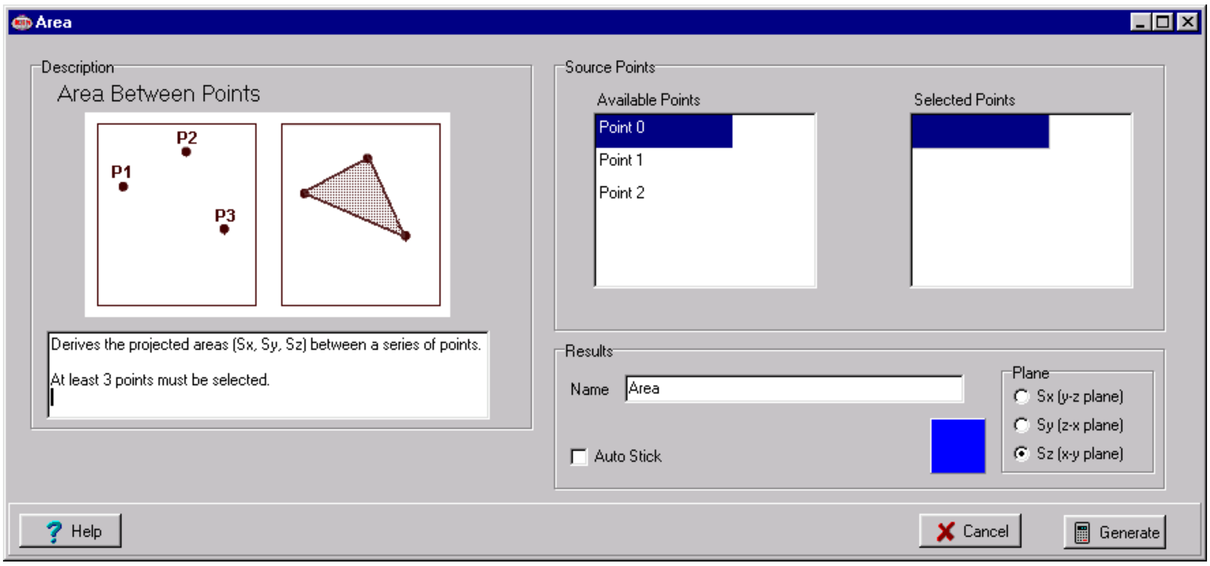



**Figure 11 - Length**

### 13.1.5. Area

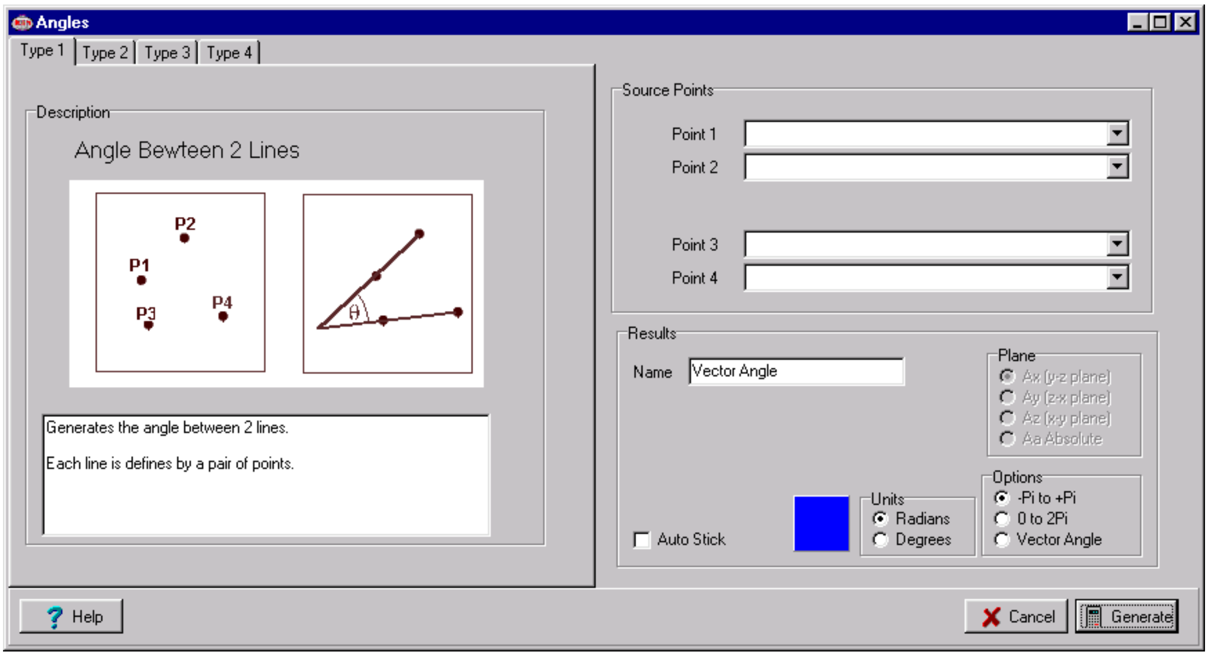
This job defines the area enclosed by a line connecting the selected measuring points. Substantially, enter the numbers of points enclosing a desired area.




The calculation of the area is performed within each 2D plane. Each points enclosing an area are projected onto each plane, that is X-Y, Y-Z and Z-X and then an area have been calculated.

### 13.1.6. Angle

Angle is an angle between two vectors. The angle selection screen is as follows :




There are the four following ways to define an angle:

| | |
|---|---|
| • Angle between two lines | Type 1 |
| • Angle between two vectors | Type 2 |
| • Angle between lines that connect two points and axis | Type 3 |
| • Angle between vector and axis | Type 4 |

From the selection screen:

| Use this… | To do this… |
|---|---|
| Type 1 \| Type 2 \| Type 3 \| Type 4 | Select the angle type to calculate |
| **Source Points** | Set the parameters of the Angle |
| **Results Name** | Give a name to the Angle Graph |
| **Units** | Select the units of the graph (Degrees or Radians) |
| **Plane** | Set the plane for which the angle is to be calculated (3D only) |
| **Opions** | Select the bounds of the angle calculation |
| **Auto Stick** | |
| **Colour (double click)** | Select a colour for the angle graph |
| **Generate** | Generate the specified Angle |
| **Cancel** | Cancel angle Generation |

#### 13.1.7. Stick (**Tools|Stick…**)

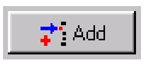
This function defines a stick image to be output. Stick images are displayed on the AVI Images. Sticks are defined as lines between two or more points. Sticks can be automatically defined when using the Length, Area or Angle functions. Alternatively they can be manually defined. To manually Define a Stick choose the **Tools|Stick** menu option. The Stick definition screen is as follows :


Sticks are defined at the top of the left hand panel. Existing Sticks are shown in the Sequence Stick group. Global Sticks are shown in the Global Stick Group.

##### *13.1.7.1. Defining a Stick*

To define a stick you must supply the following information.

1. Stick Name (to describe the stick)
2. Stick colour
3. Stick Points

| Use this… | To do this… |
|---|---|
| **Stick Name** | Give the New Stick a name |
| **Stick Colour** | Give the New Stick a colour |
| **Stick Points** | Specify the points making up the stick (see note below) |
|   | Add the defined stick to the current Sequence |

| | |
|---|---|
|  | Delete the selected points from the definition |
| ☑ Active | Specify if the stick is active (visible) in the AVI Overlay View |
| Store | Save the current Sequence Stick as a Global Stick. (see Global Sticks) |
| Delete | Delete the selected Stick from the Sequence / Global Stick list |
| ✔ OK | Close the stick definition window |

##### *13.1.7.2. Selecting Stick Points*

***IMPORTANT*** : Stick points are defined by their POINT ID not their Name. To select points to make up a stick you can type in a list of comma separated point ID's, or more simple click on the points in the preview video and the points edit area will be filled in automatically. If you cannot see a point on the current frame then you can use the video controls to play the images until the point becomes visible.

##### *13.1.7.3. Global Sticks*

Stick definitions can be stored globally and applied to any sequence. To do this you must first define a sequence stick and then STORE it globally.
To apply a global stick to a sequence you should select the global stick from the Global Stick Combo and push the ADD button.
IMPORTANT : Since Stick points are stored by their Point ID. In order to use the Global Stick functions the user must be sure to define tracked points in the same order in order that they have the same ID. Failure to do this may cause invalid results when a global stick is applied.

### 13.1.8. Apply Model

## *13.2. Method*

### 13.2.1. Transform in Space

This job sets a new co-ordinates system for each frame and re-calculates the positions of measuring points in that co-ordinates system.

The co-ordinates system defined by initial setting is fixed to the display screen of the input device or the calibration chart.

Contrarily, this job sets a co-ordinate origin on one of the measuring points in each frame and X or Y or Z axes by measuring points and to determine the other with values set by the initial set. This job is very effective at analysing the motion of measuring points relative to the moving points in images (with the moving points as the references).

For example, this job is effective to the following motion analysis:

- Motion of a dummy relative to the car body (in car collision test)
- Motion of parts of the human body relative to the waist
- Motion of a machine on a vibrating base
- Elimination of shakes in photographing.

The Transform in Space job has the following functions:

1. Specification of a co-ordinate origin
2. Specification of a co-ordinate axis
3. Mirror-Reflection of a co-ordinate axis
4. Transformation of observation co-ordinate system.

#### *13.2.1.1. Specification of a co-ordinate origin*

Select one measuring point in a frame. This function sets it as a co-ordinate origin.

#### *13.2.1.2. Mirror-inversion of a co-ordinate axis*

This function reverses the polarity (positive or negative) of a selected co-ordinate axis.

#### *13.2.1.3. Specification of co-ordinate axis*

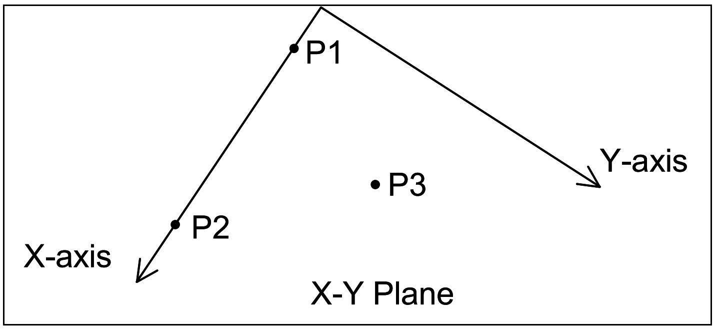
In the case of 2D analysis:

Select two measuring points in the frame. This function draws a co-ordinate axis passing through the origin in parallel to a line connecting the selected two measuring points.

In the case of 3D analysis:

Select three measuring points in the frame. This function draws a co-ordinate axis passing through the origin in parallel to a line connecting the selected first two measuring points. And this function makes a co-ordinate plane which includes the above co-ordinate axis and the selected third measuring point.

The following figure shows that it uses P1 and P2 to draw an X-axis, and it uses X-axis and P3 to make an X-Y plane. P3 will be within a Y-positive-side of an X-Y plane. Z-axis wiol be on the vertical direction against this image figure and towards you will be positive-side.



#### *13.2.1.4. Tranformation of observation co-ordinates system*

For example, let's assume that you want to measure the motion of a target object in a running car in relation to a fixed co-ordinates system of the ground by photographing the motion of the car by a high-speed motion camera mounted on another car running in parallel to the test car at the same speed. In this case, the motion of a target object in relation to the ground can be obtained if the motion of the running car in relation to the ground is already known. In this case, the motion of the running car should be uniform. The co-ordinates system fixed to the running car is called a motion co-ordinates system. Another co-ordinates system fixed to the ground is called an observation co-ordinates system. This function transforms the uniform motion of the car in the motion co-ordinates system into that in the observation co-ordinates system.

The co-ordinates (X(T), Y(T), Z(T)) of a measuring point viewed from the observation co-ordinates system at time T are expressed by:

$$X(T) = x(T) + X_0(T)$$
$$Y(T) = y(T) + Y_0(T)$$

where:

| | | |
|---|---|---|
| *x(T)* | : | X co-ordinate of a measuring point in the motion co-ordinates system |
| *$X_0(T)$* | : | X co-ordinate of an origin point of motion co-ordinates system in the observation co-ordinates system |

is calculated by

$$X_0(T) = \frac{1}{2} \times A_X \times T^2 + V_X \times T + P_X$$

where:

| | | |
|---|---|---|
| $A_X, V_X, P_X$ | : | Acceleration, velocity, and position of the origin of the motion co-ordinates system in the observation co-ordinates system at T=0 |

(*T*) and *Z*(*T*) are also treated similarly.

#### 13.2.2. Transform in Time

This function specifies a frame used as a time reference.

Usually, a frame at which measurement starts is a time reference frame (TIME=0). This function enables any frame to be set as a time reference frame. This function can also reverse the progress of time.

#### 13.2.3. Reference Frame

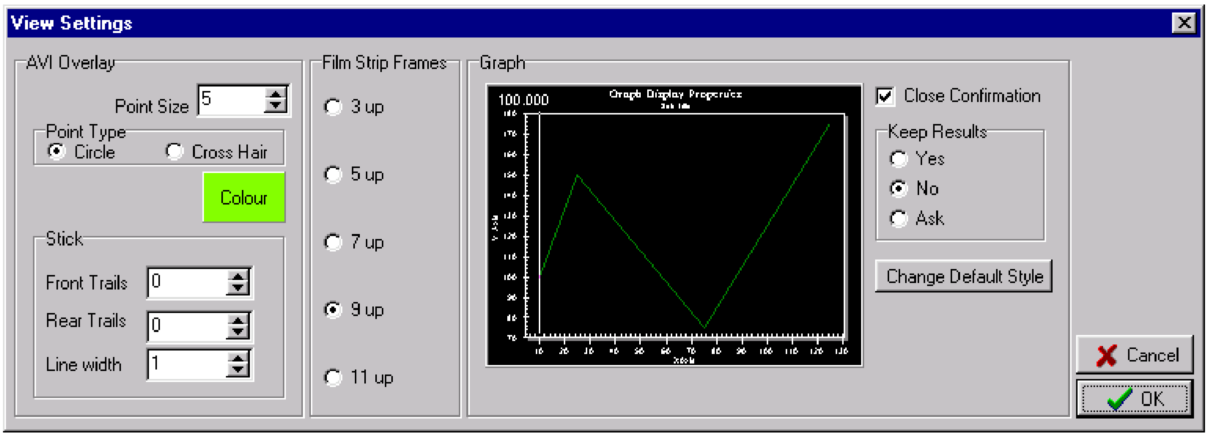
This function specifies a frame used as a reference of displacement Measurements made once the reference frame is set will use a displacement from the position of the point at the reference frame. Usually, a frame at which measurement starts is a displacement-reference frame. This function enables any frame to be set as a displacement-reference frame.

## 14. Preferences (`File|Preferences`)

A number of default user preferences may be set as follows:

### *14.1. Display Settings (`File|Preferences|Display Settings`)*

Use Display Settings to define how the various screen output should look.




#### 14.1.1. AVI Overlay

*Point Size* : is the pixel size of the tracked point locator during AVI Overlay.
*Point Type* : of the tracked point locator during AVI Overlay can be either a Circle or Crosshair.
*Point Colour* : is the colour of the tracked point locator

#### 14.1.2. Stick

Where sticks have been defined between tracked points, you can specify the line thickness of the stick and also let Movias Pro draw stick trails. The stick trails settings will let Movias Pro draw the specified number of preceding and succeeding frame sticks as well as the current stick for the current frame.

### 14.1.3. Film Strip Frames

During Movie (Film) strip output, you can specify the number of frames to view.

### 14.1.4. Graph

#### *14.1.4.1. Close Confirmation*

If checked then Movias Pro will ask you to confirm that you wish to close the graph window, otherwise it will not.

#### *14.1.4.2. Keep Results*

Movias Pro will optionally store the graph data on the results tree node when the graph window is closed depending on this setting.

#### *14.1.4.3. Change Default style*

Clicking this button allows you to define the default style of the graph. This includes the background colour, font size etc. Once the default style is changes all new graph windows will take the chosen style. *NOTE* : some setting might be overridden by Movias Pro.

## *14.2. General Preferences(`File|Preferences|General Preferences`)*

Use General Preferences to set the default camera speed (frames per second) and the default Acceleration / Velocity calculation method.

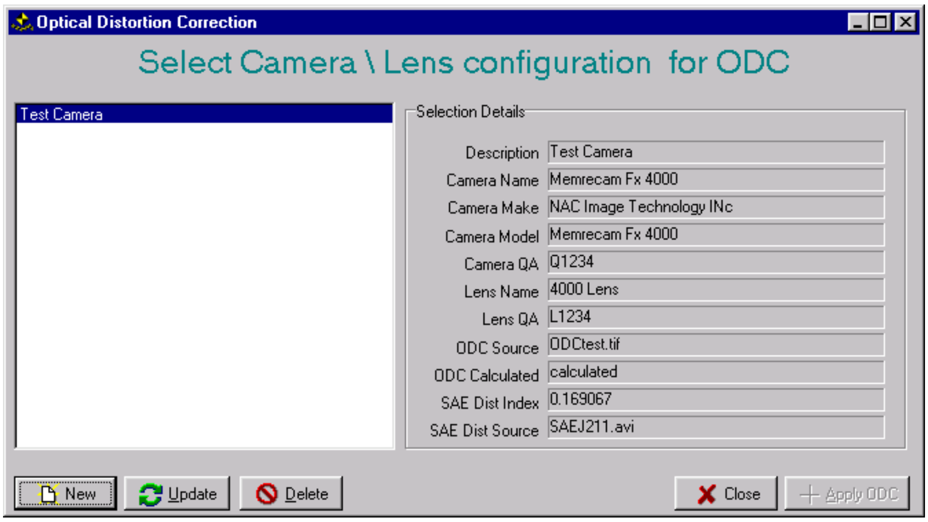
## *14.3. Directory Default(`File|Preferences|Directory Default`)*

Use this option to browse to a directory where Movias Pro will go to first when a Movias Project is created or opened.

# 15. Lens Distortion

Movias Pro can calculate the image distortion introduced by the camera and lens. Movias Pro will maintain a database of facility camera/lens combinations and the distortion factors for these combinations. To access Lens Distortion functions you should select the `Tools|Optical Distortion Correction / J211 Index…` menu option.

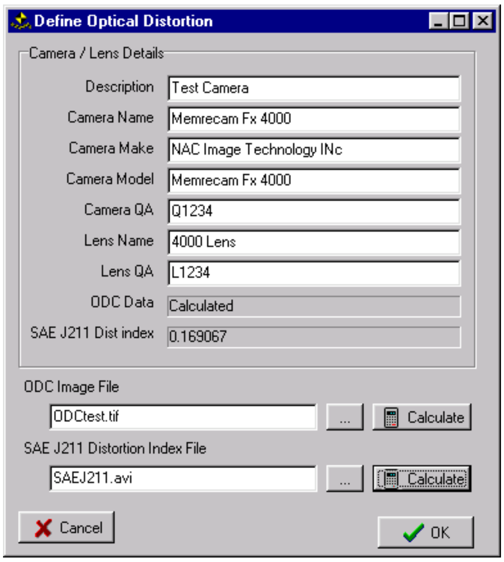
You will be presented with the ODC database screen shown below.




This Screen shows that once record currently exists in the database.

| Use this… | To do this… |
|---|---|
| **New** | To create a new Database Entry |
| **Update** | Update the selected Database Entry |
| **Delete** | Delete the selected Database Entry |
| **Close** | Close the form |
| **Apply ODC** | Apply the selected camera ODC data to the current sequence (if a sequence is active) |

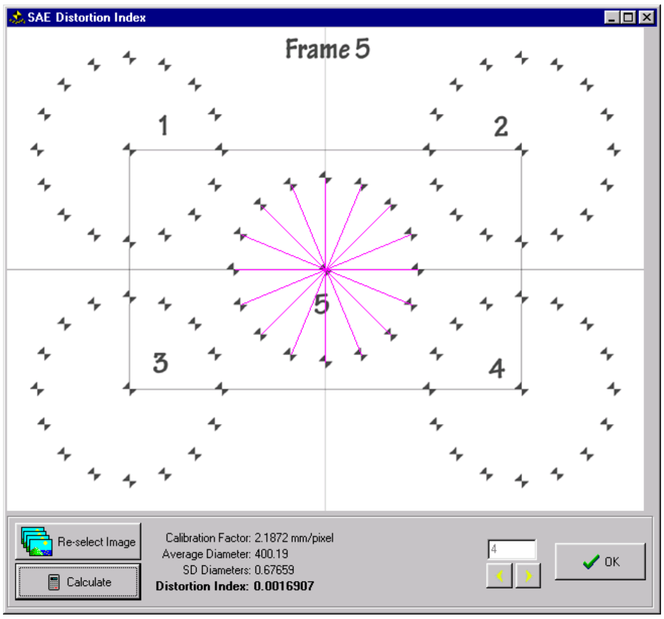
To Generate ODC information push the NEW button. You will see the screen below




Complete the Camera and lens details. You may then generate ODC data which is used to correct the lens distortion and / or calculate the J211 Distortion index. The J211 Distortion index is used for reference only and is NOT used for correcting the distortion.

### 15.1. J211 Distortion Index

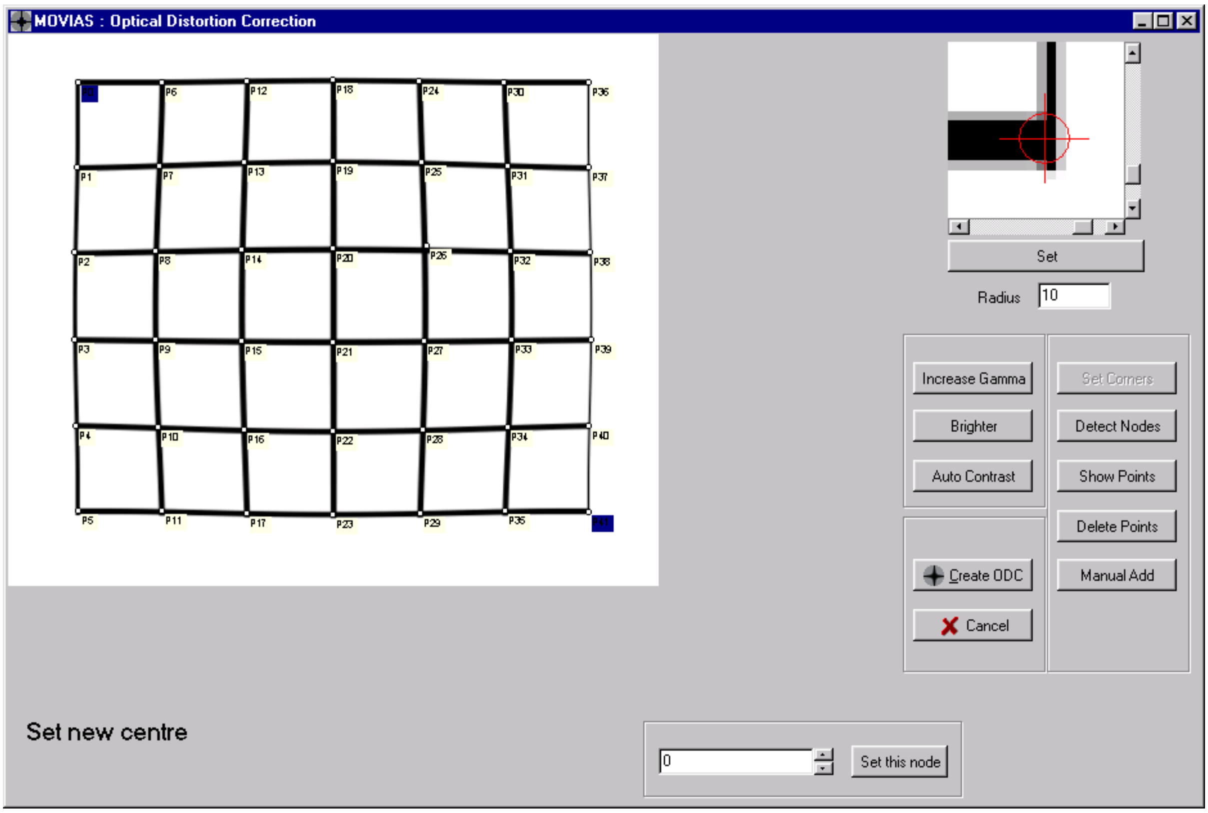
Movias Pro will calculate and store the SAE J211 Distortion index for any camera lens combination. In order to make this calculation you need to supply Movias Pro with an AVI file containing 5 frames (taken by the camera lens combination) of the J211 Distortion index Chart.
Enter the filename into the J211 Edit box or use the ellipses (…) to browse the file. Once this is done push the Calculate Button. You will see a screen as shown below.




| Use this… | To do this… |
|---|---|
| **Calculate** | Calculate the SAE J211 Distortion index |
| **Re-Select Image** | Change the AVI file selection |
| **< and >** | Step through the AVI Frames |
| **OK** | Close the form and return the calculated Index |

### 15.2. Optical Distortion Correction

Movias Pro will calculate distortion correction co-efficients. In order to make this calculation you need to supply Movias Pro with a single TIFF file containing a frame (taken by the camera lens combination) of a square grid as shown in the image below..
Enter the filename into the ODC Image File Edit box or use the ellipses (…) to browse the file. Once this is done push the Calculate Button. You will see a screen as shown below.




The grid image when photographed should be flat. You can see from the example that the grid had been distorted by the camera. Movias Pro will automatically find the crossover points of the grid and use this information to calculate the Optical Distortion Correction coefficients.

You must first inform Movias Pro of the boundaries of the grid inside the image. To do this you must perform the following tasks :

1) Click the Set Corners button.
2) Click the Top Left cornet of the Grid
3) Use the zoomed in image to position the crosshair in the correct location. Left mouse down & drag will move the image whilst Right mouse down and drag will move the crosshair.
4) Click the Set button
5) You will be prompted to do the same for the other three corners.
6) Movias Pro will then locate all the crossover locations
7) Review the points generated by Movias Pro.
8) Fine Tune Points if required

Once all the crossovers are corect you can push the CREATE ODC button. This will generate the ODC coefficients and return you to the previous screen.

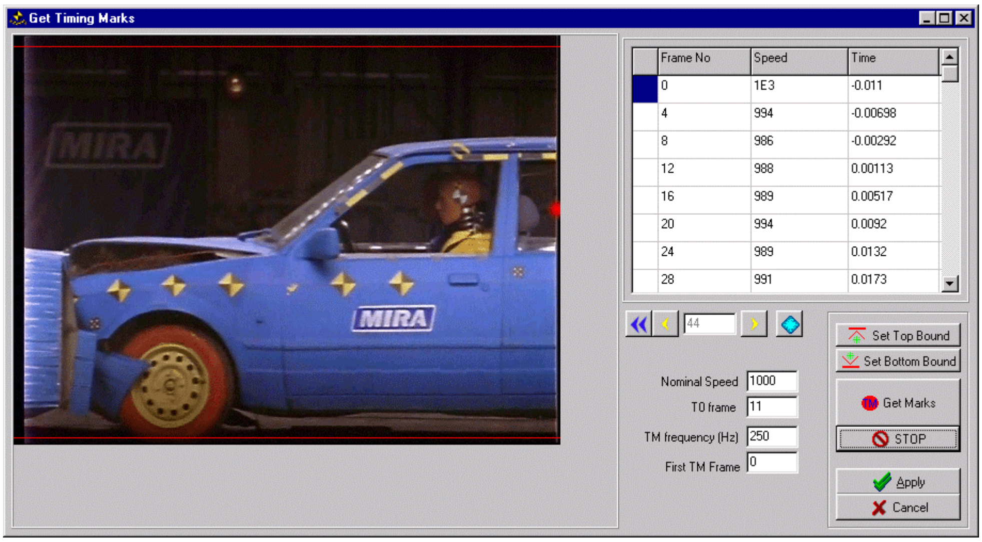
### 15.2.1. Fine Tuning ODC Points

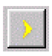
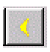
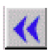
To move ODC points you should click the point. This will bring up a zoom of the point in the Zoomed image. You can pan the image and select the correct location for the point as you did with the corner points.

# 16. Time Base Correction

Movias Pro allows for Time Base Correction when working with Input data from Film. To calculate the exact time of a frame Movias Pro uses the Timing marks on the film. For Manual tracking using the AZ160F, these timing marks are input at the same time as the tracked data points. For automatic tracked sequences from AVI file, the timing marks are input separately.
To input timing marks for an AVI seqeunce where timing marks are visible select the `Tools|Time Base Correction…` menu option.

You will be presented with the Time Base Correction Screen.




| **Use this…** | **To do this…** |
|---|---|
| Set Top Bound | Define the top of the frame image (often the top of the image [default setting] ) |
| Set Bottom Bound | Define the bottom of the frame image (often the botttom of the image [default setting] ) |
| Get Marks | Begin inputing the Timing mark locations |
| **Stop** | Stop inputing the Timing mark locations |
| **Apply** | Apply the Time Base Correction to the Sequence |
| **Cancel** | Cancel Time Base Correction |
|  | Go to the next Frame |
|  | Go to the previous Frame |
|  | Rewind the Video |
|  | Set The first Frame with a visible Timing Mark |
| TM frequency (Hz) 250 | Set The Timing Mark Frequency (camera Dependant) |

### 16.1. How to apply Time Base Correction

To Apply Time Base correction to a sequence follow the steps below :

1) Enter the Timing Mark Frequency
2) Set the top and bottom bound of the image (or leave as the default top and bottom of the image). Push the button and then click the image.
3) Use the frame advance buttons to find the first frame with a timing mark.
4) Click the “Set First Timing Mark Frame” Button.
5) Push the Get Timing Marks button.
6) The system will advance the frame set in 4.
7) Click the timing mark. You should **always** click the same part of the timing mark e.g., the top most part of the mark.
8) The system will advance to the frame with the next timing mark. This is calculated using the Frequency and the Film Frame speed.
9) If the timing mark is on the next or previous frame you can use the frame advance buttons to get to the correct frame.
10) Repeat from 7 until the image sequence is finished.
11) Click Stop
12) Click Apply.
13) The TBC form will close and the time correction will be applied to your data.

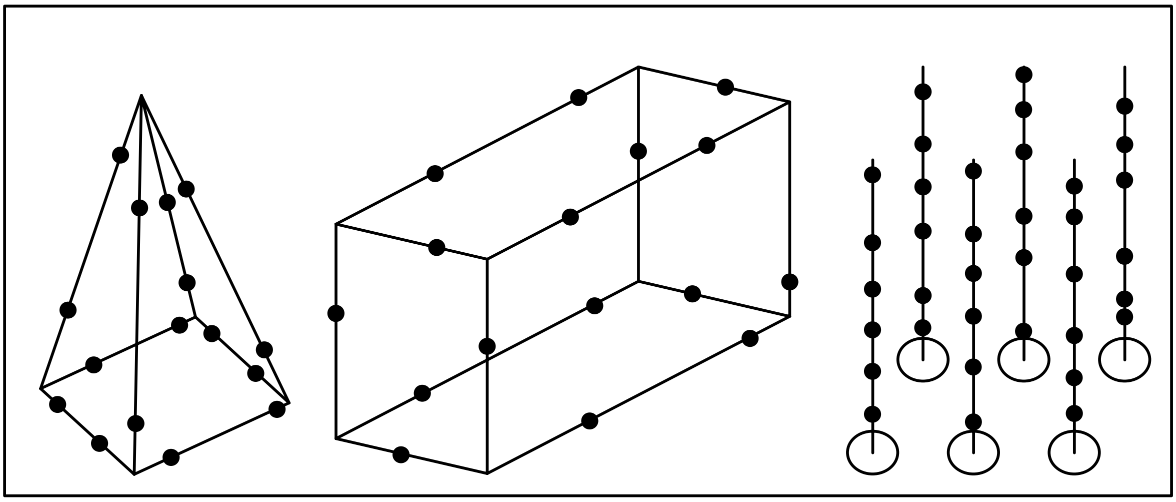
# 17. 3D Analysis

## 17.1. Introduction

To conduct a 3D analysis there are a number of processes you must complete.

## 17.2. Gathering Control Data

In order to gather 3D data you must supply Movias Pro with 3D control information. To do this you will need to set up the cameras for the test and capture a frame of a control structure. The control structure may be any three dimensional structure. Examples of structures are shown below:



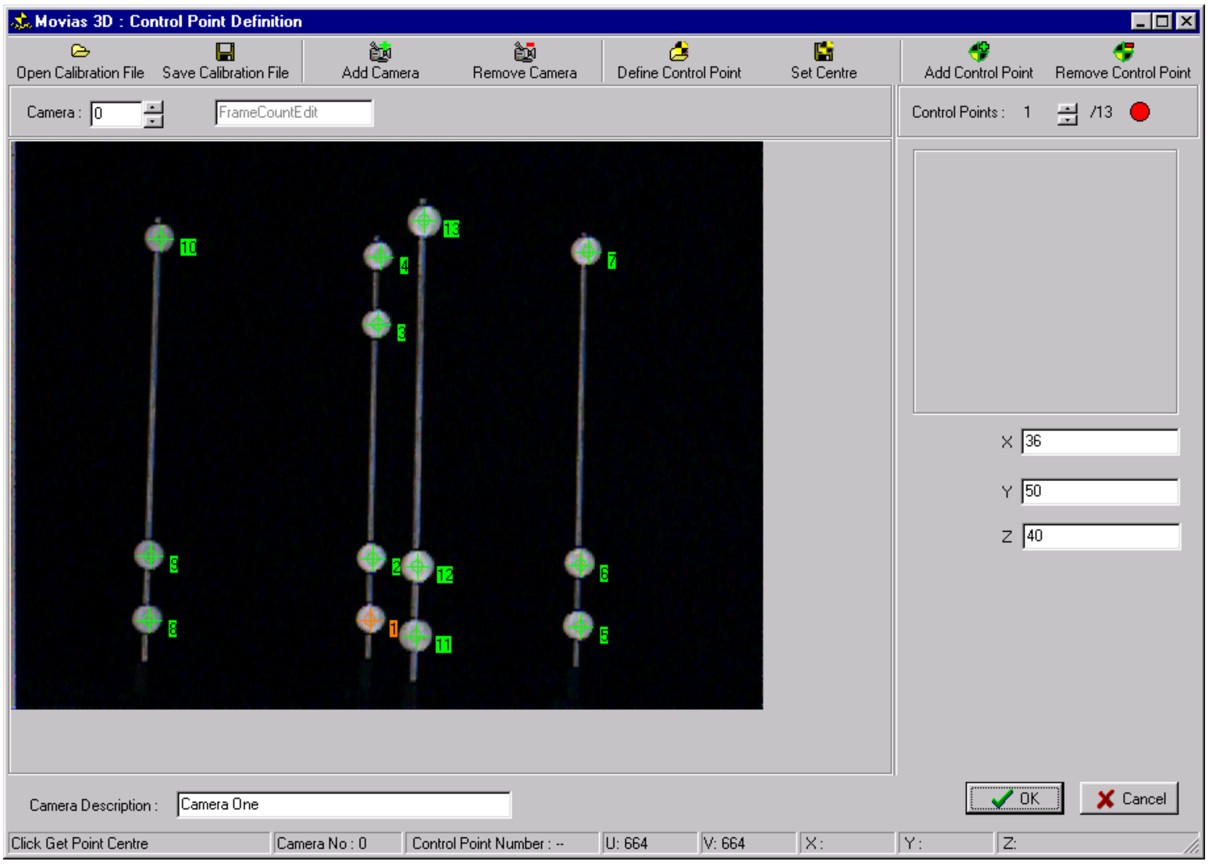
You must know the real 3D spacial coordinates (X,Y and Z) of the control points on the structure. These measurements should be taken from a fixed origin within the laboratory. You will then use Movias Pro to specify, for each camera, the 2D location of each control point within each camera image. Also you will need to input the real X, Y and Z location of the control points. Each Control point should be assigned an ID number, which must be the same for each camera view of the control structure during input of the control data.

## 17.3. Inputting Control Data

To input 3D control data you should select the `3D Construction|3D Calibration Input` menu option. 3D control data input but be done as part of a project, hence you must create a project first. If you wish to apply the same control set to a number of projects than you can create a dummy project for the purpose of inputting the 3D calibration data and then use this later.(see below).

### 17.3.1. Working with the Control Point input Screen

The 3D calibration input screen is as shown below :




| Use this… | To do this… |
|---|---|
| Open Calibration File | Open a previously saved 3D Calibration file, importing it into the current project. |
| Save Calibration File | Save the current calibration data into a file for importing into a different project |
| Add Camera | Add a camera to the calibration data set. Minimum cameras is two. |
| Remove Camera | Remove the current camera from the calibration set |
| Define Control Point | (*Note : Icon will change*!) Define the position of the current control point within the camera image. |
| Set Centre | (*Note : Icon will change!)* Define the centre position of the current calibration point – must be done after the control point has been defined |
| Add Control Point | Add control points. The default number, and minimum required is six |
| Remove Control Point | Remove Control Points |
| Camera : 0 | Scroll through the cameras |

| | |
|---|---|
|  | Scroll through the Control points |
| **X, Y, Z** | Set the real X, Y and Z location of the control points from a fixed location (origin) in the Lab. |

### 17.3.2. Suggested Process

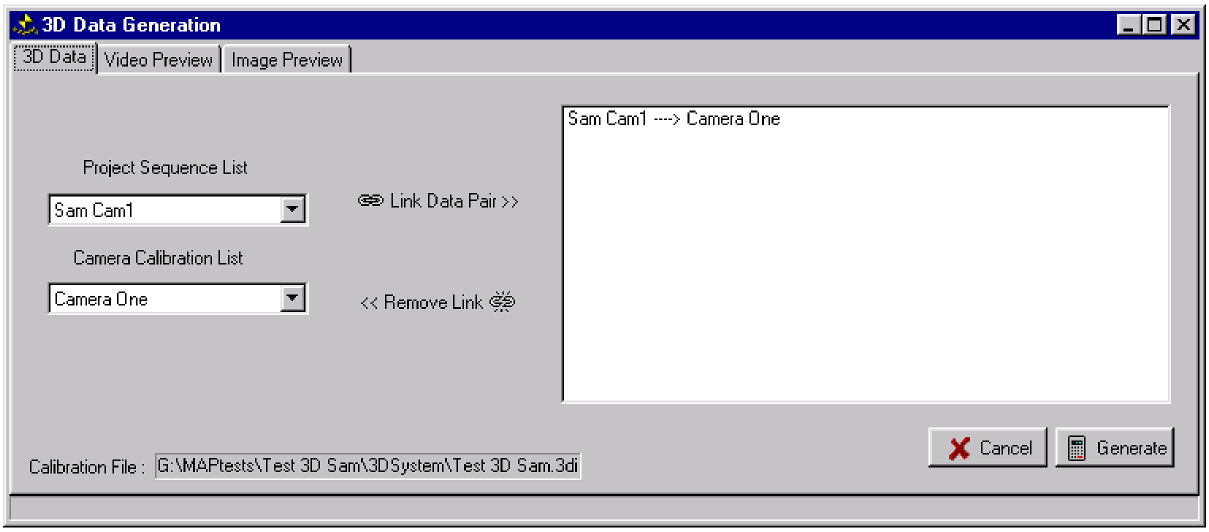
A suggested Process for 3D calibration is as follows :

1) Use “Add Control Point” button to increase the control point count to the number to be used.
2) Use the “Add Camera” Button to add the required number of cameras. You will be prompted to browse a corresponding camera file for each camera. This may be a AVI, TIFF, BMP or JPG file.
3) Use Camera Selection Scroller to go to the First Camera (camera 0);
4) Use the Control Point scroller to go the first Control point (point 1).
5) Click the “Define Control Point” Button.
6) Click the Image at the position of the control point. If you are using AVI format you may need to scroll through the frames to locate the control point.
*7)* Use the mouse to locate the centre of the control point in the zoom window. Left mouse and drag moves the image, Right mouse and drag moves the centre locator. ***NOTE : You must right mouse down on the zoom image to enable the Set Centre button – even if the centre appears to be already correct!***
8) Click the Set Centre Button.
9) Use the Control Point Scroller to go to the next control point.
10) Repeat from 5 until all control points have been defined.
11) If you miss locate a control point you can use the scroller to go back to it and repeat the process. Define Control point – Set Centre.
12) Use the camera Scroller to go to the next camera. The camera image will change to reflect the selected camera.
13) Repeat from 4. Until all cameras have be calibrated. ***IMPORTANT : The Control points must be the same number for all cameras.*** *Control point 1 in camera 1 must be the same physical point as control point 1 in camera 2. etc.*
14) Once all camera and control point data has been entered you may enter the real physical XYZ locations of the control points.
15) Use the control point scroller to go to the first control point.
16) Enter the X, Y and Z values
17) Go to the next control point.
18) Repeat from 16.
19) NOTE : it is not important which camera is currently selected during the input of XYZ data since this data should be the same for all cameras.
20) Once you are happy that all the data has been entered correctly you may click the OK Button. This will write the Calibration Data File to the current project. It will also copy the associated calibration images to the current project. These are stored in the **3Dsystem** Directory.
21) You may optionally save the calibrstion information to any location for use later. To do this push the “Save Calibration File Button”.

You 3D Calibration is now complete. You may now apply this to project sequences.

### 17.4. Applying 3D calibration data to 2D sequences

The application of 3D calibration to image sequences is done by choosing the **3D construction|3D Data Generation** menu option. You will see a screen as shown below




For each calibration camera you must associate a 2D sequence. Select the Sequence/calibration pair from the drop down boxes and click the "Link Data Pair" Button. If you make a mistake you can select the pair from the list and click the "Remove Link" button. When all the cameras have been paired you can click the "Generate" Button.

### 17.5. Optical Distortion Correction (Lens Correction)

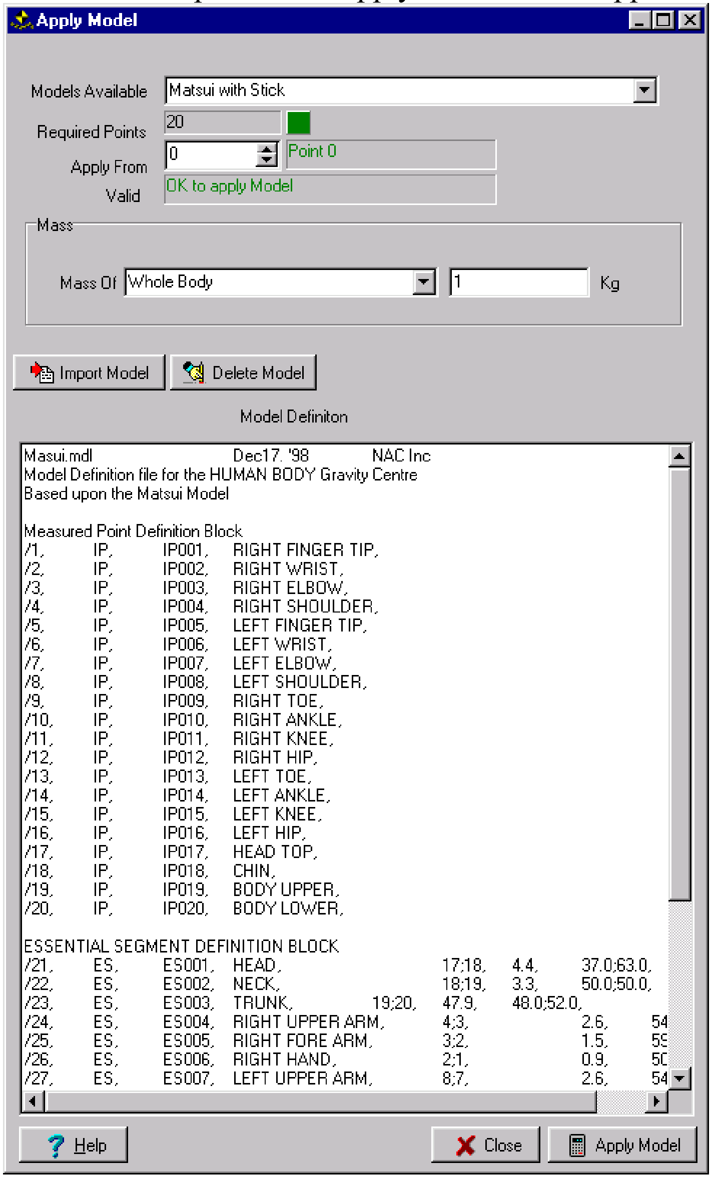
To apply lens correction to 3D sequences you must apply it to the individual 2D sequences used to generate the 3D sequence. If Lens correction is applied to the 2D sequences, the same lens correction will also be automatically applied to the corresponding Control Data Images. Lens correction MUST be applied to the 2D sequences BEFORE 3D data is generated. Applying it afterwards will not affect already generated 3D sequences.

You are not permitted to apply Lens Correction to a 3D sequence since this would be invalid.

# 18. Applying Models

For background information on Models see document (References on Model).

To apply a model to a sequence you should select the **Combination of Points|Apply Model** menu option. The Apply model screen appears as shown below :




| Use this… | To do this… |
|---|---|
| **Models Available** | Select the model to apply |
| **Required Points** | View the number of input points required for the selected model |
| **Apply From** | Select the point number in the sequence from which you require the model to be applied |
| **Mass** | Specify the mass of the Entire Object model, or and composed segment of the Model. This will be used to generate a mass for all composed segments |

| | |
|---|---|
| **Model Definition** | Display the selected models' definition as text |
| Import Model | Import a Model Definition file |
| Delete Model | Delete the selected Model Definition |
| Apply Model | Apply the selected Model to the current Sequence |

Select the model you wish to apply and click the "Apply Model" button. For a valid model application the sequence must have (Required Points) + (apply from) points.

After the model is applied Movias Pro will generate a new sequence as defined by the model.

# 19. Explanation of Calculation Formulas

## *19.1. Time Base Correction Using Timing Marks*

The film speed of a high speed camera will fluctuate to some extent. To minimise the influence of this fluctuation, timing marks are added during shooting. There are two steps to carry out this correction.

### 19.1.1. Derive the frame number and time

Frame number FNO (real number) for the $i$ th timing mark and time T are:

$$FNO = F_i + \frac{YP_i1 - Y_i}{YP1 - YP2} - OFFSET$$

$$T = \frac{1.0}{f} \times i \ \ (\mathrm{sec})$$

Where…

| | | |
|---|---|---|
| $Fi$ | : | Frame number of the frame containing the $i$ th timing mark |
| $YPi1$ | : | Y co-ordinate of the upper perforation of the frame having the $i$ th timing mark |
| $Yi$ | : | Y co-ordinate of the $i$ th timing mark |
| $YP1$ | : | Y co-ordinate of the upper perforation at initial setting |
| $YP2$ | : | Y co-ordinate of the lower perforation at initial setting |

| | | |
|---|---|---|
| *OFFSET* | : | The numeric that expresses, in number of frames, the amount of offset of the position on the frame up to the timing mark that is exposed at the same time as the frame that exposed the development with the film camera used. (This number is inherent to the film camera and will generally differ from camera to camera). |
| *f* | : | The frequency (Hz) of the light emitted by the timing mark LED |

#### 19.1.2. Time of each frame

The time data of each frame can be derived from the FNO and T of timing marks using an interpolation based upon a cubic spline curve.

### *19.2. Video Time Code and Frame Sequence Number*

When the time of the reference frame is T0 (in seconds) and the recording speed is SPD (PPS), the frame sequence number (FSQ) of the desired time T (in seconds) is expressed as:

$$FSQ = \left(T - T0\right) SPD + 1 \quad (\text{and}, T \geqq 0)$$

Where…

| | | |
|---|---|---|
| *T0* | : | The time of the reference frame (in seconds) |
| *SPD* | : | The recording speed (pictures per second) |
| *FSQ* | : | The sequence number relative to 1 |

### *19.3. 3D Conversion Using the DLT Method*

If we take the spatial co-ordinates (X,Y,Z) of the points on the subject, and make the position of the picture for points on the recording plane of one camera as (U,V), and then express this in a projection conversion equation, we have:

$$U = \frac{a_1 X + a_2 Y + a_3 Z + a_4}{a_9 X + a_{10} Y + a_{11} Z + 1} \qquad (1)$$

$$V = \frac{a_5 X + a_6 Y + a_7 Z + a_8}{a_9 X + a_{10} Y + a_{11} Z + 1} \qquad (2)$$

Here, $a_1$ to $a_{11}$ are the camera constants that determine the relationship between the recording surface of the camera and the subject. When we convert (1) and (2) and put them into an equation that will derive the camera constants, we have:

$$a_1X + a_2Y + a_3Z + a_4 - a_9XU - a_{10}YU - a_{11}ZU = U \qquad (3)$$

$$a_5X + a_6Y + a_7Z + a_8 - a_9XV - a_{10}YV - a_{11}ZV = V \qquad (4)$$

If we substitute (U,V) and (X,Y,Z) for at least six control points in equations (3) and (4), we derive $a_1$ to $a_{11}$ by method of least squares.

When we then convert (1) and (2) and place them into an equation for deriving X, Y and Z, and substitute the data obtained from two or more camera with the previous derived $a_1$ to $a_{11}$ into (5) and (6), this generates four or more equations. We then calculate these by the least squares method to derive (X,Y,Z).

$$(a_1 - a_9U)X + (a_2 - a_{10}U)Y + (a_3 - a_{11}U)Z = U - a_4 \qquad (5)$$

$$(a_5 - a_9V)X + (a_6 - a_{10}V)Y + (a_7 - a_{11}V)Z = V - a_8 \qquad (6)$$

### *19.4. Depth Correction*

#### 19.4.1. Method of Calculating the Depth Correction Coefficients

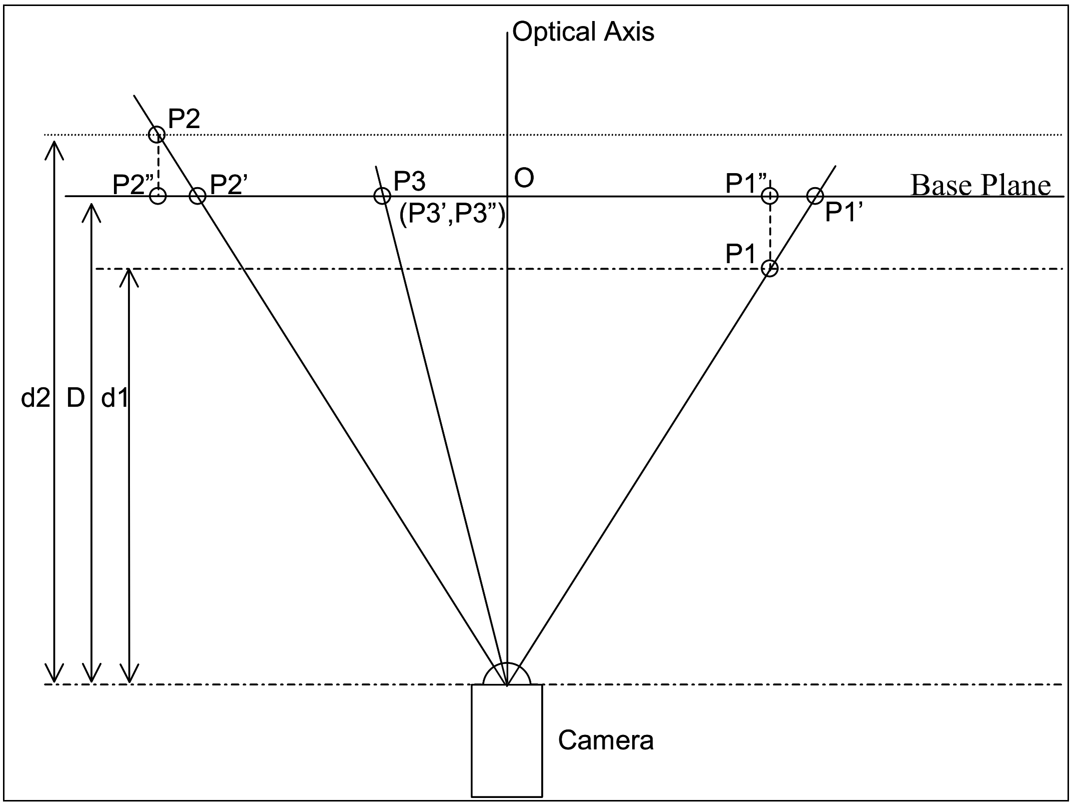



**Figure 12 – Depth Correction**

In the above diagram:

When we take…

| | | |
|---|---|---|
| O | : | Centre of optical axis |
| d1 | : | The distance from the camera to the plane normal to the camera axis that contains the point P1 |
| d2 | : | The distance from the camera to the plane normal to the camera axis that contains the point P2 |
| D | : | Distance from the camera to the base plane |
| P1, P2, P3 | : | Actual positions of measurement points |
| P1’, P2’, P3’ | : | Apparent positions of measurement points |
| P1”, P2”, P3” | : | Positions of measurement points after correction |

Then:

The depth correction coefficient for point P1 is d1/D
The depth correction coefficient for point P2 is d2/D
The depth correction coefficient for point P3 is 1.

### 19.4.2. Execution of Depth Correction

Following on from **Method of Calculating the Depth Correction Coefficients** above:

When we then take…

| | | |
|---|---|---|
| (x,y) | : | the co-ordinates of measurement points before correction |
| Depth_C | : | the depth correction coefficient of this point |
| (OAC_X,OAC_Y) | : | the co-ordinates of the centre of the optical axis |
| (X,Y) | : | the co-ordinates of the measurement points after depth correction |

Then we have:

$$X = OAC\_X + (x - AC\_X) \cdot Depth\_C$$

$$Y = OAC\_Y + (y - AC\_Y) \cdot Depth\_C$$

## *19.5. Analysis Parameter – Method*

### 19.5.1. Co-ordinate System Transformation - Movement of Origin

If the Origin is moved from its initial position, by definition (0,0,0), the co-ordinates of the point $P_0$, that is taken as the new Origin, becomes ($X_0$,$Y_0$,$Z_0$) within the Reference System.

When the point $P_0$ is the new origin, the co-ordinates of point P are considered to be converted from (X,Y,Z) to (X',Y',Z').

The following relationship is established between (X,Y,Z) and (X',Y',Z') at this time:

$X' = X - X_0$
$Y' = Y - Y_0$
$Z' = Z - Z_0$

### 19.5.2. Co-ordinate System Transformation - Rotation

Movias Pro can define a new 3D co-ordinate axis that is produced by the rotation of the original co-ordinate system by angles $\kappa$, $\phi$ and $\omega$ about the z, y and x axes respectively in a clockwise direction whilst pointing from the origin to positive values along each axis.

Then the co-ordinates of a point P'(x', y', z') in the original system are transformed to P" (x",y",z") by applying the following matrices.

Then the transformation matrix:

for rotation around the z-axis is: $$R\kappa = \begin{bmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

for rotation around the y-axis is: $$R\phi = \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix}$$

for rotation around the x-axis is: $$R\omega = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{bmatrix}$$

And, this is synthesised as:

$$R = R\omega \cdot R\phi \cdot R\kappa$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{bmatrix} \cdot \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix} \cdot \begin{bmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Therefore, P" is found by:

$$P'' = R \bullet P'$$

### 19.5.3. Smoothing

#### *19.5.3.1. Moving Mean Smoothing*

If the time series data to be smoothed is:

$$x(n), n = 0, 1, \ldots, N_1 - 1$$

Then the time series data after smoothing is:

$$y(n), n = 0, 1, \ldots, N_1 - 1$$

The basic response h(n) of the moving mean filter is assigned by:

*h(0)* = 1/2

*h(1)* = 1/2

*h(n)* = 0, *n* < 0 *or n* > 1

The method for calculating this filter is:

$$x(-1) = 0$$

$$y(n) = \frac{1}{2}\{x(n) + x(n-1)\} \quad n = 0, 1, \ldots, N_1 - 1$$

The response *h*(*n*) when the forward and reverse directions are combined and used as one filter is assigned by:

*h(-1)* = 1/4

*h(0)* = 2/4

*h(1)* = 1/2

*h(n)* = 0, *n* < -1 or *n* > 1

The equation for calculating this filter is:

$$x(-1) = 0$$
$$x(N_1) = 0$$
$$y(n) = \frac{1}{4}\{x(n+1) + 2x(n) + x(n-1)\}$$
$$n = 0,1\ldots, N_1 - 1$$

### *19.5.3.2. Butterworth Smoothing*

If the time series data to be smoothed is:

$$x(n), n = 0,1,\ldots, N_1 - 1$$

Then the time series data after smoothing is:

$$y(n), n = 0,1,\ldots, N_1 - 1$$

The sampling frequency and the smoothing filters cutoff frequency for time series data *x(n)* are indicated as:

| | | |
|---|---|---|
| Sampling frequency | : | fs (Hz) |
| Cut-off frequency | : | fc (Hz) |

And the sampling interval and cut-off frequency are:

| | | |
|---|---|---|
| Sampling interval | : | Ts (sec) |
| Cut-off angular frequency | : | $\omega$c (radians/sec) |

Between these is established:

Ts = 1/fs
$\omega$c = 2 π fc

The sampling time of time series data *x(n)* is assigned by

$$tn = nTs, n = 0,1,\ldots, N_1 - 1$$

Then the analogue BUTTERWORTH filter's frequency response function is

$$|H(\Omega)|^2 = \frac{1}{1 + (\Omega^2)^n}$$

(Only the secondary and quaternary in this software).

The frequency response of the results of converting this into a digital filter by means of a bilinear transformation is obtained by co-ordinate conversion from ω to Ω in the above equation.

$$\Omega = \frac{2}{T_s}\tan\left(\frac{\omega T_s}{2}\right)$$

The z conversion of the secondary digital BUTTERWORTH file is:

$$H(z) = \frac{b_0\left(1+z^{-1}\right)^2}{1+a_1 z^{-1}+a_2 z^{-2}}$$

Here, the coefficients, $b_0$, $a_1$ and $a_2$ are derived by:

$$a_1 = \frac{-8+2\Omega_c^2}{4+2\sqrt{2}\Omega_c+\Omega_c^2}$$

$$a_2 = \frac{4-2\sqrt{2}\Omega_c+\Omega_c^2}{4+2\sqrt{2}\Omega_c+\Omega_c^2}$$

$$b_0 = \frac{\Omega_c^2}{4+2\sqrt{2}\Omega_c+\Omega_c^2}$$

$$\Omega_c = \frac{2}{T_s}\tan\left(\frac{\omega_c T_s}{2}\right)$$

Example:

When the sampling frequency fs = 60Hz and the cutoff frequency fc = 6 Hz, it is obtained by:

$$T_s = \frac{1}{60}\sec, \omega_c = 12\cdot\pi, \omega_c T_s = 0.2\ \cdot\pi$$
$$\Omega_c = 2\cdot\tan(0.1\pi) = 0.20685\pi = 0.64984\pi$$

$$a_1 = -1.14298$$
$$a_2 = 0.41280$$
$$b_0 = 0.067455$$

$$H(z) = \frac{0.067455\left(1+z^{-1}\right)^2}{1-1.14298z^{-1}+0.41280z^{-2}}$$

The level of attenuance is:

$$3dB\ when\ f = 6H_z, \omega T_s = 0.2\pi$$
$$8.5dB\ when\ f = 9H_z, \omega T_s = 0.3\pi$$

To apply smoothing of time series data to this low-pass filter:

- requires a frequency conversion to select cutoff frequency
- requires a combination of forward and reverse direction filters to eliminate phase shift

Low-pass filter frequency is converted as shown below. Now, taking the basic low pas filter's frequency response function as:

$$H_1(Z), \quad z^{-1} = e^{-j}\theta$$

and the frequency response function of the low-pass filter after conversion:

$$H_d(Z), \quad Z^{-1} = e^{-j}\omega$$

the relation between $z^{-1}$ and $Z^{-1}$ is

$$z^{-1} = \frac{Z^{-1}-\alpha}{1-\alpha Z^{-1}}$$

Here *a* is derived taking:

$\theta_p$ : the basic low-pass filter's cut-off angle frequency
$\omega_p$ : the low-pass filter's cut-off angle frequency after conversion, as:

$$\alpha = \frac{\sin\frac{\theta_p-\omega_p}{2}}{\sin\frac{\theta_p+\omega_p}{2}}$$

The frequency response function *Hd(Z)* of the low-pass filter after conversion at this time, is obtained by substituting in the *H1(z)* equation:

$$H_d(Z) = \frac{B_0\left(1+Z^{-1}\right)^2}{1+A_1Z^{-1}+A_2Z^{-2}}$$

Here, the coefficients $B_0$, $A_1$ and $A_2$ are obtained by

$$B_0 = \frac{b_0(1-\alpha)^2}{1-a_1\alpha+a_2\alpha^2}$$
$$A_1 = \frac{-2\alpha+a_1\left(1-\alpha^2\right)-2a_2\alpha}{1-a_1\alpha+a_2\alpha^2}$$
$$A_2 = \frac{\alpha^2-a_1\alpha+a_2}{1-a_1\alpha+a_2\alpha^2}$$

The actual procedures for calculating the execution of filter is shown below:

| | | |
|---|---|---|
| Raw data | : | *x(k), k=0,1,…,$N_1$-1* |
| Intermediate data | : | *s(k), k=0,1,…,$N_1$-1* |
| Output data | : | *y(k), k=0,1,…,$N_1$-1* |

Thus, is we derive for *s(k)* in the forward direction, we have:

$$s(-2)=0$$
$$s(-1)=0$$
$$s(k)=B_0x(k)+2B_0x(k-1)+B_0x(k-2)-A_1s(k-1)-A_1s(K-2)$$
$$k=0,1,\Lambda\ N_1-1$$
$$s(N_1)=0$$
$$s(N_1+1)=0$$

and then we derive for *y(k)* in the reverse direction

$$y(N_1)=0$$
$$y(N_1+1)=0$$
$$y(k)=B_0s(k)+2B_0s(k+1)+B_0s(k+2)-A_1y(k+1)-A_2y(k+2)$$
$$k=N_1-1, N_1-2, \Lambda\ ,0$$

and conclude the calculation.

## *19.6. Virtual Points*

### 19.6.1. Type 1: Points on a Line Connection the Two points $P_1$ and $P_2$

The co-ordinates of the two points $P_1$ and $P_2$ are taken to be $(X_1,Y_1,Z_1)$ and $(X_2,Y_2,Z_2)$. The co-ordinates (X,Y,Z) of point P at the distance K times $P_1P_2$, which takes $P_1$ as the starting point in the direction from $P_1$ to $P_2$, are:

$$X = X_1 + K \cdot (X_2 - X_1)$$
$$Y = Y_1 + K \cdot (Y_2 - Y_1)$$
$$Z = Z_1 + K \cdot (Z_2 - Z_1)$$

### 19.6.2. Type 2: Rotation of a Point on a Plane (1 of 2)

On a plane that is determined by the three points $P_1$, $P_2$ and $P_3$, this derives the point obtained by rotating $P_2$ at a fixed angle around $P_1$.

The co-ordinates of the three points $P_1$, $P_2$ and $P_3$ are taken to be $(X_1,Y_1,Z_1)$, $(X_2,Y_2,Z_2)$ and $(X_3,Y_3,Z_3)$. The angle of rotation is $\theta$.

The co-ordinates of the derived points P are taken to be (X,Y,Z).

The unit vectors of $P_1P_2$ are $E_2(E_{2x},E_{2y},E_{2z})$ and the unit vectors of $P_1P_3$ are $E_3(E_{3x},E_{3y},E_{3z})$.

$$\overline{P_1P_2} = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2}$$
$$\overline{P_1P_3} = \sqrt{(X_3 - X_1)^2 + (Y_3 - Y_1)^2 + (Z_3 - Z_1)^2}$$

$$E_{2x} = \frac{X_2 - X_1}{\overline{P_1P_2}} \quad E_{2y} = \frac{Y_2 - Y_1}{\overline{P_1P_2}} \quad E_{2z} = \frac{Z_2 - Z_1}{\overline{P_1P_2}}$$
$$E_{3x} = \frac{X_3 - X_1}{\overline{P_1P_3}} \quad E_{3y} = \frac{Y_2 - Y_1}{\overline{P_1P_3}} \quad E_{3z} = \frac{Z_3 - Z_1}{\overline{P_1P_3}}$$

Consider $E_4(E_{4x},E_{4y},E_{4z})$ the vector product of $E_2$ and $E_3$,
and $E'_3(E'_{3x},E'_{3y},E'_{3z})$ the vector product of $E_4$ and $E_2$

Then the co-ordinates of the point P are given by:

$$X = \overline{P_1P_2} \times (E_{2x} \cos\theta + E'_{3x} \sin\theta)$$
$$Y = \overline{P_1P_2} \times (E_{2y} \cos\theta + E'_{3y} \sin\theta)$$
$$Z = \overline{P_1P_2} \times (E_{2z} \cos\theta + E'_{3z} \sin\theta)$$

### 19.6.3. Type 3: Rotation of Points on a Plane (2 of 2)

We shall take $P_4$ to be a point that is on a vertical line rising out of $P_1$ on a plane that is delineated by the three points $P_1$, $P_2$ and $P_3$. On the plane that is delineated by the three points $P_1$, $P_2$ and $P_4$, we will derive at this time, a point obtained by rotating $P_2$ by only a fixed angle around $P_1$.

The co-ordinates for the three points *P1*, *P2* and *P3* shall be taken, respectively, as $(X_1,Y_1,Z_1)$, $(X_2,Y_2,Z_2)$ and $(X_3,Y_3,Z_3)$. The angle of rotation shall be $\theta$.

The co-ordinates of the derived point $P$ are $(X,Y,Z)$.

The unit vectors of $P_1P_2$ are $E_2(E_{2x},E_{2y},E_{2z})$ and the unit vectors of $P_1P_3$ are $E_3(E_{3x},E_{3y},E_{3z})$.

$$\overline{P_1P_2} = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2}$$
$$\overline{P_1P_3} = \sqrt{(X_3 - X_1)^2 + (Y_3 - Y_1)^2 + (Z_3 - Z_1)^2}$$

$$E_{2x} = \frac{X_2 - X_1}{\overline{P_1P_2}} \quad E_{2y} = \frac{Y_2 - Y_1}{\overline{P_1P_2}} \quad E_{2z} = \frac{Z_2 - Z_1}{\overline{P_1P_2}}$$
$$E_{3x} = \frac{X_3 - X_1}{\overline{P_1P_3}} \quad E_{3y} = \frac{Y_2 - Y_1}{\overline{P_1P_3}} \quad E_{3z} = \frac{Z_3 - Z_1}{\overline{P_1P_3}}$$

and from $E_4(E_{4x},E_{4y},E_{4z})$ the vector product of $E_2$ and $E_3$, ($E_4 = E_2 \times E_3$) the point $P_4$ is

$$X_4 = E_{2y}E_{3z} - E_{2z}E_{3y}$$
$$Y_4 = E_{2z}E_{3x} - E_{2x}E_{3z}$$
$$Z_4 = E_{2x}E_{3y} - E_{2y}E_{3x}$$

$$\overline{P_1P_4} = \sqrt{(X_4 - X_1)^2 + (Y_4 - Y_1)^2 + (Z_4 - Z_1)^2}$$

The unit vector $E_4$ is:

$$E_{4x} = \frac{X_4 - X_1}{\overline{P_1P_4}} \quad E_{4y} = \frac{Y_4 - Y_1}{\overline{P_1P_4}} \quad E_{4z} = \frac{Z_4 - Z_1}{\overline{P_1P_4}}$$

Therefore,

$$X = \overline{P_1P_2} \times (E_{2x}\cos\theta + E_{4x}\sin\theta)$$
$$Y = \overline{P_1P_2} \times (E_{2y}\cos\theta + E_{4y}\sin\theta)$$
$$Z = \overline{P_1P_2} \times (E_{2z}\cos\theta + E_{4z}\sin\theta)$$

### 19.6.4. Type 4: Spatial Vectors for Dealing with Type 1

The co-ordinates of the two points $P_1$ and $P_2$ are $(X_1,Y_1,Z_1)$ and $(X_2,Y_2,Z_2)$. The derived vector is taken to be $P(P_x,P_y,P_z)$.

$$P_x = K \cdot (X_2 - X_1)$$
$$P_y = K \cdot (Y_2 - Y_1)$$
$$P_z = K \cdot (Z_2 - Z_1)$$

### 19.6.5. Type 5: Primary Combination of Any Two Vectors

The two vectors are given as $V_1(V_{1x},V_{1y},V_{1z})$ and $V_2(V_{2x},V_{2y},V_{2z})$ and the scale factor of those vectors is given as $K_1$ and $K_2$.

The derived vector $V(V_x,V_y,V_z)$ is:

$$V_x = K_1 V_{1x} + K_2 V_{2x}$$
$$V_y = K_1 V_{1y} + K_2 V_{2y}$$
$$V_z = K_1 V_{1z} + K_2 V_{2z}$$

### 19.6.6. Type 6: Point Moved Just by Spatial Vector V from Point P

The co-ordinates of point $P$ is taken to be $(X,Y,Z)$ and the spatial vector is taken to be $V(V_x,V_y,V_z)$. If the co-ordinates of the derived point $P'$ are taken to be $(X',Y',Z')$, then:

$$X' = X + V_x$$
$$Y' = Y + V_y$$
$$Z' = Z + V_z$$

### 19.6.7. Type 7: Unit Vectors in the Co-ordinate Axial Direction

In the X-axis direction = (1,0,0)
In the Y-axis direction = (0,1,0)
In the Z-axis direction = (0,0,1)

### 19.6.8. Type 8: Unit Vectors Connecting Two Points

Assume the co-ordinates of the two points $P_1$ and $P_2$ to be ($X_1$,$Y_1$,$Z_1$) and ($X_2$,$Y_2$,$Z$).

Assume that the unit vector is E($E_x$,$E_y$,$E_z$).

Then the unit vectors of $P_1P_3$ are $E_3$($E_{3x}$,$E_{3y}$,$E_{3z}$).

Because the distance between $P_1$ and $P_2$ is:

$$\overline{P_1P_2} = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2}$$

then the vector E is given by:

$$E_x = \frac{X_2 - X_1}{\overline{P_1P_2}} \quad E_y = \frac{Y_2 - Y_1}{\overline{P_1P_2}} \quad E_z = \frac{Z_2 - Z_1}{\overline{P_1P_2}}$$

### 19.6.9. Type 9: Component Vector

If the vector assigned is assumed to be $V$($V_x$,$V_y$,$V_z$)

Then the component vector

in the X-axis direction is ($V_x$,0.0)

in the Y-axis direction is (0,$V_y$,0)

in the Z-axis direction is (0,0,$V_z$).

## *19.7. Length and Area*

### 19.7.1. Length

When the co-ordinates of the *i*th point *P* are expressed by ($X_i$,$Y_i$,$Z_i$) in a sequence of points with a total of *n* points, the length *L* of the line segment that is a synthesis of the line segments connecting all points in order, is expressed by this equation:

$$L = \sum_{i=1}^{n-1} \sqrt{\left(X_i - X_{i+1}\right)^2 + \left(Y_i - Y_{i+1}\right)^2 + \left(Z_i - Z_{i+1}\right)^2}$$

### 19.7.2. Area

When the co-ordinates of the *i*th point *P* are expressed by ($X_i$,$Y_i$) in a sequence of points with a total of *n* points, the area *S* of the closed space obtained by connecting the first and last points in order is expressed by this equation:

$$S = \frac{1}{2} \cdot \left[\left(Y_3 - Y_1\right) \cdot X_2 + \left(Y_4 - Y_2\right) \cdot X_3 + \Lambda + \left(Y_n - Y_{n-2}\right) \cdot X_{n-1} + \left(Y_1 - Y_{n-1}\right) \cdot X_n + \left(Y_2 - Y_n\right) \cdot X_1\right]$$

## 19.8. Scalar Angle

### 19.8.1. Common Items

The scalar angle is generally derived as the angle that encloses two vectors. Here we will show how to derive the angle of enclosure with two vectors assigned.

The two vectors are $V_1(V_{1x},V_{1y},V_{1z})$ and $V_2(V_{2x},V_{2y},V_{2z})$ and the angle that encloses them is $\theta$.

From the inner product of the two vectors, we have:

$$\cos\theta = \frac{V_1 \cdot V_2}{|V_1| \cdot |V_2|}$$

$$\sin\theta = \sqrt{1-\cos^2\theta}$$

Consequently,

$$\cdot \cos\theta \neq 0 \qquad \theta = \tan^{-1}\left(\frac{\sin\theta}{\cos\theta}\right)$$

$$\cdot \cos\theta = 0 \qquad \theta = \frac{\pi}{2}$$

### 19.8.2. Type 1: Angle Crossing Two Straight Lines

Two straight lines are assumed to be $\overline{P1,P2},\overline{P3,P4}$

The co-ordinates of $P_1$, $P_2$, $P_3$ and $P_4$ are:

$$\begin{array}{ll} P1 & (X_1,Y_1,Z_1) \\ P2 & (X_2,Y_2,Z_2) \\ P3 & (X_3,Y_3,Z_3) \\ P4 & (X_4,Y_4,Z_4) \end{array}$$

The vectors for the two straight lines are:

$$\begin{aligned} V_1 &= (V_{1x},V_{1y},V_{1z}) \\ &= (X_1-X_2,Y_1-Y_2,Z_1-Z_2) \\ V_2 &= (V_{2x},V_{2y},V_{2z}) \\ &= (X_4-X_3,Y_4-Y_3,Z_4-Z_3) \end{aligned}$$

and thus $\theta$ can be derived by substituting for these vectors into the equations presented in section 12.8.1.

### 19.8.3. Type 2: Angles Enclosing Two Vectors

Here, the scalar angle common parameters remain the same.

### 19.8.4. Type 3: Angle Between Straight Line and Axis Defined by Two Points

(Angle between a straight line and an axis that can be defined by two points)

Assume that the straight line is $\overline{P1,P2}$.

Then take the co-ordinates of $P_1$ and $P_2$ as:

$$P1(X_1, Y_1, Z_1)$$
$$P2(X_2, Y_2, Z_2)$$

The vector for the straight line is:

$$\begin{aligned} V_1 &= (V_{1x}, V_{1y}, V_{1z}) \\ &= (X_2 - X_1, Y_2 - Y_1, Z_2 - Z) \end{aligned}$$

and the vector for the axis is:

$$\begin{aligned} V_2 &= (V_{2x}, V_{2y}, V_{2z}) \\ &= (1,0,0): X\!-\!Axis \\ &= (0,1,0): Y\!-\!Axis \\ &= (0,0,1): Z\!-\!Axis \end{aligned}$$

### 19.8.5. Type 4: Angle Between Vector and Axis

The vector is taken to be:

$$V_1 = (V_{1x}, V_{1y}, V_{1z})$$

The vector for the axis is:

$$\begin{aligned} V_2 &= (V_{2x}, V_{2y}, V_{2z}) \\ &= (1,0,0): X\!-\!Axis \\ &= (0,1,0): Y\!-\!Axis \\ &= (0,0,1): Z\!-\!Axis \end{aligned}$$

### 19.8.6. Displacement, Velocity and Acceleration of the Scalar Angle

If the scalar angle of the reference is taken to be $\theta_o$ and the $i$th scale angle is taken to be $\theta_i$, then the displacement $d\theta$ of the scalar angle is:

$$d\theta = \theta_i - \theta_o$$

Take the ($i$-1)th scalar angle as $\theta_{i-1}$ and the ($i$+1)th scalar angle as $\theta_{i+1}$.

The velocity $\left(\frac{d\theta}{dt}\right)_i$ of the scalar angle is:

$$\left(\frac{d\theta}{dt}\right)_i = \frac{\theta_{i+1} - \theta_{i-1}}{t_{i+1} - t_{i-1}}$$

Take the ($i$-1)th scalar angle is $\theta_{i-1}$ and the ($i$+1)th scalar angle as $\theta_{i+1}$.

The acceleration $\left(\frac{d^2\theta}{dt^2}\right)_i$ of the scalar angle is:

$$\left(\frac{d^2\theta}{dt^2}\right)_i = \frac{\left(\frac{d\theta}{dt}\right)_{i+1} - \left(\frac{d\theta}{dt}\right)_{i-1}}{t_{i+1} - t_{i-1}}$$

## 19.9. Physical Quantity

### 19.9.1. Position

The co-ordinates of the co-ordinate reference point 0 are taken to be ($X_o$,$Y_o$,$Z_o$) and the co-ordinates of the *i*th point $P_i$ are taken to be ($X_i$,$Y_i$,$Z_i$). The position of $P_i$ and its distance from the reference point at this time, are calculated as shown below.

Position's X component : $P_{xi} = X_i - X_0$

Position's Y component : $P_{yi} = Y_i - Y_0$

Position's Z component : $P_{zi} = Z_i - Z_0$

Distance : $P_{Ai} = \sqrt{\left(P_{Xi}{}^2 + P_{Yi}{}^2 + P_{Zi}{}^2\right)}$

### 19.9.2. Displacement

When the positions of the *i*th point are taken to be ($P_{Xi}$,$P_{Yi}$,$P_{Zi}$) and the positions in the displacement reference frame of the *i*th point are taken to be ($P_{Xio}$,$P_{Yio}$,$P_{Zio}$), the displacement $D_i$($D_{Xi}$,$D_{Yi}$,$D_{Zi}$) and the distance $D_{Ai}$ from the reference point are calculated as follows.

$$D_{Xi} = P_{Xi} - P_{Xio}$$
$$D_{Yi} = P_{Yi} - P_{Yio}$$
$$D_{Zi} = P_{Zi} - P_{Zio}$$
$$D_{Ai} = \sqrt{\left(D_{Xi}{}^2 + D_{Yi}{}^2 + D_{Zi}{}^2\right)}$$

### 19.9.3. Velocity

The ($i$-1)th co-ordinate of a certain point is taken to be ($X_{i-1}$,$Y_{i-1}$,$Z_{i-1}$) at time $T_{i-1}$ and the ($i$+1)th co-ordinate is ($X_{i+1}$,$Y_{i+1}$,$Z_{i+1}$) at time $T_{i+1}$. The velocity of this point at time $T_i$ is given by:

$$V_{Xi} = \frac{X_{i+1} - X_{i-1}}{T_{i+1} - T_{i-1}}$$

$$V_{Yi} = \frac{Y_{i+1} - Y_{i-1}}{T_{i+1} - T_{i-1}}$$

$$V_{Zi} = \frac{Z_{i+1} - Z_{i-1}}{T_{i+1} - T_{i-1}}$$

$$V_{Ai} = \sqrt{\left(V_{Xi}{}^2 + V_{Yi}{}^2 + V_{Zi}{}^2\right)}$$

where $V_{Ai}$ is the magnitude of the velocity at time $T_i$ .

### 19.9.4. Acceleration

The ($i$-1)th velocity of a certain point is taken to be ($V_{Xi-1}$,$V_{Yi-1}$,$V_{Zi-1}$) and time $T_{i-1}$ and the ($i$+1)th velocity is ($V_{Xi+1}$,$V_{Yi+1}$,$V_{Zi+1}$) at time $T_{i+1}$.

The $i$th acceleration of this point at time $T_i$ and its magnitude $A_{Ai}$ is calculated as follows:

$$A_{Xi} = \frac{V_{Xi+1} - V_{Xi-1}}{T_{i+1} - T_{i-1}}$$

$$A_{Yi} = \frac{V_{Yi+1} - V_{Yi-1}}{T_{i+1} - T_{i-1}}$$

$$A_{Zi} = \frac{V_{Zi+1} - V_{Zi-1}}{T_{i+1} - T_{i-1}}$$

$$A_{Ai} = \sqrt{\left(A_{Xi}{}^2 + A_{Yi}{}^2 + A_{Zi}{}^2\right)}$$

### 19.9.5. Force

When the mass of a certain point is taken to be $m$ and the $i$th acceleration of that point is taken to be ($A_{Xi}$,$A_{Yi}$,$A_{Zi}$), the $i$th force and the magnitude $F_{Ai}$ of that force are calculated as follows.

$$F_{Xi} = m \cdot A_{Xi}$$

$$F_{Yi} = m \cdot A_{Yi}$$

$$F_{Zi} = m \cdot A_{Zi}$$

$$F_{Ai} = \sqrt{\left(F_{Xi}{}^2 + F_{Yi}{}^2 + F_{Zi}{}^2\right)}$$

### 19.9.6. Kinetic Energy

Take the mass at a certain point to be *m*, and the velocity of that point to be ($V_{Xi}$,$V_{Yi}$,$V_{Zi}$). The magnitude $E_{Ai}$ of the kinetic energy at that point is then calculated as shown here:

$$E_{Xi} = \frac{1}{2} m \cdot V_{Xi}^{\ 2}$$
$$E_{Yi} = \frac{1}{2} m \cdot V_{Yi}^{\ 2}$$
$$E_{Zi} = \frac{1}{2} m \cdot V_{Zi}^{\ 2}$$
$$E_{Ai} = E_{Xi} + E_{Yi} + E_{Zi}$$

### 19.9.7. Power

Take the mass at a certain point to be m, the velocity of that point to be ($V_{Xi}$,$V_{Yi}$,$V_{Zi}$) and the acceleration to be ($A_{Xi}$,$A_{Yi}$,$A_{Zi}$).

The magnitude $PW_{Ai}$ of the power at that point is then calculated as shown here:

$$PW_{Xi} = m \cdot V_{Xi} \cdot A_{Xi}$$
$$PW_{Yi} = m \cdot V_{Yi} \cdot A_{Yi}$$
$$PW_{Zi} = m \cdot V_{Zi} \cdot A_{Zi}$$
$$PW_{Ai} = m \cdot \left( V_{Xi} \cdot A_{Xi} + V_{Yi} \cdot A_{Yi} + V_{Zi} \cdot A_{Zi} \right)$$

### 19.9.8. Momentum

Take the mass at a certain point to be *m*, and the velocity of that point to be ($V_{Xi}$,$V_{Yi}$,$V_{Zi}$). The overall magnitude $M_{Ai}$ of the momentum and its value along each axis at that point are then calculated as shown here:

$$M_{Xi} = m \cdot V_{Xi}$$
$$M_{Yi} = m \cdot V_{Yi}$$
$$M_{Zi} = m \cdot V_{Zi}$$
$$M_{Ai} = \sqrt{\left( M_{Xi}^{\ 2} + M_{Yi}^{\ 2} + M_{Zi}^{\ 2} \right)}$$

# 20. ASCII File Format

## *20.1. 2-Dimensional Import ASCII File*

2 Dimensional ASCII Import data is identical to that for 3D data but the Z column is omitted.

## *20.2. 3-Dimensional Import ASCII File*

### 20.2.1. Record Structure

This file have to be wrote line by line. Each line is called record. Every record have to be separated by CR+LF. Maximum number of character for one record excluding CR+LF is 511. There are two kind of record. That are comment description record and data description record.

### 20.2.2. Comment Description Record

Record with a symbol # at the beginning is a comment description record. MOVIAS Pro ignores this comment description record.

### 20.2.3. Data Description Record

#### *20.2.3.1. Format of data description record*

Data description record consist from the following item.

- Frame sequence number (FSN)
- Point number (PN)
- Time
- X coordinate value of point
- Y coordinate value of point
- Z coordinate value of point

The format of this record is as follows.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FSN | , (COMMA) | PN | , | TIME | , | X | , | Y | , | Z | CR+LF |

Maximum record length : 511 bytes excluding CR+LF
Item separator : Comma
Record terminator : Carriage return and Line feed (CR+LF)
Frame sequence number (FSN) :

This is a sequence number of the frame. It is an integer number and starts with 1. Maximum frame sequence number is 1000.

Point number (PN) :

It is an integer number that is greater than one. It must be unique within one frame. There must be the same number of point within all over one frame. Maximum point number is 256.

Time :

This is a lapse time of each frame. The time of the first frame must be zero. Unit of time is millisecond. Increment of time for each frame must be same. The range of value for time is from 0 to $10^{38}$.

X,Y, and Z coordinate :

This is a X, Y, and Z coordinate of the point. If the point can not be measured, then write a word “VANISH”. The range of value for coordinates is from $-10^{38}$ to $+10^{38}$. Either exponential expression like 6.5961e+001 or fixed decimal expression like 65.961 can be used.

Spaces, Tabs :

Any number of spaces or tabs can be put between item and item separator. But no space nor tab can not be put within item itself.

##### *20.2.3.2. Order of data description record*

There are two types of order. One is an order based on frame sequence numbers and the other is an order based on point numbers.
The description order base on frame sequence numbers is as follows.
First, describe the record for all points of the first frame. Then describe the record for all points of the next frame in order of point number. Repeat these procedures for all frames.
The description order based on point numbers is as follows.
First, describe the record for all frames of the point 1 in order of frame sequence number. Then, describe the record for all frames of the point 2 in order of frame sequence number. Repeat these procedures for all points.

### 20.2.4. Example

An example of description of 3D import ASCII file is shown on next page.
This is an ASCII text file described in result of the process where frame sequence numbers are from 1 to 100 and measuring points are 5 per frame.

```
#
#  MOVIAS Pro
#
#    file name : ********.***
#    date : Jan., 1  2000
#
# F-Seq,  Point, time,      X,         Y,          Z
1,      1,      0.0,      6.596100e+001,                 5.872020e+001,    3.952320e+001
2,      1,      0.5,      6.078140e+001,                 5.272670e+001,    3.602070e+001
3,      1,      1.0,      6.372930e+001,                 4.019370e+001,    2.389970e+001
        :       :         :    :    :         :
        :       :         :    :    :         :
        99,     1,        49.0,     6.089740e+002,       1.034830e+001,    1.834860e+001
        100,    1,        49.5,     VANISH,              VANISH,           VANISH
        1,      2,        0.0,      6.501030e+001,       5.780160e+001,    3.980760e+001
        2,      2,        0.5,      6.073980e+001,       5.206490e+001,    3.516390e+001
        3,      2,        1.0,      6.371260e+001,       4.022920e+001,    2.292120e+001
        :       :         :    :    :         :
        :       :         :    :    :         :
        99,     2,        49.0,     6.034930e+002,       1.980770e+001,    1.740720e+001
        100,    2,        49.5,     VANISH,              VANISH,           VANISH
        1,      3,        0.0,      6.417310e+001,       5.699560e+001,    3.839860e+001
        2,      3,        0.5,      6.071170e+001,       5.147040e+001,    3.547140e+001
        :       :         :    :    :         :
        :       :         :    :    :         :
        99,     3,        49.0,     5.990920e+002,       1.939970e+001,    1.769940e+001
        100,    3,        49.5,     VANISH,              VANISH,           VANISH
        1,      4,        0.0,      6.344030e+001,       5.629460e+001,    3.759460e+001
        2,      4,        0.5,      6.069600e+001,       5.093850e+001,    3.553350e+001
        :       :         :    :    :         :
        :       :         :    :    :         :
        98,     4,        48.5,     6.077630e+002,       1.963140e+001,    1.963180e+001
        99,     4,        49.0,     5.956860e+002,       1.911380e+001,    1.611360e+001
        100,    4,        49.5,     5.461730e+002,       1.911380e+001,    1.430070e+001
        1,      5,        0.0,      6.280280e+001,       5.569100e+001,    3.699500e+001
        2,      5,        0.5,      6.069170e+001,       5.046420e+001,    3.466520e+001
        :       :         :    :    :         :
        :       :         :    :    :         :
        98,     5,        48.5,     6.026880e+002,       1.948470e+001,    1.988440e+001
        99,     5,        49.0,     5.931940e+002,       1.893900e+001,    1.533910e+001
        100,    5,        49.5,     5.421760e+002,       1.949190e+001,    1.342130e+001
#
# END OF FILE
```

### *20.3. 3-Dimensional Export ASCII File*

3D export ASCII file can be read out by a spreadsheet calculating software such as Lotus 1-2-3 or Microsoft Excel.

An example of a 3D export ASCII file is shown below. This is an output result of the process where frame sequence numbers are from 1 to 36 and coordinate of two measuring points per frame. Line with # at the beginning is the comment line.

```
#
# << MOVIAS Pro >>
#
#   LIST DATA FILE
#
#
# ----- < Condition / Comment > -----
#  Points/Frame     :  2
#  MAX Seq.         :  36
#  Resampling (Hz)  :  10
#  Smoothing Mode   :
#  Order / N        :
#  Cuf Off Freq.    :
#  Date             :  99/09/03
#  Time             :  18:04:32
#  File Name        :  MOVIAS Pro
#  Test Date        :
#  Code No.         :  12345
#  Comment          :  abcdefghijklmnopqrstuvwxyz
#
# ---------------------------------------------
#  Position         :  Raw
#
#  F-SEQ  PNO  TIME       X        Y        Z        ABS
    1,    1,     0.0000,   6.0373,  -2.5793,  0.8976,    6.6262,
    2,    1,   100.0000,   4.0260,  -0.8715,  2.0477,    4.6003,
    3,    1,   200.0000,   2.6940,  -1.6690,  1.8227,    3.6558,
       :     :      :         :        :        :         :
       :     :      :         :        :        :         :
       :     :      :         :        :        :         :
   34,    1,  3300.0000,   4.6902,   1.1437,  0.9769,    4.9255,
   35,    1,  3400.0000,   4.0307,  -1.2294,  1.5787,    4.5000,
   36,    1,  3500.0000,   3.8067,  -0.6172, -0.1682,    3.8601,
    1,    2,     0.0000, 998.8846,  -2.8709, 1003.4551, 1415.8746,
    2,    2,   100.0000, 984.5535, 173.2462, 1003.0746, 1416.1633,
    3,    2,   200.0000, 940.9726, 340.5163, 1004.1639, 1417.6479
       :     :      :         :        :        :         :
       :     :      :         :        :        :         :
       :     :      :         :        :        :         :
   34,    2,  3300.0000, 861.8500, -500.7123, 1001.5798, 1413.0323,
   35,    2,  3400.0000, 939.1442, -339.0666, 1001.3873, 1414.1198,
```

36,      2,   3500.0000,  983.8673,  -174.7312,  1002.6735,  1415.5847,

## 20.4. Model Definition ASCII File

Model definition ASCII file is an ASCII formatted text file on which model is described. Five items, input point, virtual point, essential segment, composed segment and stick, can be described in the file. Description is performed in unit of every one line. Type and composing method are described in one line. We call a line a record. Records with "/" (slash) at their beginning are effective and considered that information on model is described. Other records are ignored as comments.
Here structure and formatting of model definition file are explained. The model definition ASCII file describes the Matsui model is shown as an example in the last stage.

### 20.4.1. Structure of Model Definition ASCII File

| | | Definition record | |
|---|---|---|---|
| | | Number | Point type |
| Input point | Up to 30 | 1<br>2<br>:<br>:<br>I | Input point (IP) |
| Definition point | Up to 10 | I+1<br>:<br>:<br>J | Virtual point (VP) |
| | Up to 20 | J+1<br>:<br>:<br>K | Essential segment (ES) |
| | Up to 10 | K+1<br>:<br>:<br>M | Composed segment (CS) |
| Stick | Up to 10 | 1<br>2<br>:<br>:<br>N | Stick (STK) |

### 20.4.2. Formatting of Model Definition ASCII File

#### *20.4.2.1. Common data for every items*

| | | | | |
|---|---|---|---|---|
| /number | Point type | Code | Name | Differs subjects to point type |

1 Number is to be a consecutive number from 1 for input point, virtual point, essential segment and composed segment. Stick is to be a consecutive number from 1 respectively. For the order of point definition and maximum definable

number, refer to the above section of "Structure of Model Definition ASCII File".

2 Point type is to be two or three alphabetic characters in capital letters.

IP : Input point
VP : Virtual point
ES : Essential segment
CS : Composed segment
STK : Stick

3 Code is to be 1 to 5 alphanumeric characters

4 Name is to be 1 to 20 characters that can be input from a keyboard. "," (comma) and ";" (semicolon) are not allowed.

5 Special symbols

| | Explained expression | Description in file |
|---|---|---|
| Delimiter for items | Thick vertical line | "," (comma) |
| Delimiter in items | Thin vertical line | ";" (semicolon) |
| End of record | ↓ | CR+LF |

### *20.4.2.2. Record of input point*

| | | | | |
|---|---|---|---|---|
| /number | IP | Code | Name | ↓ |

### *20.4.2.3. Record of virtual point*

| /number | VP | Code | Name | Type | Point number | | | Coefficient | | ↓ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | □ | □ | □ | □ | □ | |

- Type is the type number of virtual point. Numbers from 1 to 9.
- Point number is the number of input point or pre-defined virtual point. Input 0 to 3 point numbers depending on type of virtual point.
- Coefficient is to be input of 0 to 2 coefficients depending on type of virtual point. Input in real number and formatting is to be ±####.###.

### *20.4.2.4. Record of essential segment*

| /number | ES | Code | Name | Point number | | | | | Weight Coefficient | Gravity Coefficient | | | | | ↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | □ | □ | □ | □ | □ | | □ | □ | □ | □ | □ | |

- Essential segment is to be composed with input point or virtual point (except for vector).
- Point number is the number of composed element point. Input 2 to 5 point numbers. Integral numbers in one or two digits.
- Weight coefficient is weight of essential segment when whole weight is to be 100. (For example, when whole weight is 80kg and essential segment is 10kg, weight coefficient

will be 12.5.) Input in real number and formatting is to be ±####.###.

- Gravity coefficient is to be input the same numbers as numbers of point numbers input. Weight shared with each point when mass of essential segment is to be 100. Input real number and formatting is to be ±####.###.

#### *20.4.2.5. Record of composed segment*

| /number | CS | Code | Name | Point number | | | | ↓ |
|---|---|---|---|---|---|---|---|---|
| | | | | □ | □ | ……….. | □ | |

- Point number is the number of composed essential segment. Input 2 to 20 point numbers. Integral numbers in one or two digits.

#### *20.4.2.6. Record of stick*

| /number | STK | Code | Name | Color | Point number | | | | Mark number | ↓ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | □ | □ | ……….. | □ | | |

- Color is the color number at CRT output. Numbers of 1 to 8.
- Point number is the number of composed element point. Input 1 to 10 point numbers. Numbers in one or two digits.
- Mark number is to be input when only one point number is input. Integral numbers in one digit.

### 20.4.3. Example of Model Definition ASCII File

Shown below is an example of model definition ASCII file using with the Matsui model.

MATSUI.MDL Dec. 17. '98 nac Inc.
MODEL DEFINITION FILE for the HUMAN BODY GRAVITY CENTER
Based upon the MATSUI model.

MEASURED POINT DEFINITION BLOCK

| | | | |
|---|---|---|---|
| /1, | IP, | IP001, | RIGHT HAND, |
| /2, | IP, | IP002, | RIGHT WRIST, |
| /3, | IP, | IP003, | RIGHT ELBOW, |
| /4, | IP, | IP004, | RIGHT SHOULDER, |
| /5, | IP, | IP005, | LEFT HAND, |
| /6, | IP, | IP006, | LEFT WRIST, |
| /7, | IP, | IP007, | LEFT ELBOW, |
| /8, | IP, | IP008, | LEFT SHOULDER, |
| /9, | IP, | IP009, | RIGHT TOE, |
| /10, | IP, | IP010, | RIGHT ANKLE, |
| /11, | IP, | IP011, | RIGHT KNEE, |
| /12, | IP, | IP012, | RIGHT HIP, |
| /13, | IP, | IP013, | LEFT TOE, |
| /14, | IP, | IP014, | LEFT ANKLE, |
| /15, | IP, | IP015, | LEFT KNEE, |
| /16, | IP, | IP016, | LEFT HIP, |
| /17, | IP, | IP017, | HEAD, |
| /18, | IP, | IP018, | NECK, |
| /19, | IP, | IP019, | BODY UPPER, |
| /20, | IP, | IP020, | BODY LOWER, |

ESSENTIAL SEGMENT DEFINITION BLOCK

| | | | | | | |
|---|---|---|---|---|---|---|
| /21, | ES, | ES001, | HEAD, | 17;18, | 4.4, | 37.0;63.0, |
| /22, | ES, | ES002, | NECK, | 18;19, | 3.3, | 50.0;50.0, |
| /23, | ES, | ES003, | TRUNK, | 19;20, | 47.9, | 48.0;52.0, |
| /24, | ES, | ES004, | RIGHT UPPER ARM, | 4;3, | 2.65, | 54.0;46.0, |
| /25, | ES, | ES005, | RIGHT FORE ARM, | 3;2, | 1.5, | 59.0;41.0, |
| /26, | ES, | ES006, | RIGHT HAND, | 2;1, | 0.9, | 50.0;50.0, |
| /27, | ES, | ES007, | LEFT UPPER ARM, | 8;7, | 2.65, | 54.0;46.0, |
| /28, | ES, | ES008, | LEFT FORE ARM, | 7;6, | 1.5, | 59.0;41.0, |
| /29, | ES, | ES009, | LEFT HAND, | 6;5, | 0.9, | 50.0;50.0, |
| /30, | ES, | ES010, | RIGHT THIGH, | 12;11, | 10.0, | 58.0;42.0, |
| /31, | ES, | ES011, | RIGHT LEG, | 11;10, | 5.35, | 59.0;41.0, |
| /32, | ES, | ES012, | RIGHT FOOT, | 10;9, | 1.9, | 50.0;50.0, |
| /33, | ES, | ES013, | LEFT THIGH, | 16;15, | 10.0, | 58.0;42.0, |
| /34, | ES, | ES014, | LEFT LEG, | 15;14, | 5.35, | 59.0;41.0, |
| /35, | ES, | ES015, | LEFT FOOT, | 14;13, | 1.9, | 50.0;50.0, |

COMPOSED SEGMENT (WHOLE BODY) DEFINITION BLOCK

/36, CS, CS001, WHOLEBODY,21;22;23;24;25;26;27;28;29;30;31;32;33;34;35,

STICK DEFINITION BLOCK

| | | | | | |
|---|---|---|---|---|---|
| /1, | STK, | STK001, | RIGHT ARM, | 3, | 1;2;3;4;19, |
| /2, | STK, | STK002, | LEFT ARM, | 7, | 5;6;7;8;19, |
| /3, | STK, | STK003, | RIGHT LEG, | 3, | 9;10;11;12;20, |
| /4, | STK, | STK004, | LEFT LEG, | 7, | 13;14;15;16;20, |
| /5, | STK, | STK005, | BODY, | 5, | 17;18;19;20, |