ProAnalyst®

Motion Analysis Software

User Guide

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ProAnalyst User Guide

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Chapter 1. Getting Started

Introduction

Highlights

You've heard of 'image' or 'video' analysis. Welcome to the revolution - integrated 'motion' analysis. ProAnalyst is a full-featured auto-tracking software and a full-featured data analysis software package. On your video, our new feature tracking algorithms are the most accurate that we have tested. Auto-track in 1-D (along lines) or in 2-D (patterns). On your synchronized data, perform FFTs, filtering and more analyses. Then, using the graphing panel, overlay image motion onto sensor data.

Highlights:

- Over 30 different analysis 'tools' - line tracking, feature tracking, stick figure drawing, stabilization, and more.
- New chained image filtering and processing tools for greater flexibility in image manipulation.
- Easy switching between viewing of raw and processed images.
- New rotating feature and predictive tracking algorithms.
- New data analysis and graphing features including filtering and FFTs, timeline and scope view modes.
- New Project Manager - keeps track of all your files.
- New report generator lets you post test results to a server or print a report.
- Seamlessly works with files from ProCapture, MiDAS 2.0, Professional, 4.0, OS, and DA or as stand-alone analysis package.

Typical Applications

ProAnalyst is ideal for the engineer or research scientist who needs to make accurate motion analysis calculations,and deliver a final report or presentation. Typical applications include the following.

- Biomechanics and sports performance
- Combustion research (1-D line tool)
- Blood flow analysis (1-D line tool)

- Car crash testing and accident reconstruction
- Animal locomotion studies
- Heartvalve testing
- Shock/vibration testing
- Ballistics and trajectory tracking
- Golf ball club, ball and flight analysis
- Airborne flight testing (stabilization)
- Drop testing

List of Features

This is just a sample of the list of features available in this software package.

- Image Processing Features:
  - Standard image look-up table modifications
    - Brightness, Contrast, Gamma. Exponential/Logarithmic, Reverse
  - Over 30 image filters that can be chained together to create complex image processing routines
    - Pre-defined: Sobel, Laplacian, Gaussian, High Pass
    - Arithmetic: Add, Subtract, Multiply, Square, Right/Left Bit Shift, Logical AND, OR, XOR, NOT
    - Neighborhood: Blur, Median, Maximum, Minimum
    - Morphology: Erode, Dilate, Open, Close
    - LUT: Brightness, Contrast, Gamma. Exponential/Logarithmic, Reverse
    - Image: Threshold, Histogram Equalize, Despeckle
- Enhanced Collaboration and Visualization Tools:
  - New annotations allow you to draw lines, rectangles, text, etc. in each frame or across all frames. Basic length and angle measurement annotations allow you to do simple measurements on any video.
  - Timeline view allows you to view videos and data in a filmstrip format, enabling you to examine a specific frame, while still being able to see the context frames and data before and after the frame of interest.

- New Reporting Tools:
  - Report Generator can export to HTML or print directly to your printer.
  - Prints relevant video frames, data graph segments, and user added comments and annotations.
- Video Analysis Capabilities:
  - 1-D Line Tracking:
    - Track transitions along multiple lines in the video.
    - Can detect transitions based upon intensity or derivative changes..
    - Fully adjustable threshold levels.
    - Detect multiple transitions per line per frame.
    - Configurable line thickness and filtering along line.
    - Summary view provides a complete picture of the pixel values corresponding to a line for every frame of the whole event.
    - Circle fitting option uses a gradient descent algorithm to compute the optimal center and radius automatically.
  - 2-D Feature Tracking:
    - Complete editable tracking parameters
    - Tracking of rotating objects
    - Trajectory prediction using a Kalman Filter based prediction scheme
    - Enhanced line drawing for highly informative stick figures
      - Real-time display of distances between features
      - Real-time display of angles between features
    - Immediate graphing and analysis of tracked data
  - Stabilization:
    - Track features in the video that should be stationary and remove horizontal, vertical, or rotational motion in the video
    - Save stabilized video to multiple formats
  - Contour Tracking:
    - Locate and trace the outline of deformable objects over time

        - Multiple contours can be tracked simultaneously
        - Graph or export calculated quantities from each contour, such as area, perimeter, or center of mass location
    - Particle Counting, Sizing, and Flow:
        - Determine statistics (size, eccentricity factor, major axis orientation) of particles detected in each frame
        - Display histograms of distribution for each statistic
        - Perform intelligent correspondence between frames to estimate particle trajectories over time
    - Cell Tracking:
        - Track the motion of cells and calculate the distance from the cell tip to boundary walls
        - Calculate quantity of cells moving along two distinct branches
    - PIV Toolkit:
        - Estimate the motion of a dense set of particles to generate vector fields for each set of frames
        - Fully configurable interrogation window size, search region, correlation method, and vector spacing
        - Display colorized contour map of the resulting vector fields
    - Impact Excursion Toolkit:
        - Analyze the motion of a crash test dummy during impact testing.
        - Measure the maximum excursion of points on the crash test dummy relative to international safety regulation limits.
        - Display trajectory of motion, distances to safety limits, displacement grid, and graph measured quantities.
- Data Analysis Capabilities:
    - Real-time FFT on captured data and analysis results
    - Data Filtering
        - Scale, Offset, Integral, Difference, Mean, Median
        - High Pass, Low Pass, Band Pass, Band Stop

    - Butterworth, Chebyshev, Elliptic, Inverse Chebyshev
  - Enhanced Graph Configuration
    - Completely configurable line style, thickness, point style, etc.
    - Save multiple graph configurations and easily reload
- File/Project Management:
  - Graphical explorer to quickly browse through your entire video collection
    - Displays video thumbnails and data graphs, plus vital information for every recorded video in a selected directory
    - Allows you to easily playback each video or jump to any frame
    - Can play back multiple files simultaneously
  - New Project Files
    - Provides an easy way to group multiple video files together
    - Helps you manage your multiple camera recordings
    - Helps organize your collection of associated files (analysis results, calibration files, image processing settings, etc.)
  - Additional Video Save Options
    - Save frames with processing
    - Save encrypted
    - Save as partial chunks which are loaded together seamlessly (for videos over 2GB)

Installation

Installing the ProAnalyst Software

Note: ProAnalyst is designed to work on Windows operating systems, Windows 7 and up. ProAnalyst has been tested on both 32-bit and 64-bit systems.

1. Turn on your computer.
2. Insert the CD that contains the ProAnalyst software into your CD-ROM drive. The ProAnalyst software installer should automatically start. If it does not, from the Start Menu, in the Run... prompt, type `F:\ProAnalySetup.exe`, where "`F`" is the letter of

your CD drive.

3. The installer Welcome screen will appear. Verify that the program and version number are the desired program and version that you wish to install.

4. Click Next.

5. The ProAnalyst License Agreement will pop up. Read the agreement carefully.

6. If you agree to the license terms, click I accept the agreement and click Next.

7. The installer will prompt you to select the destination folder. Note: the default folder is `C:\Program Files\Xcitex\ProAnalyst\`. If possible, you are advised to use this folder for a more uniform install.

8. Click Next.

9. The installer will prompt you to give a name for the Start Menu folder. The default is `ProAnalyst`. Type in the desired Start Menu folder name.

10. Click Next.

11. The installer will provide the option for creating a desktop icon to launch the program.

12. Click Next.

13. ProAnalyst requires the Microsoft .NET Framework 2.0 to be installed on your computer. The installer will check to ensure this is installed. If the installer cannot find the .NET Framework 2.0 installer, it will prompt you to download it and install it.

14. The installer will provide a summary of the settings for the ProAnalyst installation.

15. If all settings are correct, click Install.

16. The installer will then begin the installation.

17. The installer will launch any additional installation programs as needed (Hardlock drivers, etc.).

18. At the installer has completed, click Finish.

19. Remove the CD-ROM from your CD drive.

Upgrading from previous versions of ProAnalyst

Note: it is not necessary to uninstall previous versions of ProAnalyst.

1. To upgrade from a previous version, simply run the installer for the new version and follow the instructions.

2. The installer will then install the new application and all the appropriately modified files. During the installation process, which could take many minutes, a status box will appear.

Note: If the installer prompts you that it has detected a READ ONLY file, and asks you if you wish to overwrite this file, click Yes.

3. After the installer has completed, click Finish.

4. Remove the CD-ROM from your CD drive.

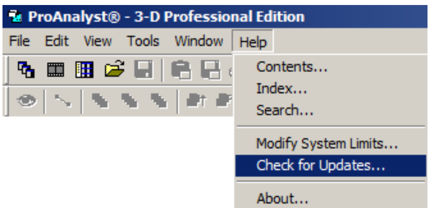
5. Restart your computer (optional).

Product Updates

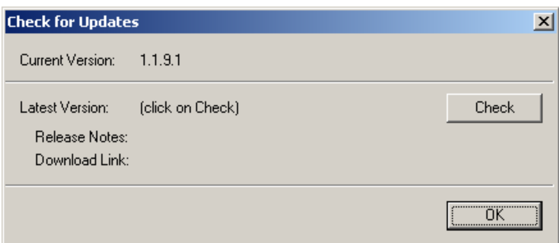
Checking for Updates

Minor updates to the product are routinely made available for download from our website. These updates introduce new features and provide bug fixes. Be sure to stay current with the latest release in order to take full advantage of the many features of this product.

In order to assist in keeping you up to date with new releases, we have provided a tool to check for new releases on our website. Select Check for Updates... from the Help menu.

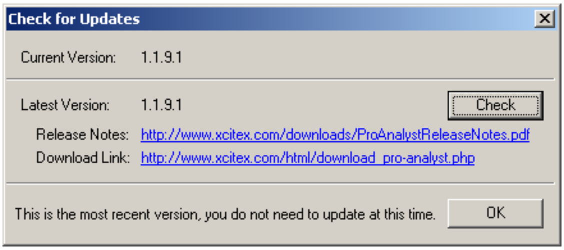


The Check for Updates dialog will appear.



Click on the Check button to contact our server and check for the latest version available for download. No communication is made with our server until the Check button is pressed. Information is only downloaded from our server, no personal information is sent to our server.

If version information is successfully obtained from our server, the dialog will display links to the release notes and the download page for the latest available version. You may review the release notes by clicking on the Release Notes link.



To download the latest version, click on the download link and follow the instructions on the web page that appears.

Chapter 2. Application Interface

Workspace View

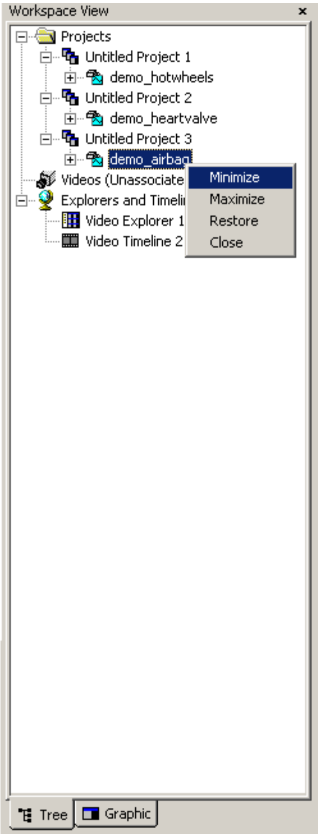
Overview

The Workspace View is a docked window, typically on the right side of the application window. It contains a listing of all the open projects, videos, explorers and timelines. There are two different possible styles for the Workspace View. These are the Tree View and the Graphic View. The Workspace View is primarily used as a source of information to see what files are currently open. You can also Minimize, Maximize, Restore, and Close windows using the Workspace View.

Tree View

The Tree View of the workspace allows you to view all open files via a standard tree layout. Click on the + and - at the root of each tree to expand and collapse each sub-tree. There are three top-level branches of the tree. These are Projects, Unassociated Videos, and Explorers and Timelines. Videos that are associated with projects will be listed under the Project tree. Videos that are not associated with any open projects are listed under the Video (Unassociated) tree.

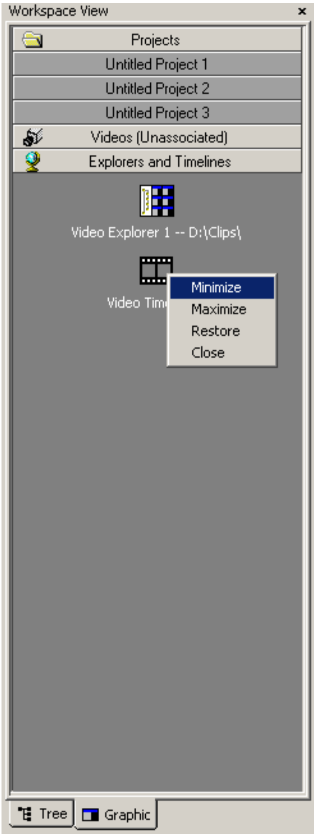
When expanded fully, the tree view displays video and data information for the selected video item.



To Minimize, Maximize, Restore, or Close any window, right-click using the mouse over any Project, Video, Explorer, or Timeline entry. Then select the desired action from the popup menu.

Graphic View

The Graphic View of the workspace allows you to view all open files via "pages". Each page can be expanded by clicking on each button. Similar to the Tree View, there are three main categories, Projects, Unassociated Videos, and Explorers and Timelines. The Projects button will show all open projects. For each project that is open, there will be a darker gray button listed under Projects. Clicking on these project buttons will show the videos that are associated with that particular project.



To Minimize, Maximize, Restore, or Close any window, right-click using the mouse over any Project, Video, Explorer, or Timeline icon in any page. Then select the desired action from the popup menu.

Drag and Drop Interaction

Dragging files from Windows Explorer onto the Workspace View or the main application window will automatically open the file if it is a recognized video or project file.

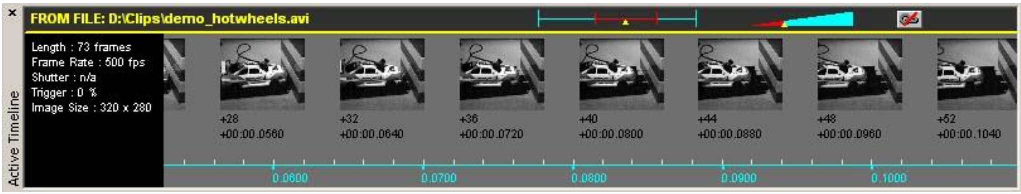
Undocking and Hiding the Workspace View

The Workspace View may be docked and undocked by double-clicking on the Workspace View title bar. Clicking on the x on the title bar will hide the Workspace View. You can show the Workspace View again by using the main View menu and selecting Workspace View.

Active Timeline

Overview

The Active Timeline displays frames from the currently active video window. If no video window is active, the timeline will appear blank. The active timeline provides a quick and easy view of the "context" of the video (frames before and after the current frame).



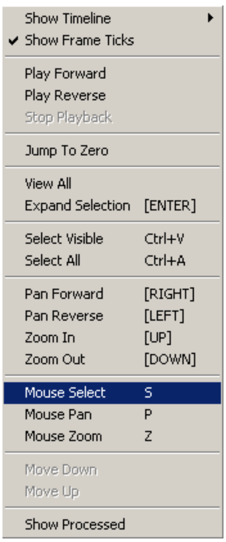
Quick Summary of Navigating a Timeline

For a complete summary of timeline interaction, see the section called “Video Timelines”.

The timeline may be panned and zoomed using the

controls. Click on the yellow triangles and drag them to the left or the right.

You can also change how the active timeline responds to mouse dragging motions by changing the mouse mode. You can change the mouse mode by right-clicking in the active timeline. A popup contextual menu will appear.



The three mouse modes are Select, Pan, and Zoom. In Select mode, mouse clicks will select frames for other operations, such as expanding. In Pan or Zoom mode, mouse dragging motions to the left and right will cause the timeline to pan and zoom accordingly.

Various visual aspects of the timeline can also be set using the contextual menu. The timeline underneath the frames may be shown or hidden. The frame tick markers may be shown or hidden. And the individual frames may be shown using the image processing settings, or shown in their raw normal format.

The timeline can also be played in forward or reverse. Playback is accomplished by smoothly panning the video to the left or the right automatically. This can also be achieved by linking the active timeline and then pressing play in the current active video window.

Linking the Active Timeline

Linking the active timeline refers to synchronizing the timeline with the current frame dis- played in the active video window. So as the video is played in the active video window, the timeline will also be centered on the same frame number. The active timeline in not linked by default since the process of redrawing the timeline will slow down the responsiveness of the program on slower computers.

Undocking and Hiding the Active Timeline

The Active Timeline may be docked and undocked by double-clicking on the Active Timeline title bar. Clicking on the x on the title bar will hide the Active Timeline. You can show the Active Timeline again by using the main View menu and selecting Active Timeline.

Toolbars

There are multiple toolbars in this application. Each of these toolbars can be undocked or hidden. To show a toolbar that has been previously hidden, just display the View menu and select the appropriate toolbar. If you wish to re-dock any visible toolbars to their original position, select Re-Dock Visible Toolbars from the View menu.

Main Toolbar

The buttons on the Main Toolbar perform the following functions.

New Project	Create a new Project window. See the section called “Projects” for more details.
New Video Timeline	Create a new Video Timeline window. See the section called “Video Timelines” for more details.
New Video Explorer	Create a new Video Explorer window. See the section called “Video Explorers” for more details.
Open	Open an existing project or video.
Save	Save the active document.

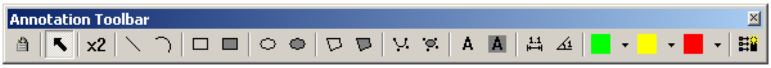
Copy Active Window to Clipboard	Copy the active window to the clipboard.
Save Active Window to File	Save the active window to a bitmap file.
Print Active Window	Print the active window.
Copy Application Window to Clipboard	Copy the entire application window to the clipboard.
Save Application Window to File	Save the entire application window to a bitmap file.
Print Application Window	Print the application window.
Generate HTML Report	Generate an HTML report for the active video.
Print Report	Generate a print report for the active video.
Print Report Preview	Preview a print report for the active video.
Generate PowerPoint Report	Generate a PowerPoint report for the active video.
About	Display information about this application.

Annotation Toolbars

The Annotation Toolbars are only active when the focus is on the video portion of a video window. The focus is set by clicking on the video image in any video window. There are two toolbars associated with annotations. One toolbar controls the drawing and default annotation settings. The second controls the visibility, ordering, and deletion of annotations. The functions on these two toolbars are also duplicated on the Annotations Control Panel, see Chapter 5, *Annotations*.

Annotation Toolbar

The buttons on the Annotation Toolbar perform the following functions.



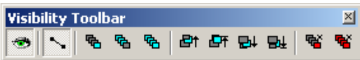
Lock Annotations	Lock annotations so that they cannot be modified.
Select Annotations	Mouse clicks will select and drag any existing annotations. This is the default mode. Select Lock Annotations to prevent any mouse interactions from modifying existing annotations. Select any of the other buttons to create new annotations.
Duplicate Annotation	Create a duplicate of the selected annotation. The duplicate copy is created slightly offset from the original.
Draw Line	Start drawing a line in the video window.

Draw Arc	Start drawing a three-point arc in the video window.
Draw Rectangle	Start drawing a rectangle in the video window.
Draw Filled Rectangle	Start drawing a filled rectangle in the video window.
Draw Ellipse	Start drawing an ellipse in the video window.
Draw Filled Ellipse	Start drawing a filled ellipse in the video window.
Draw Polygon	Start drawing a polygon in the video window. Each mouse click will add another point to the polygon. End the polygon by right-clicking on the last point. Points may be added and removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle.
Draw Filled Polygon	Start drawing a filled polygon in the video window. Each mouse click will add another point to the polygon. End the polygon by right-clicking on the last point. Points may be added or removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle.
Draw Spline	Start drawing a spline in the video window. Each mouse click will add another point to the spline. End the spline by right-clicking on the last point. Points may be added or removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle.
Draw Filled Spline	Start drawing a filled spline in the video window. Each mouse click will add another point to the spline. End the spline by right-clicking on the last point. Points may be ad- ded or removed from a polygon by using the **Insert** and **De- lete** keyboard keys when the mouse is over a drag handle.
Draw Text	Start drawing text in the video window at the location of the next mouse click.
Draw Filled Text	Start drawing text with a filled background at the location of the next mouse click.
Draw Length Dimension	Start drawing a static length dimension in the video window. The length dimension will be shown in the units that the video was calibrated in (see the section called “Multi-Plane Calibration”). If no calibration has been applied, the length dimension is shown in pixels.
Draw Angle Dimension	Start drawing an angle dimension in the video window. The angle is defined by the location of the next three mouse clicks in the video window. The angle measurement is shown in degrees and is the angle between the lines connecting the first and last point to the middle point.
Foreground Color	Sets the default foreground color for all new annotations.

	Click on the arrow to display a color selection popup win- dow.
Background Color	Sets the default background color for all new annotations. Click on the arrow to display a color selection popup win- dow.
Text Color	Sets the default text color for all new annotations. Click on the arrow to display a color selection popup window.
Default Settings	Displays a default settings dialog where the default colors, line styles, and font styles may be set for all new annotations. To modify the settings of an existing annotation, double-click on the annotation in the video window.

Visibility Toolbar

The buttons on the Visibility Toolbar perform the following functions.



Show or Hide Annotations	Shows or hides all annotations for the active video.
Show or Hide Drag Handles	Shows or hides the square drag handles used to modify annotations.
Show in Current Frame	Set the currently selected annotation to display only in the current frame.
Show in Current Frame Forward	Set the currently selected annotation to display in the current frame forward.
Show in All Frames	Set the currently selected annotation to display in all frames.
Bring Forward	Move the currently selected annotation forward in the display order..
Bring to Front	Move the currently selected annotation to the top of the display order.
Send Backward	Move the currently selected annotation backward in the display order.
Send to Back	Move the currently selected annotation to the back of the display order.
Delete Annotations in Current Frame	Delete all annotations for the current frame only. Does not delete annotations that are set to display in all

	frames.
Delete All Annotations	Delete all annotations for the active video.

Synchronized Play Controls Toolbar

The Synchronized Play Controls Toolbar controls how multiple videos will be played when they have been synchronized. The buttons on this toolbar perform the following functions.

Sync Play Time Aligned	Play synchronized videos so that they are aligned to the same time. This is useful when synchronizing videos that were recorded at different frame rates.
Sync Play Frame Aligned	Play synchronized videos so that they are aligned to the same frame number.
Sync Align to Zero Frame	Align all synchronized videos according to their zero frames.
Sync Align to Frame When Sync Pressed	Align all synchronized videos to the current frame when the synchronize checkbox was selected. This allows videos to be synchronized relative to arbitrary frames in each video. See the section called “Play Controls”.

Play All Toolbar

The Play All Toolbar can be used to automatically playback all currently opened videos sequentially. The order of playback is controlled by the window order. The last video window in the window list (shown in the Window main menu) is brought to the front and played. When the playback is finished, the next video window in the window list is brought to the front and played. To change the order of playback, click on the video windows in the reverse order that you wish the videos to be played and then click on Play All Videos Sequentially Looped.

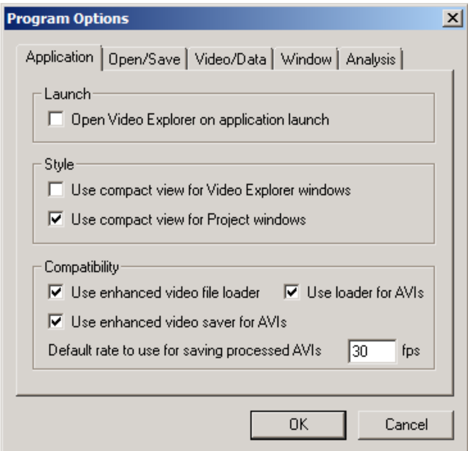
Play All Videos Sequentially Looped	Play all currently opened videos sequentially. When the end of the last video is reached, the playback begins again from the beginning of the first video.
Stop Sequential Looped Play	Stop looped playback of currently opened videos.

Program Options

Options for controlling the behavior of the application can be set by selecting Program Options from the main Edit menu. The program options are divided into four subcategories: Application, Open/Save, Video/Data, and Window. Any options that are set are saved in the Registry and restored whenever the application is run.

Application

The application options cover general application behavior options. The following items may be set or unset.



Open Video Explorer on application launch	This option will open a Video Explorer window automatically every time the application is run. Default is OFF.
Use compact view for Video Explorer windows	Uses the compact view style for all Video Explorer windows by default. See the section called “Video Explorers” for more details. Default is OFF.
Use compact view for Project windows	Uses the compact view style for all Project windows by default. See the section called “Projects” for more details. Default is ON.
Use enhanced video file loader	Check this box to use the latest version of the video file loader. This will enable you to open some other file formats other than AVI. Default is ON.
Use loader for AVI	Check this box to use the latest version of the video file loader for AVI files as well as other file formats. If this option is checked, the program will first attempt to open an AVI file using the standard AVI file loader. If this fails, then the new enhanced loader will be used to at- tempt to open the file. The new loader supports large AVI files (>1GB) and some of the newer AVI codecs.

Default is ON.

Use enhanced video saver for AVIs

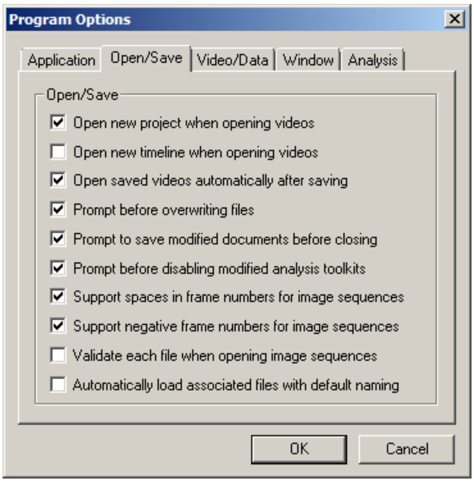
Check this box to use the latest version of the video file saver for AVI files. Checking this option enables support for saving large AVI files (>1GB) and enables the use of any associated newer AVI codecs that may be installed on your system. Note: codecs are independent programs. Certain codecs may be incompatible with ProAnalyst or exhibit unstable behavior. Uncheck this option to use the older saver if problems are encountered. Default is ON.

Default rate to use for saving processed AVIs

Specify the rate that is embedded into the AVI file when saving processed videos or when saving image sequences as AVI files. This rate is not used by this application. It is only provided to allow for saved videos to be able to be played within standard multimedia players (such as Windows Media Player) at normal playback rates. Default is 25 fps.

Open/Save

The open/save options cover all options related to opening and saving projects and videos. The following items may be set or unset.



Open new project when opening videos

Automatically open a new Project window when a video is opened if it is not already associated with an open project. Default is ON.

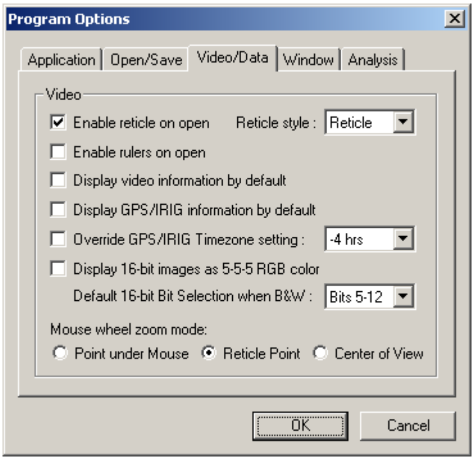
Open new timeline when opening video

Automatically open a new Timeline window when a video is opened. The new Timeline window will contain the newly opened video. Default is OFF.

Open saved videos automatically after saving	Often when saving a video file, you will want to operate on the result. This setting will automatically open all newly saved video files. Default is ON.
Prompt before overwriting files	Prompt before overwriting any existing files. Default is ON.
Prompt to save modified documents before closing	Prompt to save any documents that have been modified before the document is closed. Default is ON.
Prompt before disabling modified analysis toolkits	Prompt to save analysis toolkits that have been modified before the toolkit is disabled. Default is ON.
Support spaces in frame numbers for image sequences	Supports loading of image sequences that contain spaces in their filenames (e.g. image 1.bmp, image 2.bmp, ... , image 100.bmp). Default is ON.
Support negative frame numbers for image sequences	Supports loading of image sequences that contain hyphens to indicate negative frame numbers (e.g. image-002.bmp, image-001.bmp, image000.bmp, image001.bmp, image002.bmp, ...). If your image sequences are named in this fashion, if this you click on an image file with a hyphen without this option enabled, then the video will appear backwards and will only con- tain the negative frame numbers. If you click on a posit- ive numbered image file without this option enabled, then only the positive frames will appear in the video. Default is ON.
Validate each file when opening image sequences	Supports validation of image files when opening image sequences. Skipping the validation speeds up opening sequences with a large number of image files. Default is OFF.
Automatically load associated files with default naming	When a video file is opened, this setting will automatically open any associated files that are located in the same directory as the video. Only associated files that are named using the default naming scheme will be loaded. The default naming scheme expects filenames composed of the prefix of the video filename and the extension of the various toolkits (e.g. if the video is named `car.avi`, the default named feature tracking file should be named `car.ftk`). Default is ON for the Viewer, OFF for other versions.

Video/Data

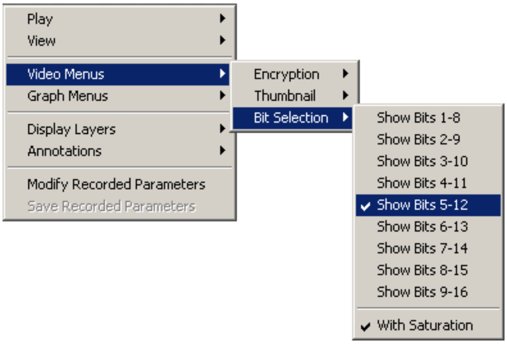
The video/data options control the initial appearance of the video and data in the Measurement windows (the section called “Measurement Window”).



Enable reticle on open	Automatically enables the reticle on all new video windows. Default is OFF.
Reticle style	Select the reticle style. Options are Reticle, Cross, or Both. Reticle draws thin vertical and horizontal lines across the entire video image at the location of the currently selected point. Cross draws small 'L' shaped objects around the currently selected point. Both draws both a reticle and cross around the currently selected point. Default is Reticle.
Enable rulers on open	Automatically enables the rulers on all new video windows. Default is OFF.
Display video information by default	Automatically displays video information drawn over the video image in all new video windows. Default is OFF.
Display GPS/IRIG information by default	Automatically displays all GPS/IRIG information over the video image in all new video windows. Default is OFF.
Override GPS/IRIG Timezone Setting	Specify the desired Timezone to be used when displaying GPS/IRIG time information. This will override any Timezone value read from the video file. Check the checkbox and select the desired offset in the drop down box on the right. Default is OFF.
Display 16-bit images as 5-5-5 RGB color	Images that contain 16-bits per pixel can be treated as grayscale or color. Select this option to display 16-bit images as 5-bits per channel RGB color images. If these are displayed as grayscale, only 8-bits can be displayed at a time. Which 8-bits to display can be selected using the context-menu (right-click) in the Measurement window, under the Video Menus, Bit Selection sub-menu. Default is OFF.

Default 16-bit Bit Selection when B&W

This sets the default bits to display when loading a 16-bit image as black and white. Which bits are displayed can be changed after the video has been opened by using the context-menu in the video window as shown below. Default is Bits 5-12.

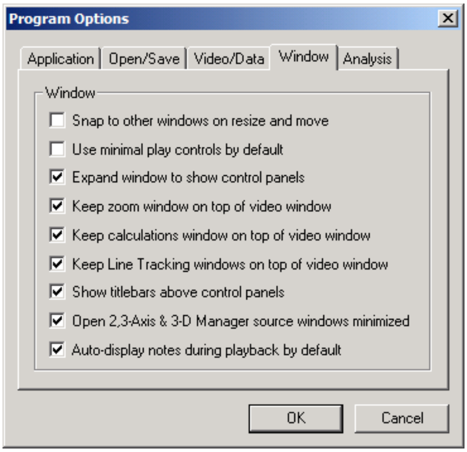


Mouse wheel zoom mode

There are three different modes for zoom control when using the mouse wheel in a video window. Point under Mouse: This mode will zoom in or out while trying to maintain the location of the point that is currently located underneath the mouse pointer. Reticle Point: This mode will center the image on the reticle and zoom in and out so that the current reticle point remains in the center of the view. Center of View: This mode will zoom in and out so that whatever is in the center of the view remains in the center. Default is Point under Mouse.

Window

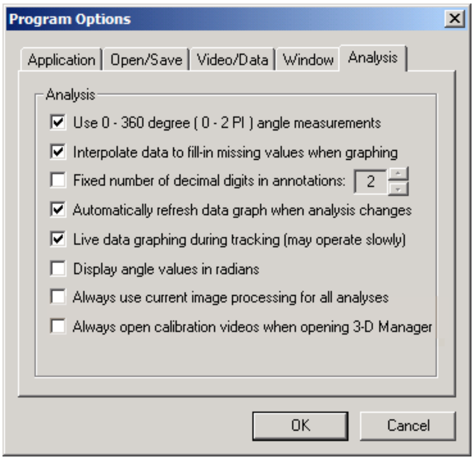
The window options control the behavior and appearance of various windows in the applica- tion.



Snap to other windows on resize and move	Automatically snaps to other window edges when a window is dragged or resized. This is convenient for lining up windows in an orderly fashion. If window dragging and resizing appears jittery, disable this option. Default is OFF.
Use minimal play controls by default	Uses minimal play controls for all new Measurement windows. See the section called “Play Controls” for more details. Default is OFF.
Expand window to show control panels	Enlarges the Measurement window outward when showing control panels. If this is not set, the Measurement window will remain the same size, and the internal video and data display sections will shrink in size to accommodate the display of the control panels. Default is ON.
Keep zoom window on top of video window	Forces the zoom window to always remain on top of the associated video window. Default is OFF.
Keep calculations window on top of video window	Forces the calculations window to always remain on top of the associated video window. Default is OFF.
Keep Line Tracking windows on top of video window	Forces the additional Line Tracking windows to always remain on top of the associated video window. Default is ON.
Show titlebars above control panels	Show titlebars above each control panel showing the name of the panel. Disable this feature if you are on a low resolution monitor where the control panel is too large to fit in the display. Default is ON.
Open 2,3-Axis & 3-D Manager source windows minimized	When a 2-Axis or 3-Axis graph or 3-D Manager file is opened, the program will attempt to open all necessary source document windows. If this option is set, the program will automatically minimize any opened source document windows. Default is ON.
Auto-display notes during playback by default	During playback, the video will pause and display any video or data note associated with the currently displayed frame. The note can remain displayed for a fixed amount of time or wait until the user clicks on the note before continuing with video playback. The display time for each note can be set from the Notes context menu in any video measurement window. See the section called “Auto-Display of Notes During Playback” for more de- tails. Default is ON.

Analysis

The window options control the behavior and appearance of various windows in the application.



Use 0 - 360 degree angle measurements

Sets the range of the angle annotations and measurements to be 0 - 360 degrees. If this option is not checked, the angle measurements will be displayed using the default -180 to +180 degree range. Default is ON.

Interpolate data to fill-in missing values when graphing

This option controls how missing values are handled when graphing analysis data. Check this option in order to automatically interpolate missing data values so that the graph remains smooth. If this option is unchecked, missing analysis values will be graphed as zero values. Default is ON.

Fixed number of decimal digits in annotations

Measurement annotations and feature lines that display lengths or angles are typically shown with two or four decimal digits. Check this option to specify a fixed number of decimal digits to use for all measurement annotations and feature lines. Default is OFF.

Automatically refresh data graph when analysis changes

Enable this option to have the data graph automatically refresh whenever analysis data changes. For long videos, this option is not recommended, since the process of updating the graph may take a significant amount of time depending on your processor speed. You may wish to perform multiple analysis changes, and then explicitly update the graph by clicking on the Refresh Graph button (the section called “Measurement Window”) when you want the graph to update. Default is OFF.

Live data graphing during tracking (may operate slowly)

Enable this option to have the data graph refresh continuously during tracking. If this option is enabled, after features are tracked in each frame, the graph is updated. This will produce a "real-time" graph of the data as it is being generated. For long videos, this option is not recommended, since the process of updating the graph may take a significant amount of time depending on your pro-

	cessor speed. Default is OFF.
Display angle values in radians	Enable this option to have all angle values displayed in units of radians instead of degrees. Default is OFF.
Always use current image processing for all analyses	Enable this option to have all Feature Tracking features and Line Tracking features use the current Image Processing settings for analysis. Normally, each feature and line can retain its own set of Image Processing features so that different settings can be used for different fea- tures. However, this may be confusing to some users. To simplify analysis, check this option to ensure that the Image Processing settings that are currently shown are the settings used for tracking all features and lines. Default is OFF.
Always open calibration videos when opening 3-D Manager	Enable this option to always open the associated calibration video files when opening a 3-D Manager file. Once a calibration has been performed, the calibration information is already stored in the 3-D Manager document. It is not necessary to open the calibration video files each time the 3-D Manager document is opened. To conserve system resources, the calibration videos should not be opened by default. Default is OFF.

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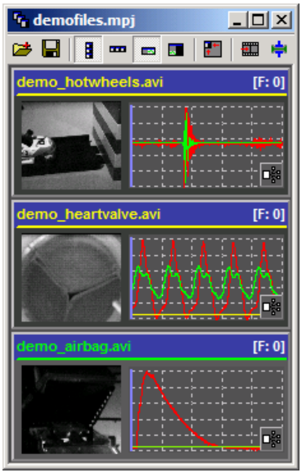
Chapter 3. Application Windows

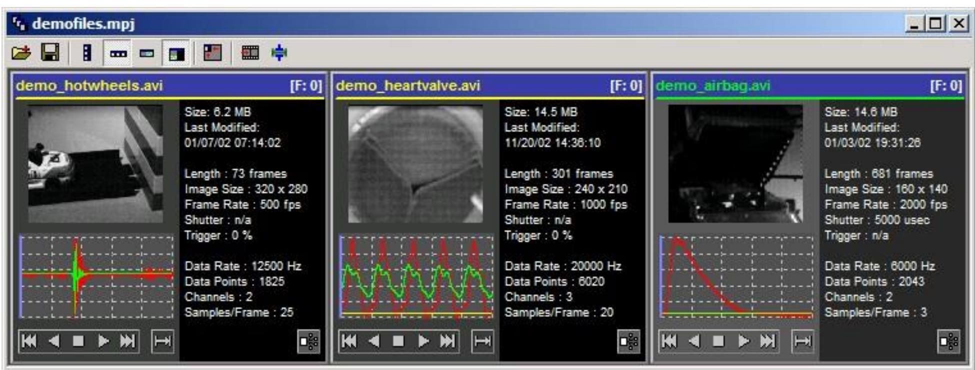
Projects

Projects are an easy way to manage multiple measurements (video and data) and the additional calibration, analysis, and processing files that are associated with each one. They also provide an interactive thumbnail view of the video and data files for easy viewing.

Compact and Normal View

Project Windows can be displayed in one of two formats, Compact or Normal. The Compact view shows only the video image and the data graph. The Normal View shows information about the video and data files and provide play controls for navigation in each video. Play con- trols are also accessible in the Compact view by right-clicking on each video.





To switch between the Compact and Normal views, click on the appropriate buttons on the toolbar.

The default viewing mode for all newly opened project windows can be set in the Program Options, see the section called “Program Options”.

In addition to the viewing mode, the drawing orientation can be switched between horizontal and vertical. To switch between the two orientations, click on the appropriate buttons on the toolbar or use the context menu by right-clicking anywhere in the Project window.

Adding and Removing Videos

There are multiple ways to add a video to a project:

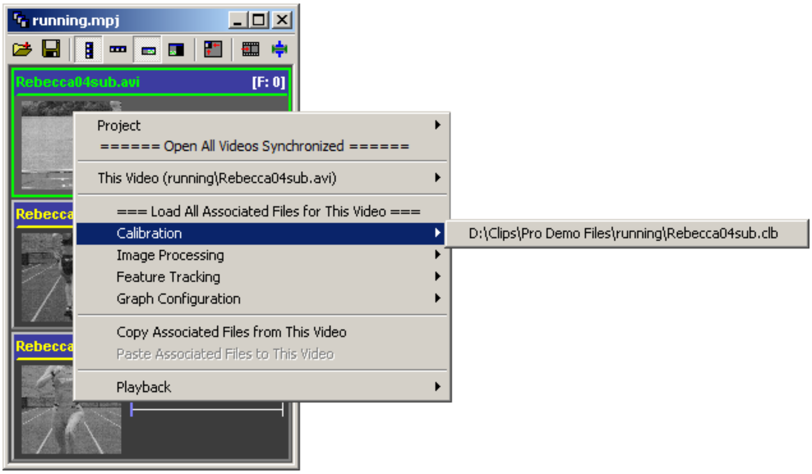
- Drag a video file from an Explorer window and drop it on the Project window.
- Drag from a non-control area of an open video window and drop it on the Project window.
- Click on the first button in the toolbar and select Add File(s)... or Add Open File(s).
- Right-click in the Project window to access the context menu, under Project, select Add File(s)... or Add Open File(s).

To remove a video from a project:

- Right-click in the Project window on the measurement to be removed. Under Project, select Remove Selected File.

Adding and Removing Associated Files

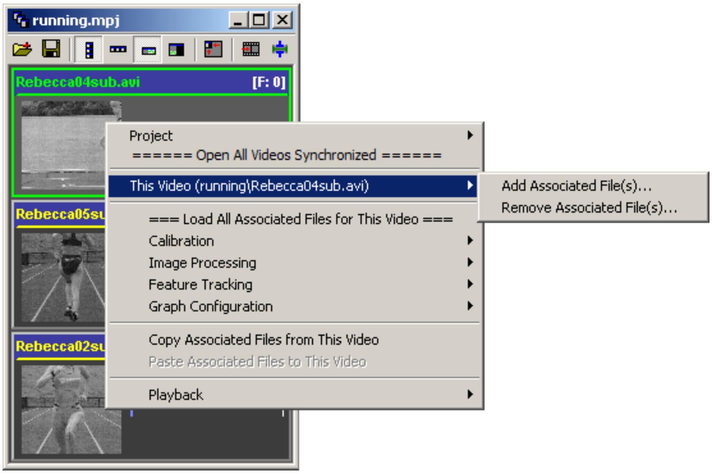
Associated files are any files that are associated with the video or the data contained in a project. These files are generated by one of the many possible analysis or processing tools in this application (image processing settings, calibration files, line track results, data filtering set- tings, ...).



A listing of the associated files is shown in the context menu. Right-click in the Project window on the video of interest to see the list of associated files.

There are two ways to add associated files to a measurement in a project:

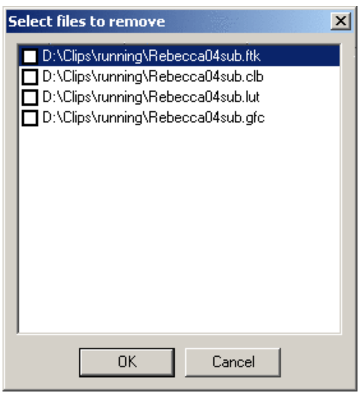
- Right-click in the Project window on the measurement of interest. Expand the submenu under the event filename, and select Add Associated File(s)....



- If a Measurement Window (the section called "Measurement Window") is already open for a given measurement, and an associated file is saved using any of the control panels in the Measurement Window, then the associated file will automatically be added to any project that contains that measurement.

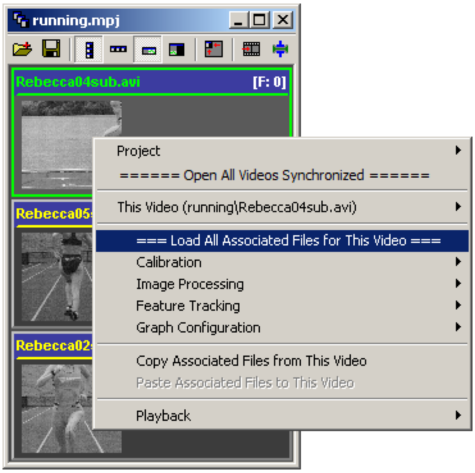
To remove an associated file for a measurement in a project:

- Right-click in the Project window on the measurement of interest. Expand the submenu under the event filename, and select Remove Associated File(s).... Select which associated files to remove from the window that appears, and click on OK.

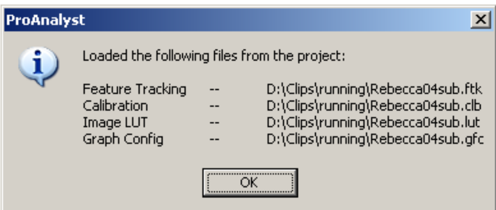


Load All Associated Files

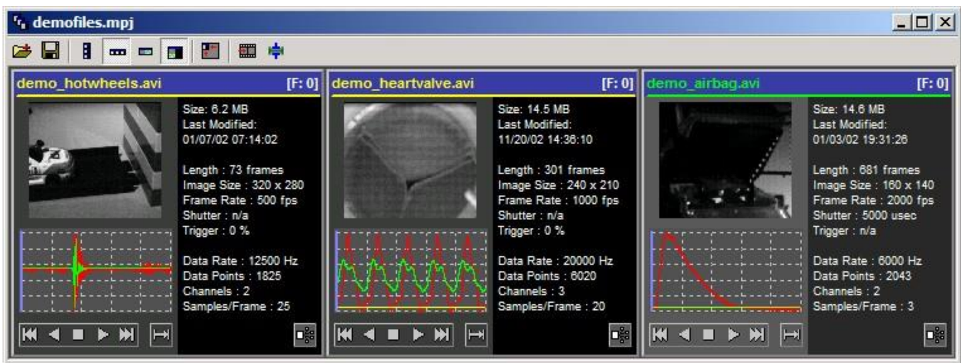
All associated files for a given video can be loaded by using the Load All Associated Files for This Video option in the context menu.



The first file in each category will be automatically loaded. If there are more than one associated file in each category, then only the first file is loaded. Once completed, a summary of the files that have been loaded will be displayed.

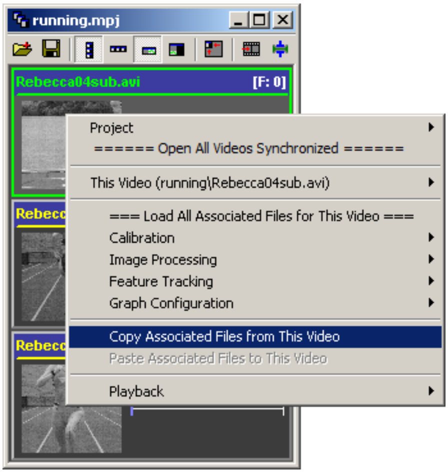


In the lower right corner of each video in the project, there is a shortcut button to load all associated files.

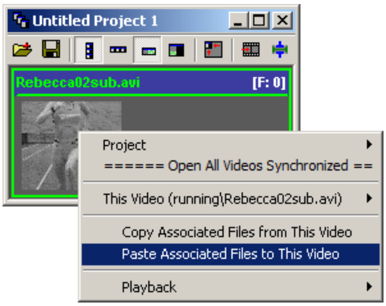


Copying and Pasting Associated Files

Often times, you will want to replicate the same set of analyses operations (calibration, tracking, graphing, etc.) on another video. To support easy replication of analysis files, Copy and Paste functions are available in the Project Window. Right-click on the video from which you wish to copy all associated files and select Copy Associated Files from This Video in the con- text menu.



The list of associated files are now stored in the copy buffer of the program. These files may be pasted onto any video in any Project Window. The target video need not be in the same Project Window as the source. Right-click on the desired video that you wish to paste the associated files onto and select Paste Associated Files to This Video in the context menu.



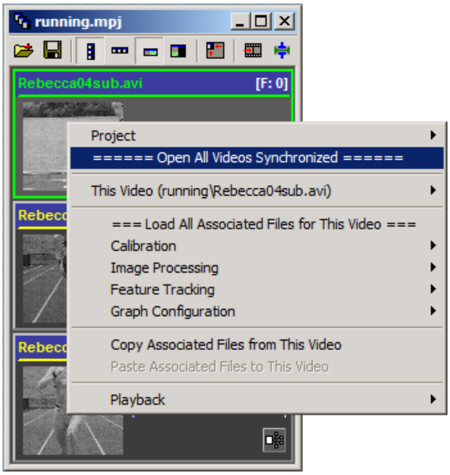
The Paste operation will produce a duplicate set of analysis files in the same directory as the target video. The associated files will be automatically renamed to match the target video. For instance, if the source video is named `runner.avi` and the target video is named `skater.avi`, an associated file named `runner.clb` would be copied to a new file named `skater.clb`.

Creating a Video Timeline Window

A Timeline Window (the section called “Video Timelines”) can be automatically generated that contains all the measurements in a project. To generate a Timeline Window, click on the Create Timeline button on the toolbar of the Project window.

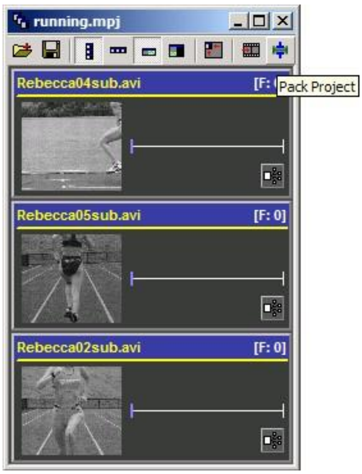
Open All Videos Synchronized

All videos contained in a project can be opened and synchronized (the section called “Play Controls”) automatically by using the Open All Videos Synchronized option in the context-menu. Right-click on any video in the project and select Open All Videos Synchronized.

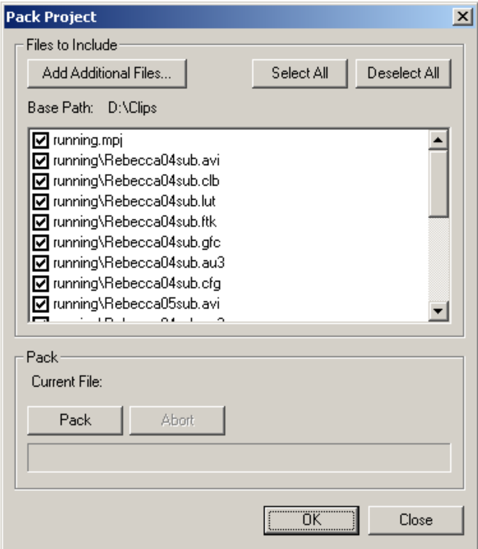


Packing Projects

A packing and unpacking mechanism is provided to simplify distribution and archiving of analysis results. After you have completed your analysis of an event and have compiled all of the videos and associated files into a project, this project can be automatically packed into a single file. Click on the Pack Project button on the toolbar or use the main File menu.



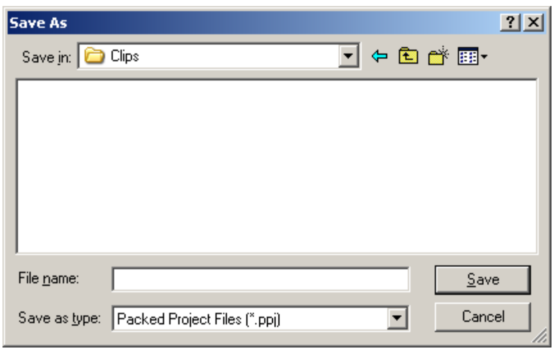
The Pack Project dialog will appear with the complete contents of the project listed. Some additional files that are automatically loaded with each video, but not normally listed as an associated file in the project, are also included. These include external data files, configuration files, binary files with notes and comments, and annotation files.



Additional files that were generated by external programs (such as Microsoft Word or Excel documents) can also be included in your packed file by clicking on the Add Additional Files button.

If the resulting packed file is too large, you may want to consider not including the video files in the packed file and distributing these separately. To not include a file in the packing process, simply uncheck the box next to the filename.

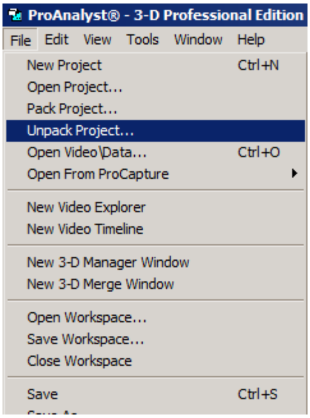
Once you are satisfied with the list of files to pack, click on the Pack button and select the packed file name in the dialog that appears.



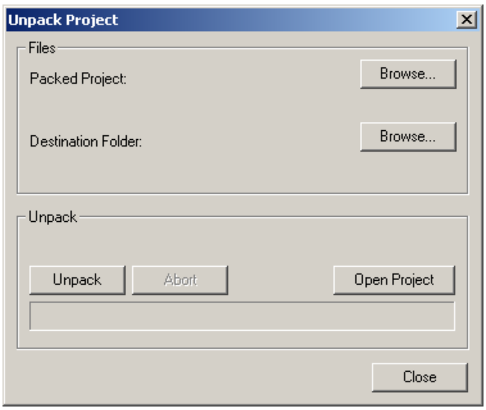
The single packed file now includes all the files that were checked.

Unpacking Projects

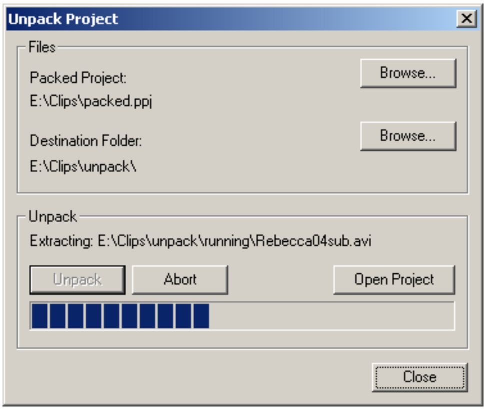
If you have used the packing mechanism to create a packed project file, you can unpack the files using the Unpack Project command from the File menu.



The Unpack Project dialog will appear. You must select the packed project file and the destination folder. Click on the Browse button next to each item.



After you have selected the packed file and destination, click on the Unpack button to extract the files.



If the files were successfully extracted, and the packed project contained a valid project file, then you can click on the Open Project button to open the project that was just unpacked.

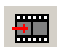
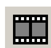
Video Timelines

Overview

The Video Timeline View is a specially designed view that allows a user to see an overview of a complete event in a filmstrip format. This view enables a user to zoom in on specific mo- ments in time while still maintaining a view of the context before and after the moment of in- terest. In addition, the strip view allows a user to view multiple events that may have been re- corded at different frame rates to be displayed aligned to one another. As one event is zoomed and panned, the other events will also zoom and pan simultaneously, maintaining perfect align- ment with one another.

The Video Timeline View can only display videos that are currently open. If a video is added to a timeline, but is not yet opened in a Measurement (the section called "Measurement Window") window, a new video window will be created first, and then the video will be added to the timeline.

Creating New Video Timelines

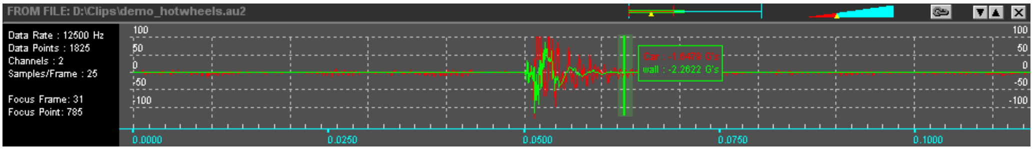
New timelines are often created by clicking on the  toolbar button of a Project (the section called "Projects") or Measurement (the section called "Measurement Window") window. This will create a new timeline which contains all the videos in the project or just the one video from the video window. New empty timelines can also be created by clicking on the  icon in the main toolbar or by using the main Tools menu, and selecting New Video Timeline.

Layout

The Timeline View is comprised of a toolbar across the top that controls the timeline settings, and a main region that contains the strips. Each strip is comprised of three regions: a title bar, an information section, and a drawing area.

There are two possible types of strips that can be drawn: a video strip and a data strip. The video strip shows individual frames from the video and the data strip plots data or analysis.

The video strip draws as many frames as possible along a horizontal timeline without overlapping any of the frames. The exact time corresponding to a drawn frame is the value on the timeline corresponding to the left edge of the frame. (This can be visualized like a flag pole planted in the timeline at the left edge of the drawn frame, and the frame is the flag extending to the right of the pole). Additional information is drawn beneath each frame, such as the frame number, time, and a bar indicating the exposure duration.



The data strip draws any associated data or analysis corresponding to a given video. The data strip is always permanently aligned to the corresponding video strip. If the video strip is panned or zoomed, the data strip will pan and zoom simultaneously, and vice versa.

Definitions

Alignment Mode	The alignment mode controls how linked strips are drawn relative to one another. Linked strips can be aligned so that frames correspond to one another in time (Time Alignment) or frame number (Frame Alignment).
Linking	One of the powerful features of the Timeline View is the ability to draw multiple events recorded at different frame rates in a time or frame synchronized fashion. When one event is panned or zoomed, all linked events are simultaneously panned or zoomed by the same amount. Linking is enabled by clicking on the chain link icon in the title bar of each strip.
Selection	These are the frames highlighted in green. The selection is used primarily for zooming in on a set of frames of interest. Most often, a user will select a set of frames by clicking and dragging the mouse over the frames and then hit **Enter** to expand and center these frames.
Frame ticks	These marks show the number and location of actual image frames relative to the visible timeline. These marks are equally spaced along the timeline.

Timeline — The line drawn across the bottom of each strip that shows either the corresponding time value or frame value across the strip. The timeline must be displayed in order to see the frame ticks and some of the comment markers.

Comment markers — Indicate where user comments have been added to the event. If the mouse is held in place above one of these green markers, a small win- dow will appear that displays the associated comment.

Data markers — Circles at locations in the graph where there are data points. This helps to visualize exactly where data points were acquired relative to the shown video.

Settings

The following settings control how the strips are drawn and manipulated. These settings can be changed via the toolbar across the top of the window.

The controls in the toolbar are divided into sections. The first toolbar item adds new videos to the timeline. The next two buttons control the Alignment Mode. The next three buttons control the Mouse Mode. The next five buttons control what items are displayed in the timelines. The final button links all videos in the timeline. Additional details regarding the various modes and displayed items are discussed below.

Alignment Mode

There are two possible alignment modes that control how linked videos are drawn relative to one another. These modes are: Time Alignment Mode and Frame Alignment Mode.

In time alignment mode, the videos are aligned such that a vertical line on the screen will intersect each linked strip at the exact same time value. For example, if you have one video that was recorded at 1000 fps and a second video recorded at 2000 fps, when they are linked, they will display such that the frames from the 2000 fps video that are aligned vertically with a frame from the 1000 fps video should have a frame number that is twice that of the 1000 fps frame number.

In frame alignment mode, the videos are aligned such that a vertical line on the screen will intersect each linked strip at the exact same frame number. Record rates are not used when videos are aligned in this mode. Only the frame number is used for alignment.

Mouse Mode

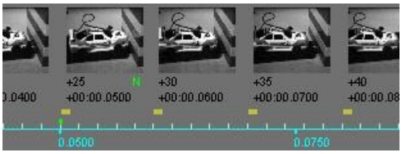
There are three possible mouse modes that control how clicking and dragging the mouse interacts with the drawn strips. These modes are: Selection, Pan, and Zoom.

Selection mode will allow you to highlight specific frames, set the focus point in the graph, and manipulate range bounds. This is the most general mode, and users will most likely remain in this mode. Panning and zooming can be accomplished in this mode either by using the pan and zoom controls in the title bar or by using keyboard or context menu controls.

For finer control of panning and zooming, the pan and zoom mouse modes are provided. When either of these modes are selected, clicking and dragging the mouse horizontally will increase or decrease the current pan or zoom setting.

Displayed Items

Many of the displayed items in the strips can be shown or hidden via the buttons in the toolbar. When objects are shown or hidden, the contents of the strip will resize to fill the available space. The configurable displayed items are: Time Line, Frame Ticks, Comment Markers, Data Markers, and Data Gridlines.



The timeline draws a line across the bottom of each strip that shows either the corresponding time value or frame value across the strip. The timeline must be displayed in order to see the frame ticks and some of the comment markers.

Frame ticks are drawn directly above the time line and indicate the presence of a video frame at that location. Depending on the current zoom level, not all video frames will be drawn. A single displayed frame may overlap many hidden frames. The Frame Ticks provide a means for knowing where and how many hidden frames are present.

Comment markers indicate where user comments have been added to the event. If the mouse is held in place above one of these green markers, a small window will appear that displays the associated comment.

Data markers will draw circles at locations in the graph where there are data points. This helps to visualize exactly where data points were acquired. Note however that the display of many data markers will result in slower interactivity due to the additional drawing requirements.

Data gridlines are the horizontal and vertical lines drawn behind the graph and the vertical scale values drawn on the left and right of the strip. The vertical lines correspond to the point where the corresponding video frame is drawn.

Title Bar Controls

The title bar contains the source of the displayed strip and a set of controls on the right side. These controls are: Pan, Zoom, Link, Move Down, Move Up, and Close.

The pan and zoom controls operate very similar to typical scrollbars. If you click and drag the red bar in the pan control, the strip will pan. If you click and drag the right edge of the red tri-angle in the zoom control, the strip will zoom. If you click outside of the red bar in the pan control or away from the right edge of the triangle in the zoom control, the pan or zoom setting will jump a fixed amount. These controls can be used in any mouse mode.

The link button indicates whether or not the strip is linked with other strips. Linking either a video or data strip for a given event will automatically link both. When linking, the strip pan and zoom settings may change in order to be in alignment with any other linked strips.

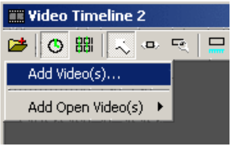
Move up and move down allow you to reorder the drawn strips. The order does not have any other effect upon the strip view other than to change the ordering of the strips.

The close button will close the strip. Closing a data strip for an event will not close the corresponding video strip, however, closing a video strip will automatically close any corresponding data strip.

Adding and Removing Strips

Strips may be added to a Timeline View in multiple ways:

- Click on the Add Video button on the toolbar and select Add Video or Add Open Video(s) from the popup menu.

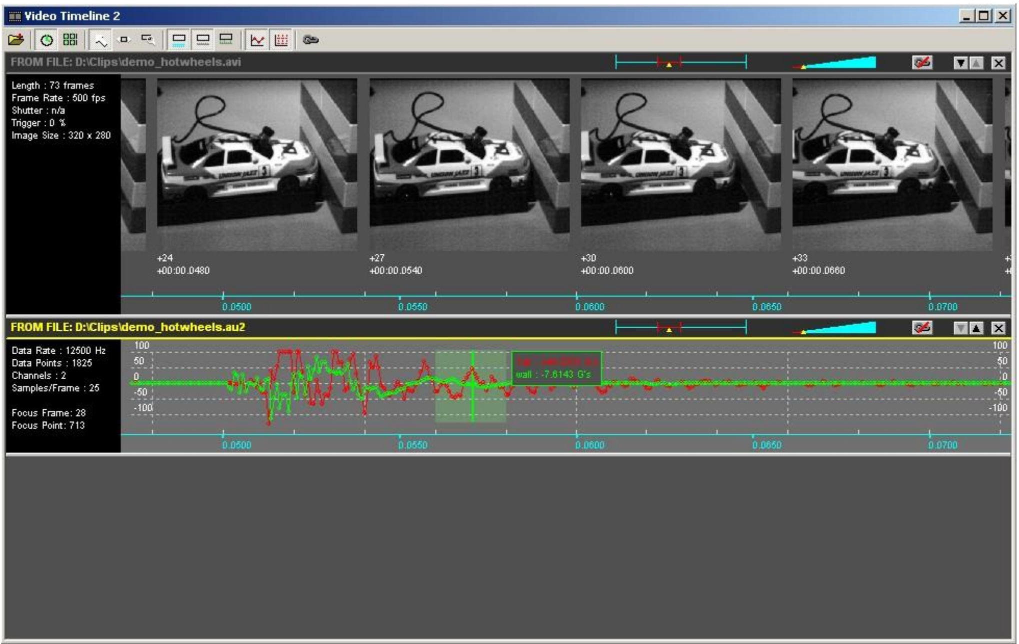


- Right-click in the Timeline View to access the context menu. It is nearly identical to the toolbar popup menu. Select Add Video or Add Open Video(s).
- Drag-and-drop from a Measurement window (the section called “Measurement Window”), Project window (the section called “Projects”), Video Explorer (the section called “Video Explorers”), or any Windows Explorer window onto the Timeline View. If the video is not yet opened in a Measurement window, a new Measurement window will be created first.

Strips may be removed by clicking on the close button in the upper right corner of each strip or via the context menu. Strips will also automatically close if the Measurement window they are associated with is closed.

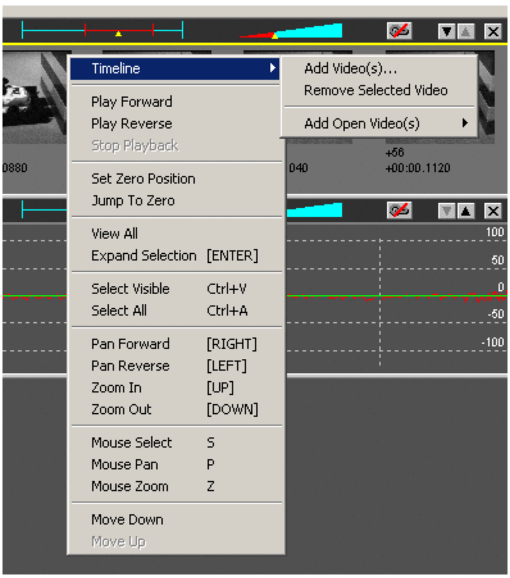
Resizing Strips

Each strip may be resized vertically by using the drag bars in between strips. There is a maximum and minimum height for each strip. As the strip is resized, the contents will be redrawn to fill the entire height. This allows the strip to show more or less frames at a time.



Navigating in a Strip

There are multiple ways to navigate around a strip. A strip may be panned or zoomed using the controls in the title bar of each strip, via context menu, using keyboard shortcuts, or by using the pan or zoom mouse mode and clicking and dragging in the strip.



A quick way to zoom in on a set of frames of interest would be to select a set of frames by clicking and dragging the mouse over these frames (in selection mouse mode), and then click **Enter**. This will center and zoom in on the current selection (shown in green).

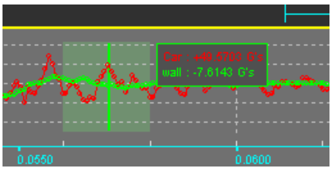
Playing Strips

Strips may be played in forward or reverse by using the commands in the context menu, as shown in the previous section. If strips are linked, they will all play simultaneously. If strips are not linked, only one strip may be played at a time. Whichever strip is selected (title bar text drawn in yellow) when the context menu is opened is the strip that will be played.

Data Strip Interaction

Data strips are automatically and permanently linked to the corresponding video. If the data strip is panned or zoomed, the corresponding video strip will also be similarly panned or zoomed. If the video or data strip is played, both will play.

When in selection mouse mode, clicking on a data strip will have a different effect than clicking on a video strip. Clicking on the data strip will not set the selection, but rather will set a location for a focus point and focus frame.

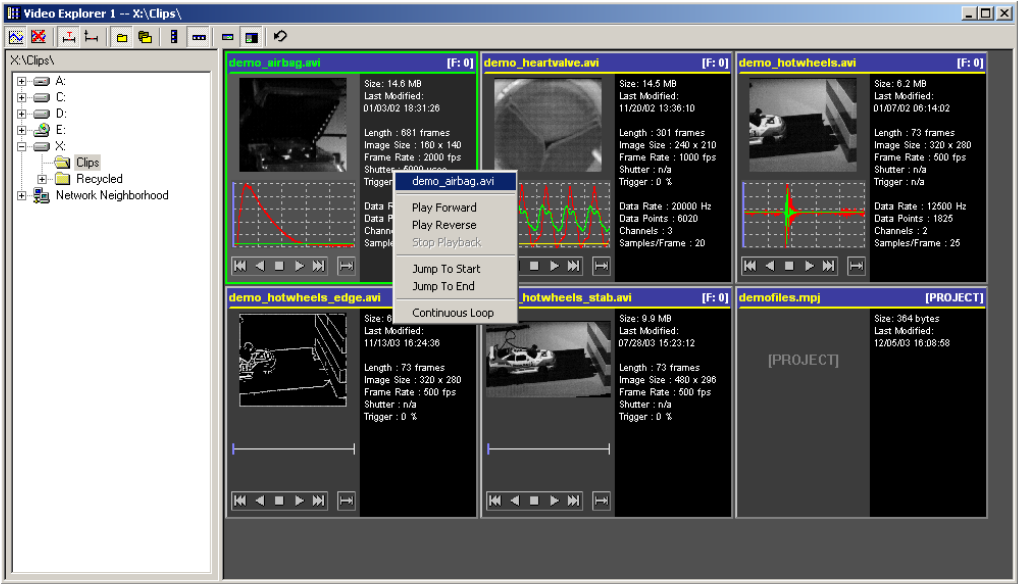


The focus frame will be shown in a blended green color and the focus point by a solid green vertical line. If enabled, a legend will be drawn that displays the labels and values for each value plotted. As the strip is panned, the focus point remains at the same fixed point on the screen and will display the values of the points underneath it.

Video Explorers

Overview

The Video Explorer window provides a very convenient mode of reviewing all your work before opening it. The Video Explorer presents a complete Windows Explorer panel along the left side of the screen and a thumbnail mosaic of the video acquisitions in the main desktop window. The Video Explorer displays all the recognized video files within the currently selected folder or in each sub-folder.



Settings

There are a number of settings that affect how the Video Explorer will appear and search for video files. These are set using the toolbar.

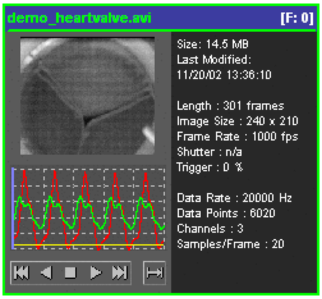
Show Data	Load and display data if it is present.
Don't Show Data	Don't load and display data. This will make loading faster since the data will not have to be loaded for each video.
Show Trigger Frame	Show the trigger frame by default for each video. Each video can be played so that it displays a different frame, this setting selects which frame is shown by default for each video found.
Show First Frame	Show the first frame by default for each video. Each video can be played so that it displays a different frame, this setting selects which frame is shown by default for each video found.
Show Videos in Current Directory	Shows videos in the currently selected directory in the Explorer pane. This is useful if multiple videos are stored in each directory.
Show Videos in Subdirectories	Shows videos in subdirectories of the currently selected directory in the Explorer page. This is useful if each

	video is stored in its own directory.
Align Vertical	Align videos vertically so that the right pane scrolls horizontally to show more videos.
Align Horizontal	Align videos horizontally so that the right pane scrolls vertically to show more videos.
Compact View	Show videos in a compact view. The compact view displays only the video image and the data graph.
Normal View	Show videos in a normal view. The normal view displays the video, data, play controls, and information panel.
Refresh	Refresh the directory listing and display of videos found.

The default viewing mode (Compact or Normal) for all newly opened Video Explorer windows can be set in the Program Options, see the section called “Program Options”.

Information Displayed

Multiple items are displayed for each video tile when the Video Explorer is set to display in a Normal View. In a Compact View, only the video and data thumbnails are visible.

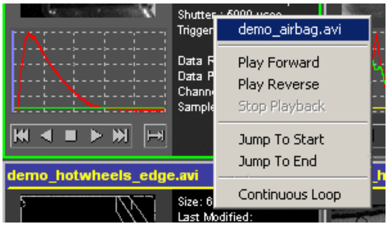


Filename	The filename of the video is displayed in the title bar.
Current Frame Number	The current frame number being shown is displayed in the upper right corner.
Video Thumbnail	A thumbnail image of the video is shown on the left panel.
Data Thumbnail or Timeline	If data is present, a thumbnail drawing of the data is shown beneath the video. If data is not present, a timeline is drawn. The data thumbnail or timeline may be clicked on to display a different video frame.
Play Controls	Standard play controls are provided for playing the video. These include: rewind, play reverse, stop, play

	forward, jump to end, and a button for setting continuous playback.
File Size and Modification Time	The file size and modification time are shown on the right panel.
Video Information	Information about the video length, size, and record information is shown in the right panel.
Data Information	If data is present, information about the data record information is shown in the right panel.

Viewing and Playing Video and Data

Each video can be played by using the play controls underneath the data graph area or by using the context (right click) menu.



You can also jump to any frame in the video by clicking in the data graph area.

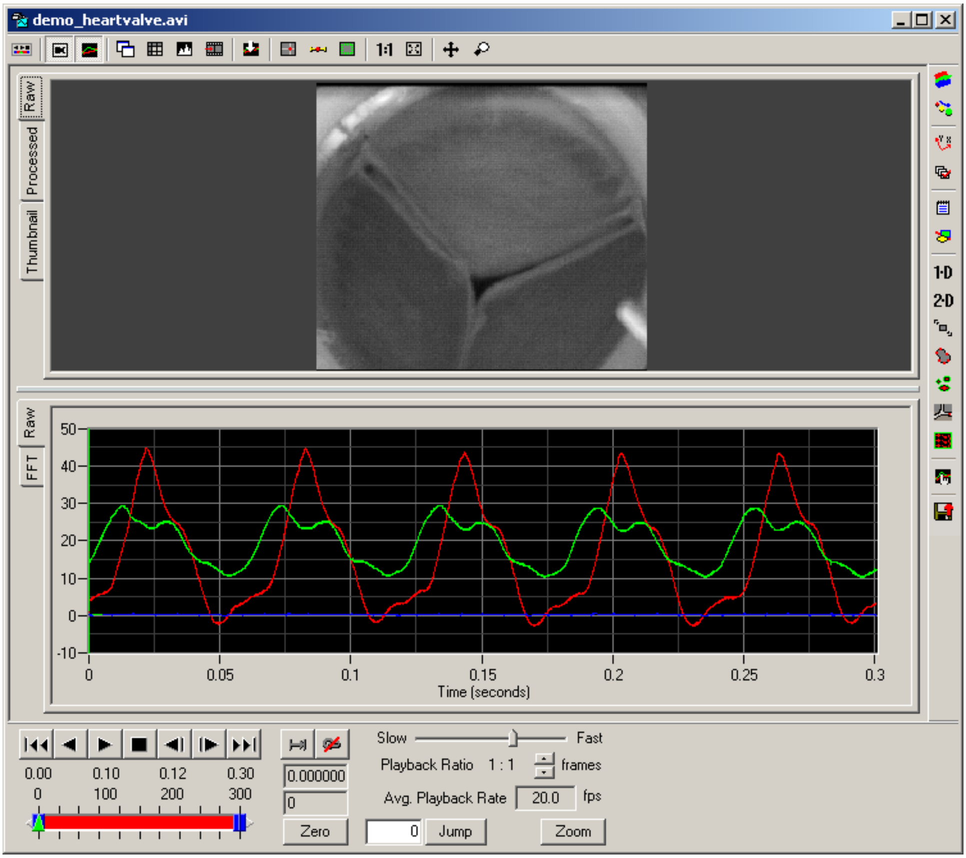
Opening Video Files

There are multiple ways to open a video file from the Video Explorer window:

- Select the video(s) you wish to open. They will be highlighted in green. Click **Enter** and the video(s) will open.
- Double-click within the video image that you wish to open and a video window will open.
- Drag and drop the video image that you wish to open onto the Workspace View (the section called "Workspace View") or any Project (the section called "Projects") or Timeline (the section called "Video Timelines") View.

Measurement Window

The Measurement window displays video and data for a single event (video and data). This window is the primary window where most analysis and viewing of the video and data will occur. There are five major components to the Measurement window: Main Toolbar, Control Panels, Video, Data, and Play Controls.



Main Toolbar

The Main Toolbar is located at the top of the Measurement window. It controls the appearance of the controls, video, and data and allows for the creation of other windows.

Toggle Play Controls	There are two styles of Play Controls that are located at the bottom of the window, normal and compact. This button cycles through these two styles or hides the controls altogether. The default style for the play controls can be set in the Program Options (see the section called “Program Options”).
Show Video	Shows or hides the video portion of the window.
Show Graph	Shows or hides the data graph portion of the window.
New Window	Creates a new duplicate window for this event. This allows you to have two windows, one showing only video

	and another showing only data. Or you can have multiple windows looking at different frames in the video.
Show Calculations	Show a calculations window for displaying analysis calculations. See the section called “Calculations Window” for more details.
Show Histogram	Show a histogram window for displaying a grayscale histogram of the currently displayed video frame.
Create Timeline	Create a new timeline window with this event. See the section called “Video Timelines” for more details.
Refresh Graph	Refresh the data graph. The data graph is capable of plotting analysis measurement results. If the analysis is modified, the graph will occasionally need to be refreshed to reflect the new data.
Enable Reticle	Enable the reticle for the video image.
Enable Midpoint Finder	Enable the midpoint finder tool. When enabled, the default reticle behavior is changed to support clicking and dragging a line in order to select the midpoint of the drawn line. A circle is also drawn around the line end- points to assist in finding the center of circular objects. Uncheck this button to restore normal reticle behavior. When the midpoint finder is enabled, after the circle is placed, holding down the **Control** key while moving the mouse around will let you place the reticle at the top, bottom, left, right, or center of the circle.
Enable Quad-Target Center Finder	Enable the quad-target center finder tool. When enabled, the default reticle behavior is changed to lock onto the center of a quad target. Uncheck this button to restore normal reticle behavior.
Enable Blob Center Finder	Enable the blob center finder tool. When enabled, the default reticle behavior is changed to lock onto the center of a blob target. Uncheck this button to restore normal reticle behavior.
Show Rulers	Show rulers for the video image.
View Actual Size	Show the video at actual size.
Fit In Window	Show the video and data as large as possible, fitted within the current window dimensions.
Pan Mode	Change the mouse interaction to pan the video or data when dragging.
Zoom Mode	Change the mouse interaction to zoom the video or data.

Control Panels

Various control panels are available to perform different operations on the video and data. These control panels are accessed via the toolbar on the right side of the window.

When each button on the toolbar is pressed, the corresponding control panel is shown or hidden. If no control panel is being displayed when a button is pressed, the entire window will enlarge to show the control panel or the video and data sections will shrink to show the control panel. The default expansion or shrinking of the Measurement window can be set in the Program Options (see the section called "Program Options"). If the toolbar button for the currently displayed control panel is pressed again, the control panel is hidden.

The standard set of control panels are the following:

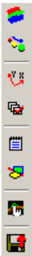


Image Processing	Adjust image brightness, contrast, and other LUT settings. See the section called "Image Processing" for more details.
Image Filtering	Specify image filters for modifying the image. See the section called "Image Filtering" for more details.
Image Calibration	Calibrate the image to real dimensions. See the section called "Multi-Plane Calibration" for more details.
Display Layers	Control what is displayed on the video image. See the section called "Display Settings" for more details.
Notes	Edit video, data, or global text notes. See the section called "Video and Data Notes" for more details.
Annotations	Add graphical annotations on the video image. See the section called "Graphical Annotations" and the section called "Static Measurements" for more details. These operations can also be accessed via the Annotations Toolbar (see the section called "Annotation Toolbars").
Graph Configuration	Configure the appearance and contents of the data graph. See the section called "Display Settings" and the section called "Data Filtering" for more details.
Save All Toolkits	Save all toolkits from one dialog. After working through all the various toolkits, this option will bring up a window where you can automatically save all open toolkits. See the section called

"Saving All Toolkits" for more details.

Additional control panels may be enabled depending upon the version you have purchased. Other specialized control panels are also available as optional toolkits. See Chapter 8, *Optional Toolkits* for more details.

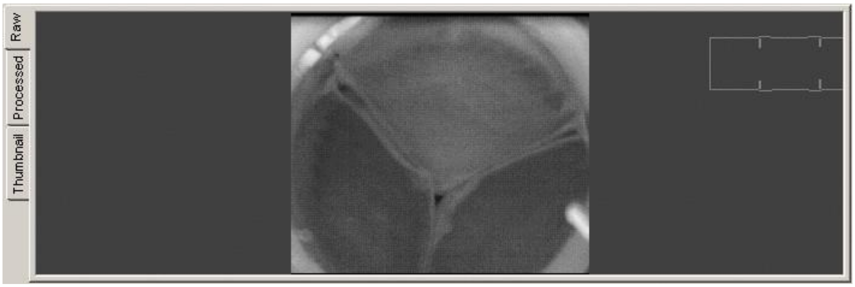
Video

This portion of the window displays images from a video file. In addition, it shows annotations, results from analyses, and other graphical overlays.

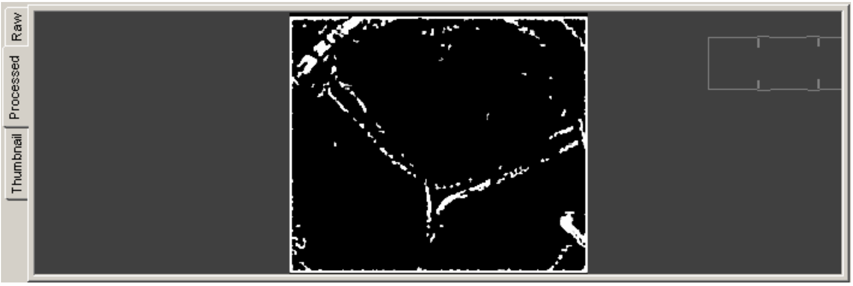
Raw, Processed, and Thumbnail

There are three tabs in the video portion of the main window:

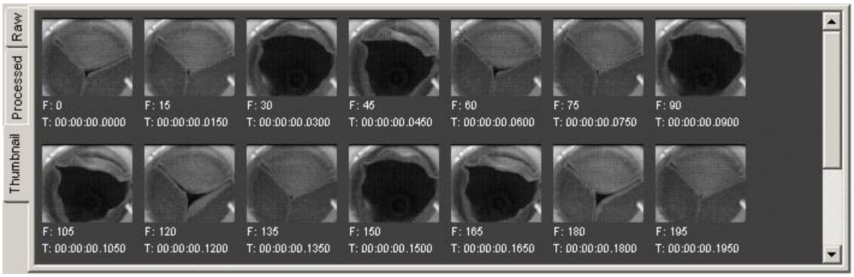
Raw — The image displayed is always the original unaltered image directly from the video source.



Processed — The image is processed using Image Processing (see the section called "Image Processing") and Image Filtering (see the section called "Image Filtering").



Thumbnail — Shows a thumbnail summary of the entire video. The size and time interval between each individual thumbnail may be adjusted using the context (right-click) menu, under Video Menus, Thumbnail or by hitting '**A**' or '**Z**' to adjust size and '**S**' and '**X**' to adjust time interval. The images are either shown as the raw images or the processed images. This setting can be changed via the context menu also, or by hitting '**P**'.



Panning and Zooming

When the video is in Raw or Processed mode, you can pan or zoom around the image.

To pan the image:

1. Set the mouse interaction to pan mode by clicking the  button on the toolbar or by holding down **Control** and **Shift** keys.
2. Click in the image and drag around to pan.
3. Click on the same button to unset the pan mode or release the keyboard keys.

To zoom the image:

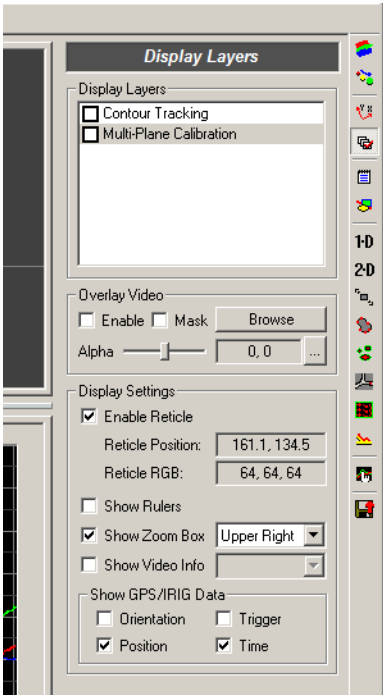
1. Set the mouse interaction to zoom mode by clicking the  button on the toolbar or by holding down **Shift** key.
2. Click in the image and drag up to zoom in and down to zoom out.
3. Click on the same button to unset the zoom mode or release the keyboard key.

You can also zoom the image by clicking on the image and spinning the scroll wheel on your mouse (if it is equipped with a scroll wheel).

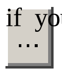
Whenever the image is zoomed in such that the complete image is not fully visible, a zoom box graphic will be drawn in one of the four corners of the display region. This graphic shows the size of the actual image by drawing four corners. The size of the visible window is drawn as a solid rectangle. This allows you to visualize what portion of the full image you are currently viewing.

Display Settings

There are many different overlays that may be drawn over the video image. Controlling the location and display of each of these items is done by using the Display Layers control panel.



There are a number of options that can be set in this control panel:

Display Layers	The upper portion of the control panel lists whatever overlays are currently available for drawing, this may include calibration results, analysis results, annotations, etc. Check or uncheck the box next to each item to have it displayed or hidden.
Overlay Video	A different video can be displayed over the currently loaded video. Click Browse to select the video to use as the overlay video. The images from the two videos will be blended together using the alpha value controlled by the slider. Moving the slider completely to the left will show the original video only. Moving the slider completely to the right will show the overlay video only. Check the Mask checkbox if pixels with a value of zero in the overlay image should be ignored. Click the  button if you want to set X and Y offsets for more precise placement of the overlaid image. The video images are displayed relative to their zero frame.
Enable Reticle	Check or uncheck the box to enable the reticle. When the reticle is enabled, crosshairs will be drawn over the video image. The crosshairs will be placed wherever the mouse is clicked in the image. The control panel displays the coordinates and the value of the pixel underneath the crosshairs.
Show Rulers	Check or uncheck the box to enable rulers. Rulers are drawn

along the border of the video display region.

Show Zoom Box

Check or uncheck the box to enable drawing of the zoom box when panned or zoomed. The zoom box can be drawn in any of the four corners of the image, or may be hidden altogether. Use the drop down box to select the location for the zoom box.

Show Video Info

Check or uncheck the box to enable drawing of video information. The video information is a set of text that is drawn over the video image that indicates the current frame, recorded rate, shutter speed, etc.. It can be drawn in any of the four corners of the image, or may be hidden altogether. Use the drop down box to select the location for the video information.

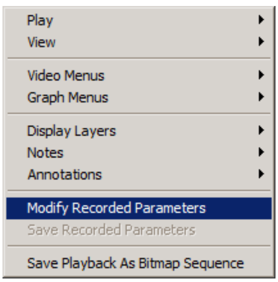
Show GPS/IRIG Data

The four different components of the GPS/IRIG information can each be enabled or disabled independently. Check or uncheck each box to enable drawing of the GPS/IRIG information, if present. The GPS/IRIG information is always drawn at the bottom of the video image.

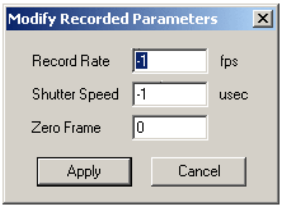
The reticle, rulers, video information, and GPS/IRIG information can all be turned on automatically every time a new video window is opened by setting the default options in the Program Options window (see the section called "Program Options").

Setting Frame Rate, Shutter Speed, and Zero

Depending upon how a video was acquired, the record rate, shutter speed, and zero frame may or may not be automatically determined by the software. If the parameters are not automatically determined, they may be modified using the Modify Recorded Parameters option in the context menu (right-click) of the Measurement Window.



This will bring up a dialog window with the record rate, shutter speed, and zero frame information.

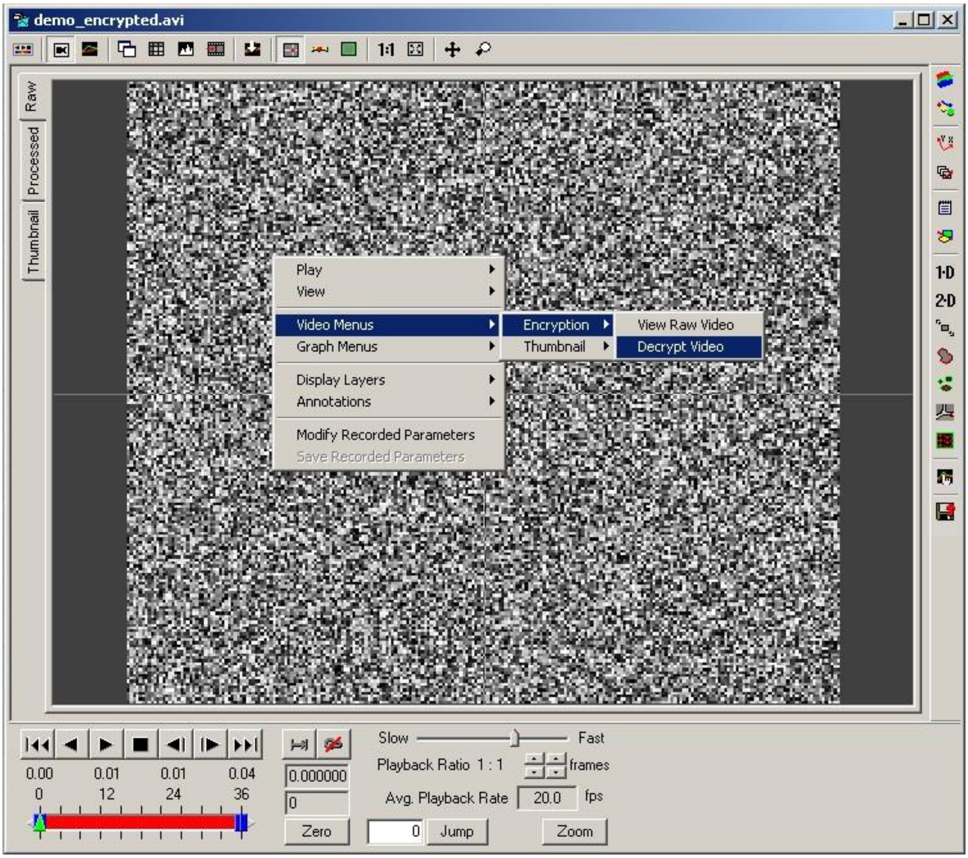


Enter the appropriate values and then click Apply. The shutter speed can be entered in microseconds, or in 1/rate notation or 1x,2x,3x,... notation. If the latter two formats are used, the value will be converted to microseconds automatically. The zero frame is the frame number rel- ative to the first frame. So if you enter 10, the tenth frame will be considered the zero frame, and hence the first frame will be numbered as -10.

After the parameters have been modified, if you wish for these settings to be loaded every time the video is loaded, the parameters must be saved. Save the parameters by using the Save Recorded Parameters option in the context menu or in the main File menu.

Viewing Encrypted Video

To play back a video that has been encrypted, you must enter the correct passphrase that was used to encrypt the video (and data). Right-click in the video window and select Video Menus, Encryption, Decrypt Video.



The Encrypt/Decrypt dialog will appear. You must enter the correct passphrase twice and then press OK.

If the passphrase is correct, the decrypted video will be displayed. If the passphrase is incorrect, the random noise pattern will continue to be displayed.

Note that the decryption is done on-the-fly for each frame just before it is rendered, a decrypted version of the video image is never stored to the hard drive.

Data

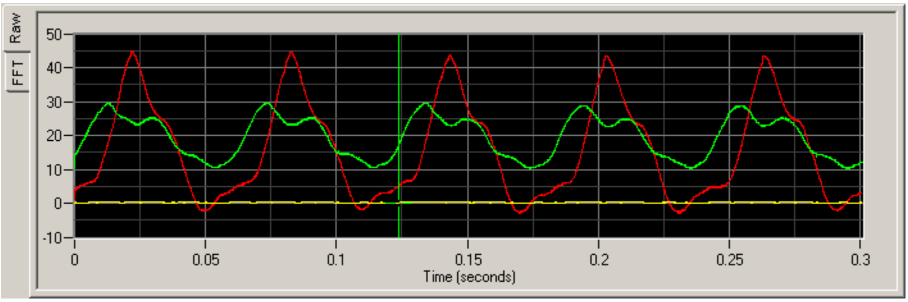
The graph window displays plots of the data acquired with the video and also the results of any analysis that has been completed. The data can be displayed versus time or the frequency content of the data can be displayed by using a Fast Fourier Transform.

When displayed versus time, if you click your mouse in the data graph, the data cursor will be moved to where the mouse was clicked and the corresponding video frame with be displayed. This allows you to navigate through your event by clicking on interesting portions of the data graph.

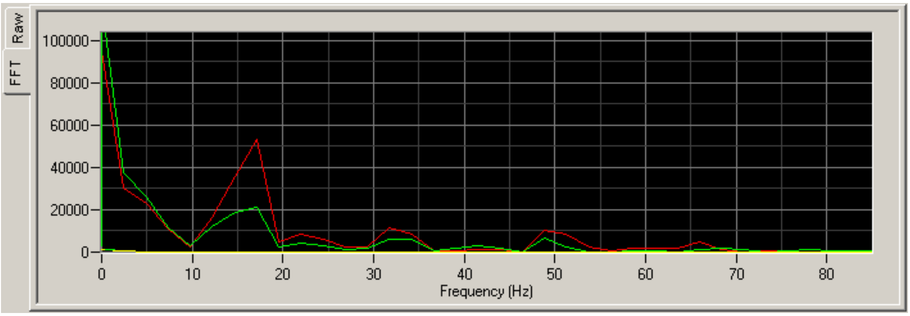
Raw and FFT (Fast Fourier Transform)

There are two tabs to the graph portion of the main window:

Raw Displays the standard data versus time graph of all data. Clicking on the graph will automatically move the video to the corresponding frame.



FFT Displays the Fast Fourier Transform of the data. The frequency range is the full range possible for the given data. Typical data will most likely be in the left portion of the resulting FFT graph. Use the pan and zoom techniques to zoom in on the frequency range of interest.



Panning and Zooming

When the data is displayed in Raw mode, you can pan or zoom around the graph.

To pan the graph:

1. Set the mouse interaction to pan mode by clicking the  button on the toolbar or by

holding down the **Control** and **Shift** keys.

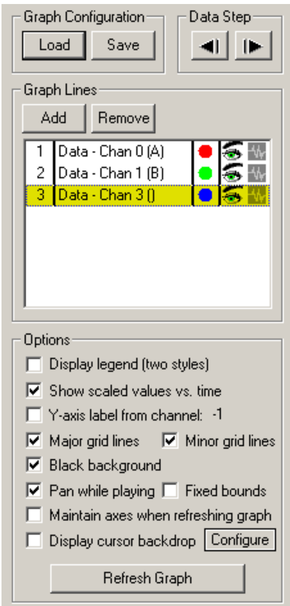
2. Click in the image and drag around to pan.
3. Click the same button to unset the pan mode or release the keyboard keys.

To zoom the graph:

1. Set the mouse interaction to zoom mode by hitting the  button on the toolbar or by holding down the **Shift** key.
2. Click in the image and drag to draw a zoom rectangle around the area of interest.
3. Double-click on the graph if you wish to zoom out fully.
4. Click the same button to unset the zoom mode or release the keyboard key.

Display Settings

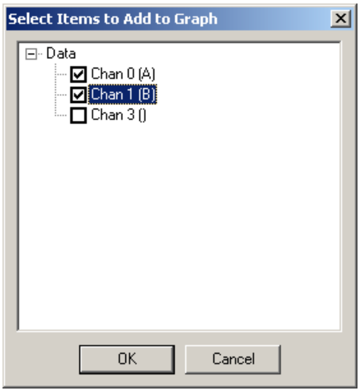
Many different settings for how the graph portion of the window appears may be controlled using the Graph Configuration control panel.



To display a new line:

1. Click the Add button.

2. A list of all currently available items for graphing will be displayed. Select which items you wish to add to the graph.



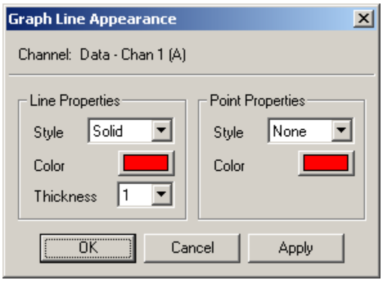
3. Click the OK button on the bottom of the list window.

To remove a line:

1. Select the desired lines from the list of displayed items.
2. Click the Remove button.

To change the color, line style, or point style of a line:

1. Double-click on the name or colored circle of the displayed item that you wish to modify.



2. Select the desired line style from the "Line Properties" section of the appearance dialog that appears.
3. Click on the color button from the "Line Properties" section and select the desired line color.
4. Select the desired thickness from the "Line Properties" section.

5. Select the point style from the "Point" section of the control panel.

6. Click on the color button from the "Point" section and select the desired point color.

7. Hit the OK or Apply button on the bottom of the appearance dialog.

Additional options can be set to change the appearance of the graph, any changes made here must be followed by clicking the Apply button in order for the changes to take effect. The pos- sible options are:

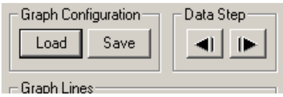
Display legend	There are two types of legends. Click the check box once and apply to get the first legend, click again and apply to get the second.
Show scaled values vs. time	The data can be shown using scaled values (e.g. pressure) or using raw unscaled values (e.g. volts). Check this box and apply to show scaled values. Uncheck to show raw unscaled values.
Y-axis label from channel	A single label can be added to the Y-axis of the graph. The label can be obtained from one of the displayed channels. To add a label to the graph, select a desired channel from the "Displayed" column and check this checkbox and click Apply.
Major grid lines	Check this box to show major gridlines in the graph.
Minor grid lines	Check this box to show minor gridlines in the graph.
Black background	The graph can be drawn against a black background or against a white background. Check this box to draw the graph with a black background.
Pan while playing	If the data graph is zoomed and the video is playing, the data that is displayed can pan so that the data displayed will always be centered upon the video image that is currently displayed. Check this box to automatically pan the data when the video is playing.
Fixed bounds	Set fixed X and Y axes bounds. Normally the graph is auto-scaled so that the X and Y axes fit the graphed data. Using this option, you can specify larger or smaller fixed X and Y axes.
Maintain axes when applying	When the Apply button is clicked, the graph is reconfigured. Usually this resets the X and Y range of the displayed graph. Check this box to maintain the same settings for the X and Y range when the Apply button is clicked.

Once you are satisfied with the appearance of the graph, the graph configuration can be saved to a file by using the Save button. Graph configurations are saved to files with the `GFC` extension. Multiple files can be generated for a single set of data so that you can easily switch between multiple representations. Saved graph configurations can be loaded by using the Load button.

For additional details on graphing and filtering, see the section called “Data Filtering”.

Stepping Through Data

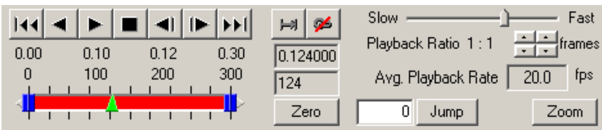
Just as you can single-step (advance one frame at a time) through the video, you can also step one data point at a time through the data. The data step buttons are located at the bottom of the Graph Configuration control panel discussed in the previous section.

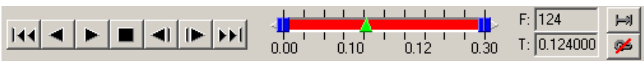


Click the left arrow to move the cursor one data point backwards. Click the right arrow to move the cursor one data point forward.

Play Controls

Play controls are located at the bottom of the main window. There are two styles for the play controls, normal and compact. You can select between these two sets of controls by clicking the Toggle Play Controls button on the main toolbar.





The components of the Play tab are described as follows:

Standard Play Controls	The standard play control buttons are shown in the upper left. These buttons are: rewind, play reverse, play forward, stop, step back- ward, step forward, and fast forward.
Slide Bar	The slide bar allows the operator to quickly move to a specific part of the playback cycle. Just click on the center green triangle of the slider and, holding down the left mouse but- ton, drag the slider to the desired position. The time and the frame numbers are displayed dir- ectly above the slide bar. The active area is displayed in red. The inactive area is displayed

	in gray.
Slide Bar Range Brackets	The slide bar range brackets are used to establish the beginning and end of the playback range. To approximately select the beginning of the playback range, click on the left blue square slider and, holding down the left mouse button, drag the slider to the desired position. Do similarly with the end of playback using the right blue square slider.
Set Zero Frame (Zero)	By clicking the Zero button, the current frame of the video playback is reset to become the Reference Frame 0 and the current datum is reset to become the Reference Datum 0.
Set Playback Rate (Slow-Fast Slider) and Avg. Playback Rate	The actual playback rate on the computer screen is determined by many factors, including the number of synchronized images, the video RAM and the speed of the computer processor. Therefore, the software provides a slider between "slow" and "fast". Set the relative speed of playback by clicking on the center post of the slider and, holding down the left mouse button, drag the slider to the desired position. Read the actual playback rate in the box below.
Playback Ratio	This feature allows users to speed up the display update rate by skipping frames. Use the up/down arrows to select the number of frames to skip. The right set of up/down ar- rows adjust the ratio by 1 and the left set of up/down arrows adjust the ratio by 10. The de- fault is 1:1 frames (all frames are shown).
Current Time	The time of the visible frame is displayed.
Current Frame	The frame number of the visible frame is displayed.
Continuous	Set the video to playback in continuous mode. If this is set, the button will show a circular arrow. When the playback reaches the end of the video, it will loop and start again from the beginning. If playing in reverse, when the video reaches the beginning, it will loop and continue playing in reverse from the end. If this is not set, the button will show a straight arrow.
Synchronized	If this is set, the button will show two links of a chain. This video will be synchronized to all other synchronized windows. This means that all synchronized windows will show the video and data corresponding to the same moment in time (or the same frame number, depending on synchronization mode). If you press play in one window, all the other windows will also

	play. If you step backward in one window, all the other windows will also step backward, etc. See the section called “Synchronized Play Controls Toolbar” for more details about synchronization modes. If this is not set, the button will show two links of a chain with a red diagonal line.
Jump to Frame (Jump)	This control allows you to go to a specific frame number in the video. Enter a frame number in the edit box and then press Jump to go to that frame.
Create Zoom Window (Zoom)	This button allows you to create a zoom window for a specific region of the video. Click on the Zoom button and then click and drag a rectangle over the area of interest in the video. A new zoom window will appear showing the area in the rectangle.

Play Control Keyboard Shortcuts

The play controls also have keyboard shortcuts that allow you to control playback of the cur- rent video using the bottom row of keys on your keyboard. The letters **Z**, **X**, **C**, **V**, **B**, **N**, **M** all correspond to the buttons shown above the slider in the Play tab. For instance, **C** corresponds to the play forward button, **V** corresponds to the stop button, etc. In addition, the '**,**' and the '**.**' keys can also be used to control the Continuous (Loop) button and the Synchronized (Link) button respectively.

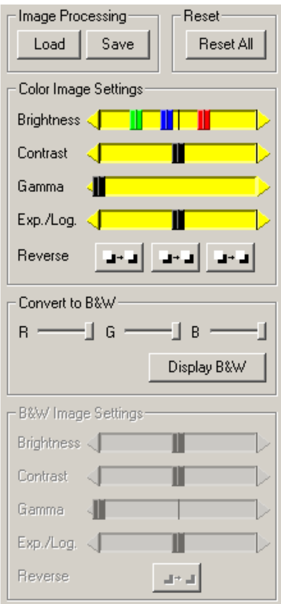
Chapter 4. Analysis

Image Processing

There are two types of image processing available for modifying the appearance of video images: Image Processing and Image Filtering. Image Processing allows for the standard set of image controls such as brightness, contrast, and gamma correction. Image Filtering allows for much more powerful image manipulation in the form of sequential filter operations. Many different image filters are provided, such as smoothing, sharpening, threshold, and despeckling filters. If both Image Processing and Image Filtering are used, the Image Processing settings are applied first, and then the Image Filtering settings.

Image Processing

The Image Processing control panel can be shown by clicking the Image Processing button on the side toolbar of the Measurement Window.



The various components of the Image Processing panel are described in the following sections.

Contrast, Brightness, Gamma, Nonlinear

The Image Processing panel allows you to set all the parameters about the image, save your settings and restore them for later use. Note that there are the same sets of sliders for color and monochrome (black and white) images. For the color settings, the red, green and blue channels are modified as a group when the slider is the default gray color. By double clicking on the slider control, the slider bars will separate into red, green, and blue channel sliders that can be adjusted independently. For greater flexibility, all images are treated as RGB color. This simplifies image processing and also allows you to add a color cast to a grayscale image by separating the channels and dragging the individual red, green, and blue sliders.

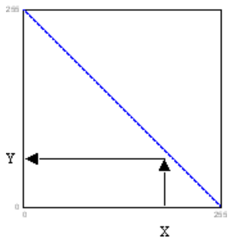
The various image settings are:

Brightness	Adjusts the brightness of the image. Higher brightness values will cause the image pixels to move closer to white (255). Lower brightness values will cause the image pixels to move closer to black (0).
Contrast	Adjusts the contrast of the image. Higher contrast will try to move colors toward white or black and reduce the grays. Lower contrast will move all colors closer to gray.
Gamma Correction	Adjusts the gamma of the image. The gamma of the image affects the brightness of the displayed result on your monitor. Higher values will brighten the image more.
Nonlinear	Adjusts the nonlinear palette function. By adjusting this value, you can change the mapping of input to output colors to be either expo- nential (more blacks) or logarithmic (more whites). A more detailed explanation is provided below.

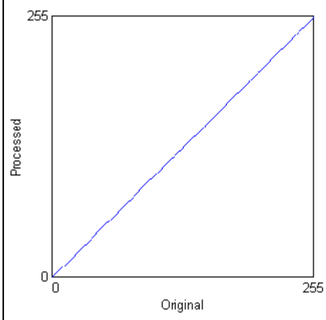
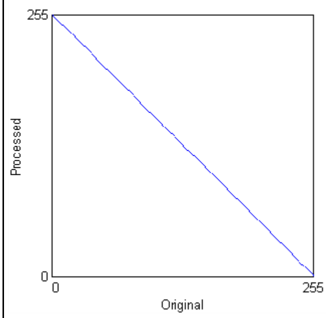
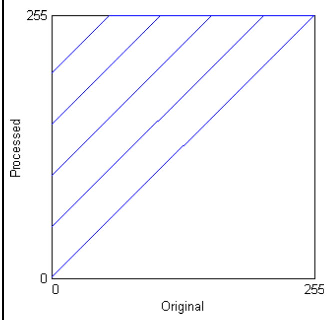
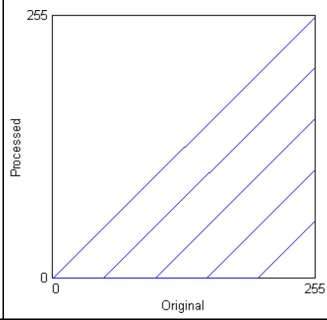
Detailed Input/Output Mappings

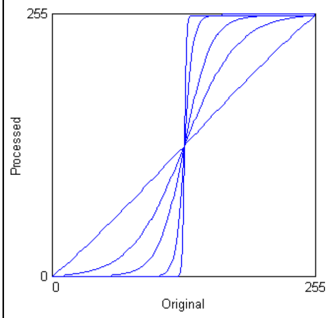
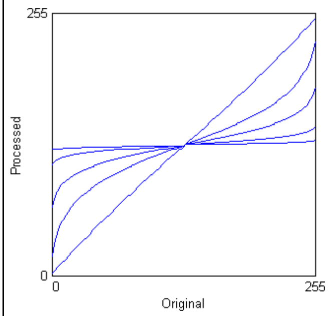
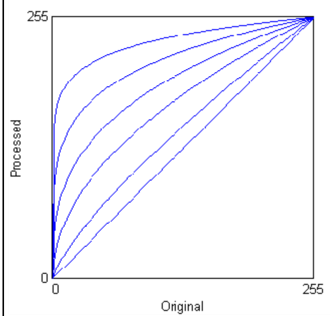
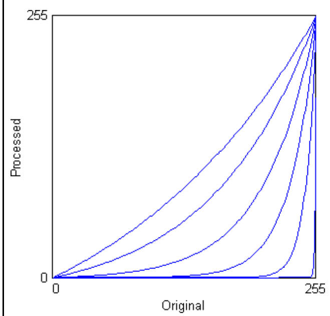
The Image Processing features allow you to improve the image contrast to enhance the tracking success. The tracking tools typically look for objects that have high contrast (white-on-black or black-on-white), changing the Look-Up Table (LUT) settings adjusts the image palette to improve the image contrast.

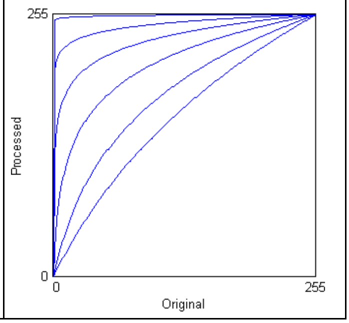
A description of these image palette options is given below. The images on the left are ex- amples of the effects of each of the palette options. The plots on the right show the mapping of pixel intensity values from the original (horizontal axis) to the processed (vertical) image after applying the new palette.



To help in understanding the palette mapping plots, here is an example using the reverse palette. For a given pixel intensity of X in the original image, we move upward at coordinate X until we intersect with the blue line, then we move horizontally to find the new pixel value in the processed image, in this case it would be Y. This is done for every pixel in the image, pro- ducing the final processed image as shown in the figures on the left.

Normal	This is the default and standard palette with no processing occurring. In other words, the processed pixels are identical to the original pixels.	
Reverse	This option uses a reverse palette, where 255 is black and 0 is white. This will invert the image so that light regions are dark and dark regions are light. Contrast is not affected.	
Brightness	Adjusts the brightness of the image. Moving the slider to the right will increase the brightness of the image by uniformly increasing the pixel intensity values. Moving the slider to the left will decrease the brightness of the image by uniformly decreasing the pixel intensity values.	 
Contrast	Adjusts the contrast of the image. Moving the slider to the right will increase the contrast of the image. This has the ef-	

	fect of moving pixel intensity values towards white (255) or black (0). Moving the slider to the left will decrease the contrast of the image. This has the effect of moving pixel intensity values towards gray (128).	 
Gamma Correction	Adjusts the gamma of the image. Gamma correction is typically used to adjust for differences in the way monitors display brightness and colors. Adjusting this slider is similar, although not identical, to adjusting the nonlinear slider. Moving the slider to the right will increase the brightness of the image in a nonlinear fashion as shown.	
Nonlinear	Adjusts the image using nonlinear input/output mappings. This slider is a combination of a logarithmic (moving slider to the right) and exponential (moving slider to the left) palette. The logarithmic palette increases the contrast in dark regions and decreases the contrast in light regions. This has the effect of bring out more detail in the dark regions and making light regions very light.	

	The exponential palette increases the contrast in light regions and decreases the contrast in dark regions. This has the effect of making dark regions darker and bringing out more detail in lighter regions.	

Reversing Channels

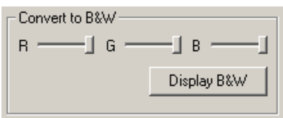
You may also convert images between color and monochrome and adjust the individual channels of the image. Note that all the analysis toolkits use only monochrome representations of images.

To reverse a monochrome image or individual channels of a color image, click on the reverse buttons at the bottom of the color and black and white sections of the panel.

Reverse Changes the color palette such that whites and blacks are reversed. In addition, for color images, each individual channel of RGB color is reversed. For color re- versals, Red is reversed to Cyan, Green is reversed to Magenta and Blue is re- versed to Yellow.

Converting between Color and Monochrome

To display a color image as monochrome or to reset a monochrome image to its original color (if recorded in color), the following options are available:



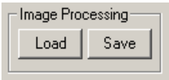
Display B&W	Converts color images to monochrome images using the conversion factors indicated by the R, G, and B sliders.
R Scale	Amount of red channel to include when converting from color to monochrome.
G Scale	Amount of green channel to include when converting from color to monochrome.

B Scale	Amount of blue channel to include when converting from color to monochrome.

Saving Image Processing Settings

Once you find a good set of LUT settings, you can save the Image Processing settings and then reload them at a later time or apply these saved settings to another video image. So, for ex- ample, you may optimize one image for tracking performance and then apply those same image processing settings to all images in the same experiment or application. The image processing settings are saved into an LUT (Look-Up Table) format for later retrieval.

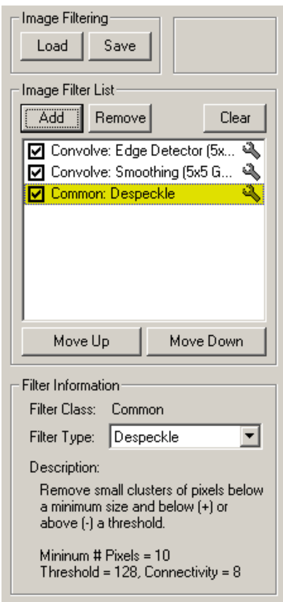
The save/load buttons are found at the top of the Image Processing control panel.



Save To File	Save current settings to file. Image processing files have the `LUT` file extension.
Load From File	Allows previously stored image settings to be loaded for this image.

Image Filtering

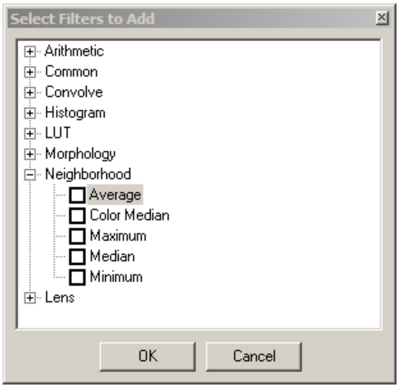
A sequence of image filters can also be applied to the video images. These filters can be added using the Image Filtering control panel.



The upper portion of the panel lists the current filters that have been added and whether they are active or not. Check or uncheck the box next to each filter to enable that filter. The order of the filters can be changed by selecting a filter and then clicking the Move Up and Move Down buttons.

Adding and Removing Filters

New filters can be added by clicking the Add button. New filters are always added to the end of the sequence. The order can be changed using the Move Up and Move Down buttons. When you click the Add button, the Add Filter dialog will appear:



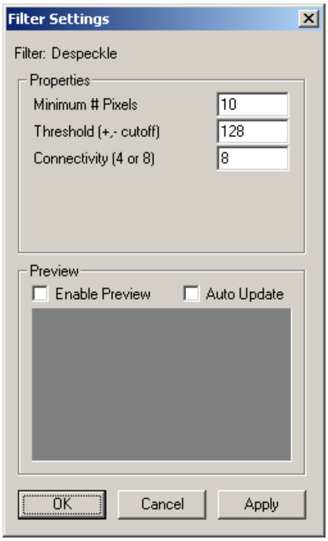
Select the Filter Class and the Filter Type of the filter that you wish to add. A complete listing and description of the available filters is given in the section called “List of Available Filters”.

Filters can be removed by selecting a filter in the list and then clicking the Remove button. To remove all filters, click the Clear button.

Modifying Filter Properties

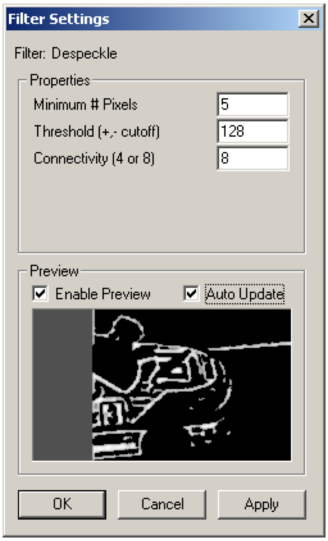
After a filter has been added, you cannot change the Filter Class, but you can change the Filter Type. If you must change the Filter Class, remove the filter and add a new filter of the correct class. To change the Filter Type, click on the filter in the list and select a new Filter Type from the drop-down box in the lower portion of the control panel.

Some filters have editable properties and others do not. When you double-click on a filter in the list that has editable properties or click on the wrench icon in the list, these properties will be displayed in a separate pop-up dialog window.



Edit the properties and then click Apply for the changes to take effect.

A preview option is available to help in tuning the filter properties. To enable the preview, check the Enable Preview checkbox in the lower portion of the pop-up dialog window.



The portion of the video that is displayed in the preview region can be adjusted by clicking and dragging within the preview area.

The preview area will display the processed video with all filters applied up to and including the current filter. The filters in the filter list after the current selected filter are not applied to the image displayed in the preview area.

If the Auto Update checkbox is selected, then the parameters entered into the upper portion of the dialog will be automatically applied to the current filter for the preview image without having to be applied. If Auto Update is not checked, then in order to see the effect of any parameter changes, you must click the Apply button.

Saving and Loading Image Filters

A set of filters can be saved to a file. These files can then be reloaded for another video, or multiple sets of filters can be defined for a single video. To save or load image processing settings, use the Save and Load buttons at the top of the control panel.

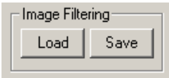


Image filters and settings are saved to files with the `IMP` extension.

List of Available Filters

- Arithmetic

  Perform basic arithmetic operations on all pixels in the image.

Addition/Subtraction	Adds or subtracts a specified parameter value from all pixels in the image. Use positive values to add and negative values to subtract.
Invert (Logical NOT)	Performs a logical NOT (~) operation on all pixels in the image.
Left Bit Shift	Performs a left bit shift (<<) operation on all pixels in the image. Shifts by a specified number of bits.
Logical AND	Performs a logical AND (&) operation with a specified parameter value for all pixels in the image.
Logical OR	Performs a logical OR (|) operation with a specified parameter value for all pixels in the image.
Logical XOR	Performs a logical XOR (^) operation with a specified parameter value for all pixels in the image.
Multiplication	Multiplies all pixel values with a specified parameter value.
Multiplication (Scaled)	Multiples all pixel values with a specified parameter value with scaling, so that the maximum value is limited to 255.
Pre-Subtraction	Subtracts all pixels in the image from a specified parameter value. Parameter value should be positive.

Right Bit Shift	Performs a right bit shift (>>) operation on all pixels in the image. Shifts by a specified number of bits.
Square	Squares each pixel in the image.

- Common

  Common image operations such as thresholding and despeckling. Filters with the (slow) designation often take a long time to process a single frame.

Alpha Blending	Blends each displayed image with the previously displayed images using the alpha value specified. The alpha value should be between 1 and 255. A value of 1 will keep the original frame, ignoring all new frames. A value of 255 will always show the new frame, ignoring all previous frames. The type controls how the images are blended. (More information on type is pending. It is recommended you use the default value of 3.)
Despeckle (slow)	Removes speckles in the image beneath a given size and threshold. The image is first thresholded using a fixed grayscale parameter value. Then all speckles beneath a given size are removed. Speckle size is computed assuming four point connectivity or eight point connectivity. Four point connectivity means that only points to the left, right, top, and bottom will be considered connected to a given pixel. Eight point connectivity also includes the diagonal upper-left, upper-right, lower-left, and lower-right pixels.
Fill Center of Objects (slow)	Attempts to fill the interior of enclosed objects. For example, this filter would attempt to fill the interior of objects that appear like a donut (white ring with a black center) with white, resulting in a solid white circle. Depending on the complexity of the image, this filter may not successfully fill.
Flip Both (Rotate 180)	Flip the image horizontally and vertically. This is equivalent to rotating the image 180 degrees.
Flip Horizontal	Flip the image horizontally.
Flip Vertical	Flip the image vertically.
Frame Difference	Computes the difference in pixels from the specified frame to the current frame. Only one of these filters may be active at a time. If multiple are added, only the first one will be en-

	abled. An option to this filter controls the style of differencing that is computed. If the style is 0, then the absolute difference between frames is computed. If the style is -1, then the current frame A is subtracted from the previous frame B, with only positive values displayed. If the style is 1, then the previous frame B is subtracted from the current frame A, with only positive values displayed.
Initial Frame Background Removal	Performs approximate background removal by checking for differences above a specified threshold from the specified frame of video. If a pixel value is above the specified threshold, it is displayed normally. If a pixel value is be- low the specified threshold, it is displayed as black.
Local Background Removal	Performs approximate background removal by using local averaging.
Reverse Despeckle (slow)	Removes speckles in the image above a given size and threshold. The image is first thresholded using a fixed grayscale parameter value. Then all speckles above a given size are removed. Speckle size is computed assuming four point connectivity or eight point connectivity. Four point connectivity means that only points to the left, right, top, and bottom will be considered connected to a given pixel. Eight point connectivity also includes the diagonal upper-left, upper-right, lower-left, and lower-right pixels.
Reverse Threshold (Mask)	Performs a threshold operation on the image. All image pixels above the threshold will be set to black (0). All image pixels below the threshold will be set to the original image value.
Strobe Effect	Produces images that are a combination of all previously displayed images by performing a logical OR operation with every new frame. To reset the combined image, disable and reenable the filter by clicking on the check box next to this filter in the filter list. Only one of these filters may be active at a time. If mul- tiple are added, only the first one will be en- abled.
Threshold (Binary)	Performs a threshold operation on the image. All image pixels below the threshold will be set to black (0). All image pixels above the threshold will be set to white (255).
Threshold (Mask)	Performs a threshold operation on the image.

	All image pixels below the threshold will be set to black (0). All image pixels above the threshold will be set to the original image value.
Threshold (Niblack)	Performs a threshold operation on the image based on the Niblack method. This filter is useful for detecting text and edges.
Threshold (Sauvola)	Performs a threshold operation on the image based on the Sauvola text method. This filter is useful for detecting text and edges.
Unsharp Mask	Performs a sharpening technique on the image. A blurred, or "unsharp" positive image is used to create a mask of the original image. The unsharped mask is then combined with the negative image, creating an image that is less blurry than the original.
Zero Border	Sets all pixel values to zero near the left, right, top, and bottom borders.
Zero Circle	Sets all pixel values to zero inside a circular region in the image.
Zero Outside Circle	Sets all pixel values to zero outside a circular region in the image.
Zero Region	Sets all pixel values to zero within the rectangular region defined by the left, right, top, and bottom values.

- Convolve

  Convolution of the image with fixed convolution filters. The actual filter coefficients are provided at the end of the descriptions, each row is separated by a semicolon.

Checker Corner Detector	Convolves with two filters to locate corners of checkerboard patterns, one filter to locate black-white,white-black checkerboards and the second to locate white-black,black-white checkerboards.
Edge Detector (3x3 Center High Pass)	Convolves the image with a basic high-pass filter to find edges. Equivalent to the Laplacian (3x3). [-1 -1 -1 ; -1 8 -1 ; -1 -1 -1]
Edge Detector (3x3 Laplacian High Pass)	Convolves the image with a Laplacian high-pass filter to find edges. [-1 -1 -1 ; -1 8 -1 ; -1 -1 -1]
Edge Detector (5x5 Center High Pass)	Convolves the image with a basic high-pass filter to find edges. [-1 -1 -1 -1 -1 ; -1 -1 -1 -1 -1 ; -1 -1 24 -1 -1 ; -1 -1 -1 -1 -1 ; -1 -1 -1 -1 -1]
Edge Detector (5x5 Laplacian High Pass)	Convolves the image with a Laplacian high-

	pass filter to find edges. [-1 -3 -4 -3 -1 ; -3 0 6 0 -3 ; -4 6 20 6 -4 ; -3 0 6 0 -3 ; -1 -3 -4 -3 -1]
Horizontal Edges (3x3 Prewitt)	Convolves the image with a horizontal Prewitt gradient filter to find horizontal edges. [1 1 1 ; 0 0 0 ; -1 -1 -1]
Horizontal Edges (3x3 Sobel)	Convolves the image with a horizontal Sobel gradient filter to find horizontal edges. [1 2 1 ; 0 0 0 ; -1 2 -1]
Sharpening (3x3 Center)	Convolves the image with a basic sharpening filter to sharpen the image. [-1 -1 -1 ; -1 16 -1 ; -1 -1 -1] / 8
Smoothing (3x3 Gaussian Low Pass)	Convolves the image with a Gaussian low-pass filter to smooth the image. [1 2 1 ; 2 4 2 ; 1 2 1] / 16
Smoothing (5x5 Gaussian Low Pass)	Convolves the image with a Gaussian low-pass filter to smooth the image. [2 7 12 7 2 ; 7 31 52 31 7 ; 12 52 127 52 12 ; 7 31 52 31 7 ; 2 7 12 7 2] / 571
Vertical Edges (3x3 Prewitt)	Convolves the image with a vertical Prewitt gradient filter to find vertical edges. [-1 0 1 ; -1 0 1 ; -1 0 1]
Vertical Edges (3x3 Sobel)	Convolves the image with a vertical Sobel gradient filter to find vertical edges. [-1 0 -1 ; -2 0 2 ; -1 0 1]

- Histogram

  Many of the following operations require a range to be specified as a parameter to the filter. A range is specified by three RGB center values and three RGB ranges. A pixel value is inside the range if it is within R +/- dR, G +/- dG, and B +/- dB, where dR, dG, dB are the RGB ranges.

Channel Gains	Applies independent gains to the RGB channels.
Channel Offsets	Applies independent offsets to the RGB channels.
Color Select (Binary)	Selects pixels in the image that are within a specified color range. If a pixel is outside the range, the output pixel is set to black (0). If a pixel is within the range, the output pixel is set to white (255).
Color Select (Mask)	Selects pixels in the image that are within a specified color range. If a pixel is outside the range, the output pixel is set to black (0). If a pixel is within the range, the output pixel is set to the original pixel value.
Equalize	Computes the histogram of the image and per-

	forms a remapping so that the resulting histogram attempts to equalize the occurrence of each pixel value.
Inverse Select (Binary)	Selects pixels in the image that are outside a specified color range. If a pixel is outside the range, the output pixel is set to white (255). If a pixel is within the range, the output pixel is set to black (0).
Inverse Select (Mask)	Selects pixels in the image that are outside a specified color range. If a pixel is outside the range, the output pixel is set to the original pixel value. If a pixel is within the range, the output pixel is set to black (0).
Threshold Pixel Count	Computes the histogram of the image and performs an adaptive threshold. The actual threshold value is determined by counting the number of bright pixels that will be kept or the number of dark pixels that will be removed. Set the direction to 1 to specify the number of bright pixels to keep. Set the direction to 0 to specify the number of dark pixels to remove.

- LUT

  Each of the following operations are equivalent to the controls in the Image Processing panel (the section called “Image Processing”).

Brightness	Modifies the brightness of the image. A single parameter value between -255 to +255 is used to adjust the brightness. Negative values will make the image darker, positive values will make the image brighter.
Contrast	Modifies the contrast of the image. A single parameter value between -255 to +255 is used to adjust the contrast. Negative values will decrease the white-black difference, positive values will increase the white-black difference.
Gamma (x10)	Modifies the gamma of the image. A single parameter value between 0 to 100 is used to adjust the gamma. Values are 10x the conventional values, for instance 20 would be a gamma of 2.0.
Nonlinear	Applies a nonlinear (exponential/logarithmic) LUT to the image. A single parameter value between -255 to +255 is used to adjust the nonlinear LUT. Negative values will apply an exponential LUT, positive values will apply a logarithmic LUT.

Reverse	Reverses the image, making white black and black white.
RGB to Gray	Converts the image from RGB to grayscale with weights on each RGB channel.
RGB to HSV	Converts the image from RGB to HSV color space.

- Morphology

  Morphological operations can be used to grow or shrink regions or open and close regions. Each operation can be repeated a specified number of times.

Break Connections (Open)	Performs the specified number of erosion operations followed by the specified number of dilation operations.
Close Connections (Close)	Performs the specified number of dilation operations followed by the specified number of erosion operations.
Make Thicker (Dilate)	Performs dilation on the input image. The output pixel is set to the maximum of the pixel values in a 3x3 area around each input pixel.
Make Thinner (Erode)	Performs erosion on the input image. The output pixel is set to the minimum of the pixel values in a 3x3 area around each input pixel.

- Neighborhood

  A neighborhood is specified by providing a width and height and anchor coordinates. The anchor specifies where the neighborhood is relative to the pixel of interest. For instance, for a 5x5 neighborhood to be centered on the pixel of interest, specify the anchor to be 3,3.

Average	Replaces each pixel in the output image with the average of pixels in the neighborhood of each pixel.
Color Median	Replaces each pixel in the output image with the median of pixels in the neighborhood of each pixel.
Maximum	Replaces each pixel in the output image with the maximum of pixels in the neighborhood of each pixel.
Median	Replaces each pixel in the output image with the median of pixels in the neighborhood of each pixel.
Minimum	Replaces each pixel in the output image with the minimum of pixels in the neighborhood of each pixel.

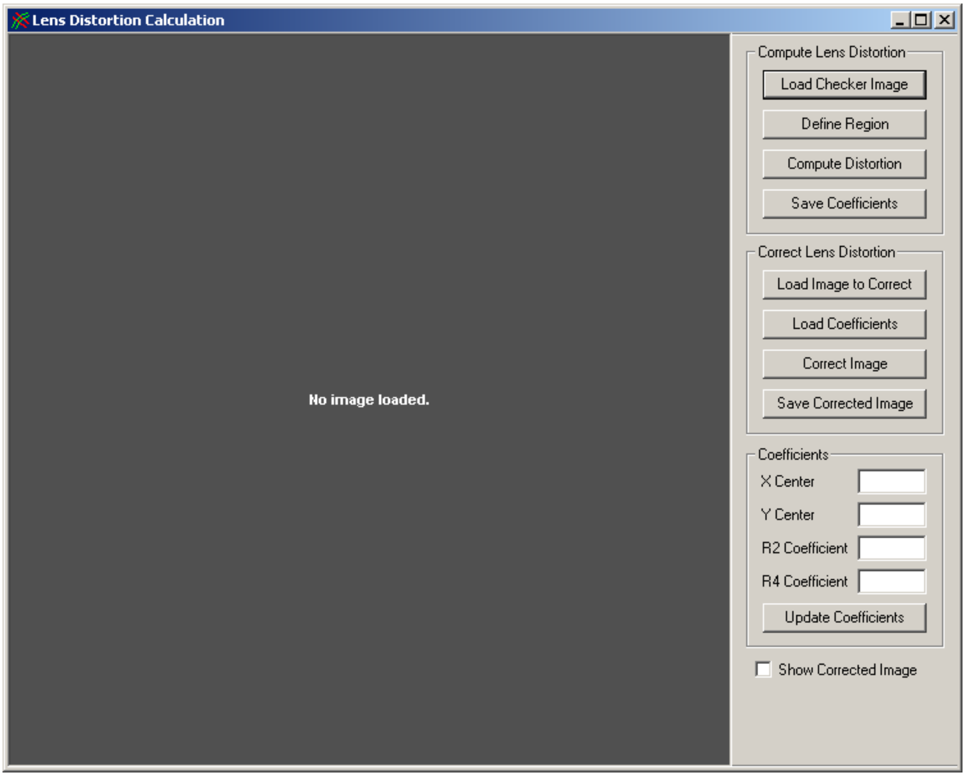
- Lens

  Lens filters perform operations that are related to lens artifacts, such as radial distortion.

Radial Distortion	Compensates for radial lens distortion. Use the Lens Distortion Calculation Tool to calculate suitable parameters (the section called “Lens Distortion Calculation Tool”).

Lens Distortion Calculation Tool

The Lens Distortion Calculation Tool can be accessed from the main menu bar under Tools and then select Lens Distortion Calculation.



For each lens and camera combination that will be used, an image of a checkerboard pattern should be acquired if lens distortion correction is required. The resulting coefficients computed from this tool are only applicable to the camera and lens combination used to capture the checkerboard image. If a different camera or lens is used, another distortion calculation must be performed.

To compute lens distortion coefficients:

1. Capture an image of a checkerboard pattern using the camera and lens that will be used in testing.

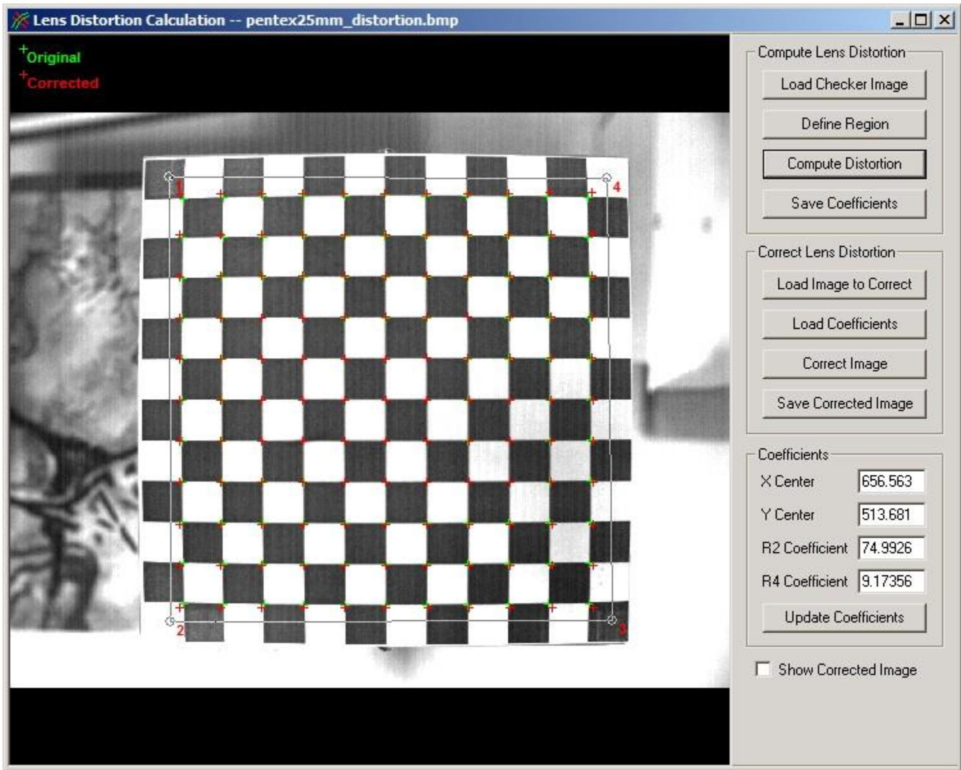
2. Click Load Checker Image and select the checkerboard image file (BMP, TIFF, or JPEG).

3. Click Define Region and click the left mouse button on four points that enclose a checkerboard region. Make sure that the lines connecting the four points that you have selected do not cross a boundary for a row or column of squares. Select the points so that each point is located inside of a checkered square. Do not draw the region outside the entire checkerboard pattern.

4. If you would like to redraw the region, click Define Region again and reselect the four points.

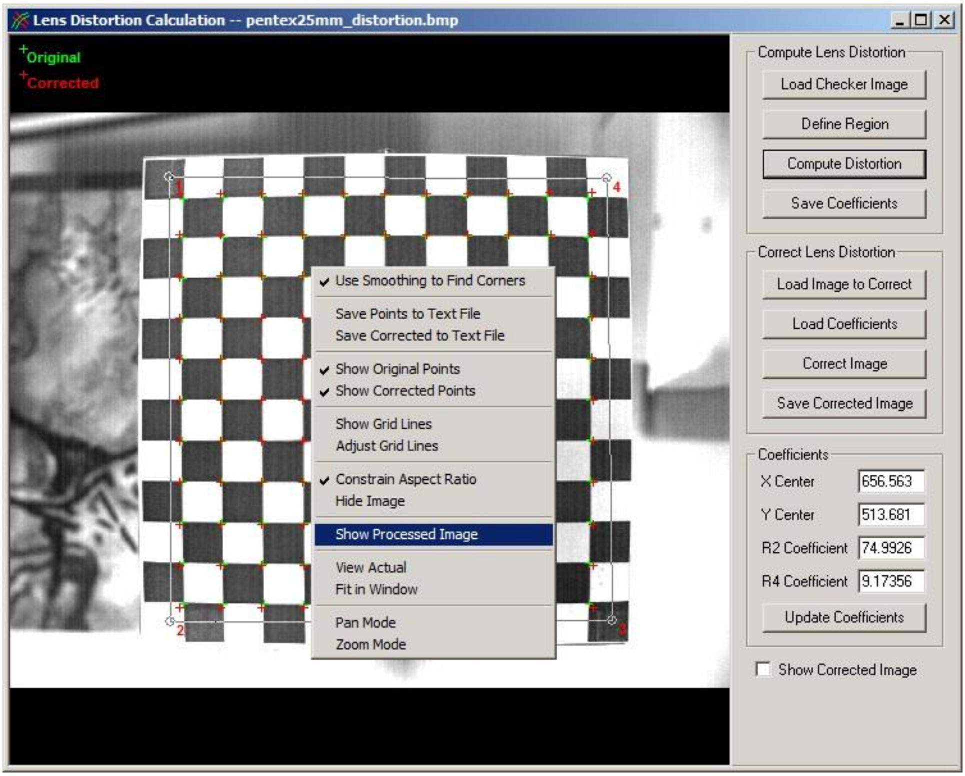
5. Click Compute Distortion. The distortion coefficients will be computed. If the R2 and R4 coefficients are zero, then lens distortion correction is not required. If you wish to view the corrected image, you can click the Correct Image button.

6. If you wish to save the coefficients to a file, click the Save Coefficients button to create a lens coefficient file (`*.lens`).



The four coefficients that are produced from the Lens Distortion Calculation can be manually input or loaded into the Lens Radial Distortion image processing filter to compensate for lens distortion.

If you encounter difficulties locating the checkerboard corners or computing the lens distortion, there are a number of tools available via the context menu.



Use Smoothing to Find Corners	Applies a smoothing filter on the image before attempting to locate checkerboard corners.
Save Points to Text File	Save the coordinates of the original corner points to a text file. This can be used to do your own custom processing on the corner points to determine the lens distortion correction.
Save Corrected to Text File	Save the coordinates of the corrected corner points to a text file.
Show Original Points	Show the green markers for the original checkerboard corner points.
Show Corrected Points	Show the red markers for the corrected checkerboard corner points.
Show Grid Lines	Show grid lines over the image. These lines can be used to manually set the distortion coefficients using trial and

error. Values can be manually entered into the edit boxes on the right panel. After clicking the Update Coefficients and Correct Image buttons, lines that should be straight in the image can be compared to the grid lines to determ- ine the effectiveness of the correction.

Adjust Grid Lines
: The grid lines that are displayed over the image can be adjusted to produce and inclined, non-perpendicular set of lines. Select this option and then click the left mouse button and drag the mouse in the image to adjust the grid lines.

Constrain Aspect Ratio
: The image is normally shown with the normal aspect ratio of the native image. The image can also be displayed with an unconstrained aspect ratio by checking this item. This option can be very useful in determining if a row of points is straight by adjusting the window size to pro- duce a skinny and tall image or a short and wide image.

Hide Image
: Check this option to hide the original image. This option is useful when you only wish to see the located and corrected point markers. This option is often used in combination with unconstraining the aspect ratio.

Show Processed Image
: This option can be checked to show the processed image that is analyzed to locate the checkerboard corners. If you are having difficulty in locating corners, you can examine the processed image and see what portions of the image are creating difficulties for the automatic location scheme.

View Actual
: Show the image at the actual image resolution.

Fit in Window
: Set the zoom so that the entire image is shown.

Pan Mode
: Select this mode to pan the image by clicking and dragging using the left mouse button.

Zoom Mode
: Select this mode to zoom the image by clicking and dragging using the left mouse button.

Multi-Plane Calibration

Overview

Calibrating an image serves the following functions:

- converts and scales the recorded video image to real-world dimensions (e.g. inches, meters, etc.)

- rotates the image to remove any unwanted tilt introduced during the recording process from the analysis process
- establishes an origin (0,0) and X,Y coordinate plane for motion analysis (direction of motion).

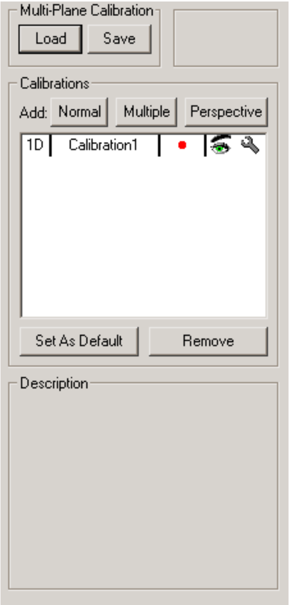
Image calibration requires measurement information about some feature in the image. We suggest that you include a horizontal ruler in the picture or some equivalent frame of reference that has both a well-defined scale and known rotational orientation. After an image is calibrated, you can change the units of measure at any time in each Calculations Window or Analysis pan- el.

Multiple calibrations can now be defined for a single video. Each calibration can either be a normal calibration or a perspective calibration. Other tracking and analysis toolkits can be set to assign specific calibrations to specific features. See the section on each analysis toolkit to find more information.

The multi-plane calibration is saved by default to a file with the same prefix as the video and with a '`mcl`' extension. This file is loaded automatically whenever the video is opened. If there is a previous single-calibration file with a '`clb`' extension present, the '`clb`' file will be loaded as the first normal calibration in the multi-plane calibration toolkit.

Multi-Plane Calibration Panel

The Multi-Plane Calibration panel contains a list of the calibrations that have been defined and a brief description of the currently selected calibration.



To add a normal calibration, click Normal. To simultaneously add multiple normal calibrations that are based on an existing Normal calibration, click Multiple. To add a perspective calibration, click Perspective. To remove a calibration, click on the desired calibration(s) in the list and then click the Remove button below the list of calibrations.

Each calibration must have a unique name. The names are used to identify which calibration is assigned to each of the analysis toolkit features. If the names are not unique, the first calibration in the list with the desired name will always be used. To change the name, double-click on the name in the list and set the new name in the dialog that appears.

Each calibration can also be given a different color. This aids in identifying the various calibration axes that are drawn in the video image. To change the color of a given calibration, click on the colored circle in the calibration list. A color selection dialog will appear.

One calibration must be set as the Default calibration. This calibration will have a 'D' following the calibration number in the list. This default calibration is used by the Annotations toolkit and some of the analysis toolkits that do not support setting of independent feature properties (e.g. Particle, Cell Tracking). The default calibration can be changed at any time by clicking on a calibration in the list and then clicking the Set As Default button.

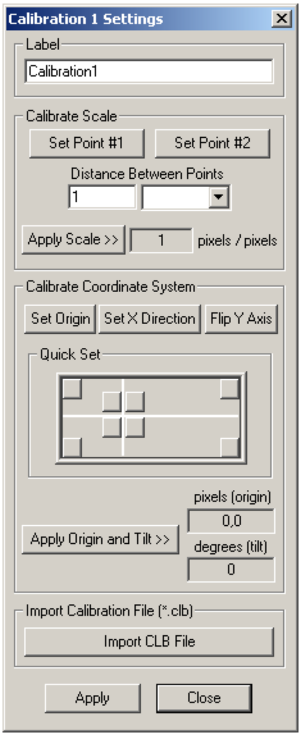
When a calibration is being edited, the calibration will also be drawn in magenta to highlight the changes that are being made. The changes are not actually applied to the selected calibra- tion until you click the Apply button at the bottom of the settings dialogs.

Normal Calibration

The normal calibration assumes that the plane of the video image is perpendicular to the camera. The normal calibration is capable of representing a constant scale factor across the entire image and perpedicular coordinate system. Two points in the video image that are separated by a known distance are used to compute a constant scale that is used across the entire image area. Two additional points are used to specify the origin and orientation of the perpendicular coordinate system. The X and Y coordinate axes must be perpendicular (90 degrees) to each other.

Calibrating the Scale

To set the calibration scale:



1. Within the video image, find a known frame-of-reference object. Left-click on one end of the object, using the reticle as a guide.

2. Click Set Point #1.

3. Within the video image, left-click on the other end of the known object.

4. In the settings dialog, click Set Point #2.

5. Type the distance between the points and choose the unit of measure from the drop-down list (e.g. inches, meters, etc.).

6. Click the Apply Scale >> button to set the scale factor.

Calibrating the Coordinate System

The coordinate system is defined to include the origin (0,0 point) and the X,Y axes. The co-ordinate system is used in the motion analysis of video.

To calibrate the origin and axes of the coordinate system:

1. Choose a point in the image that will serve as the origin of your coordinate system. Left-click on one end of the object, using the reticle as a guide. In the settings dialog, click Set Origin. The coordinate system marker moves such that its 0,0 position is on the selected

point. Note that the moved marker is shown in red and the original marker position is shown in purple.

2. Determine the appropriate positive X-axis direction, and left-click anywhere in the image in that direction. The coordinate X,Y markers will rotate to align the X direction with the new reticle position.

3. In the settings dialog, click Set X Direction.

4. In the image, the coordinate markers will automatically rotate to align the X axis between the origin and the current point.

5. A default Y-axis will also be drawn at a right angle to the X-axis. To flip the Y axis (e.g. reverse the positive Y direction), click the Flip Y Axis button in the Calibrate tab.

6. Click Apply Origin And Tilt >> Apply Origin and Tilt to set the calibration. The origin location and the tilt degrees are shown in the text boxes on the right side of the Calibrate tab.

You must click Apply at the bottom of the planar calibration dialog to apply the settings to the selected calibration.

Loading Old-Style Calibration Files

The previous calibration toolkit only allowed for a single Normal calibration. These calibra- tions were saved to files with the `CLB` extension. There are multiple methods for loading these `CLB` files into the new Multi-Plane Calibration toolkit:

1 If the `CLB` file has the default naming (the same prefix as the video file plus the `CLB` ex- tension), then the program will automatically load this file when the video is opened, and assign the calibration a default name of "From CLB File".

2 `CLB` files may still be added to Project files and loaded in the typical fashion (right-click in the project and select from the pop-up menu).

3 In the settings dialog for a Normal Calibration, buttons near the bottom of the dialog allow for loading of `CLB` files.

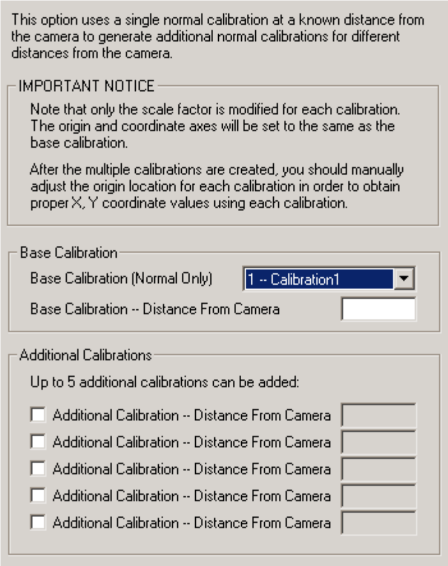
Adding Multiple Calibrations

Multiple normal calibrations can be added that are derived from an existing normal calibration. Typically this is done when the points used for calibration are at a known distance from the camera and you wish to define additional calibrations that are at different distances from the camera. As with all normal calibrations, all planes of motion should be parallel to one another and perpendicular to the camera. The distance from the camera to the known calibration must be known, and the distances to each of the new calibration planes must be known.

The normal calibration assumes that the plane of the video image is perpendicular to the cam- era. The normal calibration is capable of representing a constant scale factor across the entire image and perpedicular coordinate system. Two points in the video image that are separated by a known distance are used to compute a constant scale that is used across the entire image area. Two additional points are used to specify the origin and orientation of the perpendicular coordinate system. The X and Y coordinate axes must be perpendicular (90 degrees) to each other.

Adding Multiple Calibrations

To add multiple calibrations, click the Multiple button in the Multi-Plane Calibration panel. The following dialog window will appear:



Perform the following steps to add multiple calibrations:

1. Select the calibration that will be used to create the additional calibrations from the drop down list. This calibration must be fully defined before proceeding. If no defined calibration has been created yet, click Cancel and define a calibration first. Note that this calibration is only used to create the new calibrations. The resulting calibrations will not be linked together. So any subsequent changes to the base calibration will not automatically be propagated to the additional calibrations.

2. Enter the distance from the camera to the calibration plane in the base calibration.

3. Click the checkboxes for up to five (5) additional calibrations that will be created.

4. Enter the distance from the camera to each of the new calibrations that will be created.

5. Click Apply.

Please note that only the scale factors for the new calibrations have been modified. The origin and coordinate axes are copied from the base calibration. In most cases, these will not reflect the proper origin for the newly added calibrations. The origin and the coordinates axes for each new calibration should be modified to provide consistent XY coordinates over all the calibrations.

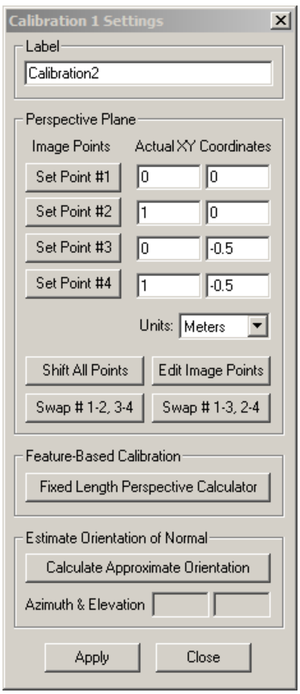
Perspective Calibration

The perspective calibration is capable of representing any perspective transformation of the image coordinates. This allows you to define planes of motion that are moving towards the camera, away from the camera, tilted upward or downward, or a combination of those.

Four points with known locations are required. These four points must lie in the same plane in the world. The four points do not need to be spaced equally apart. They can be at any location in the world, as long as they all lie within a single plane and the X and Y locations of these points in that plane are known. After you have entered these points, a perspective transforma- tion is computed that can calculate the real world coordinates of any point in the video image, assuming the point lies in the plane defined by the four known points.

Specifying Known Points

A typical method for performing perspective calibration would be to place a rectangular object of known size along the path of motion. Let us say that the object is square and has a width and height of 50 inches. We can then use the four corners of the object as the four known points.



To calibrate the perspective calibration:

1. In the video image, click on the upper-left calibration point (for example, the upper-left corner of the rectangular calibration object), then click Set Point #1 in the settings dialog.

2. In the video image, click on the upper-right calibration point (for example, the upper-right corner of the rectangular calibration object), then click Set Point #2 in the settings dialog.

3. Repeat for the lower-left calibration point and click Set Point #3.

4. Repeat for the lower-right calibration point and click Set Point #4.

5. If you wish to shift the entire set of four points in the image, click on the new location for point #1 in the image and then click Shift All Points.

6. If you wish to manually edit any of the four points in the image, click Edit Image Points.

7. If you have selected the points in the image in the wrong order, you can click the Swap #1-2, 3-4 or the Swap # 1-3, 2-4 buttons to adjust the point selection so that the points are ordered correctly.

8. Enter the real world X and Y coordinates of the points next to each of the Set Point buttons.

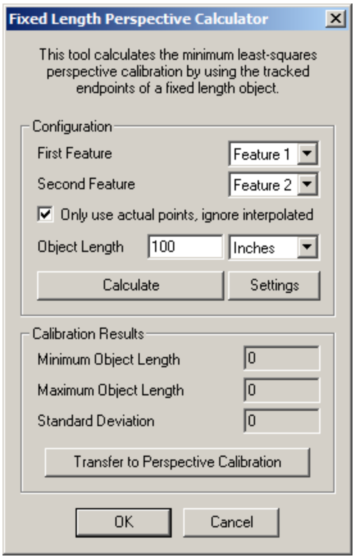
9. Select the units of the X and Y coordinates that you have just entered.

10. Click Apply, and the newly defined coordinate axes should be drawn in the image. Note that if the origin of your coordinate frame is computed such that it is outside of the video image, you may need to zoom out beyond the limits of the image to see the origin.

Fixed Length Perspective Calculator

The Fixed Length Perspective Calculator is a tool that calculates the best-fit perspective calibration for a fixed-length moving object. This tool can be useful for golf, baseball, or any application where a known-length object is moving in a flat plane.

The Fixed Length Perspective Calculator requires that a perspective calibration be added to a video and that Feature Tracking is enabled. At least two features must be automatically or manually tracked and located in at least 3 frames of video. The features can be actual or interpolated tracked points. The tracked features should mark the two endpoints of an object of known length that moves in a single plane of motion.



To use the fixed length perspective calculator:

1. Select the feature number for the first and second features that were tracked using Feature Tracking.
2. Check the Only use actual points, ignore interpolated box if you wish to only use actual tracked points. Uncheck the box if you wish to also use interpolated tracked points.
3. Enter the length of the object and select the proper units.
4. Click Calculate.
5. Upon completion, a results window will be shown. If the final error measure is less than 0.001, the results are satisfactory.
6. If the final error measure is more than 0.002, click Calculate again.
7. If the results are satisfactory, click Transfer to Perspective Calibration to apply the results to the perspective calibration.

Estimate Orientation of Normal

To approximately calculate the orientation of the normal to the plane corresponding to a perspective calibration:

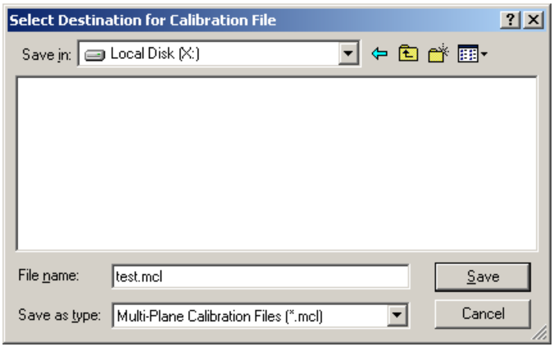
1. Click Calculate Approximate Orientation on the Calibration Settings dialog.
2. The message "Calculating Solution" appears briefly, and the estimated sign of Azimuth and Elevation angle results are shown in the fields.

3. Click Apply and then Close.

Saving and Loading Calibration Settings

To save the current calibration values to disk at any time, click on the Save File button in the Multi-Plane Calibration panel.

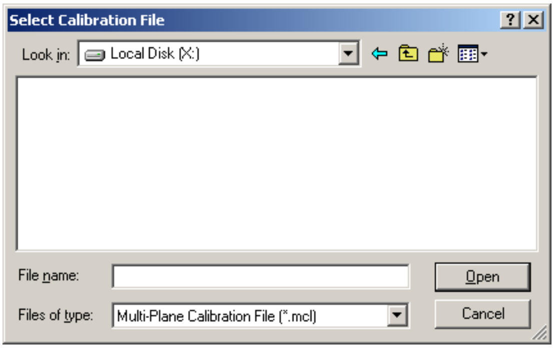
The Select Destination for Calibration File dialog box appears:



Enter the filename and click the Save button. Calibration files are saved with the `MCL` file extension.

To load a previously stored calibration onto an image, click the Load File button in the Multi-Plane Calibration tab.

The Select Calibration File dialog window appears:



Select the calibration file you wish to apply to the image and click the Open button.

Displaying Calibration Markers

The calibration markers can be toggled on and off the video in the Video window at any time -- for example, during image processing, during analysis or during normal viewing.

The visibility of the calibration marker is controlled via the right-click contextual menu or the Display Layers panel. To enable or disable the visibility of the calibration markers, right-click anywhere within the video, select Display Layers, and then Display Layers: Multi-Plane Calibration, or select Feature Tracking or Line Tracking, and then Show Calibration.

Line (1-D) Tracking

Overview

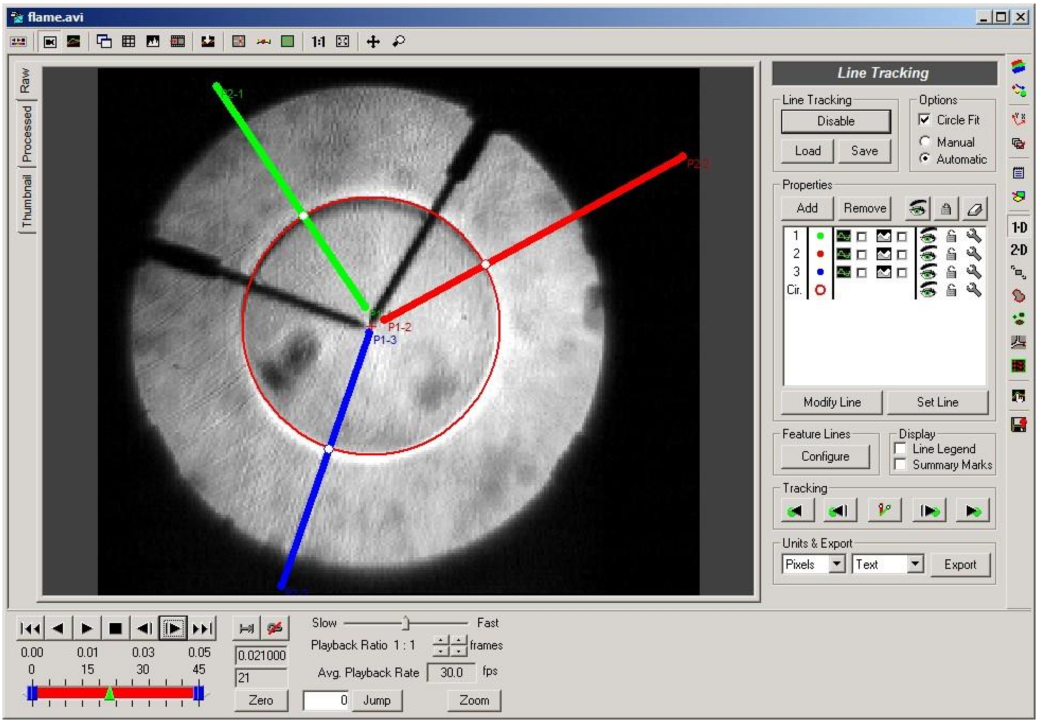
The Line Tracking control panel enables you to do automatic one-dimensional (1-D) tracking of features contained in your video files. This analysis toolkit allows you to place up to 64 lines in arbitrary locations within your video frame and detect features that match a given set of user-supplied criteria.

The toolkit is capable of detecting peaks in intensity or derivative of intensity along a line and detecting points of transition that exceed a configurable threshold value for intensity or derivative of intensity. You can limit your search to black-to-white transitions or white-to-black transitions or search for both. Up to 20 targets that satisfy the specified criteria can be found for each line in each frame of your video.

The Line Tracking control panel can also use the resulting data to compute a best-fit circle. A fixed center point for the circle may be specified, or a least-squares optimization method can be used to find the best center location.

The resulting line and circle information can be exported to Excel for reporting or more exhaustive analysis. The video scene scale and orientation can be calibrated to use real world units that can be used when exporting.

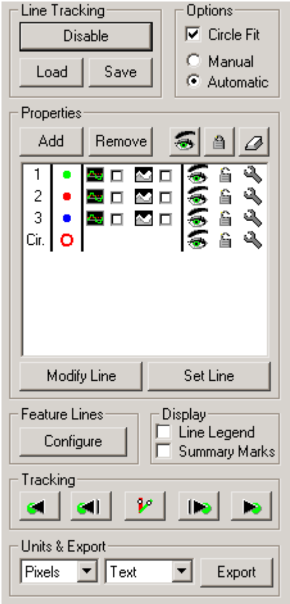
In this next image, the Line Tracking toolkit is used to find the leading edge of a flame front that is expanding out from the center. The lines are set to detect changes in intensity from black to white to detect the edge of the flame. A circle fit is also enabled to estimate the radius of the flame front.



Many tools for enhanced visualization of line information are provided. The Line View win- dow provides instant feedback for configuring the location, threshold, thickness, and other set- tings that will produce the best results for your tracking needs. The Summary View generates a bitmap image of the pixels or their derivative along a given line as a function of time, giving you a snapshot of your complete video in a single image.

Line Track Panel

The Line Track Panel follows the standard layout of analysis toolkits.



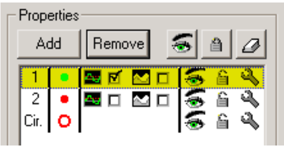
Brief summary of the various controls on this panel:

Enable/Disable	The first step in any Line Track analysis is clicking the Enable button in the upper left of the panel. This initializes memory and sets up configuration information. This must be done for each video that you wish to analyze. When you are done with the analysis, you can click this button again to disable the Line Track analysis and free the associated memory.
Load	Saved Line Track analysis files can be loaded using this button. All tracking results except for the summary view contents will be reloaded from the saved file. Line Track files are saved with the `LTK` file extension.
Save	Save Line Track analysis configuration and results to a file. All tracking results except for the summary view contents will be saved to the file. Line Track files are saved with the `LTK` file extension.
Circle Fit	Enable circle fitting for this analysis. This will add another row, labelled 'Cir.', in the Properties section of the panel through which the circle fitting parameters can be set.
Manual	Set point selection to Manual mode. This mode allows you to manually select points in the video and store them as track points. When in Manual mode, the closest point on the currently selected line is added when the Set Point (Set Line) button is clicked.

Automatic	Set point selection to Automatic mode. This is the nor- mal behavior. In this mode, tracking of line transitions is done automatically when Track Forward or Track Back- ward are clicked.
Add	Add a new line to the analysis. The line will be added in the default location (horizontal across the center of the video). Use the Modify Line and Set Line buttons to change the location of the line.
Remove	Remove a line from the analysis. Select the line to re- move by clicking on the appropriate row in the proper- ties section. Then click the Remove button.
Toggle Visibility of All Lines	Show or hide all lines in the analysis. If the majority of lines are currently visible, all lines will be hidden. If the majority of lines are hidden, all lines will be shown.
Toggle Lock on All Lines	Lock or unlock all lines in the analysis. If the majority of lines are currently unlocked, all lines will be locked. If the majority of lines are locked, all lines will be un- locked.
Clear All	Clears all analysis results for all lines. A message box will appear to confirm that you wish to delete all analysis results. The line locations and properties will remain the same.
Modify Line	Modify the location of the line in the video. Click this button and then click and drag the mouse over the video image at the location where the line should be placed. If you would like to keep one endpoint fixed and modify the other, you can move your mouse over the endpoint (marked P1 or P2) and drag just that end point to a new location. When you are satisfied with the line that you have placed, click the Set Line button. Holding down the **Control** key while dragging the mouse will constrain the line to be drawn horizontally or vertically.
Set Line	This button is only used to complete a Modify Line oper- ation. Click Modify Line and set the line location as de- sired, then click Set Line to accept the new location of the line. In Manual mode, this button changes to the Set Point button to manually select a track point for the cur- rently selected line.
Configure Feature Lines	Lines can be configured to be drawn between tracked features. Click on this button to display the Line Config- uration dialog. The feature line configuration is identical to the feature line configuration in the Feature (2-D) Tracking toolkit. See the section called “Configure Lines” for more information.

Line Legend	When enabled, displays a legend in the upper left corner of the video image indicating the coordinates of each of the analysis lines.
Markers in Summary View	When enabled, red markers will be displayed in the Summary Views to show the location of the tracked points on each line. Since the Summary Views are regenerated each time a video is tracked, you must re-track the video in order for a change to take effect.
Track Backward	Perform the line track analysis from the current frame backward in the video. When tracking is in progress, you can click on the center button to Abort tracking.
Track One-Frame Backward	Perform the line track analysis for the previous video frame only.
Track Current Frame	Perform the line track analysis for the current video frame only.
Track One-Frame Forward	Perform the line track analysis for the next video frame only.
Track Forward	Perform the line track analysis from the current frame forward in the video. When tracking is in progress, you can click on the center button to Abort tracking.
Export	Exports the results for the line tracking and circle fit. The export units are specified by the left most drop-down selection. The export format is specified using the middle drop-down selection.

The properties listing is composed of seven columns.



Line Number/Circle	Line number or circle indicator for each line. Double-clicking on this column will also bring up the settings dialog for the given line or circle.
Line Color	Each line is automatically assigned a color when added, however, if you wish to change the color for any reason, click on this column and a color selection dialog will appear.
Line View	Click on the checkbox next to the graphic icon to display the line view for the given line.

Summary View
: Click on the checkbox next to the graphic icon to display the summary view for the given line.

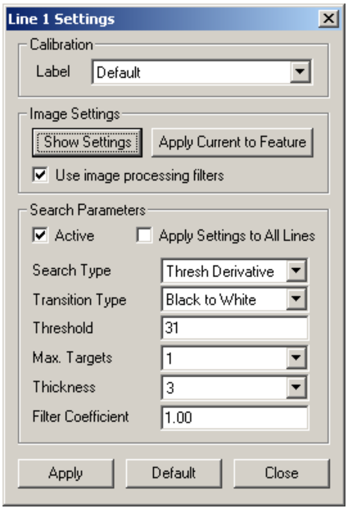
Visibility
: Each line can be displayed or hidden individually. This does not affect whether or not a line is used in tracking (for that, use the Active check box in the settings dialog). This setting only affects whether or not the line is drawn in the image.

Lock/Unlock
: Lock or unlock this line. If a line is locked, the tracked points and settings will not be modifiable.

Settings
: Click on this icon to show the settings dialog for this particular line or circle.

Line Properties

The Line Properties dialog allows configuration of how tracked points are determined for each line. The Line Properties dialog is accessed by double-clicking on the line number or clicking on the Settings icon in the Properties section of the Line Track control panel. 



Calibration
: Each line can use its own calibration (see the section called "Multi-Plane Calibration") settings. The list of currently defined calibrations is shown in the drop down box. Select the specific calibration label to be used with this line, or select Default to use whichever calibration is set as the default calibration.

Show Settings
: Each line can maintain its own set of Image Processing (see the section called "Image Processing") settings. These LUT settings are typically the settings that were

active when the line was added. Click on this button to display the image using the image processing (LUT) settings associated with this line.

Apply Current to Feature

This button allows the image processing (LUT) settings for a given line to be changed to whatever settings are currently active. In order to change the LUT settings associated with a line, change the LUT settings so that the desired appearance is achieved (see the section called “Image Processing”), and then click this button.

Use image processing filters

While each line can have its own set of Image Processing settings, all lines share the single set of Image Filters (see the section called “Image Filtering”) defined for the video. However, each line can be set to use the image fil- ters or to not use them. Check this box to have the image filters applied to the video for this particular line when analyzing.

Active

This box indicates whether or not this line will be included in the tracking. If the line is not active, no points will be tracked. This is useful if you wish to temporarily disable a line without having to remove it.

Apply Settings to All Lines

If this box is checked, then any modifications you make to the line properties will be applied to all lines that are currently present. Any lines that are added later will not automatically have these settings. Instead, newly added lines will start off with the default properties.

Search Type

There are four possible search types:

- Peak Intensity
- Peak Derivative
- Threshold Intensity
- Threshold Derivative

The peak intensity setting returns the point of highest intensity along the line. The peak derivative setting returns the point of highest derivative along the line. These two settings always return a single target. The threshold value is not applicable for these search types.

The threshold intensity and threshold derivative settings require a threshold value and can return multiple matches for each frame. For threshold intensity, the search will return points where the pixel intensity crosses the threshold value in either the positive or negative direction or both depending on the transition type selected. For the threshold derivative, the search will return points where the magnitude of the derivative (change in pixel intensity) exceeds the specified threshold. The threshold will apply to positive or negative derivative values or both depending on the transition type selected.

Transition Type

There are three possible transition types:

- Black to White
- White to Black
- Both

For the threshold intensity search type and a black- to-white transition type, the program will search for points where the intensity value crosses the threshold value from a darker pixel to a lighter pixel. For white- to-black transitions, the program will search for points where the intensity value crosses the threshold value from a lighter pixel to a darker pixel. If a selection of both is made, then both darker-lighter and lighter-darker threshold crossings will be found.

For the threshold derivative search type and a black- to-white transition type, the program will search for points where the derivative (change in intensity) exceeds the threshold in the positive direction. This is because a black-to-white transition would have a positive derivat- ive value. For a white-to-black transition type, the pro- gram will search for points where the magnitude of the derivative (absolute value) exceeds the threshold in the negative direction, since white-to-black transitions would have negative derivative values. If a selection of both is made, then the program searches for any points where the absolute value of the derivative exceeds the threshold. Not all points that exceed the threshold are re- turned, only the points at which a transition is made from before the threshold to beyond the threshold.

Threshold

The threshold value is used for the threshold intensity and threshold derivative search types. In general, the threshold value is always positive and the transition type dictates which direction of crossing is examined for in- tensity and which sign of the derivative is examined. See the previous section on transition type for more details.

A negative threshold does not make sense for a threshold intensity search type. However, for the threshold derivat- ive search type, one case in which the threshold value could be negative would be if your image had regions of large derivative and you wish to find regions of small de- rivative. For instance, if the derivative along a line is primarily negative and then approaches zero in the region of interest, you could select a black-to-white transition type and specify a negative threshold value.

The Line View window discussed in this section will greatly aid in specifying an appropriate threshold value for each case.

Max. Targets

The maximum targets setting specifies how many matches should be detected for each line in each frame. The value can range from 1 to a maximum of 20. For the peak intensity and peak derivative search types, only a single point can be returned. Therefore, the maximum targets setting is only applicable for the threshold search types. In the threshold cases, multiple points may satisfy the threshold and transition criteria. The setting of max- imum targets allows you to limit your consideration to a fixed number of points.

Thickness

Two techniques are provided to handle noisy image data. The thickness of each line is configurable, up to a maximum width of 20 pixels. The program will average the pixel values along a direction perpendicular to the line. In addition to specifying thickness for each line, you are also able to specify the coefficient for a first order filter that is applied to smooth the pixel data before pro- cessing.

The thickness of each line can be set from between 1 and 20 pixels. Increasing the thickness of a line can be used to smooth the intensity values used by the program for detecting transitions. For a line thickness greater than 1, the intensity value for a given point is computed as the average of the intensity values at neighboring points along a line perpendicular to the P1-P2 line. The thick- ness of the line governs how many neighboring points to use when computing the average.

The thickness of the line drawn in the video image will reflect the actual thickness setting. You can use this to visualize which pixels will be used for the averaging computation.

Filter Coefficient

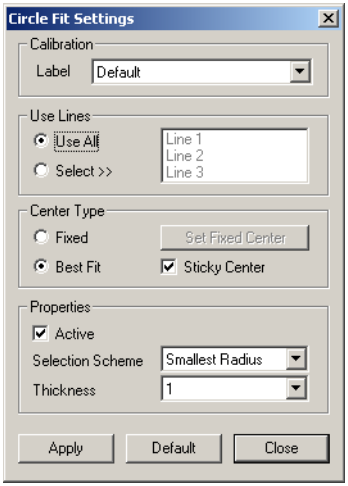
Two techniques are provided to handle noisy image data. The thickness of each line is configurable, as described above. In addition to specifying thickness for each line, you are also able to specify the coefficient for a first order filter that is applied to smooth the pixel data before processing.

The filter coefficient provides another means to smooth the pixel data prior to searching. The filter is a first-order

	filter applied to the intensity values from P1 to P2. A value of 1.0 produces the exact unfiltered intensity val- ues. Values less than 1.0 will smooth the data and values greater than 1.0 will introduce more noise.
Apply	Apply the settings to the line or all lines. Changes will not be applied unless this button is clicked.
Default	Load the default settings for the line properties into this dialog. The settings are not applied until the Apply but- ton is clicked.
Dismiss	Close the dialog. Settings will not be applied unless the Apply button was clicked.

Circle Properties

The Circle Properties dialog allows configuration of the circle fit. The Circle Properties dialog is accessed by double-clicking on the "Cir." label or clicking on the wrench icon in the Proper- ties section of the Line Track control panel. To enable circle fitting, check the Circle Fit box in the upper left of the Line Track control panel.



Calibration	The circle fit can also use its own calibration (see the section called “Multi-Plane Calibration”) settings. The list of currently defined cal- ibrations is shown in the drop down box. Select the specific calibra- tion label to be used with the circle fit, or select Default to use whichever calibration is set as the default calibration.
Use Lines	Not all of the lines that have been added may be intended for use by the circle-fitting algorithm. You can selectively choose which lines will be used by checking the appropriate boxes. If not all the lines

will be used, you must uncheck the 'Use All' box before un-checking the boxes for the lines that will not be used.

Fixed Center

When computing the best-fit circle, a fixed center location can be used or a variable center can be used. When using a fixed center, the algorithm tries to find the best radius that will fit all the points.

The fixed center will default to the center of the video image. If a different center should be used, click your mouse in the video image at the desired point and then click on the Set Center button. A red '+' mark will be shown when the fixed center type fit is being used, to indicate the location of the center.

Best Fit Center

When using three or more lines, the best location (in a least-squares sense) for the center and the corresponding value for the radius of the circle can be computed for each frame. A gradient descent approach is used to compute the location of the center and the radius.

When using the best-fit center, the quality of the line track results will greatly affect the circle-fitting algorithm. For instance, if you are using three lines and at a particular frame only two of the lines found suitable transition points, then best-fit circle for two points would place the center at their midpoint and have a radius of half the dis- tance between them. This will likely be nowhere near the center found for the case when all three lines found suitable transitions. For these situations, it may be helpful to check the Sticky Center box. When this is checked, if the number of transition points drops from three or more down to two or one, then the previously computed cen- ter is used as if it were a fixed center until three or more transition points are found again.

Active

The circle-fitting algorithm can be activated or disabled using this checkbox. If the circle fitting is disabled, then new fit values are not computed during tracking. Any prior circle fit values or circle fit settings will remain. This is equivalent to locking the circle in the Line Track control panel.

Selection Scheme

When multiple targets are available for a given line, the circle-fitting algorithm must decide which among these multiple targets to use for the fit. There are four different possible techniques for the algorithm to use in selection. These are:

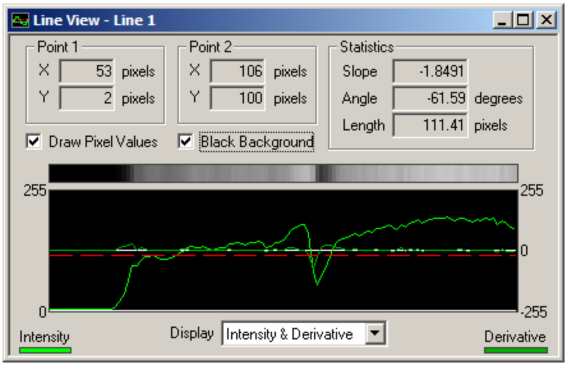
- Smallest Radius
- Largest Radius
- Closest to Previous
- Closest to Predicted

The Smallest Radius option would select the point that is closest to the last computed center. The Largest Radius option would select the point that is farthest from the last computed center. The Closest to

	Previous option would select the point that is closest to the last point that was selected for this line. And the Closest to Predicted would use the selected points from the last frame and the frame before to predict where the point would be in the current frame and then se- lects the point which is closest to this prediction.
Thickness	This option allows you to specify how thick the circle is drawn. It is only used for visual representation of the resulting circle and has no impact on any part of the algorithm.
Apply	Apply the settings to the line or all lines. Changes will not be applied unless this button is clicked.
Default	Load the default settings for the line properties into this dialog. The settings are not applied until the Apply button is clicked.
Dismiss	Close the dialog. Settings will not be applied unless the Apply button was clicked.

Line View

The Line View provides valuable information for selecting appropriate line properties to produce the best tracking results. There are separate Line View windows for each line.



Across the top of the window, the line view shows the coordinates of the end points P1 and P2 and basic statistics for slope, angle, and length of the line. The slope is the change in X divided by the change in Y from P1 to P2. The angle is the angle relative to horizontal, with 0 degrees corresponding to P2 located to the right of P1. The length is the length of the line from P1 to P2 in pixels.

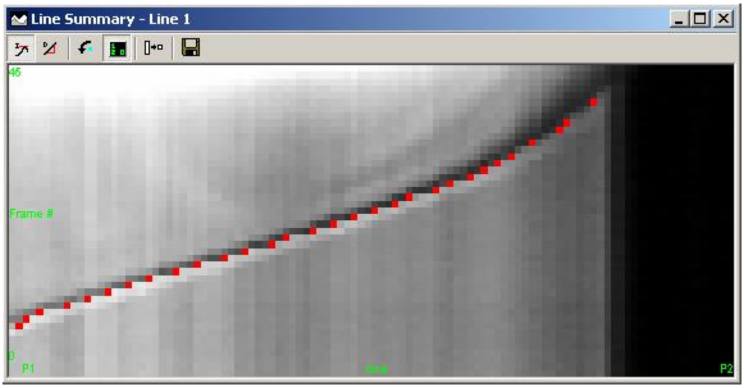
The main portion of the line display window is a graph of the intensity and derivative of the pixels of the image corresponding to the particular line. The Display selection beneath the graph allows you to select whether to view just the intensity, derivative, or both. The units for intensity are along the left side of the graph and the units for derivative along the right. The threshold line is shown as a red dashed line.

Two checkboxes are provided to display the pixels values and to use a black background. Displaying the pixel values will draw the intensity values of the pixels corresponding to the line in the rectangular bar above the main graph. The intensity values used are values after the averaging from the thickness of the line and after filtering. Use the black background option if you have chosen a light color for your line which is difficult to see with the white background.

To aid in visualization, you can change the vertical scale of the main graph by clicking on the graph and either rolling your mouse wheel or pressing **A** or **Z** on your keyboard. You can pan the graph in the vertical direction by either clicking and dragging with your left mouse button or pressing **S** and **X** on your keyboard. Double-clicking in the graph window will reset the zoom and pan to the default values.

Summary View

After (or during) a tracking run, you can bring up a Summary View for each of the lines. The Summary View contains images that are composed from the intensity and derivative values under the line for each frame in the video.



One axis represents the pixels from P1 to P2 and the other axis represents frame number (or a measure of time). If you have selected Markers in Summary View in the Line Track control panel, then red pixels will be drawn at the locations where points were found that match your specified transition criteria.

All options for the Summary View are accessed via the toolbar or context menu. You can bring up the context menu by right-clicking in the window. The same options are available from both the toolbar or context menu.

Show Intensity	View the intensity summary image. Each line in the image represents the value of the pixels underneath the line in each frame of the video.
Show Derivative	View the derivative summary image. Each line in the image represents the derivative of the pixels underneath the line in each frame of the video.
Show Rotated	View the image as pixels versus frame number or frame number

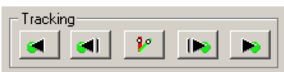
	versus pixels.
Show Axis Labels	Shows or hides the axis labels shown in green at the left and bottom of the image.
Make Pixels Square	The summary view window can be resized arbitrarily. This will sometimes distort the pixels so that they are rectangular, not square. Pressing this button will use the current width of the win- dow and adjust the height of the window such that the pixels are drawn square. Note that this may result in the window being res- ized off the bottom of the screen. In this case, either drag the win- dow to a smaller width and perform this operation again or rotate the image and then make the pixels square.
Save Image to File	Use this button to save the currently displayed image can to a bitmap file.

The summary view can be a useful tool for analyzing tracking results. For instance, in the previous image, the flame front edge is shown by the red markers. We can measure the angle of the line formed by the markers to estimate the velocity of the edge. We can also note that the red markers form nearly a straight line in the center of the image, but deviate from the line at the beginning and end. This indicates that the edge is speeding up or slowing down during those periods.

Tracking

After lines have been placed and properties defined, in order to obtain results, tracking must be run. All tools described so far are used for setting up the parameters for tracking but do not actually execute any of the line search or circle-fitting algorithms.

When you are satisfied with your line and circle properties, click on the Track Forward or Track Backward button to begin tracking. Tracking will commence from the currently dis- played frame until the end or beginning of the video. When tracking is running, the track but- tons will change to an Abort button. Clicking on Abort will stop the tracking.



Since tracking begins from the currently displayed frame, in most situations, you will want to jump to the first frame of the video before beginning tracking. You can do this by clicking on the double-backward arrow button in the Play Controls (see the section called “Play Controls”).

If you begin tracking forward from an intermediate frame of the video, all tracking results prior to that frame will be preserved. In this manner, you can use one set of tracking parameters for the first portion of a video and a different set for the second portion. Similarly with tracking backward.

If you wish to observe the tracking results frame-by-frame, you can use the single-step tracking buttons: Track One-Frame Backward and Track One-Frame Forward. This will perform the analysis on one frame only and then stop. In addition, if you simply wish to process the current frame, click on the Track Current Frame button in the center. This is useful if you are tuning your tracking parameters. You can adjust the parameters, analyze the current frame, and see the effect on the current frame.

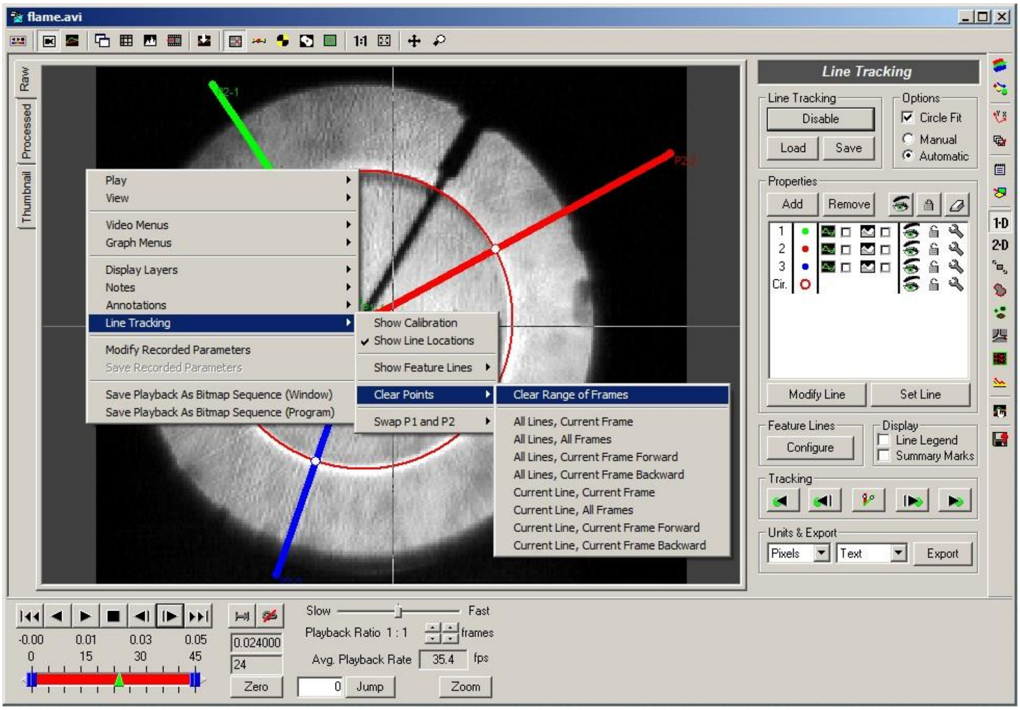
Manual Tracking

Manual tracking is performed on a per-frame basis; the user cycles through each relevant frame and manually marks the feature locations by clicking the mouse. Manual tracking mode is selected by clicking on the Manual mode in the upper left corner of the Line Tracking control panel.

To add a manual point or to modify the location of a point:

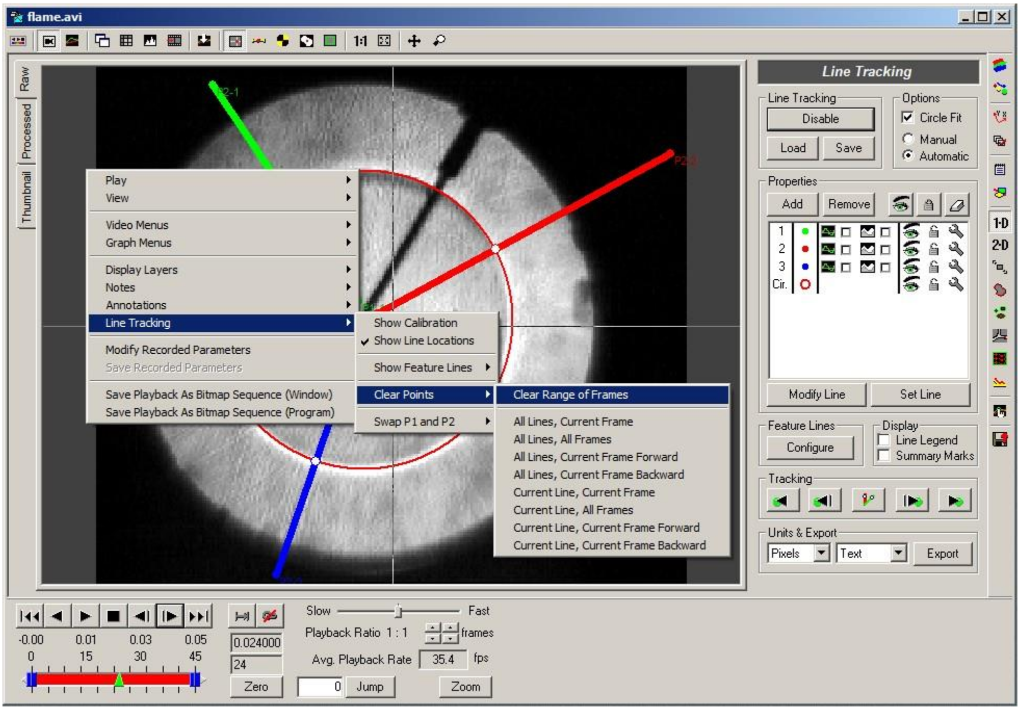
1. Select the line in the line properties list that you wish to add a track point to by clicking on the corresponding row.
2. Click in the image window to place the reticle in the desired position.
3. Click the Set Point button in the Line Track control panel.

To remove a point, use the Clear Features context menu (right-click in the window).



Additional Display Options

Additional options for changing display settings, clearing points, or swapping the orientations of lines are available via the context menu.



Show Calibration

Show or hide the current calibrations that have been defined.

Show Line Locations

Show or hide the line track lines. This option behaves differently than the visibility setting in the list of lines. The track points will still remain visible even if the corresponding lines have been hidden when using this option.

Show Feature Lines

Show or hide the lines drawn between tracked points that were defined using the Feature Lines, Configure button in the Line Tracking panel. See the section called "Configure Lines" for more information.

Clear Points

Clear a single point for a single line or clear many points for multiple lines using the options in this submenu.

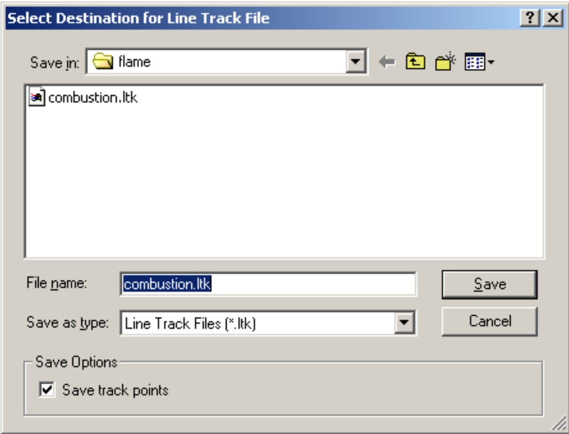
Swap P1 and P2

The direction in which a line is drawn can be critical, since edges are detected by moving along the line from P1 to P2. Use this option to swap the locations of P1 and P2 for a single line or all lines.

Saving and Loading

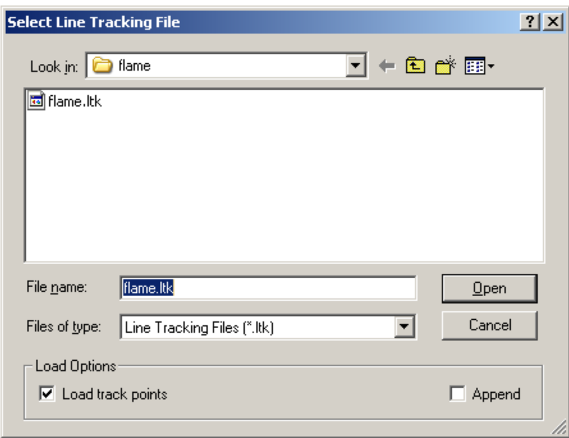
All Line Track settings and results can be saved to a file for later use. This allows you to do multiple analyses on the same video file, store the configuration and results, and later load the appropriate analysis whenever you need it. Line Track settings saved from one video can also be loaded on another video. This allows you to configure the line track lines and settings for one video, then load and apply these settings to many more videos where the same type of ana- lysis is to be conducted.

To save the analysis settings and results, click the Save button at the top of the Line Track panel. Line Track settings and results are stored to files with the `LTK` file extension.



If you only want to save the feature settings, uncheck the Save track points checkbox in the Save Options. This is useful if you intend to use this file to define line and circle settings for different videos.

To load a saved analysis file, click the Load button at the top of the Line Track panel.

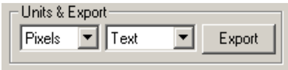


Uncheck the Load track points checkbox in the Load Options if you do not want to load the track points stored in the file. This is useful if you only want to use the line and circle settings contained in a track file that may have been saved from a different video.

If the Append checkbox is selected, the lines and track points from the selected file will be appended to any lines that are currently configured. This is a useful method for comparing results from two different analyses of the same video.

Units and Exporting

After a successful tracking run, you can export the data to a variety of formats to perform any additional custom analysis or graphing. The units used for exporting and graphing can be selected here.



Units
: You can select what set of units to use for exporting the tracking results. If no calibration has been done on the video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.

Format
: You can select what format to export to: Text, Excel Blank, Excel Template, or Diadem. Results for each of the lines and for the circle fit will be exported to the resulting file.

  In all formats, the line settings and the line track data will be output for each line and the circle fit settings and circle fit data will be output.

  The line track data is composed of the following information: frame number, time (if we know the record rate of the video), the X and Y coordinates of the tracked point, the distance from the tracked point to P1 along the line, whether the transition was white-to-black or black-to-white, and the intensity level of the image at the tracked point. If multiple targets were allowed for each line, then for every frame, there will be multiple rows in the output, one for each target. Values of 1 indicate that a tracked point was not found for that frame.

  The circle fit data is composed of the following information: frame number, time, the X and Y coordinates of the center, and the radius. If a fixed center was selected, then the X and Y coordinates of the center will always be the same.

  When exporting to a text file, information for each line and for the circle fit is appended to the single output text file. WordPad will be launched on the text file that was just exported.

  For Excel Blank, a new workbook will be created that contains multiple sheets. The first set of sheets will correspond to each of the lines that have been added. The last sheet will contain the circle-fitting results. Excel Template produces the same results, however, the data is imported into an existing Excel file that is used as a template. You can put in any formulas and graphs into the template file, and these will be recomputed and regenerated when the new data is exported into it.

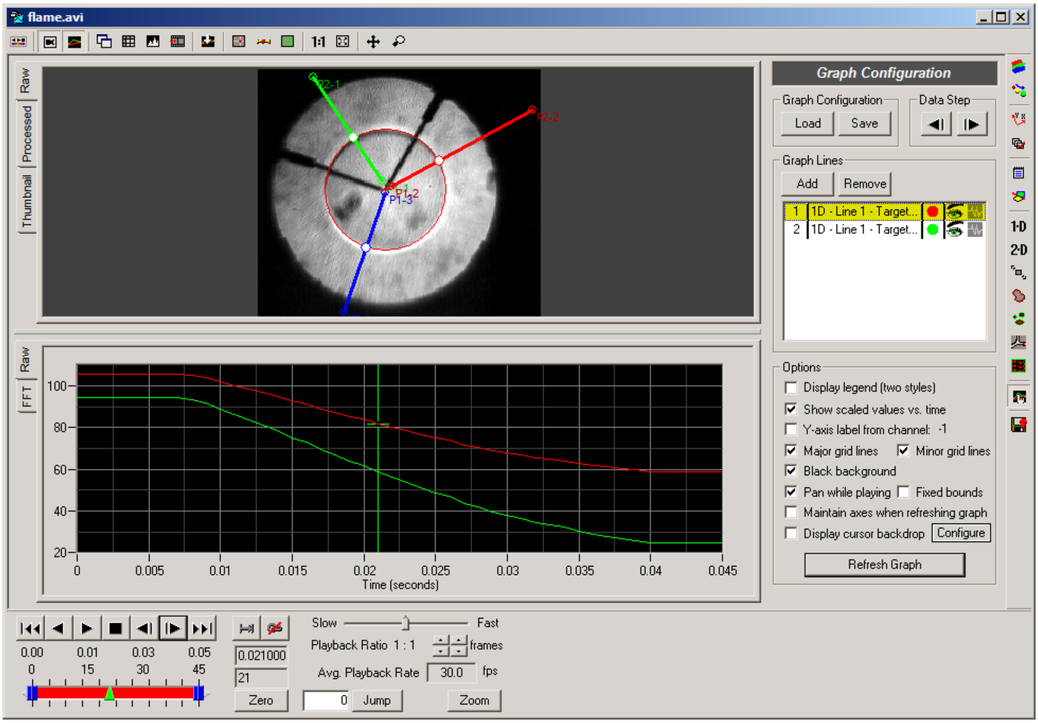
  For Diadem, the results are exported to a `DAT` file that can be loaded by Diadem.

Export
: When you are satisfied with your tracking results, and have selected your export units and format, click the Export button to export the results.

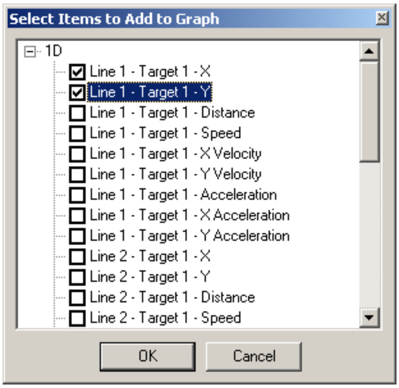
See the section called “Exporting Data or Analyses” for additional details regarding exporting.

Graphing

Line tracking results can be immediately displayed in the Measurement Window graph section. Once line tracking is complete, use the Graph Configuration control panel to add line tracking results to the graph section.



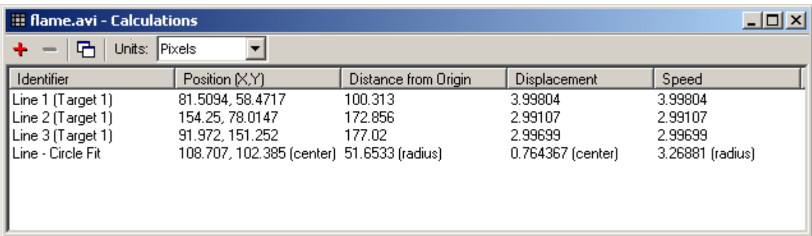
After clicking the Add button, a listing of available items to graph is presented. For each line and target, the X and Y coordinates, distance to the origin, and speed can be graphed. In addi- tion, if any feature lines have been configured to display angle or line dimensions, these can also be graphed. Select the items that you wish to graph and click the OK button at the bottom of the dialog.



For more details on configuring the other options in the Graph Configuration panel, see the section called “Display Settings”.

Calculations

Immediate simple calculation results such as position and velocity can be displayed for each line and circle using the Calculations Window associated with a Measurement Window.



See the section called “Calculations Window” for more details.

Feature (2-D) Tracking

Overview

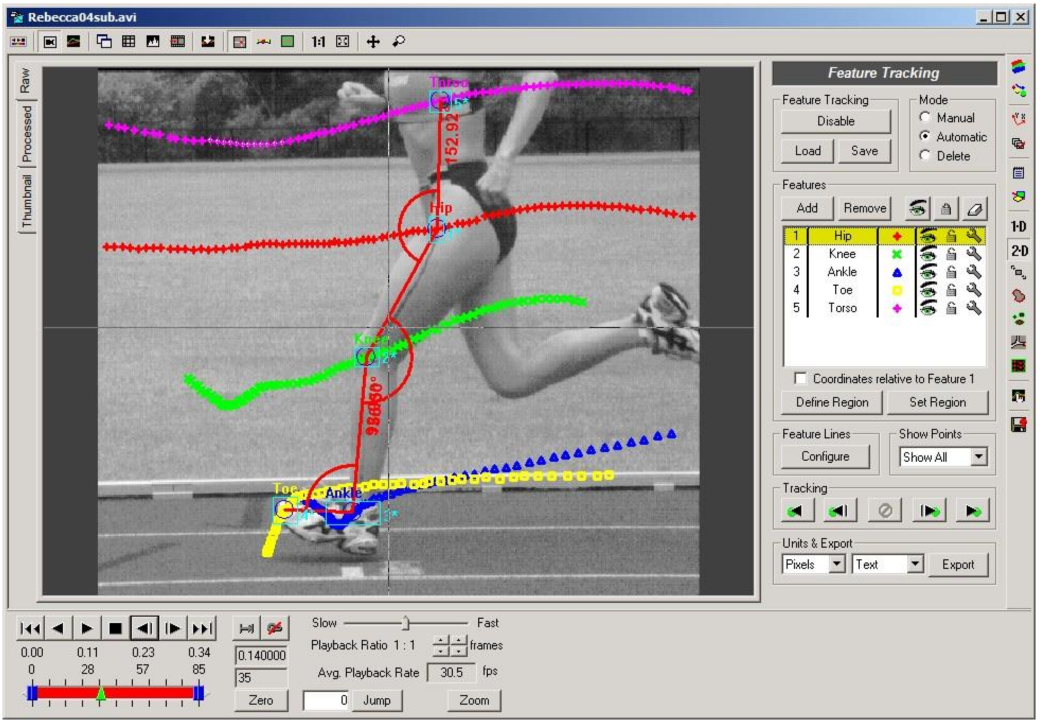
Tracking is the ability to select a distinct feature and determine its frame-by-frame motion characteristics (e.g. position, velocity, etc.) over time, with respect to the plane of the image.

There are two general methods of tracking:

- Automatic (Auto) Tracking asks the user to select the feature location in a single initial frame. The feature is defined as a rectangular region of pixels in the initial frame. Auto Tracking then does all the work of stepping through subsequent frames, while automatically finding and tracking the feature along the way. This method is effective for most applica- tions.

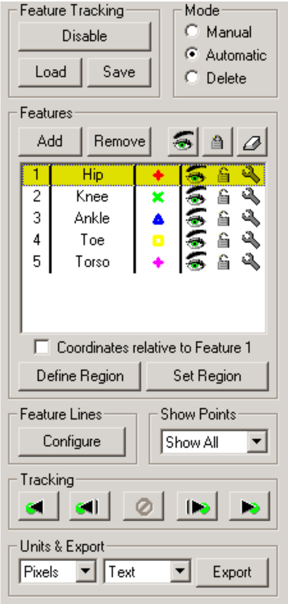
- Manual Tracking requires the user to step through the video one frame at a time, using the mouse to select the location of the feature in each frame. This method is preferable for low-quality images or very irregular feature paths not suitable for Auto Tracking.

A total of 256 features can be defined for tracking. Points can be defined for each of these features using automatic tracking or manual tracking or both.



Feature Track Panel

The Feature Track Panel follows the standard layout of analysis toolkits.



Enable/Disable	The first step in any Feature Track analysis is clicking the Enable button in the upper left of the panel. This initializes memory and sets up configuration information. This must be done for each video that you wish to analyze. When you are done with the analysis, you can click this button again to disable the Feature Track analysis and free the associated memory.
Load	Saved Feature Track analysis files can be loaded using this button. All tracking results and feature configuration will be reloaded from the saved file. Feature Track files are saved with the `FTK` file extension.
Save	Save Feature Track analysis configuration and results to a file. All tracking results and feature configuration will be saved to the file. Feature Track files are saved with the `FTK` file extension.
Manual/Automatic/Delete Mode	Select whether the tracking toolkit should operate in Manual, Automatic, or Delete mode. The mode only affects how new track points are added to or removed from the analysis. You can switch between Manual, Automatic, and Delete mode at any time.
Add	Add a new feature to the analysis. Use the Define Region and Set Region buttons to define a template for the feature.
Remove	Remove a feature from the analysis. Select the feature to remove by clicking on the appropriate row in the proper-

	ties section. Then click the Remove button.
Toggle Visibility of All Features	Show or hide all features in the analysis. If the majority of features are currently visible, all features will be hidden. If the majority of features are hidden, all features will be shown.
Toggle Lock on All Features	Lock or unlock all features in the analysis. If the majority of features are currently unlocked, all features will be locked. If the majority of features are locked, all features will be unlocked.
Clear Selected Feature(s)	Clears all analysis results for the selected features. A message box will appear to confirm that you wish to delete the track points.
Coordinates relative to Feature 1	Check this box to compute all coordinates relative to Feature 1. This option allows you to compute the relative motion between two moving features.
Define Region/Interpolate	When in automatic mode, click on this button to define a region for a feature. Click and drag a rectangle in the image to be used as a template for a feature. After dragging a rectangle, it may be repositioned by clicking and dragging it in the image. Click the Set Region button when you are satisfied with the region you have defined, or click Define Region again to redraw another rectangle. When in manual mode, this button becomes the Interpolate button. Click on this button to perform interpolation for any frames that do not have track points.
Set Region/Set Point/Delete Point(s)	When in automatic mode, click Set Region when you are satisfied with the feature region you have defined after pressing Define Region. When in manual mode, click Set Point when the reticle is located over the point in the image where you would like to add a feature point. When in delete mode, click Delete Point(s) to delete the currently highlighted points.
Configure Feature Lines	Lines can be configured to be drawn between tracked features. Click this button to display the Line Configuration dialog.
Show Points	The track points from all frames, past frames, the current frame, or no track points can be shown in the video.
Track Forward	Perform the automatic feature track analysis from the current frame backward in the video. When tracking is in progress, click the center button to Abort tracking.

Track One-Frame Forward	Perform the automatic feature track analysis for the next video frame only.
Track Backward	Perform the automatic feature track analysis from the current frame backward in the video. When tracking is in progress, click the center button to Abort tracking.
Track One-Frame Backward	Perform the automatic feature track analysis for the previous video frame only.
Export	Exports the results for the feature tracking. The export units are specified by the left most drop-down selection. The export format is specified using the middle drop-down selection.

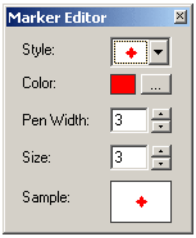
The feature properties listing is composed of six columns.

Feature Number	Indicates the feature number. Double-clicking on this column will also bring up the Track Settings dialog for the given feature.
Feature Label	Displays the label for the feature. The label is set in the Track Settings dialog that appears when the Settings column is clicked.
Marker	Displays the marker for the feature. The marker can be modified by double-clicking on this column to bring up the Marker Editor.
Visibility	Each feature can be displayed or hidden individually. Click on this column to hide or display track points for this feature.
Lock/Unlock	Lock or unlock this feature. If a feature is locked, the tracked points and settings will not be modifiable.
Settings	Click on this icon to show the Track Settings dialog for this particular feature.

Automatic Tracking

Marker Editor

The appearance of each feature marker can be modified using the Marker Editor dialog. This dialog appears when you double-click on the marker in the feature properties listing in the control panel.



Style — Four different marker styles are available:

- Cross
- X
- Triangle
- Square

Color — Click on the button next to the color square to bring up the color selection dialog. Select the desired color for the marker.

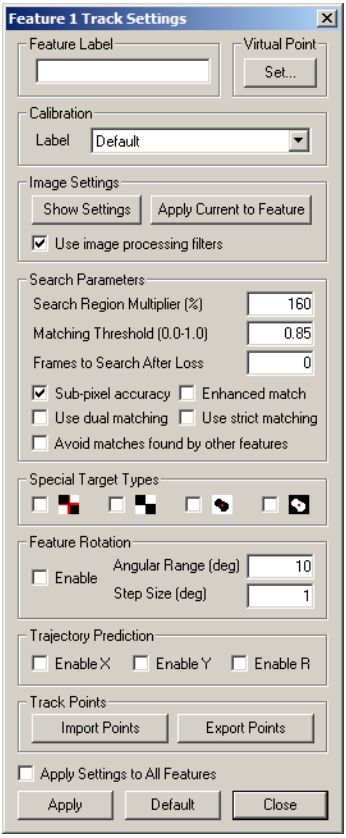
Pen Width — Sets the thickness of the lines that are used to form the markers.

Size — Sets the overall size of the entire marker.

Sample — Provides a sample of the resulting marker using the settings that have been configured above.

Track Settings

The Track Settings dialog can be displayed by clicking on the Settings icon  or by double-clicking on the feature label in the feature properties listing. The Track Settings dialog is where parameters can be set that control how automatic tracking is performed.



Calibration

Each feature can use its own calibration (see the section called "Multi-Plane Calibration") settings. The list of currently defined calibrations is shown in the drop down box. Select the specific calibration label to be used with this feature, or select Default to use whichever calibration is set as the default calibration.

Feature Label

Enter a label for the feature that is displayed in the feature properties listing and over the feature region in the video image.

Show Settings

Each feature can maintain its own set of Image Processing (see the section called "Image Processing") settings. These LUT settings are typically the settings that were active when the feature was added. Click this button to display the image using the image processing settings associated with this feature.

Apply Current to Feature

This button allows the image processing (LUT) settings for a given feature to be changed to whatever settings are currently active. In order to change the LUT settings associated with a feature, change the LUT settings so that

	the desired appearance is achieved (see the section called "Image Processing"), and then click this button.
Use image processing filters	While each feature can have its own set of Image Processing settings, all features share the single set of Image Filters (see the section called "Image Filtering") defined for the video. However, each feature can be set to use the image processing filters or to not use them. Check this box to have the image processing filters applied to the video for this particular feature when analyzing.
Search Radius Multiplier	Configure how large of an area to search for template matches. This is a percentage of the initial region size that was defined for this feature. A value of 100 (%) in- dicates that the algorithm should search in a region as large as the initial region size. Larger values will result in larger search areas, which will take a longer time to search. A typical value for this parameter is 300. The search region can be shown in the video image through the context menu (right-click) in the video image.
Matching Threshold (used to be called Threshold Tolerance)	Configure the sensitivity of the matching algorithm. The tracking algorithm assigns a value between 0 and 1 to all points within the search region indicating how well they match the template region. All values below a set threshold are ignored. A threshold value of 1.0 indicates that only a perfect match will be accepted. Lower this value if the tracking algorithm fails to track a feature. A typical value for this parameter is 0.75. This value is also used to determine a threshold intensity value when using the third or fourth Special Target Type option described below.
Frames to Search After Loss	Configure if the tracking algorithm should continue to try searching for a match beyond a frame where the feature was lost. This parameter sets how many frames the algorithm should continue beyond the frame where it lost the feature. If the feature is found again, the tracking will continue as normal.
Sub-pixel accuracy	Enabling sub-pixel accuracy attempts to estimate the best fit match to the template at a sub-pixel level. This option is typically always enabled, however, if only pixel accuracy is preferred, uncheck this option.
Enhanced match	Enabling enhanced matching attempts to improve the matching by enhancing the template image and search region. This option is only available if sub-pixel accur- acy is also enabled. Enabling this option will increase the processing required for tracking and may result in a noticeable increase in the time required for tracking. Using this option with the third or fourth Special Target type will automatically set the threshold to assume that the

	background is perfectly white (255) or perfectly black (0) when calculating the center of the blob.
Use dual matching algorithm	Enable this to use a two-pass dual matching algorithm to avoid false matches. This technique will be more able to distinguish features that have both dark and light features. Enabling this option will result in a marginal increase in processing required.
Use strict matching algorithm	Enable this to use a stricter matching algorithm to avoid false matches. Note that this may lead to more frequent loss of targets during tracking. To compensate for this, you can lower the tolerance or increase the Frames to Search After Loss.
Avoid matches found by other features	Enable this to make newly tracked features avoid any existing points tracked by other features.
Special Target Types	Enable this if your target is one of the special targets shown. The first and second checkerboard targets can be used for a quad-target, checkerboard, or bow-tie pattern. When enabled, these options will use special algorithms to locate the selected target. Only the size and the initial location of the feature region is used to initiate tracking. The special algorithms automatically compensate for target rotation, so all rotation options are disabled if these options are enabled. When using a special target type, define the region so that it is just large enough to enclose the target. Do not make the region larger than necessary. The first special target type with the red lines uses a line fitting algorithm to detect the lines dividing the white and black regions and then returns the intersection of these lines. The second special target type uses an ideal- ized template composed of pure white and pure black values to initiate tracking. The third and fourth special target types are designed to locate the center of mass of a black blob or a white blob respectively. These last two special target types will return the center of the largest continuous black or white area found within the search region. The Matching Threshold value is used as a threshold on the image prior to performing blob detec- tion. For example, when locating white blobs, a Match- ing Threshold value of 0.75 would apply a threshold of 0.75*255=191 to the search region before locating blobs.
Enable (Feature Rotation)	Enable feature rotation when tracking. The algorithm will try comparing rotated versions of the template with the search region to find a match. The best match over all the rotation range will be returned as the final match.
Angular Range	The rotation range in degrees to search for matches. The template will be rotated plus or minus this value in degrees in intervals of the step size.

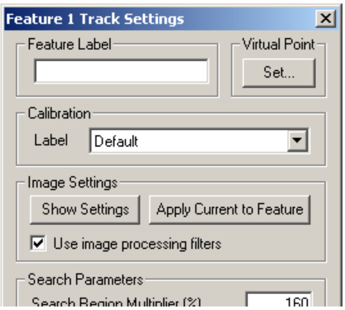
Step Size	The step size to use over the rotation range to search for matches. For example, a rotation range of 10 degrees with a step size of 1 will examine the range of -10 to 10 degrees in 1 degree increments.
Enable X Trajectory Prediction	Enable trajectory prediction in the horizontal direction. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Enable Y Trajectory Prediction	Enable trajectory prediction in the vertical direction. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Enable R Trajectory Prediction	Enable trajectory prediction for rotation. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Import Points	X and Y track point data can now be loaded from a text file and drawn in the video as if they had been manually tracked. Click this button to select a text file to load tracking point coordinates from. The text file must be formatted such that each line contains one X and one Y value separated by a comma. The X and Y values should be in units of pixels. The origin of the coordinate frame is the upper left corner of the image, with the Y axis positive downward and the X axis positive to the right. This function can also now recognize the full exported text file from the main Feature Tracking panel. If a full ex- port file is selected, the program will prompt you to se- lect which feature to import. Only the data for a single feature can be imported. The data in the export file should be in uncalibrated pixel units in order for the im- port to render the points properly. No reverse transform- ation is performed to convert from calibrated units back to pixels when importing.
Export Points	X and Y track point data can be saved to a text file. Click this button to export the track point coordinates for this feature to a text file. The values are output in units of pixels. The origin of the coordinate frame is the upper left corner of the image, with the Y axis positive down- ward and the X axis positive to the right.

Apply Settings to All Features	Check this box to apply the above settings to all currently defined features.
Apply	Apply the settings to the feature. Changes will not be applied unless this button is clicked.
Default	Load the default settings for the feature properties into this dialog. The settings are not applied until the Apply button is clicked.
Dismiss	Close the dialog. Settings will not be applied unless the Apply button was clicked.

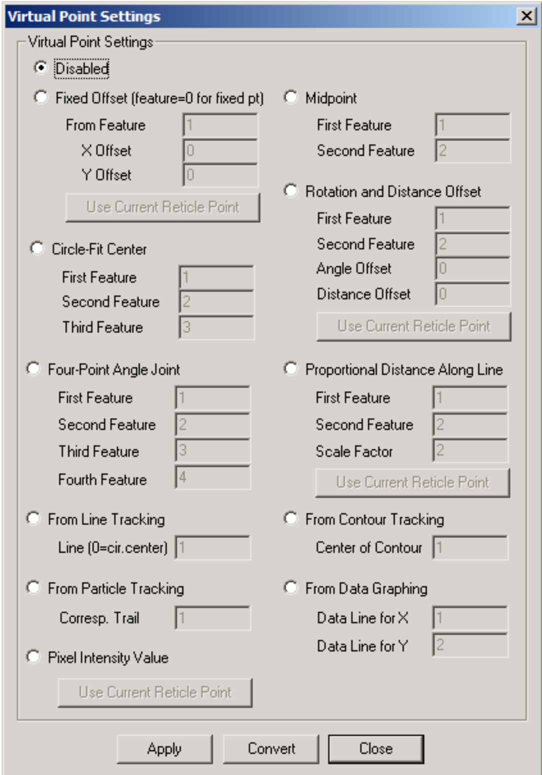
Virtual Points

Features can be defined by using other features. These special features are called Virtual Points in the software. You cannot automatically or manually add points to a feature that is defined as a virtual point. They are "virtual" because they do not exist on their own. Their points are defined relative to other features.

To create a virtual point, track your real features as you normally would. Add a new feature and open the feature settings dialog.



Click the Set... button in the Virtual Point area in the feature settings dialog.



Select one of the available styles of virtual points from the Virtual Point Settings dialog.

The following virtual point styles are available:

Fixed Offset	Define the virtual point as a fixed X,Y offset from another feature. The X,Y coordinates must be defined in pixels using the default image coordinate frame (positive X is to the right and positive Y is down). If the From Feature value is set to 0, then a constant fixed point can be created. The X and Y coordinates of the constant fixed point should be entered into the X and Y Offset fields. The Use Current Reticle Point button can also be used to se- lect the current reticle point.
Circle-Fit Center	Define the virtual point as the center of a circle defined by three other features.
Four-Point Angle Joint	Define the virtual point as the point of intersection of the two lines formed by four points. One line is defined by the First and Second features. The second line is defined by the Third and Fourth features.
From Line Tracking	Define the virtual point using the tracked coordinates from a specific line from the Line Tracking Toolkit. If a

	line number of 0 is used, then the center of the circle fit from the Line Tracking Toolkit is used.
From Particle Tracking	Define the virtual point using the coordinates of a correspondence trail from the Particle Tracking Toolkit.
Pixel Intensity Value	Define the virtual point to track the intensity of a single pixel. Position the reticle and click the Use Current Reticle Point button to select the virtual point. You must perform tracking to compile the data. Results will appear as: X - Frame #, Y - R value, Distance - G value, Speed - B value.
Midpoint	Define the virtual point as the midpoint of two other features.
Rotation and Distance Offset	Define the virtual point as the point located at a fixed angle and distance offset from a line. The line is specified as the line connecting the First Feature to the Second Feature. The angle offset must be specified in degrees, the distance offset must be specified in pixels. The angle is calculated in the counter-clockwise direction from the First Feature to the Second Feature to the Virtual Point.
Proportional Distance Along Line	Define the virtual point as a point along a line defined by the First and Second features. The scale factor controls where along this line the virtual point is placed. If the scale factor is 0, the point is placed at the First feature location. If the scale factor is 1, the point is placed at the Second feature location. If the scale factor is 2, then the point is placed twice as far from the First feature as the Second feature.
From Contour Tracking	Define the virtual point using the tracked coordinates of the center from a specific contour from the Contour Tracking Toolkit.
From Data Graphing	Define the virtual point using data graph lines as X, Y coordinates (data will be interpreted as pixel coordinates).

After you have selected the desired style and specified the parameters, click Apply and then Close.

To convert the virtual point coordinates to manually tracked feature coordinates in Feature Tracking, click Convert.

The data from a virtual point feature can be graphed, exported, and processed exactly the same as a real feature.

Tracking

After feature regions have been defined and the track settings have been set, tracking must be run. All tools described so far are used for setting up the parameters for tracking but do not actually execute any of the feature tracking algorithms.

When you are satisfied with the feature settings, click on the Track Forward or the Track Backward button to begin tracking. Tracking will commence from the currently displayed frame until the end or beginning of the video. When tracking is running, the center button will become enabled. Clicking the center Abort button will stop the tracking.

Since tracking begins from the currently displayed frame, in most situations, you will want to jump to the first frame of the video before beginning tracking. You can do this by clicking the double-backward arrow button in the Play Controls (see the section called “Play Controls”).

If you begin tracking forward from an intermediate frame of the video, all tracking results prior to that frame will be preserved. In this manner, you can use one set of tracking parameters for the first portion of a video and a different set for the second portion. Similarly with tracking backward.

If a feature is "lost", meaning the algorithm is unable to locate a suitable match for a feature in a frame, tracking for that feature will stop. You can try to redefine a new template for the fea- ture in the frame that it was lost and track forward from that frame onward. Or you can try modifying the Image Processing (see the section called “Image Processing”) or Image Filtering (see the section called “Image Filtering”) settings to make the feature more prominent so that it is easier to track and then try the tracking procedure again.

Single-step tracking is available using the Track One-Frame Forward and Track One-Frame Backward buttons. This will perform the tracking for a single frame only. Note that using this single-step function uses the features in the current frame as the template for tracking. Repeatedly using the single-step tracking to track an entire video will produce different results that tracking using the Track Forward button. This is because the single-step tracking will re- define the template for every frame.

Manual Tracking

Adding and Removing Points

Manual tracking is performed on a per-frame basis; the user cycles through each relevant frame and manually marks the feature locations by clicking the mouse. Manual tracking mode is selected by clicking on the Manual mode in the upper left corner of the Feature Tracking control panel.

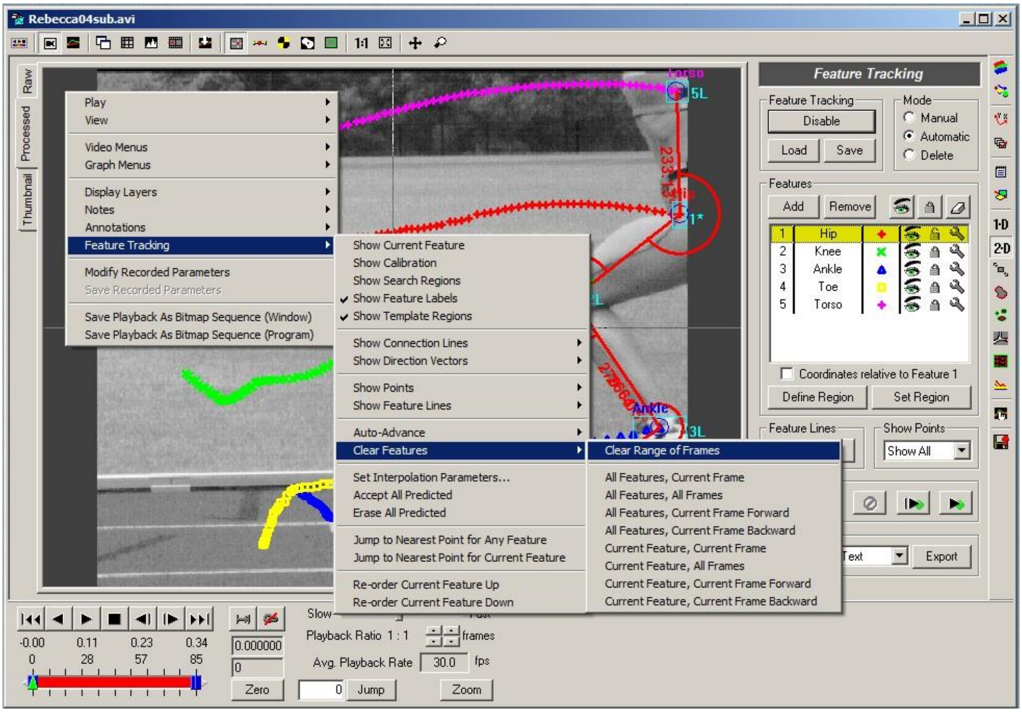
To add a manual point or to modify the location of a point:

1. Select the feature in the feature properties list that you wish to add a track point to by clicking on the corresponding row.

2. Click in the image window to place the reticle in the desired position.

3. Click the Set Point button in the Feature Track control panel or hold down the **Control** key and click the right mouse button.

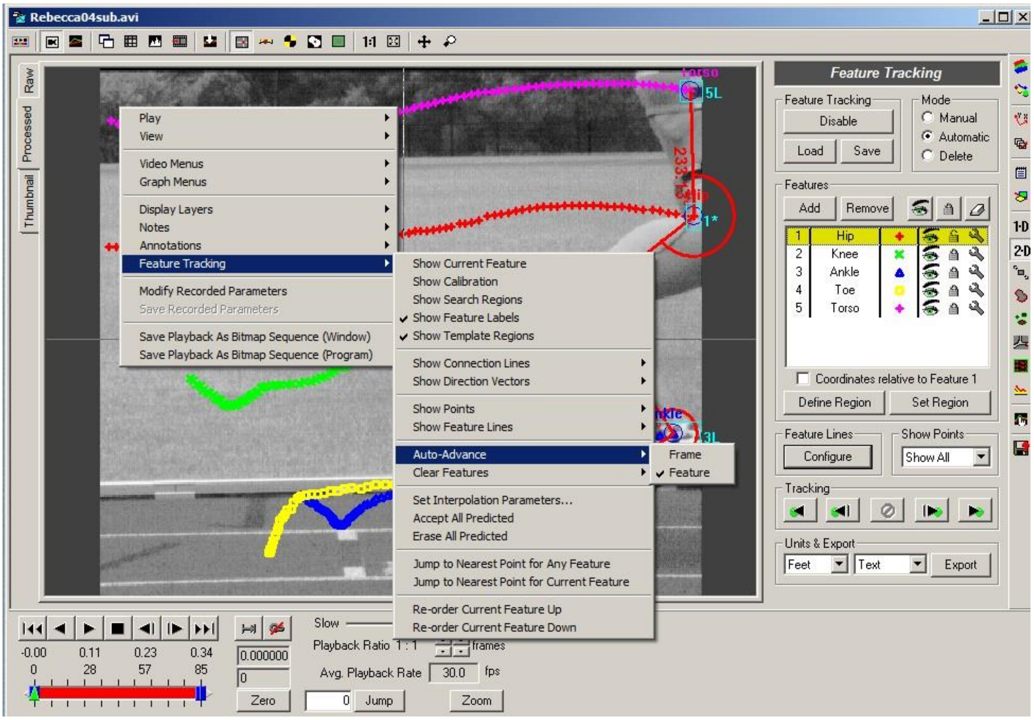
To remove a point, use the Clear Features context menu (right-click in the window).



Automatic Advance

When doing manual tracking, using the automatic frame and feature advancing features are very helpful in speeding up the process. These features when enabled will automatically ad- vance to the next unlocked feature after you have set a point manually. If the current feature is the last feature in the list, then the frame will advance to the next frame and the feature will be set to the first unlocked feature.

The Automatic Advance features are enabled via the context menu (right-click in the window).

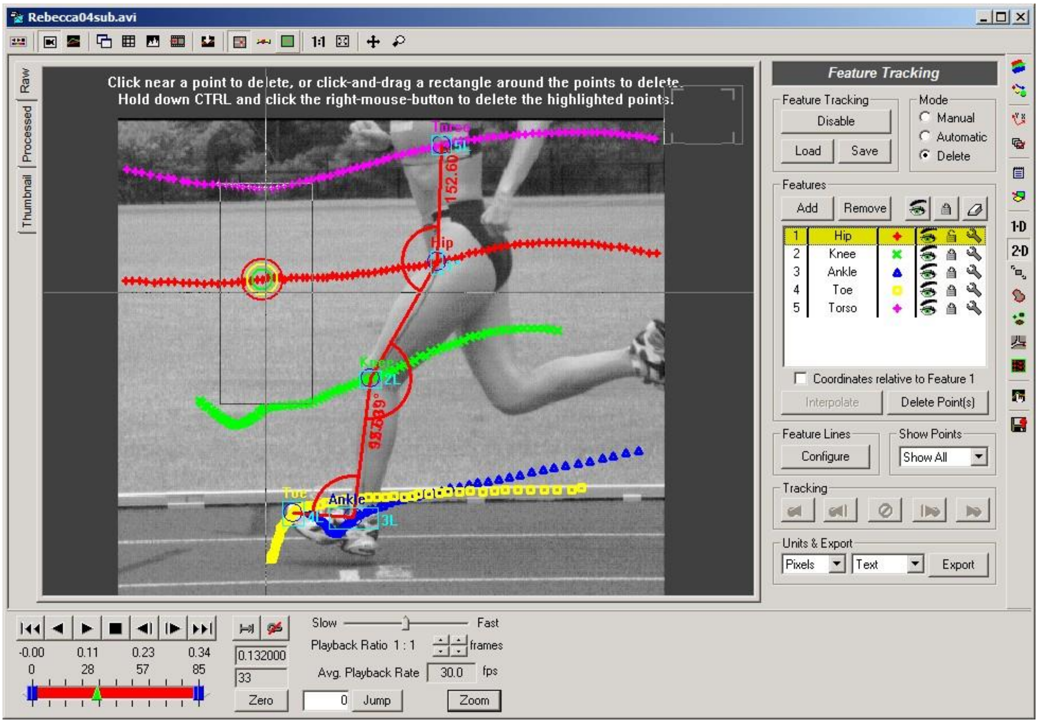


If automatic feature advancing is enabled without automatic frame advancing, then when the last feature is reached, the feature will stop advancing. If automatic frame advancing is enabled without automatic feature advancing, then the frame will only advance when you set a point for the last feature in the list.

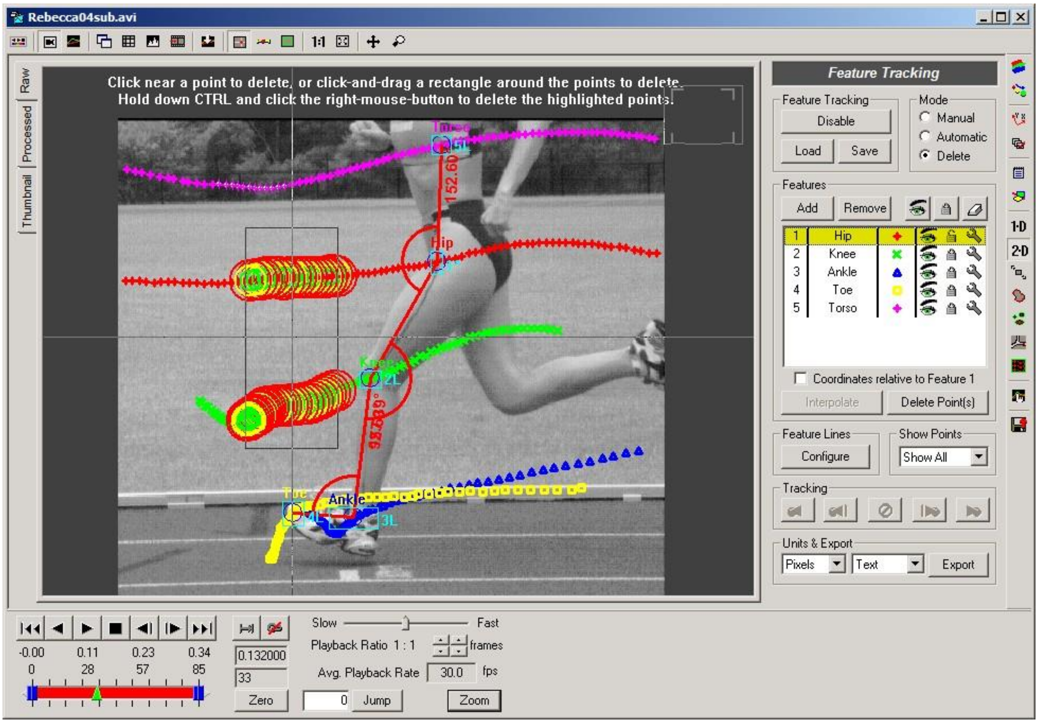
Delete Mode

In addition to Automatic Mode and Manual Mode, there is a third mode used exclusively for deleting tracked points. Click on Delete in the Mode section of the panel to enable Delete Mode.

While in Delete Mode, clicking anywhere in the video will highlight the nearest tracked point. Holding down the **Control** key and clicking the right mouse button will delete the highlighted point.



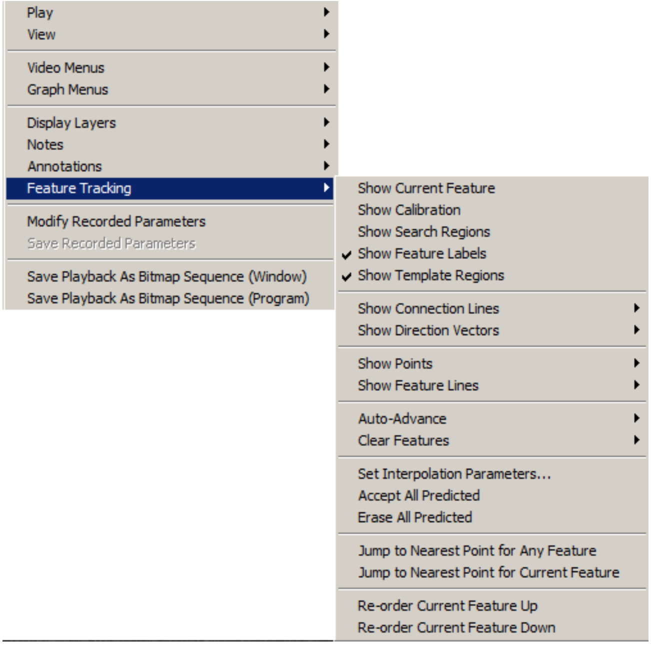
In order to delete multiple points, you can click and drag a rectangle in the image. Any tracked points inside of the rectangle will be highlighted for deletion. Hold down the **Control** key and click the right mouse button to delete the highlighted points.



Only points that are currently being displayed on the screen will be highlighted for deletion. You can control which points are being deleted by hiding some features, locking some features, or changing the Show Points setting in the main panel.

Additional Display Options

There are a number of display options that are accessed via the context menu. Right-click on the video in order to view the additional display options.

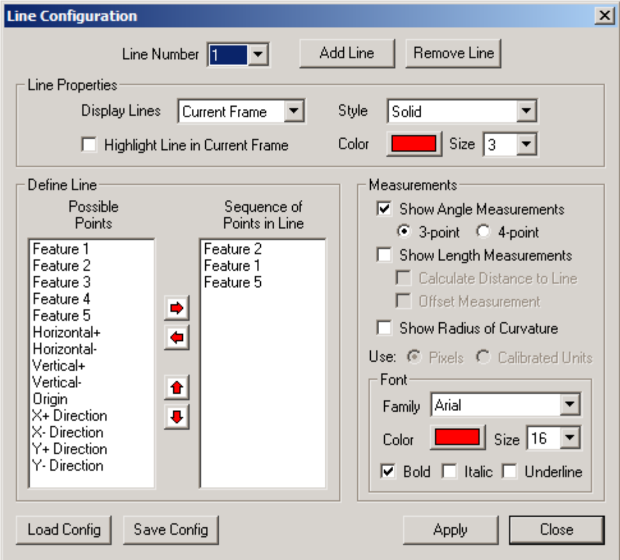


Show Current Feature	Show current feature indicator in the video image.
Show Calibration	Show current calibration indicators.
Show Search Regions	Show the corners of the search regions for automatic tracking for each feature. Note that these search regions are centered on the current feature location and do not incorporate trajectory prediction offsets. This requires template regions to be shown in order to be visible.
Show Feature Labels	Show feature labels above the template regions. This requires template regions to be shown in order to be visible.
Show Template Regions	Show the rectangular regions that are used to define the feature templates to track.
Show Connection Lines	Show lines connecting all track points for each feature in all frames or past frames. Additional display options can also configure the width of the connection lines and how many frames in the past to draw the connecting line when displaying past frames. If a length is specified, the line will be drawn in decreasing size, from the full size at the current point to the smallest size at the end of the length. This option can be used to produce a comet trail effect, graphically illustrating the speed and path of a feature.
Show Direction Vectors	Show arrows indicating the direction of motion of each

	feature from the current frame to the next frame. This can be configured to be shown for the current frame, past frames, or all frames. The scale of the length of the ar- row can be set using the Set Vector Scale menu option.
Show Points	Show all points, current point, past points, or no points. Additional display options can also configure how many frames in the past to display points when showing past points. If a length is specified, the points will be drawn in decreasing size from full size at the current point to the smallest size at the end of the length. This may be used to produce a comet trail effect, similar to that avail- able using Connection Lines.
Show Feature Lines	Show configured lines between features. This option brings up the Configure Lines dialog, as described in the next section.
Auto-Advance	Set the automatic advance settings for tracking. This op- tion was explained in the previous section.
Clear Features	Clear feature points for tracking. This option was ex- plained in the previous section.
Set Interpolation Parameters	Set the number of feature points to be used to calculate interpolated points. Independent values can be set for the number of points before and after the missing values.
Accept All Predicted	Show the configuration dialog with interpolation para- meters.
Erase All Predicted	Clear all interpolated track points.
Jump to Nearest Point for Any Fea- ture	Jump to the frame corresponding to the nearest tracked point from any feature from the current reticle position.
Jump to Nearest Point for Current Feature	Jump to the frame corresponding to the nearest tracked point from the current selected feature from the current reticle position.
Re-order Current Feature Up	Re-orders the current feature so that the current feature is exchanged with the previous feature in the list.
Re-order Current Feature Down	Re-orders the current feature so that the current feature is exchanged with the next feature in the list.

Configure Lines

Once features have been tracked, lines can be configured to be drawn between features. These lines are configured by clicking the Configure button in the Feature Lines section of the Feature Tracking control panel. This will display the Line Configuration dialog.



To add a new line:

1. Click the Add Line button.

2. Select whether you want the line to be drawn in the currently displayed frame only, past frames, all frames, or in none of the frames. Also, select whether you would like to highlight the line in the current frame. This is useful for distinguishing the line in the current frame from the other lines in past or all frames.

3. Set the line style, color, and thickness.

4. Select which points should be connected by the line. All possible features and points are listed in the left column. Select which points to add and hit the right arrow button. The left arrow button can be used to remove selected points from the right column. The up and down arrows allow you to reorder the sequence of points in the line.

5. Lines can also be configured to display active measurements of the angle between line segments or the lengths of line segments. Select whether you wish to have angle or length dimensions drawn with the lines.

   - Angle measurements can be computed using 3-points or 4-points. If 3-point is selec- ted, the angle between three points is computed using the second point as the vertex. If 4-point is selected, the intersection of the lines formed by the first two and last two points is computed and used as the vertex. Angle measurements are always shown in degrees.

   - Length measurements can be shown in units of pixels or in the currently selected calibrated units. The distance between each point in the sequence list will be displayed next to the line connecting the points. If Calculate Distance to Line is selected, the perpendicular distance to a line can also be computed when at least 3 points are specified in the sequence list. For every three points, the perpendicular distance from the first point to the line formed by the next two points is computed and shown. The length measurement can be shown directly on the line connecting the points or it can be offset to one side by checking Offset Measurement.

- Radius of curvature measurements can be shown based upon the sequence of points in the line. The radius of curvature is calculated as the radius of a circle that is fit to the points in the line. The radius of curvature can be shown in units of pixels or in the currently selected calibrated units.

6. If you have checked an angle or length measurement, you can change the font, color, size, and appearance of the measurement label.

7. Click the Apply button to apply the changes.

To modify the properties of a line, select the line number that you wish to modify in the top drop down box. Make the changes. Then click Apply.

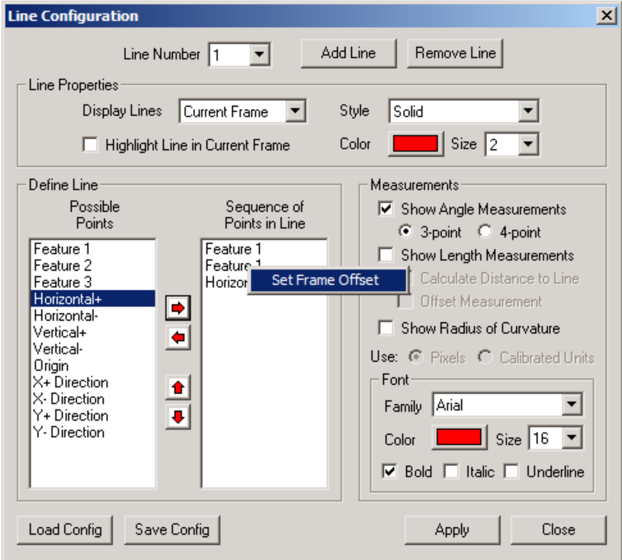
To remove a line, select the line number to remove in the top drop down box. Click the Re- move Line button.

Line configurations are automatically saved with the rest of the Feature Track settings when the Feature Tracking panel is saved. They will be automatically restored when the saved file is re-loaded.

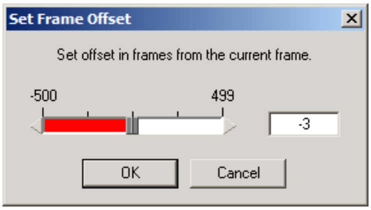
Line configurations can also be saved to special Line Configuration files (`*.lcf`). Click the Save Config button to save the current line configuration to a file. Click Load Config to load a configuration from a previously saved file.

Frame Offset

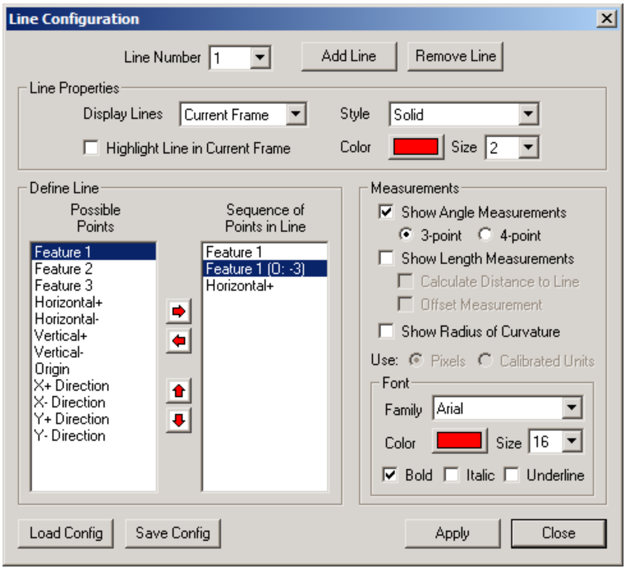
For every Feature item added to the sequence of points, a Frame Offset can be specified. A Frame Offset allows you to use the coordinates of the Feature in a previous or subsequent frame in the video (backward or forward in time). You can set a Frame Offset value for every feature in the list by right-clicking on a Feature item in the listing of Sequence of Points in Line,



The Frame Offset value can be set from -500 frames (backward) to 499 frames (forward).



Once a Frame Offset is set, the Feature listing will indicate the offset by displaying "(O: #)" after the Feature number, where "#" is the Frame Offset value.

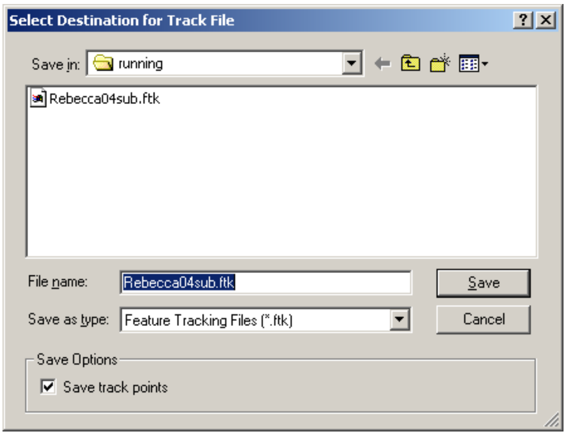


The above example shows how you might calculate the angle relative to horizontal of the direction of motion of Feature 1.

Saving and Loading

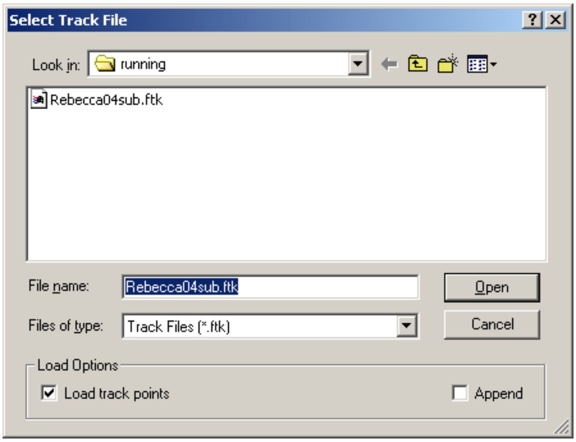
All Feature Track settings and results can be saved to a file for later use. This allows you to do multiple analyses on the same video file, store the configuration and results, and later load the appropriate analysis whenever you need it. Feature Track settings saved from one video can also be loaded on another video. This allows you to configure features and settings for one video, then load and apply these settings to many more videos where the same type of analysis is to be conducted.

To save the analysis settings and results, click the Save button at the top of the Feature Track control panel. Feature Track settings and results are stored to files with the `FTK` file extension.



If you only want to save the feature settings, uncheck the Save track points checkbox in the Save Options. This is useful if you intend to use this file to define feature settings for different videos.

To load a saved analysis file, click the Load button at the top of the Feature Track control panel.

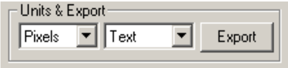


Uncheck the Load track points checkbox in the Load Options if you do not want to load the track points stored in the file. This is useful if you only want to use the feature settings con- tained in a track file that may have been saved from a different video.

If the Append checkbox is selected, the features and track points from the selected file will be appended to any features that are currently configured. This is a useful method for comparing results from two different analyses of the same video.

Units and Exporting

After a successful track is completed, you can export the data to a variety of formats to perform any additional custom analysis or graphing.



Units You can select what set of units to use for exporting the tracking results. If no calibration has been done on the video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.

Format You can select what format to export to: Text, Excel Blank, Excel Template, or Diadem. Results for feature will be exported to the resulting file.

The feature track data is composed of the following information: frame number, time (if we know the record rate of the video), and the X and Y coordinates of each of the tracked feature points.

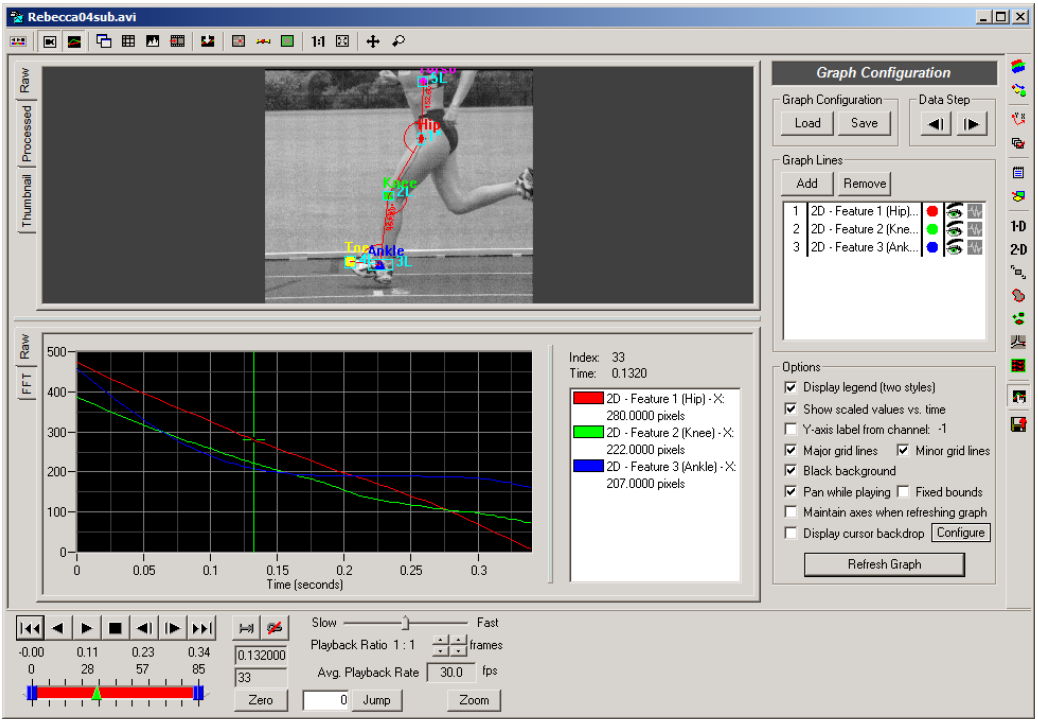
Exporting to Excel Blank and Excel Template export the same data. However, Excel Template exports the data into an existing Excel file that is used as a template. You can put in any formulas and graphs into the template file, and these will be recomputed and regenerated when the new data is exported into it.

Export When you are satisfied with your tracking results, and have selected your export units and format, click on the Export button to export the results.

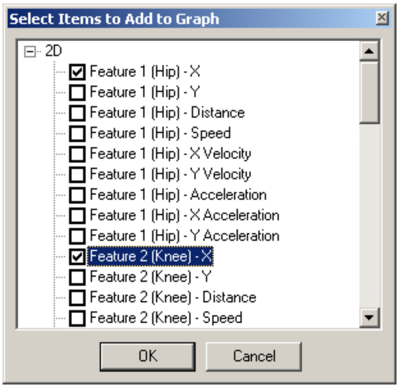
See the section called “Exporting Data or Analyses” for additional details regarding exporting.

Graphing

Feature Track results can be immediately displayed in the Measurement Window graph section. Once tracking is complete, use the Graph Configuration control panel to add feature tracking results to the graph section.



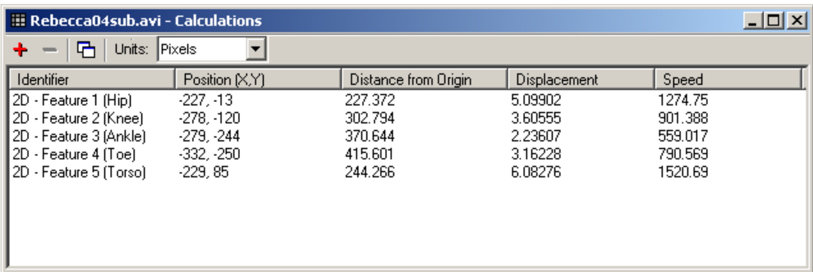
After clicking the Add button, a listing of available items to graph is presented. For each feature, the X and Y coordinates, distance to the origin, and speed can be graphed. In addition, if any feature lines have been configured to display angle or line dimensions, these can also be graphed. Select the items that you wish to graph and click the OK button at the bottom of the dialog.



For more details on configuring the other options in the Graph Configuration panel, see the section called “Display Settings”.

Calculations

Immediate simple calculation results such as position and velocity can be displayed for each feature using the Calculations Window associated with a Measurement Window.



See the section called “Calculations Window” for more details.

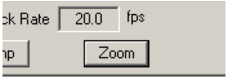
Zoom Window

Overview

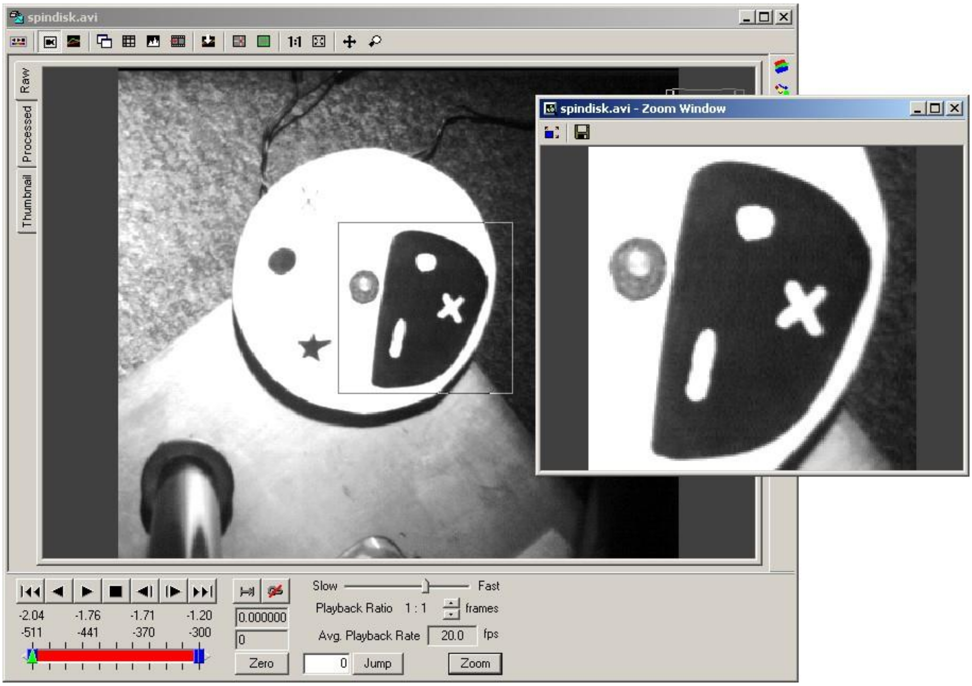
For every Measurement Window, a Zoom Window can be created. The Zoom Window allows you to enlarge a rectangular region of the video window. As the video is played or manipulated, the Zoom Window will also play and reflect the same changes as seen in the Measurement Window. The rectangular zoom region can also be saved from each frame in the video to create a new video file that only contains the zoomed region.

To create a zoom window:

1. Hit the Zoom button in the Play Controls bar on the bottom of the Measurement Window.



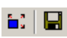
2. Click and drag a rectangle in the video image. The Zoom Window will appear once the mouse button is released.



3. After the rectangle is placed, clicking and dragging in the window will move the rectangle.

4. If you need to resize the rectangle, click on the Zoom button again and redraw the rectangle in the video image.

Once you have created the Zoom Window, you can also modify the zoom region and you can save the zoom region to create a new video file using the controls in the Zoom Window.



Modify Zoom Rectangle	Modify the dimensions and location of the zoom rectangle.
Save Zoom Region	Save the sub-region of the video to a new video file.

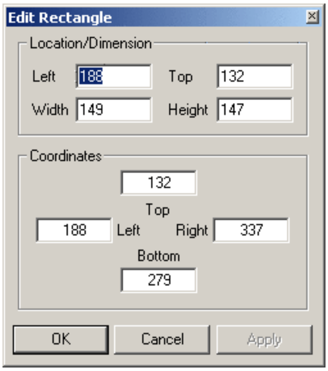
The zoom window can also be set to always remain on top of the corresponding video window. This option is set in the Window tab of the Program Options (see the section called “Program

Options").

Modifying Zoom Region

Once it has been created, there are multiple ways to change the location or size of the zoom region.

- The zoom region can be moved by simply clicking on a different location in the video image of the Measurement Window.
- To resize the zoom region, a new zoom region can be created using the Zoom button.
- The Modify Zoom Rectangle button on the toolbar (or in the context menu) of the Zoom Window can be used which will bring up the Edit Rectangle dialog window.

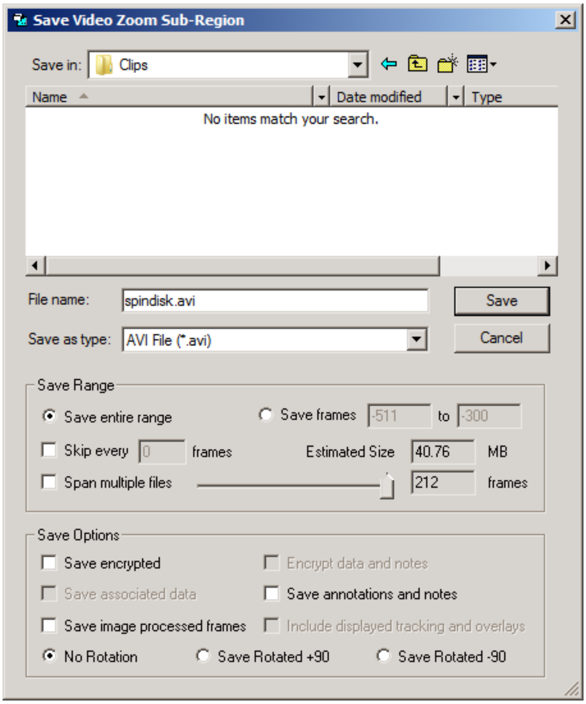


In this window, the exact coordinates and size of the rectangle can be specified. Click on OK or Apply to save the changes.

Sub-region Saving

The zoom region of each frame in the video can be saved to a separate video file. This is useful if only a portion of the video image is of interest. Saving a sub-region will result in a reduced file size and also allows you to remove possibly distracting background portions of the video.

To save a sub-region, create the Zoom Window. In the Zoom Window, use the Save Zoom Region button on the toolbar or select Save Zoom Region in the context-menu (right-click) of the window. The Save Video Zoom Sub-Region dialog will appear. This dialog is the same as the standard Save dialog, except that it is calculating sizes based upon the zoom sub-region selected.



See the section called “Saving Video Files” for more details on the Save dialog and save options.

Calculations Window

Overview

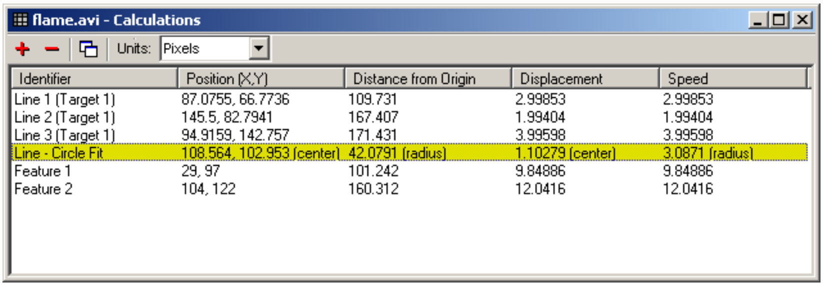
The Calculations Window displays a quick set of common calculations for analysis track points from various analysis toolkits.

The common calculations include position, distance from origin, displacement, and speed.

Position	Position is given as the X and Y coordinates of the point relative to the calibrated origin. If no origin has been calibrated, then the default origin of the upper-left corner is used.
Distance from Origin	The distance from the origin is the distance to the calibrated origin. If no origin has been calibrated, then the default origin of the upper-left corner is used.
Displacement	The displacement is the distance the point has moved from the previous frame.
Speed	The speed is the displacement divided by the time. If no record rate is available for the video, a default record rate of 1 fps is

used and the speed will be equal to the displacement.

The values shown in the Calculations Window correspond with the frame that is currently displayed in the Measurement Window (see the section called “Measurement Window”). As the Measurement window is played, the values in the Calculations Window will update to reflect the currently displayed frame.

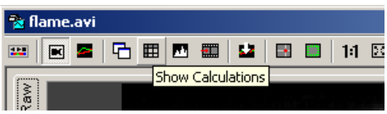


All values are shown in the units specified at the top of the window.

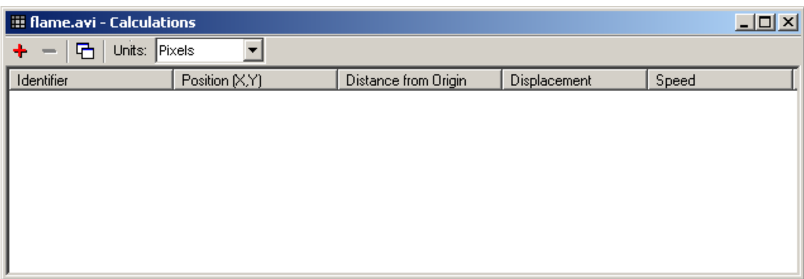
Multiple Calculations windows can be created for a single video and each window can be configured to display different set of analysis track points. Each Calculations window can also be configured to show the results in different units.

Creating a Calculations Window

You need to have completed an analysis before any calculations can be displayed. Once you have completed your analysis, a Calculations Window can be created by clicking the Show Calculations button on the Measurement Window (see the section called “Measurement Window”) toolbar. Clicking this button will show or hide the Calculations window(s).

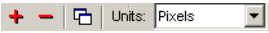


Initially an empty Calculations Window will appear.



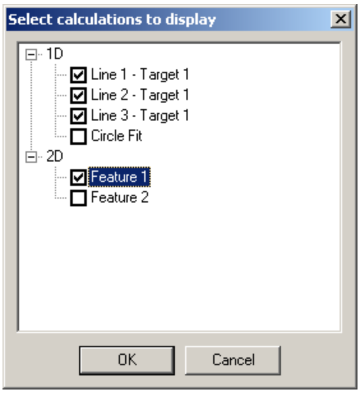
Displaying Calculations

All Calculations window settings are controlled via the toolbar.

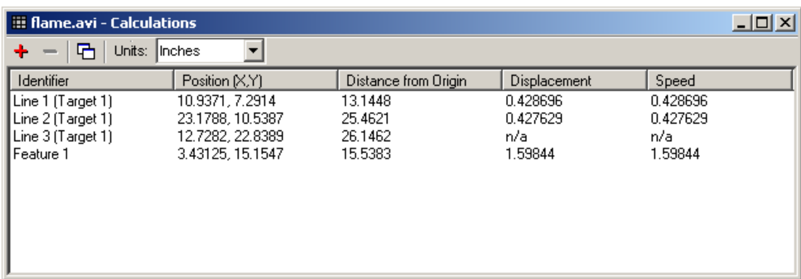


Add Measurement	Add a new measurement to this Calculations Window.
Remove Measurement	Remove the selected measurement from this Calculations Window.
New Window	Create a new Calculations Window for this video.
Units	Set the desired units for the displayed calculations in this window. The video needs to be calibrated first in order to use any units other than Pixels.

To add a measurement to the Calculations Window, click the Add Calculation button on the toolbar.



A listing of all available analysis targets and features are listed in the window that appears. If this window is empty, then no analysis has been completed. Select which items you wish to dis- play in this Calculations window and click OK.

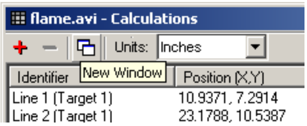


Values of "n/a" indicate that there is no value for the currently displayed video frame. This occurs when tracking has not yet been done for this frame of the video, or the target was lost in the current frame (for position and distance) or previous frame (for displacement or speed).

To remove a measurement from the Calculations Window, select the item to be removed by clicking on the appropriate row in the window. Then click the Remove Calculation button on the toolbar. The Add Calculation popup dialog can also be used to remove calculations by unchecking the calculations to be removed.

Creating Multiple Calculations Windows

A new Calculations Window can be created by clicking the New Window button on the Calculations Window toolbar.

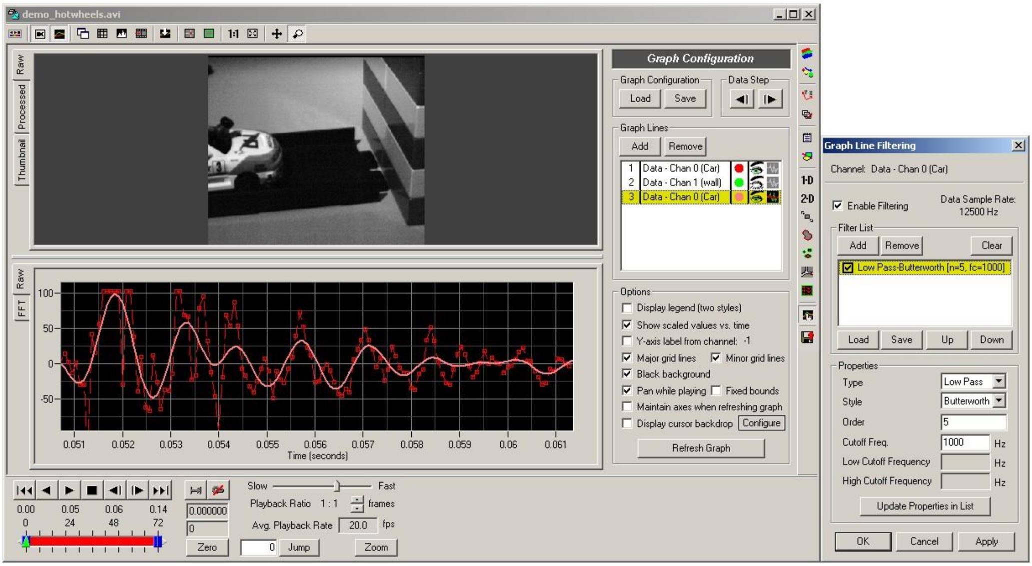


Another Calculations Window will be created. The new Calculations Window will also be tied to the same Measurement Window. As the Measurement Window is played, both Calculations Windows will update appropriately.

Data Filtering

Overview

In addition to displaying data and analysis results, the data and analysis can also be filtered to perform operations such as noise removal. These filtering options are available via an additional popup dialog from the Graph Configuration panel. In the center of the Graph Configuration panel is the listing of Graph Lines. The columns of the Graph Lines listing display the item number, item description, line color, visibility, and filter settings. The filtering options for a given line can be accessed by clicking on the filter settings icon in the last column.



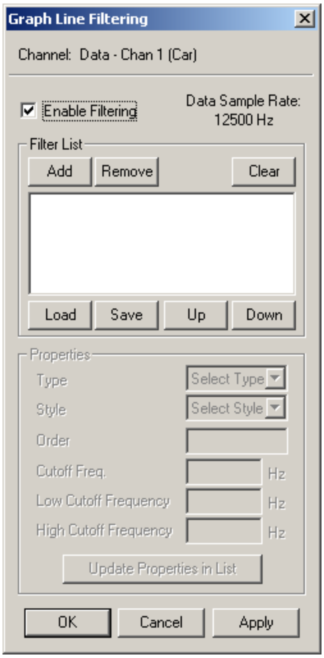
If the filter settings icon is shown in gray, then filtering is disabled for that item. If the filter settings icon is shown in color, then filtering is enabled for that item. Filtering can be enabled for all graphed items. For each item, multiple filters may be chained together to perform more complex filtering operations.

Note that the same data can be graphed using multiple lines, each with or without filtering enabled. For instance, to have a raw and filtered version of the first data channel, simply add the same data line multiple times, click on the filter settings icon for one of the lines and set the filter settings. See the section called "Display Settings" for more information on adding graph items.

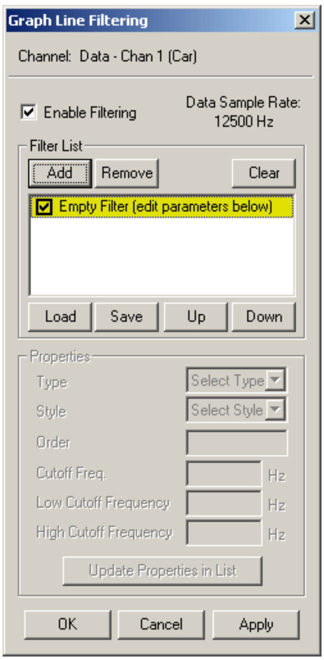
Adding and Removing Filters

To add a filter, click the filter settings icon in the Graph Lines listing in the Graph Configuration panel, and perform the following steps:

1. Select the channel to filter in the Graph Lines listing and check the Enable Filtering checkbox.

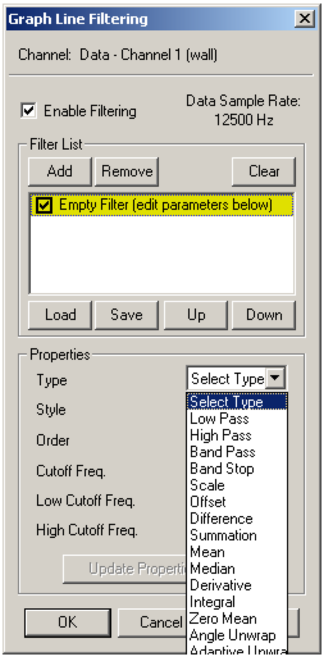


2. Click on Add New in the Filter List section.

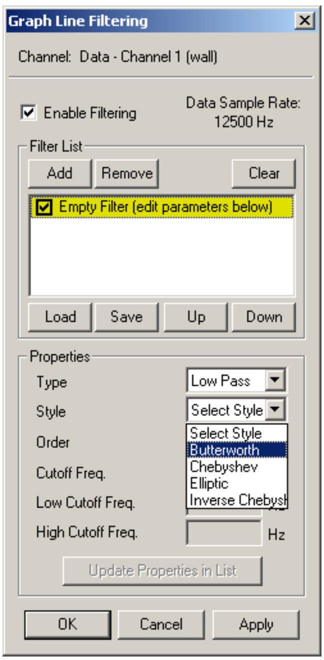


3. Select the newly added filter by clicking on it in the list. For a complete listing of available filters, see the section called "List of Available Filters". Set the type of the filter in the

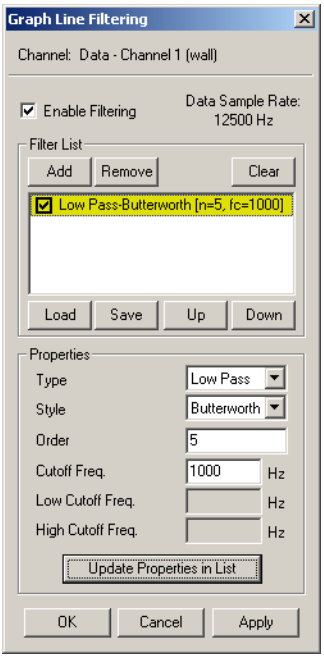
Properties section.



4. Select the style of the filter if necessary.



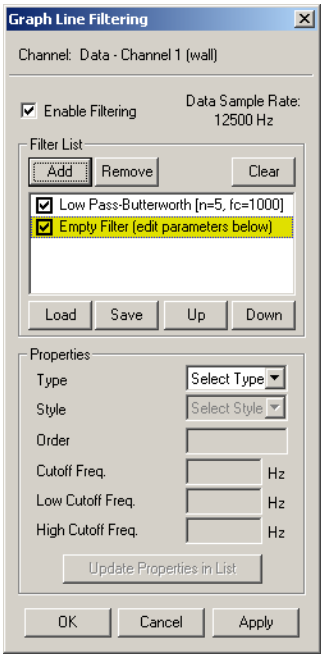
5. Set the other properties that are necessary for the filter type selected. The editable properties will be shown in white.



6. Click Update Properties in List to update the properties in the list.

7. Click Apply to apply the settings to the graph.

The process can be repeated in order to add more than one filter. The second filter will be applied to the results from the first filter.



To rearrange the order of filtering, select a filter from the list in the Filter List section and use the Move Up and Move Down buttons.

To remove a filter from the list, select the filter and click the Remove button.

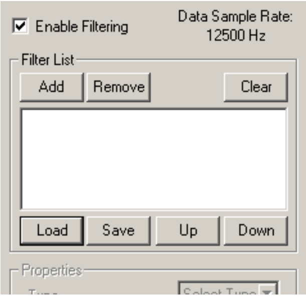
Each filter can be individually enabled and disabled by clicking on the checkbox next to each filter name in the Filter List. Using this feature, you can add multiple filters with different settings and easily see the effect of each filter by enabling/disabling one at a time.

To remove all filters and to completely remove filtering from a channel, select the correct channel at the top of the control panel and uncheck the Enable Filtering checkbox.

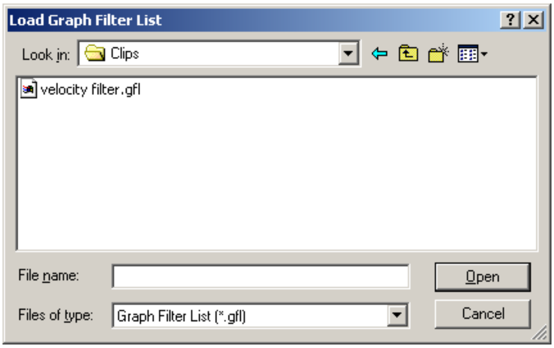
Loading and Saving Filter Lists

Common combinations of filters can be saved to file and loaded for multiple data channels. Filter lists are saved to files with the `GFL` file extension. These files are not directly associated with any particular video or data file, but may be loaded and applied to any data channel or analysis result from any video.

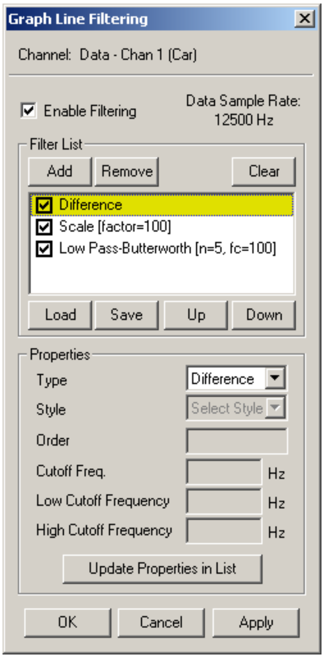
To load a saved filter list, click the Load button underneath the Filter List section in the filter settings dialog.



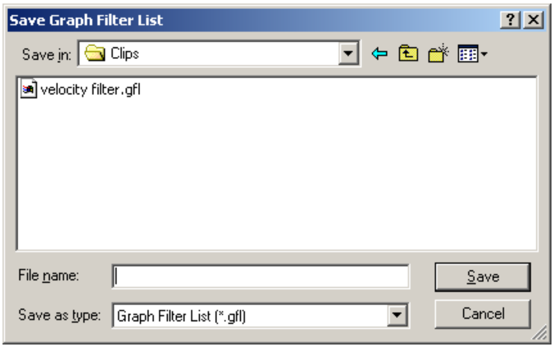
The standard file selection dialog will appear. Select the filter list file desired.



Once the filter list is loaded, it will appear in the Filter List section in the center of the Filtering panel. The parameters for each of the filters in the list can be specified using the procedure described in the previous section. Once you are satisfied will all the filter settings, click the Apply button at the bottom of the panel to apply the newly loaded filter list.



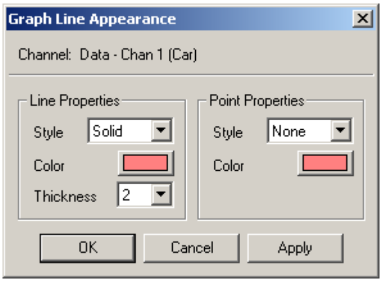
To save the current filter list to a file, click the Save button under the Filter List section in the Filtering panel. The standard save dialog will appear.



Enter the desired filename and click Save.

Changing Appearance

To change the appearance of any graphed item, double-click on the description or the line color icon in the Graph Lines listing of the Graph Configuration dialog. The following Graph Line Appearance dialog will appear.

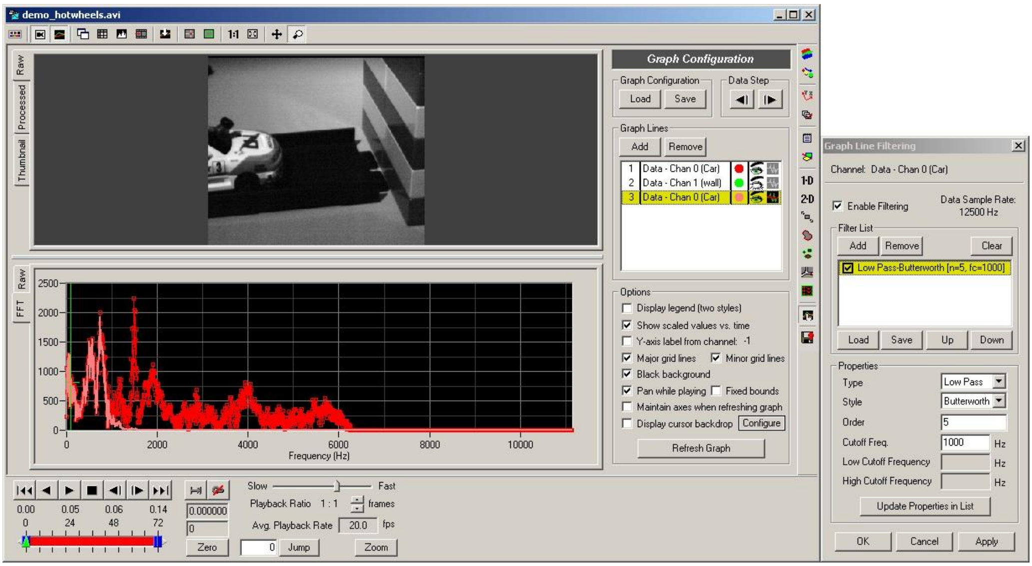


Modify the desired settings and click OK or Apply to apply the changes to the displayed graph. Also see the section called "Display Settings" for additional details on setting graph appearance settings.

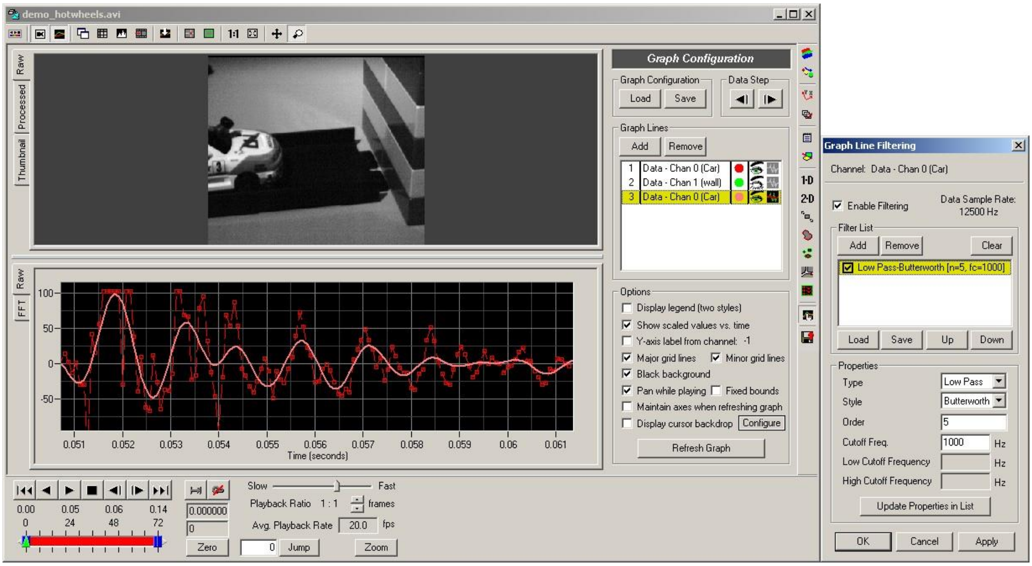
Using the FFT

For filters that depend on frequency cutoffs (low pass, high pass, band pass, and band stop), the FFT can be a valuable tool in determining cutoff frequencies. The FFT of the data can be shown by clicking on the FFT tab in the data section of the Measurement Window (see the sec- tion called "Display Settings").

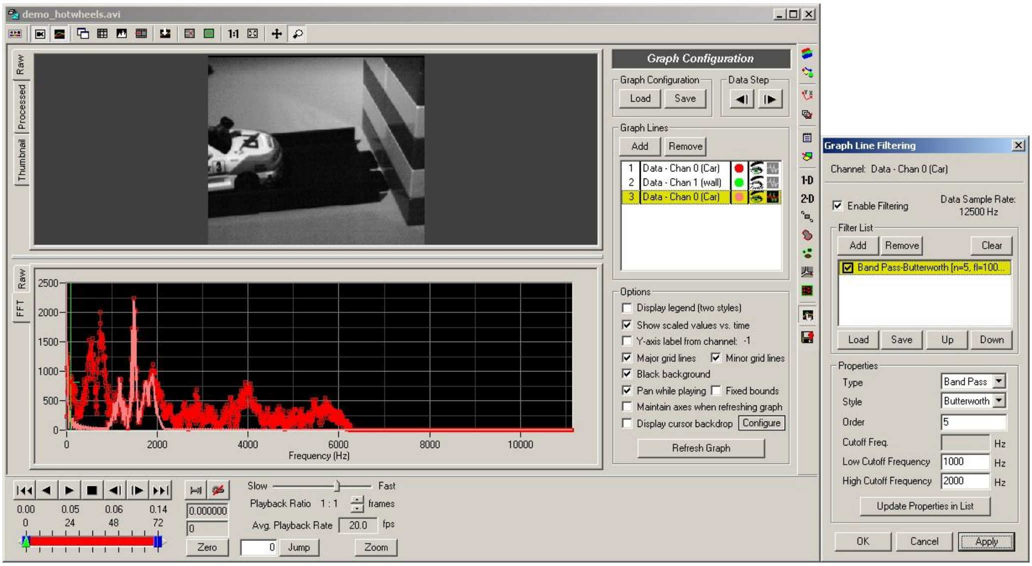
In the example below, we see that the data has frequency content beyond 6000 Hz. If we are in- terested in only the low frequency signal, we can use a low pass filter. Here we show the FFT of the original data and the resulting data after including a low pass filter with cutoff of 1000 Hz. The FFT clearly shows that the frequency content of the original signal and the filtered sig- nal closely match for values below the cutoff frequency.



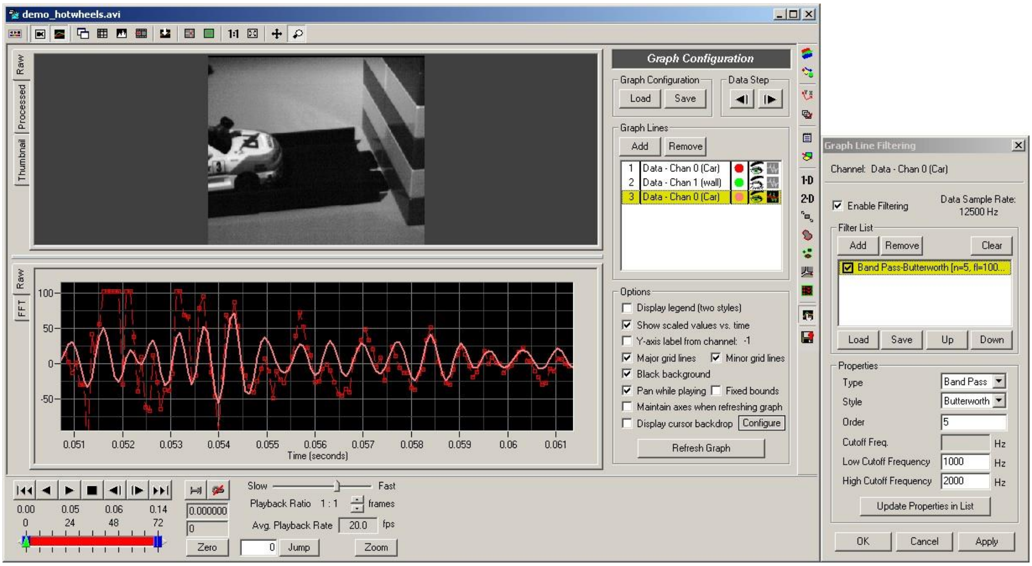
The resulting data graph shows the result of removing the high frequency signals.



Similarly, we could use the band pass filter to isolate signals between 1000 Hz and 2000 Hz. The FFT shows the results of the filter eliminating low and high frequency signals.

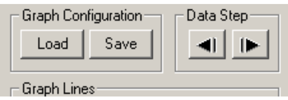


Switching back to the Raw tab, we can see the original data and the band pass filtered data which has removed the low frequency and the high frequency signal.



Saving and Loading

All appearance and filter settings can be saved to a file and reloaded. Multiple configuration files can be stored on your hard drive for different filtering scenarios. The settings are saved to graph configuration files that have the `GFC` file extension.



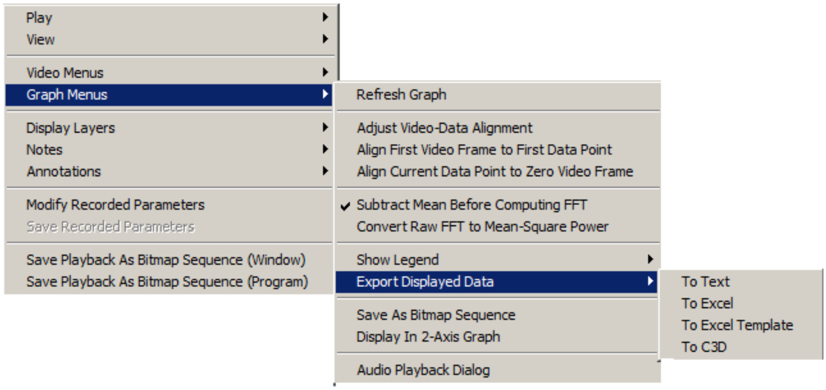
The graph configuration settings can be saved by clicking the Save button at the bottom of the control panel.

To load the graph configuration settings, click the Load button.

Saved graph configurations can be applied to different recordings as long as they have the same number of data channels or analysis results. For instance, if your graph configuration is set to filter the second data channel and this configuration is loaded for an event that has only one data channel, the configuration for the second channel will be ignored.

Exporting Displayed Data

If you have filtered your data and you wish to export the filtered results to an external application, right click in the graph and select Export Displayed Data from the context menu. This will export the actual data that is used to generate the graph.



In addition to exporting the data, the measurement graph can also save the "playback" of the entire graph to a bitmap sequence. The Window operation directly copies the graph window to a bitmap file. If any other windows are located on top of the graph window area, these portions of the graph will be obscured. Make sure that there are no other windows obscuring the graph window when you perform the save operation. To save the graph as a video, select Save Playback As Bitmap Sequence (Window) from the context menu. You can save the entire ProAnalyst workspace and all the displayed windows by using the Save Playback As Bitmap Sequence (Program) selection on the context menu.

List of Available Filters

A complete listing of the available filters for data:

Low Pass	Filters out high frequency signals above a certain cutoff frequency, allows low frequency signals to pass through unmodified. There are four different styles: Butterworth, Chebyshev, Elliptic, and Inverse Chebyshev.
High Pass	Filters out low frequency signals below a certain cutoff frequency, allows high frequency signals to pass through unmodified. There are four different styles: Butterworth, Chebyshev, Elliptic, and Inverse Chebyshev.
Band Pass	Filters out low and high frequency signals below a low cutoff frequency and above a high cutoff frequency, allows frequencies between the low and high cutoff values to pass through unmodified. There are four different styles: Butterworth, Chebyshev, Elliptic, and Inverse Chebyshev.
Band Stop	Filters out frequencies between a low and high cutoff frequency, allows low frequency signals below the low cutoff and above the high cutoff to pass through unmodified. There are four different styles: Butterworth, Chebyshev,

	Elliptic, and Inverse Chebyshev.
Scale	Multiplies the data points by a user specified scale factor.
Offset	Offsets the data points by a user specified offset value. Offset can be positive or negative.
Difference	Computes the finite difference of the signal. Subtracts the previous data point from the current data point. Use this in conjunction with a scale operation to obtain the equivalent of discrete differentiation. Often it is necessary to filter the result of discrete differentiation with a low pass filter to obtain smooth velocity/acceleration results.
Summation	Computes the sum of the signal over time. Starting from the first data point, this filter sets the current data point to the sum of all previous data points.
Mean	Computes the mean of the data points over a moving window. The moving window is defined as the current point plus or minus a user specified half-width. For example, for a half-width of 100, the filter will compute the median of the previous 100 data points, the current data point, and the next 100 data points.
Median	Computes the median of the data points over a moving window. The moving window is defined as the current point plus or minus a user specified half-width. For ex- ample, for a half-width of 100, the filter will compute the median of the previous 100 data points, the current data point, and the next 100 data points.
Derivative	Computes the derivative of the signal. Subtracts the previous data point from the current data point and divides by the sample time. This operation is commonly known as discrete differentiation. Often it is necessary to filter the result of discrete differentiation with a low pass filter to obtain smooth derivative (velocity/acceleration) results.
Integral	Computes the integral of the signal over time. Starting from the first data point, this filter sets the current data point to the sum of all previous data points multiplied by the time for each sample.
Zero Mean	Computes the mean of the entire data set and then sub- tracts the mean from the data, resulting in a data set with zero mean.
Angle Unwrap	This filter handles "unwrapping" of angle measurements. When a change in the data value exceeds the Min. Step Size value specified, the filter will shift the data by 360 degrees to attempt to produce a smooth graph.

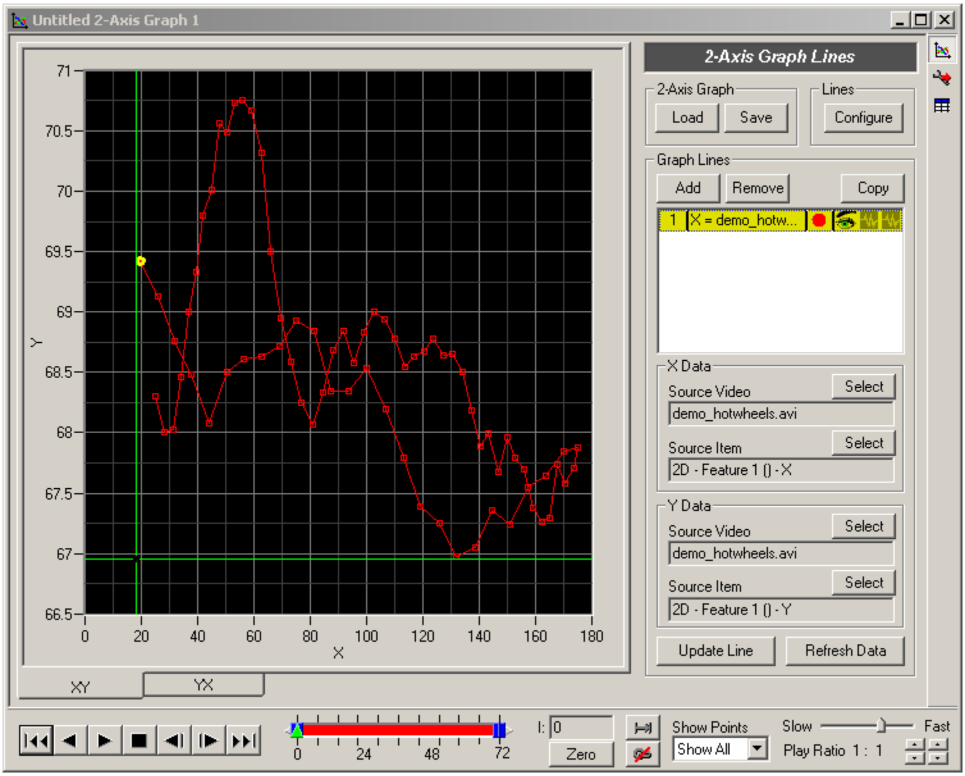
Adaptive Unwrap	This filter is similar to the Angle Unwrap filter, however, the correction amount is not fixed to 360. This filter will attempt to predict how much of an offset is required to produce a continuous graph when large jumps are encountered.
Zero Initial	This filter applies an offset so that the first data point becomes zero. This is useful if you wish to compare the trend of multiple data sets that have different initial val- ues.
Outlier Removal	This filter attempts to remove outlier values from a data sequence. A simple algorithm is used to determine outliers to be ignored. If the difference between the current data value and the previous data value is greater than the minimum step size parameter value, the current data value is considered an outlier and is ignored. Ignored values are replaced with linearly interpolated values.
Smoothing (Mean-Median)	This filter combines the Mean and Median filters into one. The combination of computing a mean followed by a median is a common way of smoothing data. This filter conveniently combines the Mean and Median filters into a single filter so that you only need to set the half-width once.
Threshold (Binary)	This filter performs a threshold operation on the data. All data values that are below the minimum bound or above the maximum bound are set to 1.0. All data values between the minimum bound and the maximum bound are set to 0.0.
Threshold (Mask)	This filter performs a threshold operation on the data. All data values that are below the minimum bound or above the maximum bound are left the same. All data values between the minimum bound and the maximum bound are set to 0.0.
Integral w/ Zero Reset	This filter computes the integral of portions of the data signal between zero values. If all data values are non-zero, this filter is identical to the Integral data filter. However, when a data value of 0.0 is encountered, this filter will reset the integral computation to 0.0 and the integration begins again.
Subtract Unfiltered	This filter subtracts the original unfiiltered data from the current filtered data.
Maximum	This filter generates a new set of data where all values are set to the maximum value of the input data.
Minimum	This filter generates a new set of data where all values are set to the minimum value of the input data.

Absolute Value	This filter generates a new set of data where all values are set to the absolute value of the input data.
Inverse (1/x)	This filter generates a new set of data where all values are set to the inverse value of the input data (1/x). This filter was previously the Invert filter, which generated the negative of the input values. To obtain the negative values instead, use the Scale filter with a scale factor of -1.
Combine With Another	This filter combines the current data (including any filters applied above this filter) with the data from a previous graph line (including any data filters). Different operations can be selected to specify how to combine the current data with the previous graph line. The available operations are: Add, Subtract, Multiply, Divide, and Magnitude. For Add, Subtract, Multiply, and Divide, the operations are A+B, A-B, A*B, A/B, where A is the current data and B is the data from the previous graph line. The Magnitude opera- tion results in output of the form sqrt(A*A+B*B).
CFC Filter	This filter implements a Channel Frequency Class (CFC) filter that is commonly used in automotive applications. The filter implements a low-pass 4-channel Butterworth filter, as described in SAE J211. This filter can be used to smooth signals that contain high frequency noise.

2-Axis Graphing

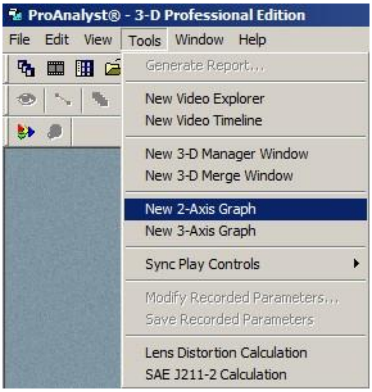
Overview

In addition to the standard data vs. time graphing available in the Measurement Window, you can also create multiple 2-Axis Graph windows. These windows allow you to graph data from different video sources simultaneously. The 2-Axis Graph window also allows for logarithmic axes for X or Y or both.

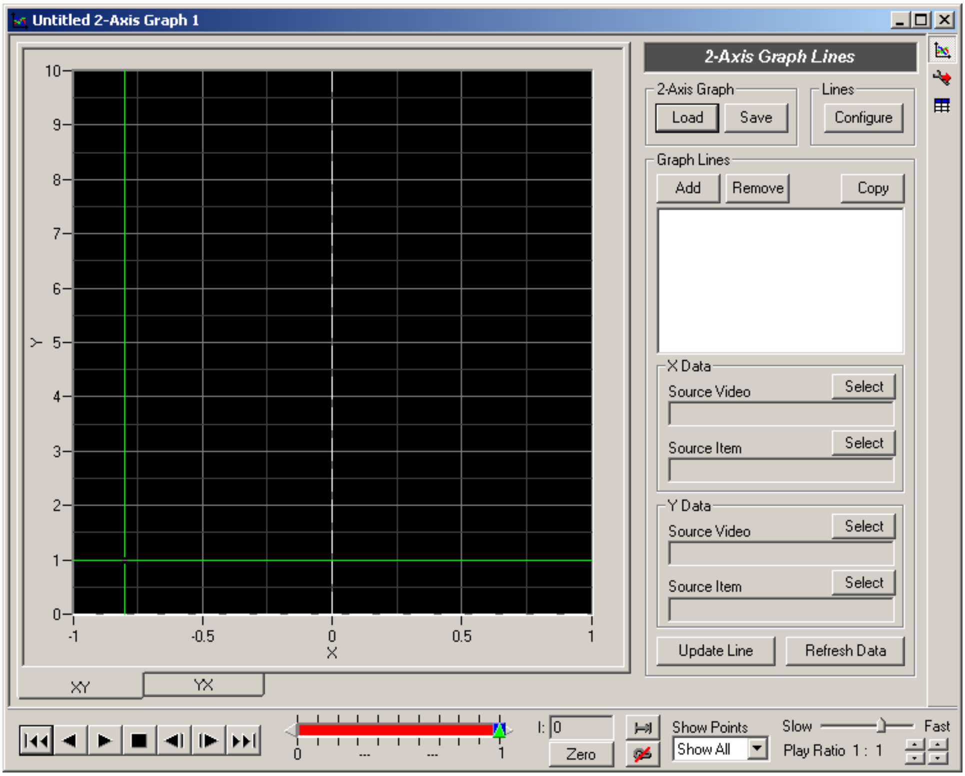


Creating a New 2-Axis Graph

To create a new 2-Axis Graph window, select New 2-Axis Graph from the Tools menu.

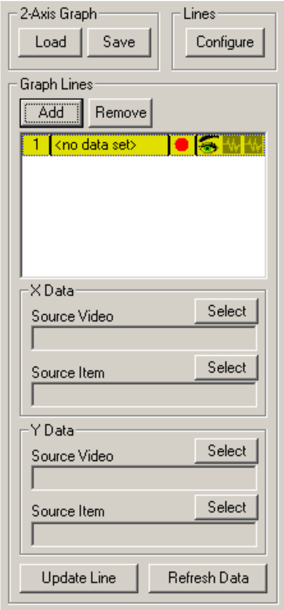


This will create an empty 2-Axis Graph window.

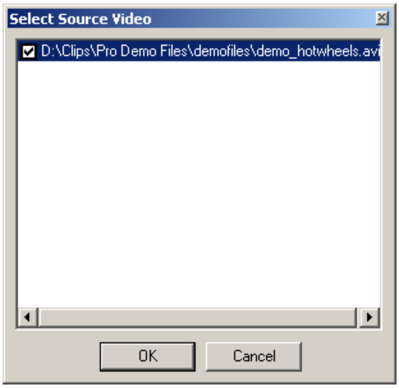


2-Axis Graph Lines

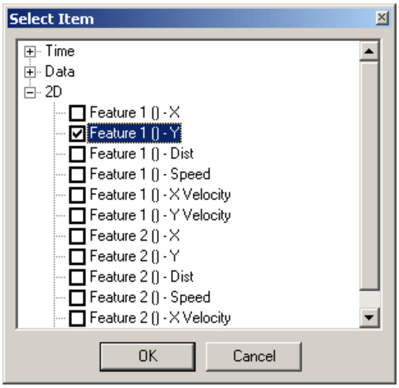
Multiple lines can be graphed within the same window. To add additional lines to a 2-Axis Graph window, click Add in the 2-Axis Graph Lines panel.



The source video and source items must be set for the X and Y Data. The source video must be open, and the corresponding source item must be enabled in order for the data to be available for graphing. Click Select next to the source video line to select a source from among the cur- rently opened videos.



After the source video has been selected, the source item must be selected. Click Select next to the source item line to select a data item from the source video. In order for items to be graphed, they must be enabled in the source video window. For instance, in order to graph 2-D feature tracking data, the Feature Tracking toolkit must be enabled for the selected video.

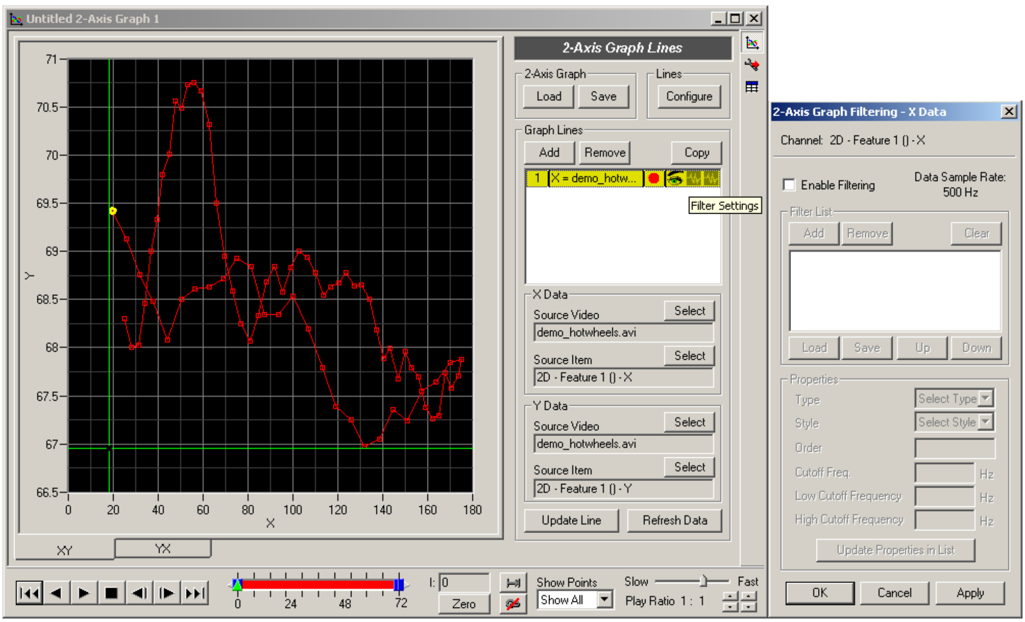


After you have set the source video and items for both the X and Y data, click Update Line and then Refresh Data.

The graph line information in the Graph Lines listing should update to reflect the new source information.

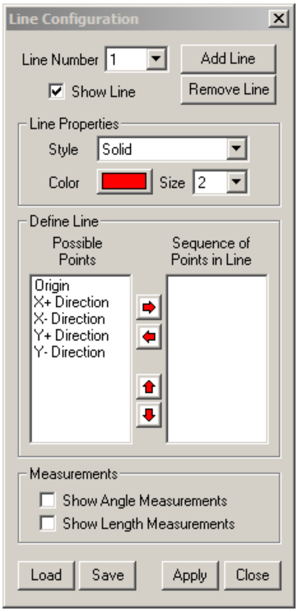
The line and point style for the graph line can be modified by double-clicking on the name or colored circle in the Graph Lines listing. The line appearance dialog is identical to the standard graph line appearance dialog. See the section called "Changing Appearance" for more information.

Filtering can also be applied to both the X and Y data independently. Click icons in the two filter columns of the Graph Lines listing to display the filter configuration dialog. The filter configuration dialog is identical to the standard graph filter configuration dialog. See the section called "Data Filtering" for more information.



2-Axis Graph Connection Lines

An arbitrary number of custom lines may be drawn between graph points. Click the Configure button in the Lines section of the 2-Axis Graph Lines Panel.



Click the Add Lines button to add a new line. Click the Remove Line button to remove the currently selected line in the Line Number drop-down box.

Each line may have its own set of properties. Set the style, color, and size of the line in the Line Properties section of the dialog.

A line will be drawn between the sequence of points shown in the right list box. Select items from the list of possible points in the left list box and click on the right arrow button to add them to the sequence. To remove items from the sequence, select the items in the right list box and click on the left arrow button. To rearrange items in the sequence, select the items to move and click on the up or down arrow buttons.

Simple angle and length measurements can also be displayed next to the feature lines. The length measurements will be shown at the midpoint of each line segment. The length will be displayed in the calibrated units. The angle measurements will be shown at the joint (middle point) of every three point segment. Angle measurements are always shown in degrees.

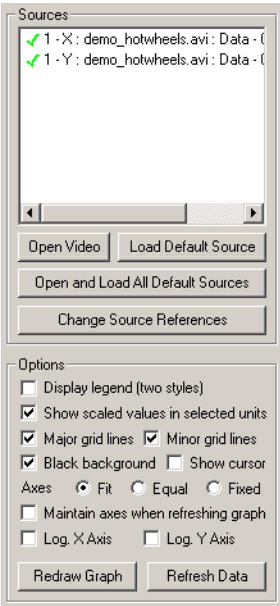
When you are done configuring all lines, click the Apply button and then the Close button.

Line configuration files (`*.lcf`) can also be loaded or saved from this dialog using the Load and Save buttons. These files are interchangeable with the files generated by Feature Tracking or Line Tracking.

2-Axis Graph Sources and Options

In order for the data to be graphed, the source video and source item must be currently open. The 2-Axis Graph Sources/Options control panel lists the source videos and items in the upper portion of the panel. A green check next to an item indicates that the corresponding source video is currently open. A red X indicates the corresponding source video is not currently open.

No checking is done for whether the source item is available in the corresponding source video. For instance, the green check indicates that the video is open, but no checking is done to see if the 2-D Feature Tracking toolkit is currently enabled. An error message is displayed when the graph is refreshed if a source video or item is unavailable.

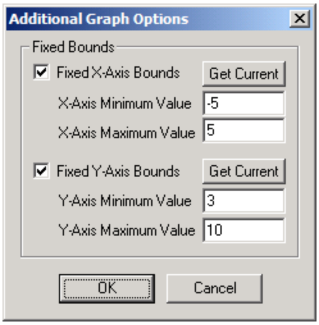


If a video is currently not open, you may select the line in the Sources listing and click the Open Video button to open the video file. If the video is open, but the specific analysis toolkit is not loaded, you can click the Load Default Source button to load the default toolkit file for the selected video if the file exists. To open all videos and default sources, click Open and Load All Default Sources. Note that if you saved your analysis files to non-default names, the auto- matic loading may fail. For instance, if your video is named test.avi, the default Feature Track- ing filename would be test.ftk. If the test.ftk file does not exist, then loading the default source will not work. To change to a different source video, click Change Source References. You will be asked to select the source video to change, and then to select the new source video to use. Click OK to confirm.

Additional options that affect the appearance of the graph can be set in the lower portion of this control panel. Change each option and then click the Refresh Graph button to apply the changes without reloading the data. Click Refresh Data to apply the changes and also reload all graph data.

Display legend	There are two types of legends. Click on the checkbox once and refresh to get the first legend, click again and refresh to get the second.

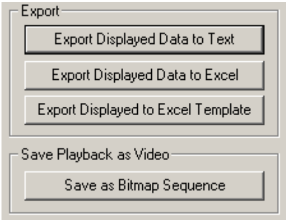
Show scaled values in selected units	The data can be shown using scaled values in selected units (e.g. inches, pressure) or using unscaled units (e.g. pixels, volts). Check this box and refresh to show scaled values. Uncheck to show unscaled values.
Major grid lines	Check this box to show major gridlines in the graph.
Minor grid lines	Check this box to show minor gridlines in the graph.
Black background	The graph can be drawn against a black background or against a white background. Check this box to draw the graph with a black background.
Show cursor	Check this box to enable a green cursor. The green cursor can be moved anywhere in the graph by clicking on the desired point. The coordinates of the cursor can be shown by displaying the legend.
Axes	There are three options for setting the axis ranges. Fit automatically sets the axis ranges to fit the entire range of displayed data for each axis independently. Equal determines the largest range of data over all the axes and then sets each axis range to be equal in length to the largest range. Fixed allows you to specify fixed values for each axis range. Shown below is the dialog that ap- pears when setting fixed bounds. Use the checkboxes to enable fixed bounds for a given axis. Click the Get Cur- rent button to populate the edit boxes with the current ax- is bounds.



Maintain axes when refreshing graph	When the graph is refreshed, the X and Y range of the displayed graph is typically reset. Check this box to maintain the same settings for the X and Y range when the graph is refreshed.
Log. X Axis	Check this box to graph the X axis using a logarithmic scale.
Log. Y Axis	Check this box to graph the Y axis using a logarithmic scale.

2-Axis Graph Data Exporting

The data used to generate the graph may be exported to a Text file or to Excel. Click the Data button on the left toolbar to display the 2-Axis Graph Data panel.

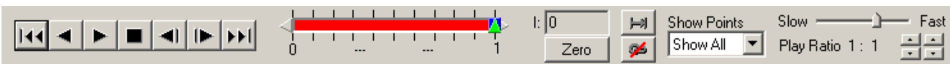


The data is exported in a undecorated format to either a text file or an Excel spreadsheet. The first and second columns are the X and Y data for the first graph line. The third and fourth are the X and Y data for the second graph line, and so on.

In addition to exporting the data, the 2-Axis graph can also save the "playback" of the entire graph to a bitmap sequence. The Window operation directly copies the graph window to a bit- map file. If any other windows are located on top of the graph window area, these portions of the graph will be obscured. Make sure that there are no other windows obscuring the graph window when you perform the save operation. To save the graph as a video, select Save Play- back As Bitmap Sequence (Window) from the context menu. You can save the entire ProAna- lyst workspace and all the displayed windows by using the Save Playback As Bitmap Sequence (Program) selection on the context menu.

2-Axis Graph Play Controls

The 2-Axis Graph includes special play controls for moving through the graphed data. The play bar shows the index of the current frame and the total number of data points that are graphed. The current point on each graphed line is highlighted with a yellow indicator. As the graph is "played", the index of the current point is changed and the graph is updated.



Additional options can affect the playback and appearance of the graph:

Zero — Click this button to adjust the zero index of the graph. This is helpful for adjusting the synchronized playback of multiple videos or graphs.

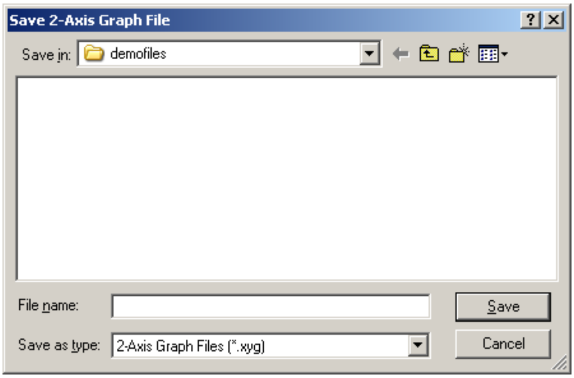
Continuous (C) — Check this box to enable continuous playback. When the end of the graph line is reached, playback will begin again at the beginning. If playing backwards, playback will begin again at the end.

Synchronize (S) — Check this box to enable synchronized playback with other synchronized windows. Note that if the program is doing Time-based synchronized playback, the frame rate of the video of the first video source will be used as the frame rate for the graph. See the section called

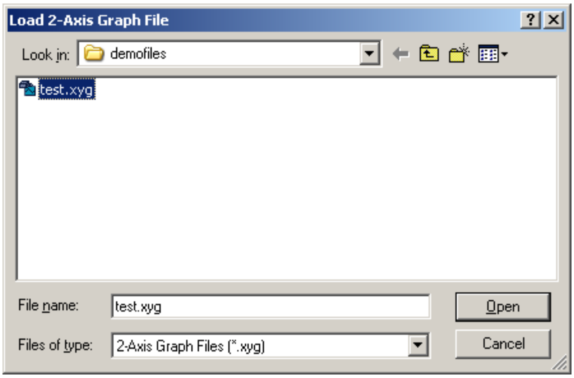
	"Synchronized Play Controls Toolbar" for more information about synchronized playback options.
Show Points	The graph can be configured to show all points, the current point only, or past points.

Saving and Loading

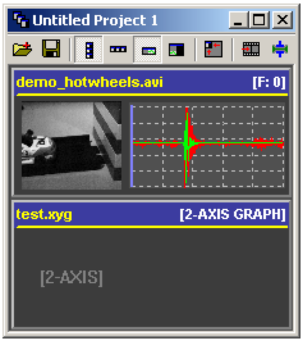
All 2-Axis Graph line data, appearance, and filter settings can be saved to a file and reloaded. The settings are saved to an 2-Axis Graph configuration file with the `XYG` file extension. Click the Save button in the 2-Axis Graph Lines control panel to save the settings to a file.



To load the graph configuration settings, click the Load button in the 2-Axis Graph Lines control panel.



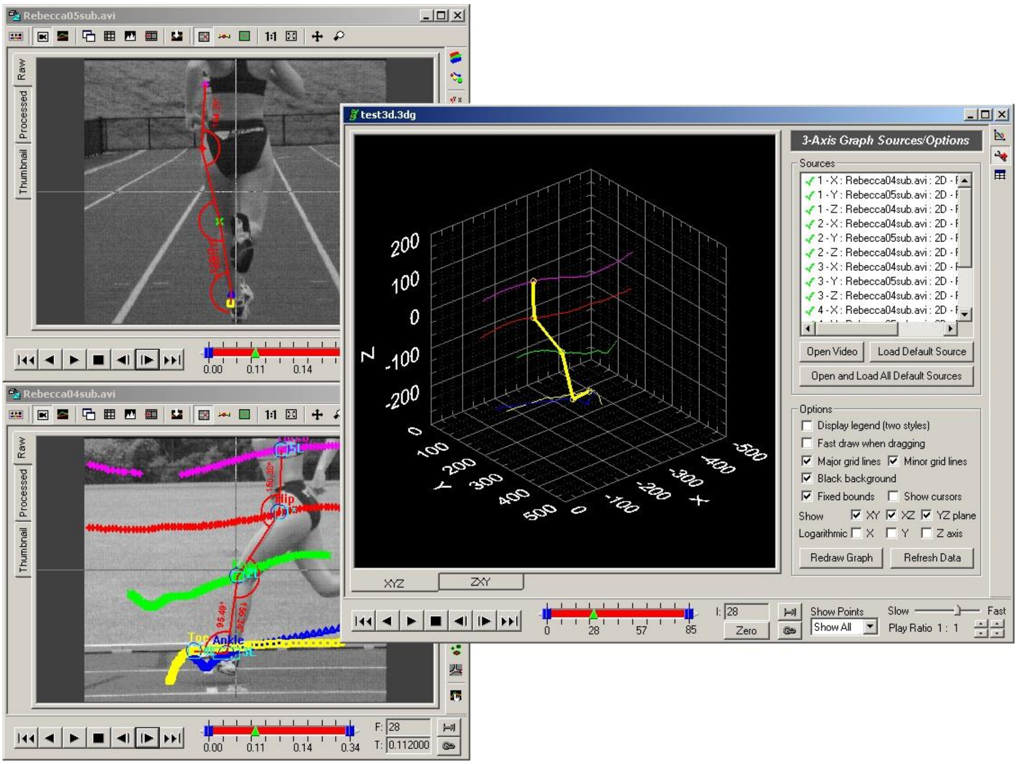
Since the 2-Axis Graph depends on data from other video sources, it is convenient to add 2-Axis Graph files to projects containing the necessary video sources. 2-Axis Graph files can be added to projects in the same manner that videos are added to projects. You can use the Add Video button on the toolbar or the context menu or you can drag and drop from an open 2-Axis Graph window onto a project window.



3-Axis Graphing

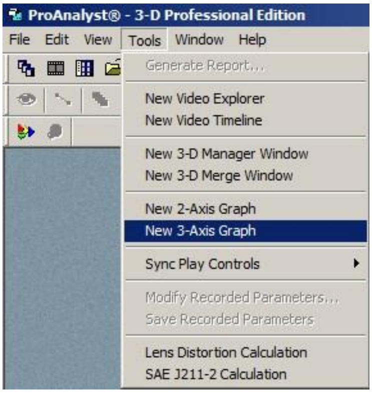
Overview

In addition to the standard data vs. time graphing available in the Measurement Window, you can also create multiple 3-Axis Graph windows. These windows allow you to graph data from different video sources simultaneously. The 3-Axis Graph window also allows for logarithmic axes for X and/or Y and/or Z.

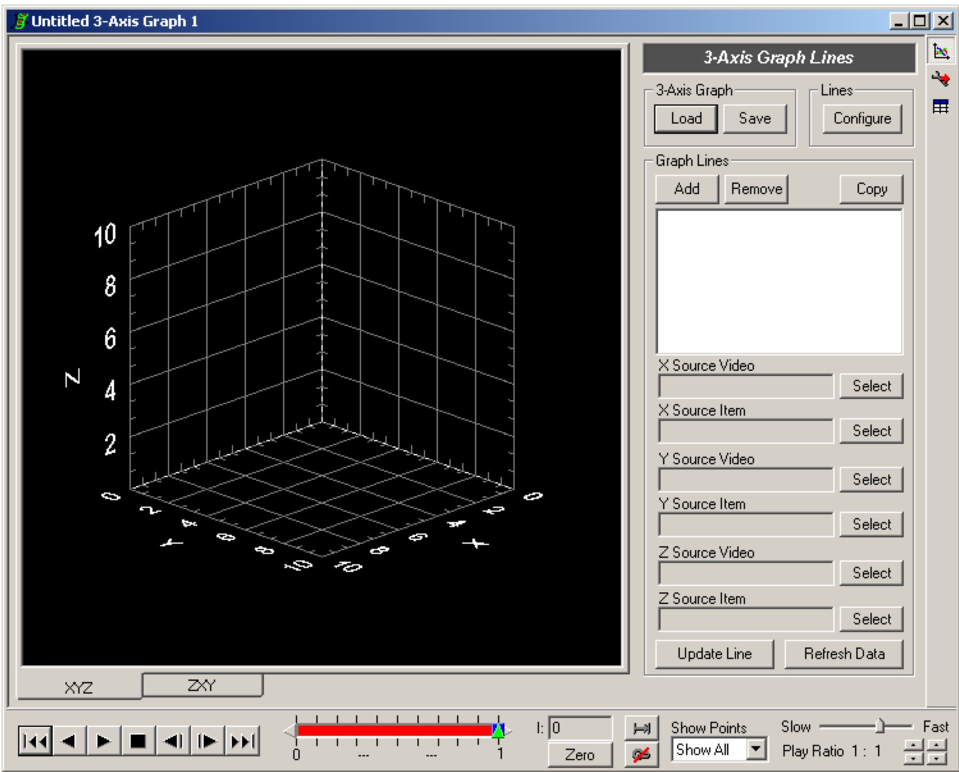


Creating a New 3-Axis Graph

To create a new 3-Axis Graph window, select New 3-Axis Graph from the Tools menu.



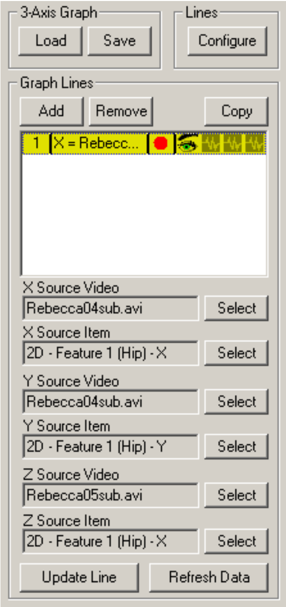
This will create an empty 3-Axis Graph window.



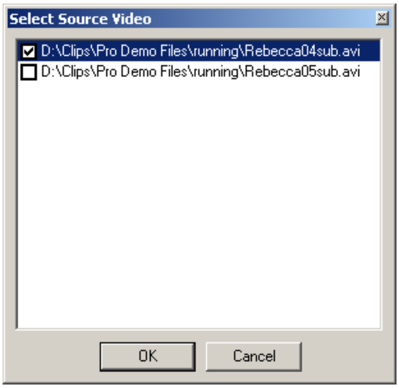
3-Axis Graph Lines

Multiple lines can be graphed within the same window. To add additional lines to a 3-Axis

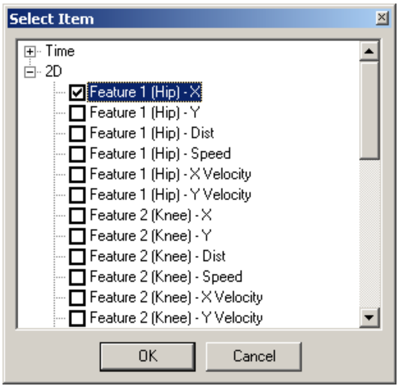
Graph window, click Add in the 3-Axis Graph Lines panel.



The source video and source items must be set for the X, Y, and Z Data. The source video must be open, and the corresponding source item must be enabled in order for the data to be avail- able for graphing. Click Select next to the source video line to select a source from among the currently opened videos.



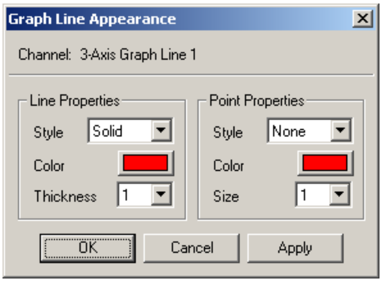
After the source video has been selected, the source item must be selected. Click Select next to the source item line to select a data item from the source video. In order for items to be graphed, they must be enabled in the source video window. For instance, in order to graph 2-D feature tracking data, the Feature Tracking toolkit must be enabled for the selected video.



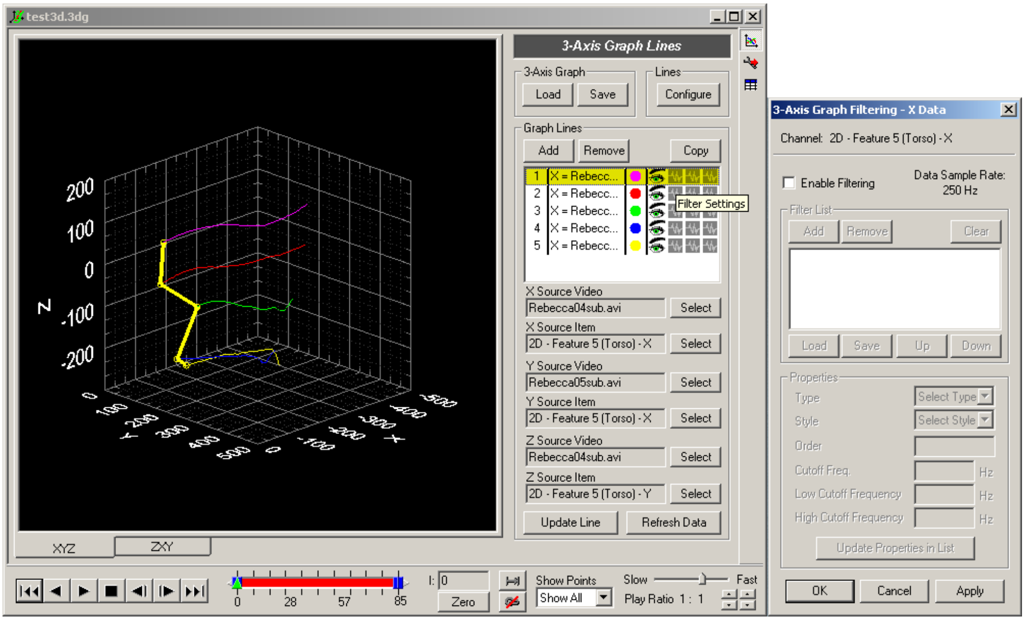
After you have set the source video and items for the X, Y, and Z data, click Update Line and then Refresh Data.

The graph line information in the Graph Lines listing should update to reflect the new source information.

The line and point style for the graph line can be modified by double-clicking on the name or colored circle in the Graph Lines listing. The line appearance dialog is identical to the standard graph line appearance dialog. See the section called "Changing Appearance" for more information. Note that you are able to adjust the point size for the 3-Axis graph lines.

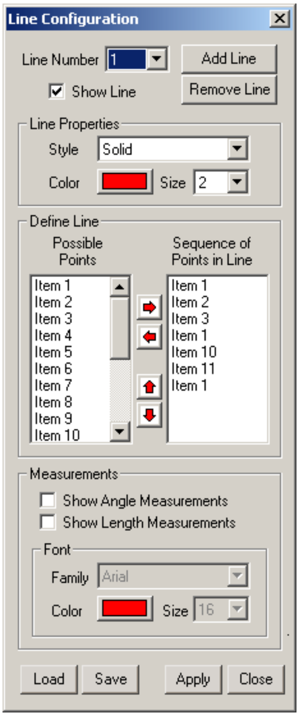


Filtering can also be applied to both the X, Y, and Z data independently. Click icons in the three filter columns of the Graph Lines listing to display the filter configuration dialog. The fil- ter configuration dialog is identical to the standard graph filter configuration dialog. See the section called "Data Filtering" for more information.



3-Axis Graph Connection Lines

An arbitrary number of custom lines may be drawn between graph points. Click the Configure button in the Lines section of the 3-Axis Graph Lines Panel.



Click the Add Lines button to add a new line. Click the Remove Line button to remove the currently selected line in the Line Number drop-down box.

Each line may have its own set of properties. Set the style, color, and size of the line in the Line Properties section of the dialog.

A line will be drawn between the sequence of points shown in the right list box. Select items from the list of possible points in the left list box and click on the right arrow button to add them to the sequence. To remove items from the sequence, select the items in the right list box and click on the left arrow button. To rearrange items in the sequence, select the items to move and click on the up or down arrow buttons.

Simple angle and length measurements can also be displayed next to the feature lines. The length measurements will be shown at the midpoint of each line segment. The length will be displayed in the calibrated units. The angle measurements will be shown at the joint (middle point) of every three point segment. Angle measurements are always shown in degrees.

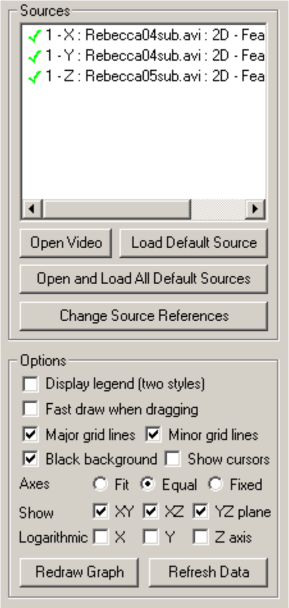
When you are done configuring all lines, click the Apply button and then the Close button.

Line configuration files (`*.lcf`) can also be loaded or saved from this dialog using the Load and Save buttons. These files are interchangeable with the files generated by Feature Tracking or Line Tracking.

3-Axis Graph Sources and Options

In order for the data to be graphed, the source video and source item must be currently open. The 3-Axis Graph Sources/Options control panel lists the source videos and items in the upper portion of the panel. A green check next to an item indicates that the corresponding source video is currently open. A red X indicates the corresponding source video is not currently open.

No checking is done for whether the source item is available in the corresponding source video. For instance, the green check indicates that the video is open, but no checking is done to see if the 2-D Feature Tracking toolkit is currently enabled. An error message is displayed when the graph is refreshed if a source video or item is unavailable.

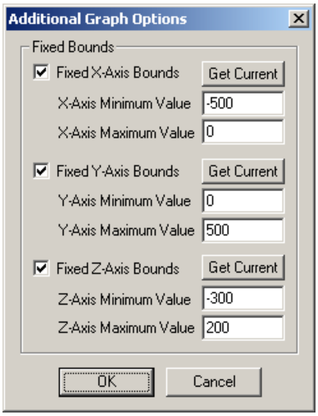


If a video is currently not open, you may select the line in the Sources listing and click the Open Video button to open the video file. If the video is open, but the specific analysis toolkit is not loaded, you can click the Load Default Source button to load the default toolkit file for the selected video if the file exists. To open all videos and default sources, click Open and Load All Default Sources. Note that if you saved your analysis files to non-default names, the auto- matic loading may fail. For instance, if your video is named test.avi, the default Feature Track- ing filename would be test.ftk. If the test.ftk file does not exist, then loading the default source will not work. To change to a different source video, click Change Source References. You will be asked to select the source video to change, and then to select the new source video to use. Click OK to confirm.

Additional options that affect the appearance of the graph can be set in the lower portion of this control panel. Change each option and then click the Refresh Graph button to apply the changes.

Display legend	There are two types of legends. Click the checkbox once and refresh to get the first legend, click again and refresh to get the second.
Fast draw when dragging	If you are on a slower computer, you may want to enable fast drawing when dragging. The graph will then only draw the outline of the axis planes and graph points when rotating, panning, or zooming the graph.
Major grid lines	Check this box to show major gridlines in the graph.
Minor grid lines	Check this box to show minor gridlines in the graph.
Black background	The graph can be drawn against a black background or against a white background. Check this box to draw the

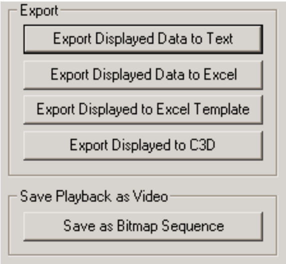
	graph with a black background.
Show cursors	Check this box to display green cursor lines and cursor co-ordinates next to each of the current graph points.
Axes	There are three options for setting the axis ranges. Fit automatically sets the axis ranges to fit the entire range of displayed data for each axis independently. Equal determines the largest range of data over all the axes and then sets each axis range to be equal in length to the largest range. Fixed allows you to specify fixed values for each axis range. Shown below is the dialog that appears when setting fixed bounds. Use the checkboxes to enable fixed bounds for a given axis. Click the Get Current button to populate the edit boxes with the current axis bounds.



Show XY, XZ, YZ Plane	Check these boxes to display the XY, XZ, or YZ planes.
Log. X, Y, and Z Axes	Check these boxes to graph the X, Y, or Z axes using a logarithmic scale.

3-Axis Graph Data Exporting

The data used to generate the graph may be exported to a Text file or to Excel. Click the Data button on the left toolbar to display the 3-Axis Graph Data panel.

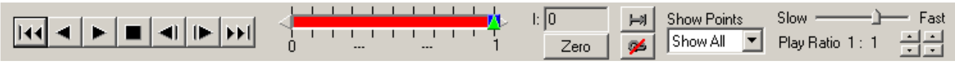


The data is exported in a undecorated format to either a text file, an Excel spreadsheet, an Excel spreadsheet using a template, or a C3D file. The first, second, and third columns are the X, Y, and Z data for the first graph line. The fourth, fifth, and sixth columns are the X, Y, and Z data for the second graph line, and so on.

In addition to exporting the data, the 3-Axis graph can also save the "playback" of the entire graph to a bitmap sequence. The Window operation directly copies the graph window to a bitmap file. If any other windows are located on top of the graph window area, these portions of the graph will be obscured. Make sure that there are no other windows obscuring the graph window when you perform the save operation. To save the graph as a video, select Save Play- back As Bitmap Sequence (Window) from the context menu. You can save the entire ProAna- lyst workspace and all the displayed windows by using the Save Playback As Bitmap Sequence (Program) selection on the context menu.

3-Axis Graph Play Controls

The 3-Axis Graph includes special play controls for moving through the graphed data. The play bar shows the index of the current frame and the total number of data points that are graphed. The current point on each graphed line is highlighted with a yellow indicator. As the graph is "played", the index of the current point is changed and the graph is updated.

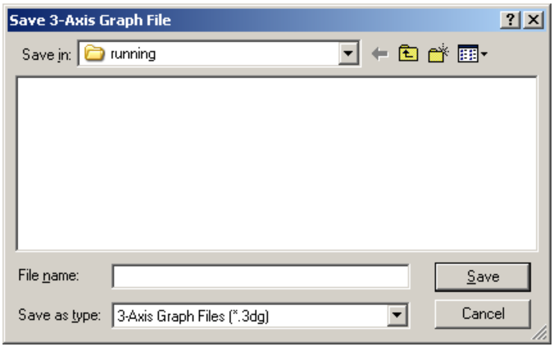


Additional options can affect the playback and appearance of the graph:

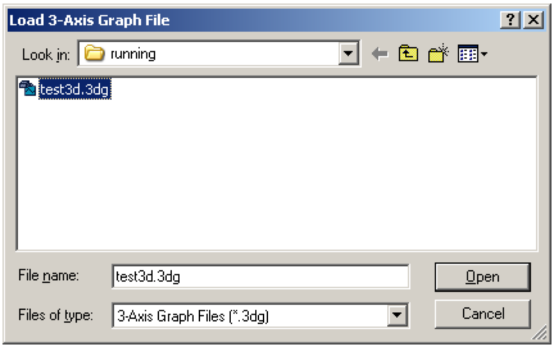
Zero	Click this button to adjust the zero index of the graph. This is helpful for adjusting the synchronized playback of multiple videos or graphs.
Continuous (C)	Check this box to enable continuous playback. When the end of the graph line is reached, playback will begin again at the beginning. If playing backwards, playback will begin again at the end.
Synchronize (S)	Check this box to enable synchronized playback with other synchronized windows. Note that if the program is doing Time-based synchronized playback, the frame rate of the video of the first video source will be used as the frame rate for the graph. See the section called “Synchronized Play Controls Toolbar” for more information about synchronized playback options.
Show Points	The graph can be configured to show all points, the current point only, or past points.

Saving and Loading

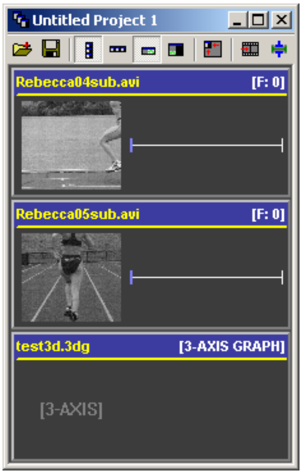
All 3-Axis Graph line data, appearance, and filter settings can be saved to a file and reloaded. The settings are saved to an 3-Axis Graph configuration file with the `3DG` file extension. Click the Save button in the 3-Axis Graph Lines control panel to save the settings to a file.



To load the graph configuration settings, click the Load button in the 3-Axis Graph Lines control panel.



Since the 3-Axis Graph depends on data from other video sources, it is convenient to add 3-Axis Graph files to projects containing the necessary video sources. 3-Axis Graph files can be added to projects in the same manner that videos are added to projects. You can use the Add Video button on the toolbar or the context menu or you can drag and drop from an open 3-Axis Graph window onto a project window.



3-D Manager

Overview

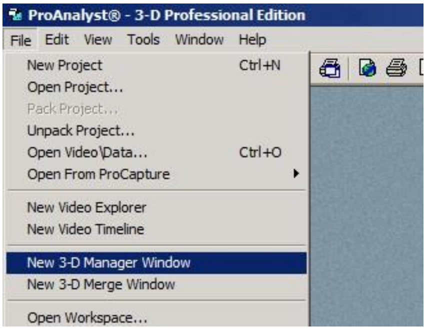
The 3-D Manager is the main interface used by the 3-D Edition. You must have the 3-D Edition licensed in order to open a 3-D Manager window.

The 3-D Manager allows you to perform precise camera calibration for a pair of cameras. Using this calibration, resulting measurement images captured by both cameras may be used to calculate precise 3-D coordinates of points in the field of view.

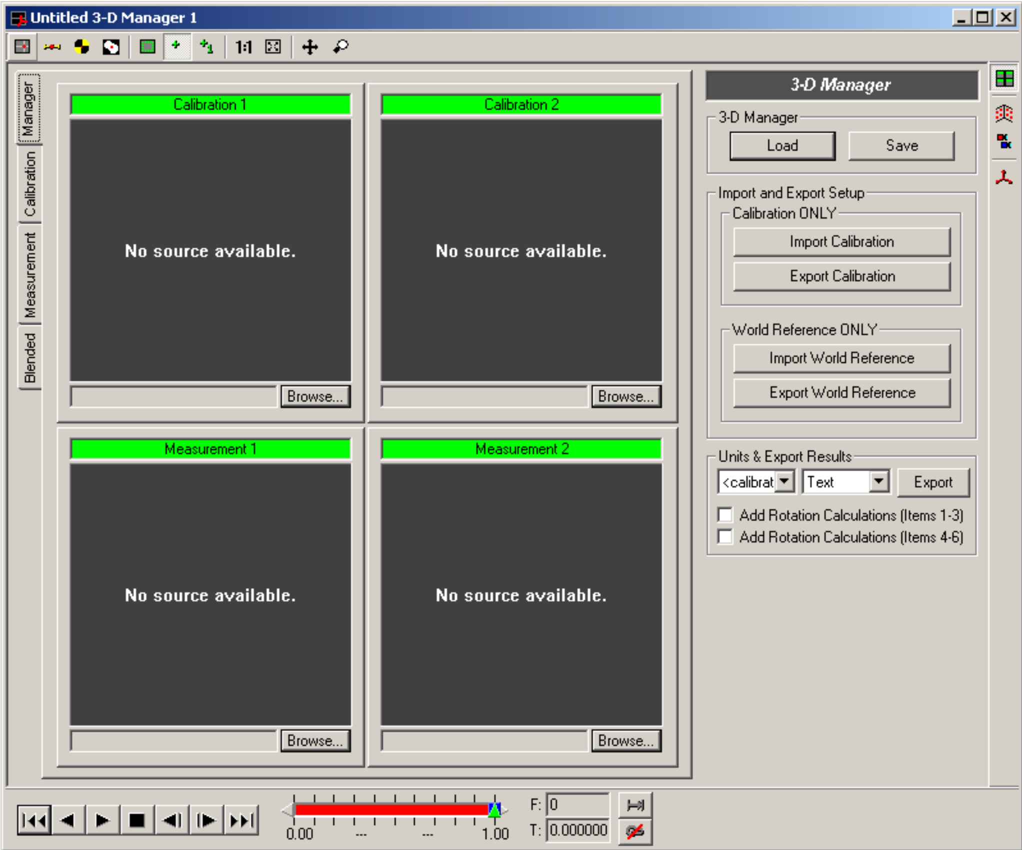
The 3-D Manager interfaces seamlessly with all the other analysis and graphing tools. The 2-D image processing, filtering, and tracking toolkits are used to track points of interest in each of the measurement videos. The 3-D Manager then uses these tracked points, along with the 3-D camera calibration, to compute 3-D coordinates for each point. These 3-D coordinates may be exported or graphed using the 3-Axis graph window.

Manager Window

A new 3-D Manager window can be created by selecting New 3-D Manager from the File menu or the Tools menu.



The 3-D Manager window is comprised of a toolbar across the top, a control panel on the right, and video area on the left.



Manager Toolbars

The main toolbar buttons are located at the top of the 3-D Manager window. The controls affect both top and bottom calibration or measurement video displays.

Enable Reticle	Enable the reticle for the video image.
Enable Midpoint Finder	Enable the midpoint finder tool. When enabled, the default reticle behavior is changed to support clicking and dragging a line in order to select the midpoint of the drawn line. A circle is also drawn around the line end- points to assist in finding the center of circular objects. Uncheck this button to restore normal reticle behavior.
Enable Quad-Target Center Finder	Enable the quad-target center finder tool. When enabled, the default reticle behavior is changed to lock onto the center of a quad target. Uncheck this button to restore normal reticle behavior.

Enable Blob Center Finder	Enable the blob center finder tool. When enabled, the default reticle behavior is changed to lock onto the center of a blob target. Uncheck this button to restore normal reticle behavior.
Show Rulers	Show rulers for the video image.
Show Point Markers	Show reference point markers in the calibration views.
Show Point Labels	Show reference point numbers next to the reference point markers in the calibration views. Show Point Markers must be set for labels to be visible.
View Actual Size	Show the video at actual size.
Fit in Window	Show the video and data as large as possible, fitted within the current window dimensions.
Pan Mode	Change the mouse interaction to pan the video or data when dragging.
Zoom Mode	Change the mouse interaction to zoom the video or data.

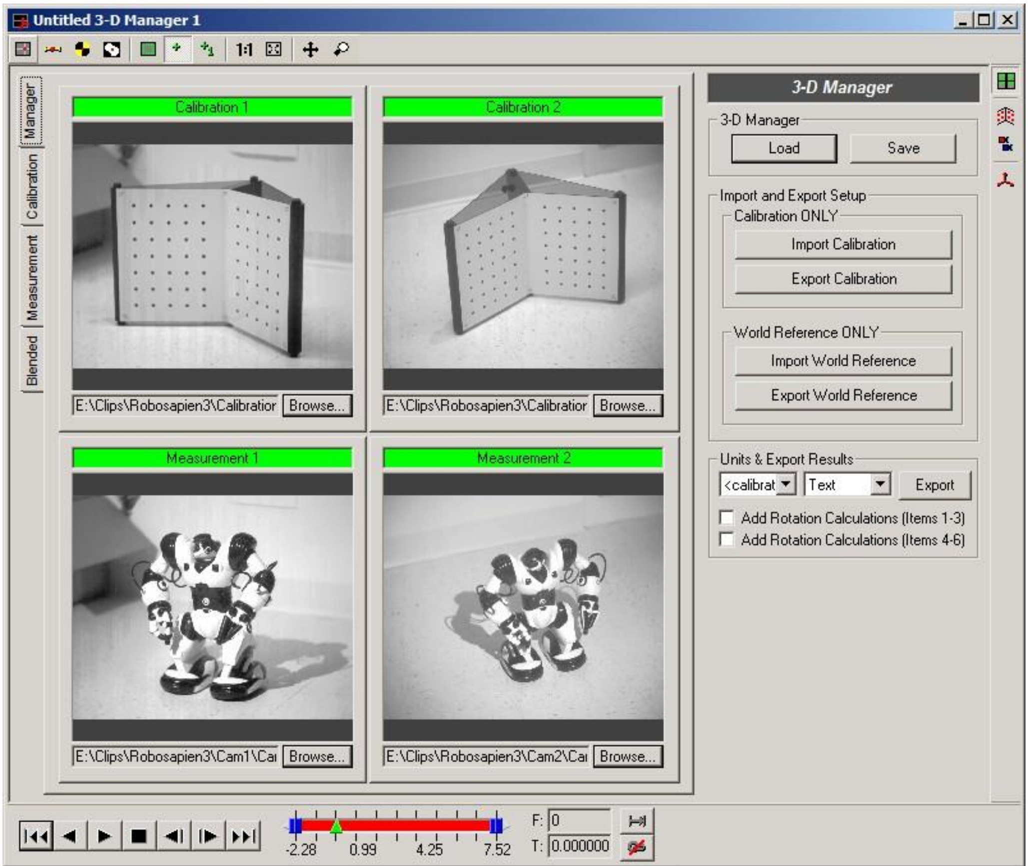
Control panels are located on the right side of the 3-D Manager window. These panels contain controls to perform various functions. When each button on the toolbar is pressed, the corresponding control panel is shown or hidden. The side toolbar buttons roughly correspond to the tabs in the video area.

Manager	Show/hide the 3-D Manager panel. This panel is also where the Load/Save and Export controls are located.
Calibration	Show/hide the 3-D Calibration panel. Use the controls on this panel to perform camera calibration.
Measurement	Show/hide the 3-D Measurement panel. Use the controls on this panel to compute measurements.
World Reference Frame	Show/hide the 3-D World Reference panel. Use the controls on this panel to transform the reference frame for all measured points. The controls on this panel can also be used to view a blended combination of the calibration and measure- ment images.

Manager Source Videos

The 3-D Manager requires two calibration images and two measurement videos. The two calibration images are used to compute calibrations for each of the cameras. The two measurement videos are analyzed independently, using the numerous 2-D analysis tools. The analysis results are then combined with the camera calibration to produce 3-D coordinates for each point.

To select calibration and measurement videos, click on the Browse button beneath each video area. You can also drag-and-drop videos into each of the video areas to set the calibration and measurement videos.



Each calibration and measurement video is opened in a standard 2-D Measurement Window. These windows are normally minimized when they are opened, so that they do not clutter the workspace. Double-clicking on any one of the four views will raise the corresponding 2-D Measurement Window for that video. If you do not wish to have the 2-D Measurement Windows automatically minimized, you can unset this option in the Program Options dialog (see the section called “Program Options”).

The next step is to perform calibration on the calibration images and then measurements on the measurement images. If necessary, the coordinate frame may be transformed using a World Reference Frame. Each step in the process: Calibration, Measurement, and World Reference Frame definition is explained in the following sections.

3-D Calibration

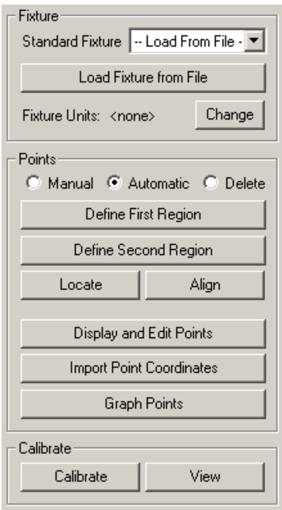
Camera calibration is required in order to compute precise 3-D coordinates of points from a pair of cameras. The camera calibration procedure attempts to determine the location, orienta- tion, and internal parameters of each camera.

Calibration requires a calibration fixture. This fixture can be a standard fixture supplied with the software or it can be a custom made collection of reference points at known locations. This fixture is placed in the field of view of both cameras. All reference points on the fixture must be visible by both cameras.

Prior to capturing the videos of the actual event for measurement, a set of calibration images must be acquired. The fixture should be placed in the field of view of both cameras and a set of calibration images/videos captured. The cameras should not be moved between capturing the calibration images and the actual event. If the cameras are disturbed in any way, a new calibration must be computed. If the cameras are not moved between events, the same calibration may be used for each event. A new calibration is not required unless the cameras have been adjusted or have moved since the last calibration.

Calibration Panel

The Calibration Panel contains all controls necessary for computing calibrated camera parameters for a pair of cameras.



When the Calibration Panel is shown, the Calibration tab containing the two calibration images is automatically shown.

Calibration Fixture

There are two options for specifying the location of points on the fixture being used. If the fixture is a standard fixture, the fixture should be listed in the Standard Fixture drop-down box. If it is not a standard fixture, or it is not listed in the drop-down box, the fixture point coordinates must be loaded from a fixture file.

Standard Fixture

When the program is installed, a set of standard fixture files is also installed in the Program Files directory for this application. Standard fixtures are all fixture files that are located in this Fixtures directory. When a new 3-D Manager window is created, the Fixtures directory is scanned for fixture files, and all models and serial numbers are listed here. Select the appropriate model and serial number for your fixture and the corresponding fixture file will be loaded.

Load Fixture from File

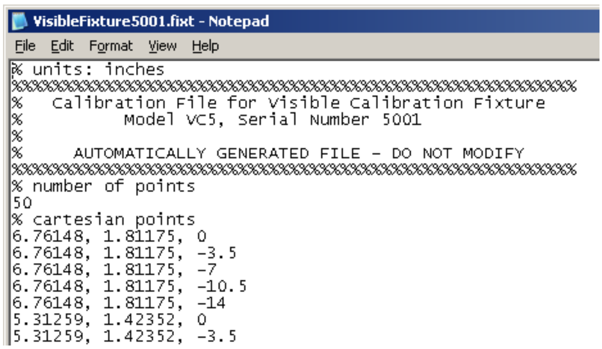
If you are not using a standard fixture, you must create a custom fixture file. The fixture file is a standard text file with special formatting. Comment lines begin with a per- cent (%) symbol.

The first line of the file should indicate the units used for all coordinates in the file. Note that this first line should be a commented line. This is the only commented line that is processed. Acceptable units are the same units listed in the Units drop-down box in the Manager Panel.

The next non-commented line indicates how many reference points are located on the fixture.

The remaining lines in the file are comma-separated X, Y, and Z coordinates of each of the reference points.

An example of a fixture file is shown below. The fixture coordinates are given in units of inches and there are 50 points on this fixture.



VisibleFixture5001.fixt - Notepad

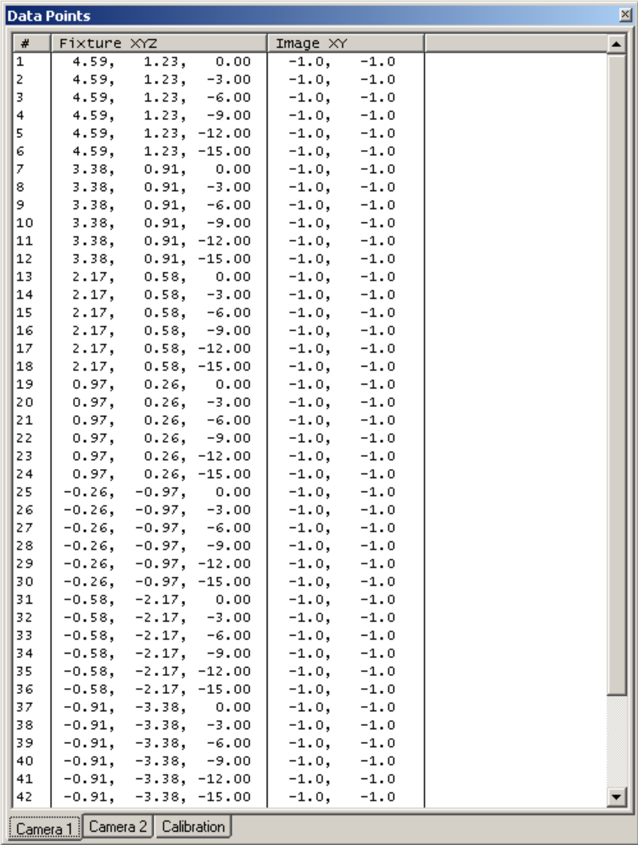
File Edit Format View Help

```
% units: inches
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Calibration File for Visible Calibration Fixture
%          Model VC5, Serial Number 5001
%
%     AUTOMATICALLY GENERATED FILE - DO NOT MODIFY
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% number of points
50
% cartesian points
6.76148, 1.81175, 0
6.76148, 1.81175, -3.5
6.76148, 1.81175, -7
6.76148, 1.81175, -10.5
6.76148, 1.81175, -14
5.31259, 1.42352, 0
5.31259, 1.42352, -3.5
```

Fixture Units

After a fixture file is loaded, the units of the coordinates contained in the fixture file is displayed here. The units may be changed by using the Change button. This button can also be used to set the units for manually entered fixture XYZ coordinates.

After a fixture file has been loaded, a dialog window will appear showing the fixture points that were just loaded. The image points are shown as -1,-1 since they have not been located in the calibration images yet. Once the fixture point coordinates have been loaded, the next step is to locate the points in each of the calibration images.



Data Points

#	Fixture XYZ	Image XY
1	4.59, 1.23, 0.00	-1.0, -1.0
2	4.59, 1.23, -3.00	-1.0, -1.0
3	4.59, 1.23, -6.00	-1.0, -1.0
4	4.59, 1.23, -9.00	-1.0, -1.0
5	4.59, 1.23, -12.00	-1.0, -1.0
6	4.59, 1.23, -15.00	-1.0, -1.0
7	3.38, 0.91, 0.00	-1.0, -1.0
8	3.38, 0.91, -3.00	-1.0, -1.0
9	3.38, 0.91, -6.00	-1.0, -1.0
10	3.38, 0.91, -9.00	-1.0, -1.0
11	3.38, 0.91, -12.00	-1.0, -1.0
12	3.38, 0.91, -15.00	-1.0, -1.0
13	2.17, 0.58, 0.00	-1.0, -1.0
14	2.17, 0.58, -3.00	-1.0, -1.0
15	2.17, 0.58, -6.00	-1.0, -1.0
16	2.17, 0.58, -9.00	-1.0, -1.0
17	2.17, 0.58, -12.00	-1.0, -1.0
18	2.17, 0.58, -15.00	-1.0, -1.0
19	0.97, 0.26, 0.00	-1.0, -1.0
20	0.97, 0.26, -3.00	-1.0, -1.0
21	0.97, 0.26, -6.00	-1.0, -1.0
22	0.97, 0.26, -9.00	-1.0, -1.0
23	0.97, 0.26, -12.00	-1.0, -1.0
24	0.97, 0.26, -15.00	-1.0, -1.0
25	-0.26, -0.97, 0.00	-1.0, -1.0
26	-0.26, -0.97, -3.00	-1.0, -1.0
27	-0.26, -0.97, -6.00	-1.0, -1.0
28	-0.26, -0.97, -9.00	-1.0, -1.0
29	-0.26, -0.97, -12.00	-1.0, -1.0
30	-0.26, -0.97, -15.00	-1.0, -1.0
31	-0.58, -2.17, 0.00	-1.0, -1.0
32	-0.58, -2.17, -3.00	-1.0, -1.0
33	-0.58, -2.17, -6.00	-1.0, -1.0
34	-0.58, -2.17, -9.00	-1.0, -1.0
35	-0.58, -2.17, -12.00	-1.0, -1.0
36	-0.58, -2.17, -15.00	-1.0, -1.0
37	-0.91, -3.38, 0.00	-1.0, -1.0
38	-0.91, -3.38, -3.00	-1.0, -1.0
39	-0.91, -3.38, -6.00	-1.0, -1.0
40	-0.91, -3.38, -9.00	-1.0, -1.0
41	-0.91, -3.38, -12.00	-1.0, -1.0
42	-0.91, -3.38, -15.00	-1.0, -1.0

Camera 1 | Camera 2 | Calibration

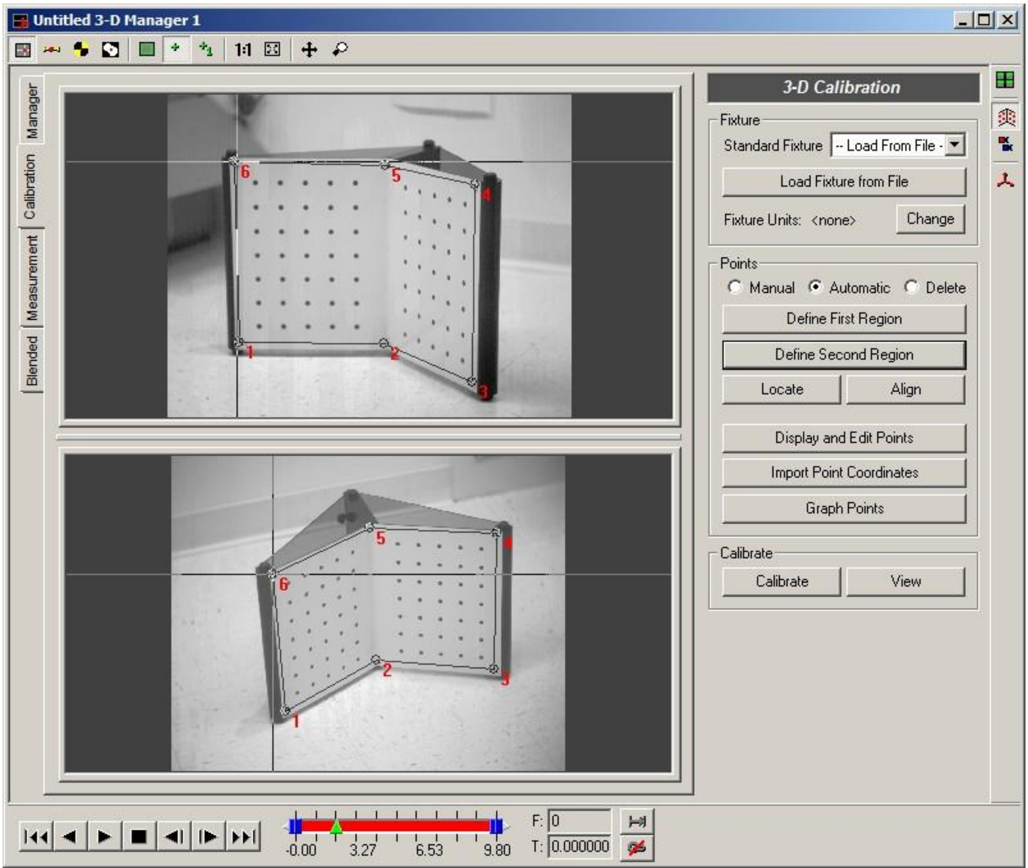
Fixture points coordinates may also be manually entered. To do so, switch to Manual mode (described in the next section) and add points for each fixture point. In the Data Points dialog, the fixture coordinates will now be -1, -1, -1. Double-click on each line and enter the fixture XYZ coordinates in the Edit Point dialog that appears.

Locating Points

There are two methods for locating fixture points in each of the calibration images: Manual and Automatic. The automatic method can be used for standard fixtures. The manual method must be used for custom fixtures.

Automatic Mode

The automatic method relies upon the user to define regions that enclose the fixture points. These regions are defined by six points of a polygon. The order of the points is important. The first point should be closest to the first point as defined in the fixture file. The second point should be located close to the joint of the fixture. The rest of the points should continue to enclose the remaining fixture points. The region should fully enclose all fixture points and not include regions outside of the fixture. This helps eliminate distracting backgrounds. If a mistake is made in placing the six points, click on the Define button and begin again.



Define First Region

Click on this button to begin the process of clicking on six points in the top image to enclose all fixture points.

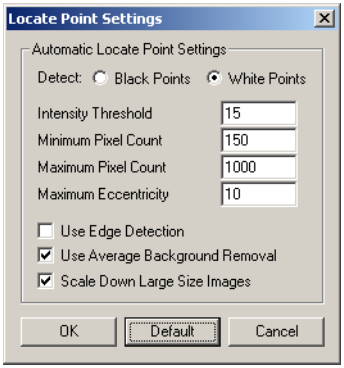
Define Second Region

Click on this button to begin the process of clicking on six points in the bottom image to enclose all fixture points.

Locate

After both first and second regions have been defined, click on this point to attempt to automatically locate and sort the fixture points. The locate process utilizes a number of parameters to control how points are identified. These parameters may be changed by right-clicking on the image and selecting Locate Point Settings for either the top or bottom image.

Changes in lighting, resolution, field of view, and other factors alter the appearance of the fixture. A number of parameters may be adjusted in order to compensate for these changes.



The settings in this dialog control how the image is processed and how the points are identified from the processed image.

Detect: Black or White

This refers to the color of the points in the processed image, not the actual fixture. Depending on whether you are using edge detection or average background removal, this may be the opposite of the color of the actual fixture points.

Intensity Threshold

Specify the threshold on the intensity of the processed image. All pixel values below this threshold will be set to black, all pixel values above this threshold will remain unchanged.

Minimum Pixel Count

Specify the minimum allowable size of a fixture point in number of pixels.

Maximum Pixel Count

Specify the maximum allowable size of a fixture point in number of pixels.

Maximum Eccentricity

Specify the maximum allowable eccentricity of each fixture point. Most fixture points are round (eccentricity of 1.0). Specifying this maximum prevents the algorithm from locating long lines of white pixels.

Use Edge Detection

Use an edge detection algorithm to process the image before locating points. Note that if this option is set, each fixture point should appear as a ring (only the outer edge of each fixture point will be identified). In this case, you can either locate the white boundary around each fixture point, or locate the black area inside of each fixture point.

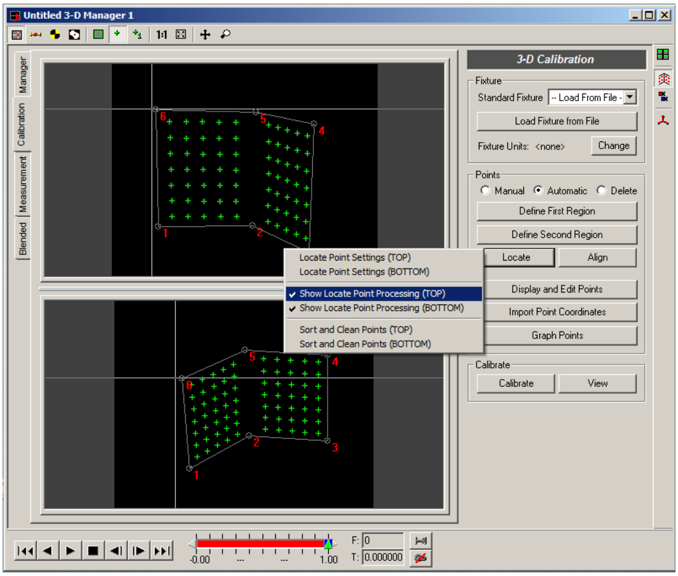
Use Average Background Removal

If this option is checked, the average pixel value in a region around a pixel is computed and then subtracted from the current pixel. This has the effect of removing the local back- ground and highlighting local changes in intensity. This is very useful for removing partial bright spots across the face of the fixture. Note that if this option is set, the Intensity Threshold is typically much lower than if this option is not set.

Scale Down Large Size Images

For very high resolution images, the locate point process may be very time consuming. In order to speed up the process, if the image size is very large, the image is scaled down before processing if this option is checked.

To aid in tuning the locate parameters, the processed image that is used to identify the fixture points can be displayed. Right-click on the image and select Show Locate Point Pro- cessing. This image should contain all processed pixels that meet the Intensity Threshold requirement. If a fixture point is shown in white that is not identified by a green mark, then the Minimum Pixel Count, Maximum Pixel Count, or Maximum Eccentricity parameters must be adjusted to allow for this fix- ture point to be identified. If no white pixels are shown where a fixture point should be, then the Intensity Threshold must be decreased.



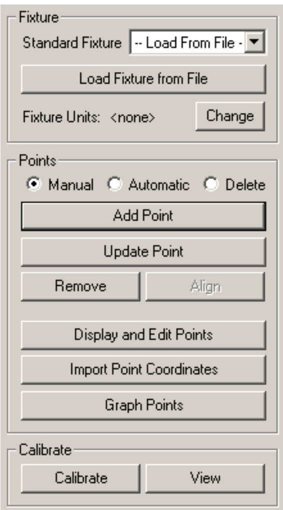
In addition to the Locate Point Settings, if all the fixture points still cannot be located, the entire set of Image Processing (the section called “Image Processing”) and Image Filtering (the section called “Image Filtering”) tools may be used in the 2-D window to modify the image so that it is easier to process. Change the settings in each of the 2-D windows, then click on both image windows in the 3-D Manager window and the processed image should appear.

Align

After all points have been located, we can exploit the fact that the points should lie on straight lines to correct small errors in the automatic location of the fixture points. Click on this button to take each set of points and align them so that they form straight lines. A good procedure is to Calibrate immediately after locating the points, make note of the calibration results, then Align and Calibrate again. If the calibration results do not improve after alignment, click on Locate again to revert back to the unaligned point locations and click on Calibrate again.

Manual Mode

Manual mode requires the user to click on each fixture point in the upper and lower calibration images and then click on the Add Point button. When Manual mode is enabled, the list of Data Points is automatically displayed. If a mistake is made, click on the point of interest in the list of Data Points, then click on two new locations in the upper and lower calibration images and then click on the Update Point button. Similarly, if you wish to remove a point, click on the point of interest in the Data Points window and then click on the Remove Point button.

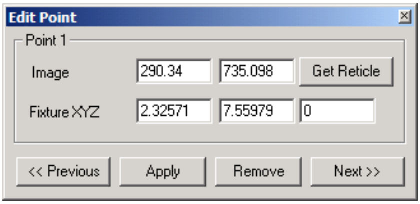


Add Point

Add a point to the Data Points dialog window using the current reticle locations of the top and bottom images.

Update Point	Update the selected point in the Data Points dialog window with the cur- rent reticle locations of the top and bottom images.
Remove	Remove the selected point in the Data Points dialog window.
Align	After all points have been located, we can exploit the fact that the points should lie on straight lines to correct small errors in the automatic location of the fixture points. Click on this button to take each set of points and align them so that they form straight lines.

Double-clicking on a point in the Data Points dialog will also bring up an Edit Point dialog. You may directly type in the image coordinates, get the current reticle coordinates, or update the fixture point coordinates in this dialog.



Fixture points can also be manually located by using a keyboard and mouse shortcut. Place the reticle in one image at the location of a fixture point by using the Left Mouse Button. When the reticle is properly placed, hold down the Control key and click the Right Mouse button to update the currently selected fixture point for that image. The currently selected fixture point is shown in yellow in the Data Points dialog window. After using the Control + Right Mouse button shortcut, the currently selected point will automatically increment. Using this technique, you can rapidly select all the fixture points in one image, then repeat the procedure for the second image.

Displaying and Importing Points

After all points have been located, the fixture points and the corresponding image locations for each of the fixture points can be displayed in the Calibration Points dialog.

Display and Edit Points	Show the Calibration Points dialog window. Right-click in this window to save the point coordinates to a text file. The coordinates are saved exactly as displayed. To include more significant digits for each column, increase the column width by dragging the dividing lines between the columns.
Import Point Coordinates	Import image coordinates for fixture points from a text file. This is a third technique for locating fixture points in the pair of calibration images. If some external pro- gram is used to locate the points, the coordinates in each of the images can be loaded using this button. There are three acceptable formats for the text file:

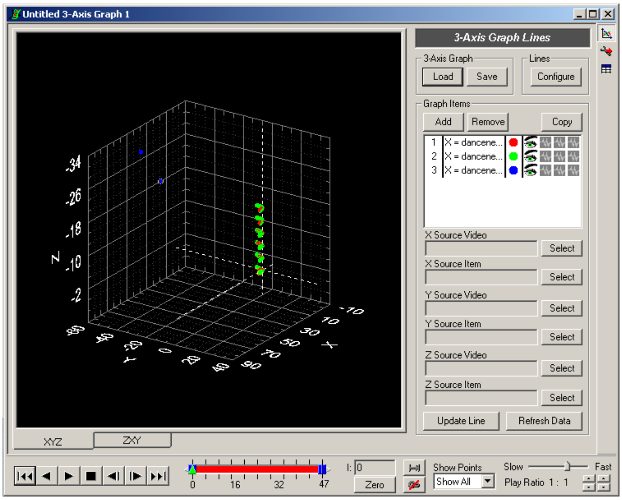
1. The first type of format contains coordinates for both the upper and lower calibration images. The first line of the text file contains the number of points in the top image; the next lines contain comma-separated X and Y coordinates of each of the top points; then the next line contains the num- ber of points in the bottom image, and the next lines after that contain comma-separated X and Y co- ordinates of each of the bottom points.

2. The second type contains coordinates for only one of the calibration images (upper or lower). The first line contains the number of points, and each sub- sequent line contains the X and Y values. The soft- ware will prompt whether to load these coordinates into the upper view or the lower view.

3. The third type of text file is exported from the Dis- play and Edit Points window. Using this method, you can save the calibration point coordinates from a different 3-D Manager window and import the points into your current 3-D Manager window. To save the calibration point coordinates from a differ- ent 3-D Manager window, show the Display and Edit Points window from that 3-D Manager calibra- tion panel; click on the desired camera tab; adjust the column widths to show the desired number of significant digits; then right-click in the window and select "Save to Text File" to save the table of coordinates. In your current 3-D Manager window, after clicking the Import Point Coordinates button, select the text file you just saved. The software will detect that this file was generated from a different 3-D Manager and prompt whether to load the point coordinates into the upper or lower view.

Graph Points

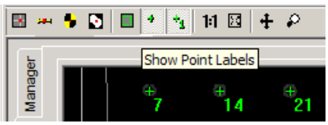
Generate a 3-Axis graph containing the fixture points, calibrated fixture point estimated locations, and estim- ated camera positions (See the section called “3-Axis Graphing”).



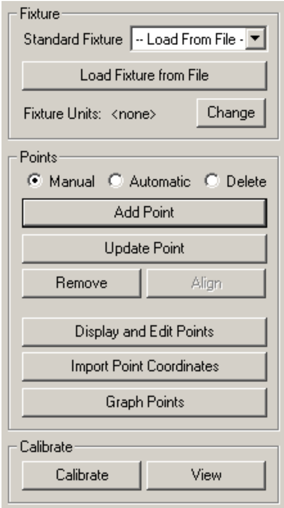
The normal configuration options for the 3-Axis graph can be used to configure the graph display as desired. See the section called “3-Axis Graphing” for more in- formation.

Manually Removing Single Points

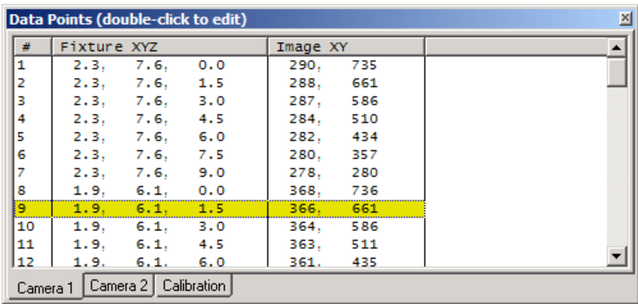
Manual mode can also be used to correct extraneous points that were located using the Automatic procedure. If there were a few misidentified points from the automatic procedure, you can display point numbers for each located point by clicking on the Show Point Labels button on the toolbar.



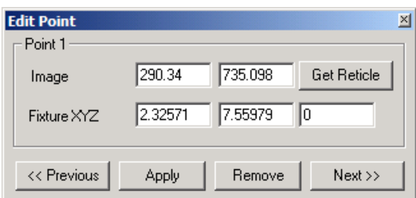
Click on the Display and Edit Points button in the 3-D Calibration panel.



If you wish to remove the point from the top view, select the Camera 1 tab on the bottom of the Data Points dialog. If you wish to remove the point from the bottom view, select the Camera 2 tab on the bottom of the Data Points dialog.

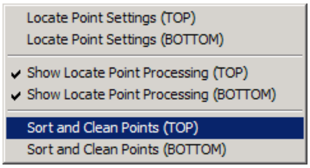


Double-click on the point number that you wish to remove and the Edit Point dialog will appear.



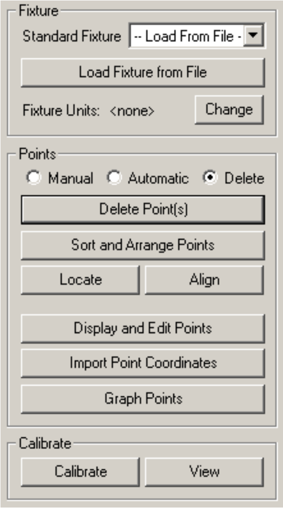
Click on the Remove button to remove the selected point from the selected camera view.

After all extraneous points have been removed from both views, the remaining points may require re-numbering in order for them to be sequentially sorted. Right-click in the 3-D Manager window and select Sort and Clean Points for the top and/or bottom views.

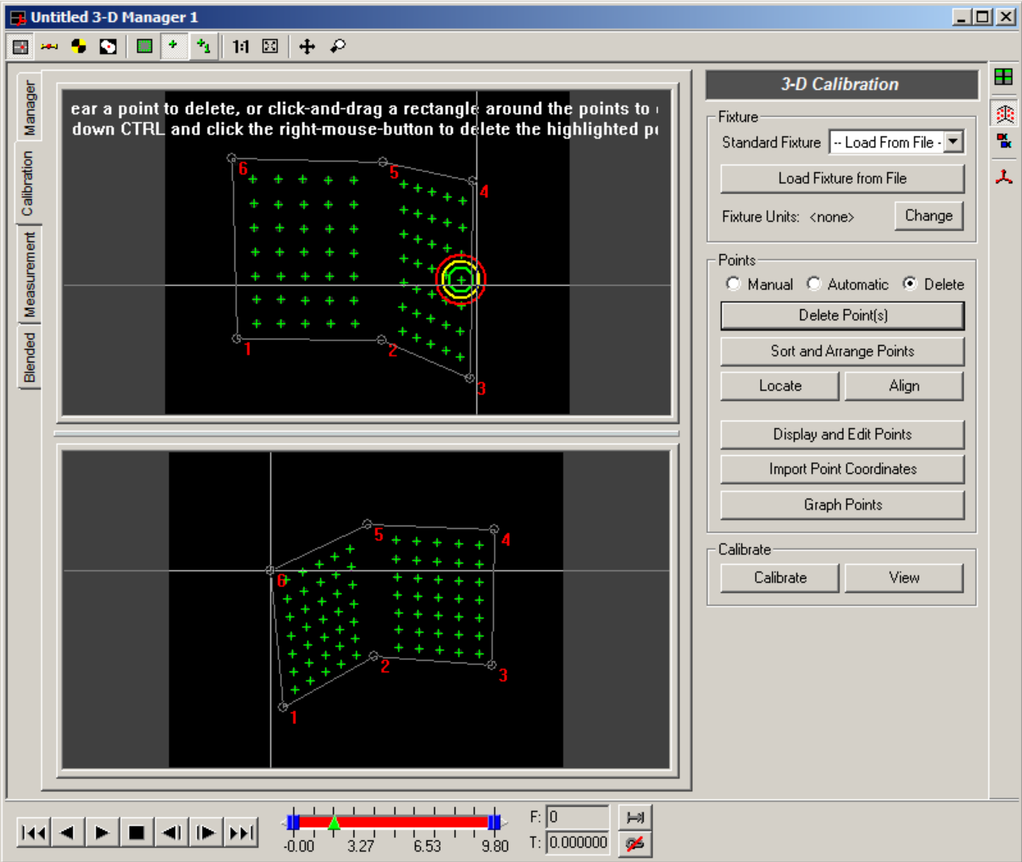


Delete Mode

When using automatic point location for standard calibration fixtures, three possible outcomes can occur: too few points are found, too many points are found, or the correct number of points is found. If there are too many or too few points, the Locate Point Settings can be modified, and the process can be repeated to improve the results. Points can also be manually edited. Delete mode can be used to manually remove calibration points in the case where too many points were found with the Automatic procedure.



While in Delete Mode, clicking anywhere in the image will highlight the nearest located point. Holding down the Control key and clicking the right mouse button will delete the highlighted point. You can also click the Delete Point(s) button on the panel to delete any highlighted points.

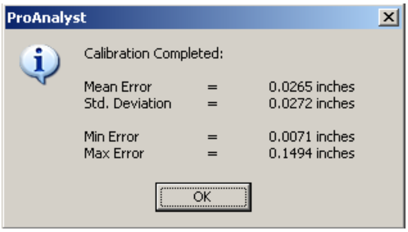


In order to delete multiple points, you can click and drag a rectangle in the image. Any located points inside of the rectangle will be highlighted for deletion. Hold down the Control key and click the right mouse button to delete the highlighted points or click the Delete Point(s) button.

After deleting points, the points that remain often are not properly sorted and numbered. To correct this, click the Sort and Arrange Points button to sort and renumber the remaining points so that they are correctly numbered for standard calibration fixtures. This will sort the points in either the top or bottom view, depending on which view was last modified.

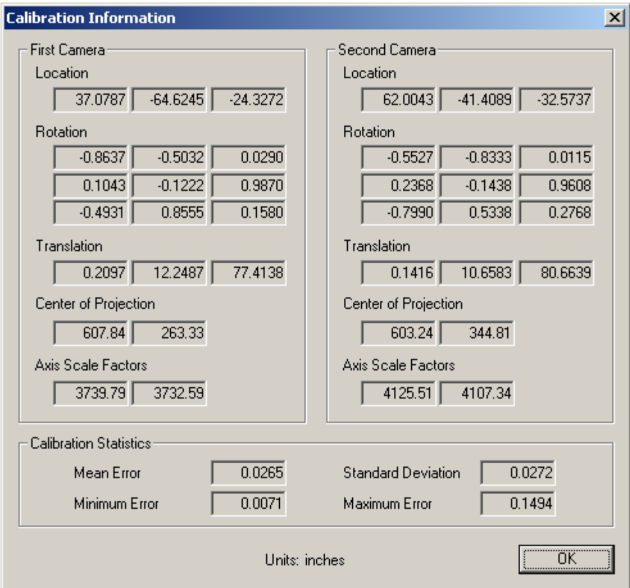
Calibrating

Once all the fixture points have been located in the top and bottom image, click on the Calib- rate button. The calibration process occurs in four stages. A dialog window will appear to in- dicate the current progress. When the calibration is complete, a dialog window showing the cal- ibration statistics will be shown.



If the calibration statistics are unsatisfactory, double check that the fixture has been loaded properly and that the fixture points have been identified properly. Be sure to check Show Point Labels in the toolbar and verify that the fixture points are numbered properly to match the order of the points in the fixture file.

If you are satisfied with the calibration, full calibration statistics can be seen by clicking on the View button.



This dialog shows the estimated camera position, orientation, and internal parameters.

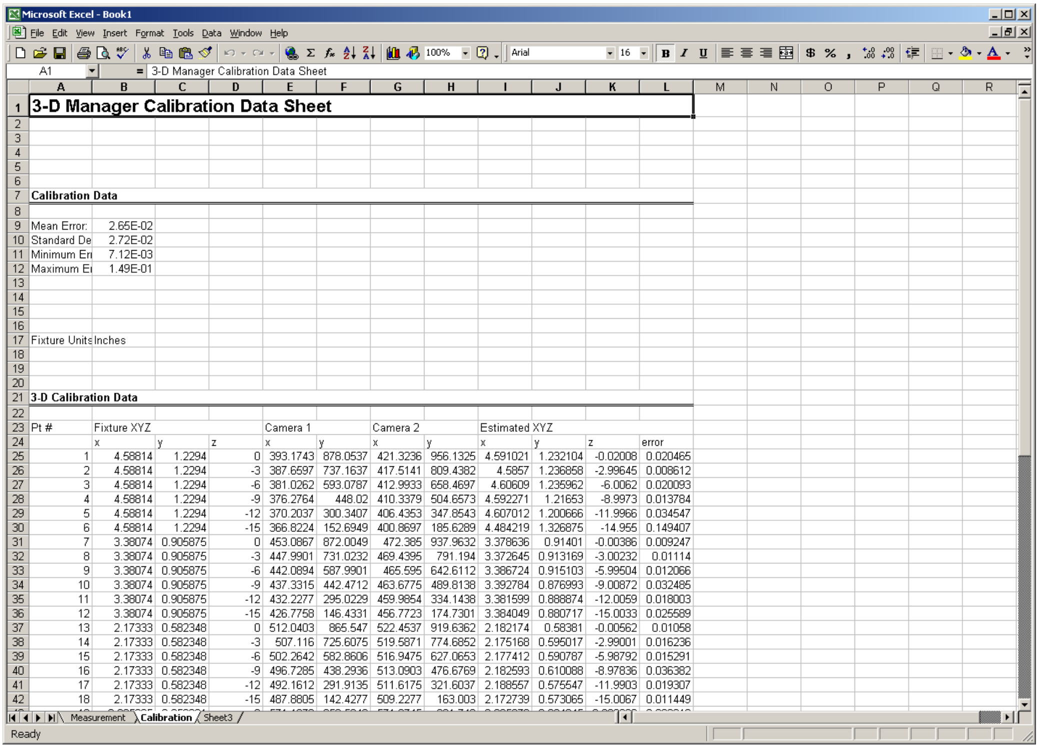
Saving, Loading, and Exporting Calibration

Saving and loading is accomplished through the Manager panel of the 3-D Manager window. When the 3-D Manager file is saved, the calibration information is also saved with it. The calibration information can be saved independently of the 3-D Manager file. This is useful if you wish to use the same calibration for multiple events. The calibration can be exported and then imported to any number of other 3-D Manager windows.

Import Calibration	Import calibration information from a 3-D Calibration file (`*.cal3d`).
Export Calibration	Export calibration information into a 3-D Calibration file (`*.cal3d`).

The 3-D Calibration file contains information on calibration images, fixture point information, image point information, feature regions, and locate point settings.

In addition to exporting to a 3-D Calibration file, calibration information is also exported to an Excel or Text document when the entire 3-D Manager document is exported using the Export button in the Units & Export Results section. The calibration information is contained on the second sheet of the Excel workbook, or is contained in the text file after the measurement points.



	A	B	C	D	E	F	G	H	I	J	K	L
1	3-D Manager Calibration Data Sheet											
7	Calibration Data											
9	Mean Error:	2.65E-02										
10	Standard De	2.72E-02										
11	Minimum Err	7.12E-03										
12	Maximum Er	1.49E-01										
17	Fixture Units	Inches										
21	3-D Calibration Data											
23	Pt #	Fixture XYZ			Camera 1		Camera 2		Estimated XYZ			
24		x	y	z	x	y	x	y	x	y	z	error
25	1	4.58814	1.2294	0	393.1743	878.0537	421.3236	956.1325	4.591021	1.232104	-0.02008	0.020465
26	2	4.58814	1.2294	-3	387.6597	737.1637	417.5141	809.4382	4.5857	1.236858	-2.99645	0.008612
27	3	4.58814	1.2294	-6	381.0262	593.0787	412.9933	658.4697	4.60609	1.235962	-6.0062	0.020093
28	4	4.58814	1.2294	-9	376.2764	448.02	410.3379	504.6573	4.592271	1.21653	-8.9973	0.013784
29	5	4.58814	1.2294	-12	370.2037	300.3407	406.4353	347.8543	4.607012	1.200666	-11.9966	0.034547
30	6	4.58814	1.2294	-15	366.8224	152.6949	400.8697	185.6289	4.484219	1.326875	-14.955	0.149407
31	7	3.38074	0.905875	0	453.0867	872.0049	472.385	937.9632	3.378636	0.91401	-0.00386	0.009247
32	8	3.38074	0.905875	-3	447.9901	731.0232	469.4395	791.194	3.372645	0.913169	-3.00232	0.01114
33	9	3.38074	0.905875	-6	442.0894	587.9901	465.595	642.6112	3.386724	0.915103	-5.99504	0.012066
34	10	3.38074	0.905875	-9	437.3315	442.4712	463.6775	489.8138	3.392784	0.876993	-9.00872	0.032485
35	11	3.38074	0.905875	-12	432.2277	295.0229	459.9854	334.1438	3.381599	0.888874	-12.0059	0.018003
36	12	3.38074	0.905875	-15	426.7758	146.4331	456.7723	174.7301	3.384049	0.880717	-15.0033	0.025589
37	13	2.17333	0.582348	0	512.0403	865.547	522.4537	919.6362	2.182174	0.58381	-0.00562	0.01058
38	14	2.17333	0.582348	-3	507.116	725.6075	519.5871	774.6852	2.175168	0.595017	-2.99001	0.016236
39	15	2.17333	0.582348	-6	502.2642	582.8606	516.9475	627.0653	2.177412	0.590787	-5.98792	0.015291
40	16	2.17333	0.582348	-9	496.7285	438.2936	513.0903	476.6769	2.182593	0.610088	-8.97836	0.036382
41	17	2.17333	0.582348	-12	492.1612	291.9135	511.6175	321.6037	2.188557	0.575547	-11.9903	0.019307
42	18	2.17333	0.582348	-15	487.8805	142.4277	509.2277	163.003	2.172739	0.573065	-15.0067	0.011449

3-D Measurement

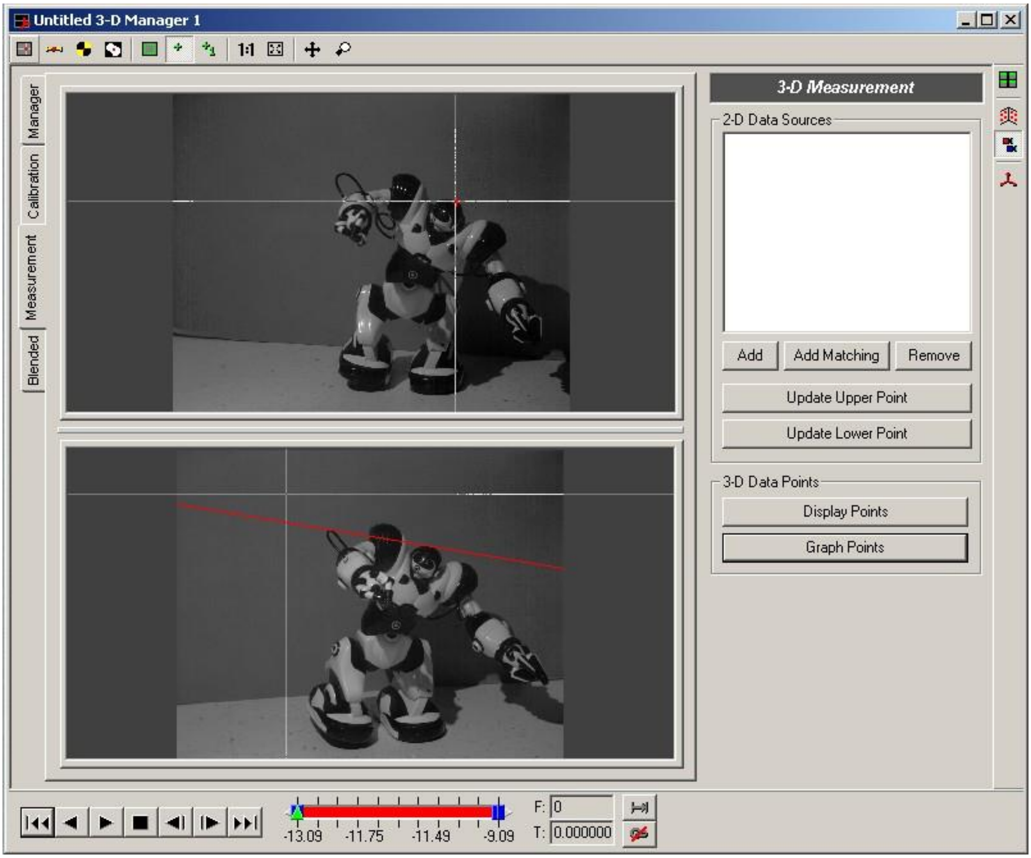
The 3-D Manager is designed to build upon the many analysis tools already available for tracking features in videos. All the image processing, image filtering, and analysis toolkits can be used to obtain tracking information from each of the two measurement videos.

After each of the two measurement videos have been analyzed separately, the 3-D Measure- ment panel can combine tracking information from the various 2-D analysis toolkits (e.g. 1-D Line Tracking (the section called “Line (1-D) Tracking”), 2-D Feature Tracking (the section called “Feature (2-D) Tracking”)) to obtain 3-D coordinates. For instance, the top video can be analyzed using 1-D Line Tracking, and the bottom video can be analyzed using 2-D Feature Tracking. The results can then be combined to compute the 3-D coordinates of each of the tracked points.

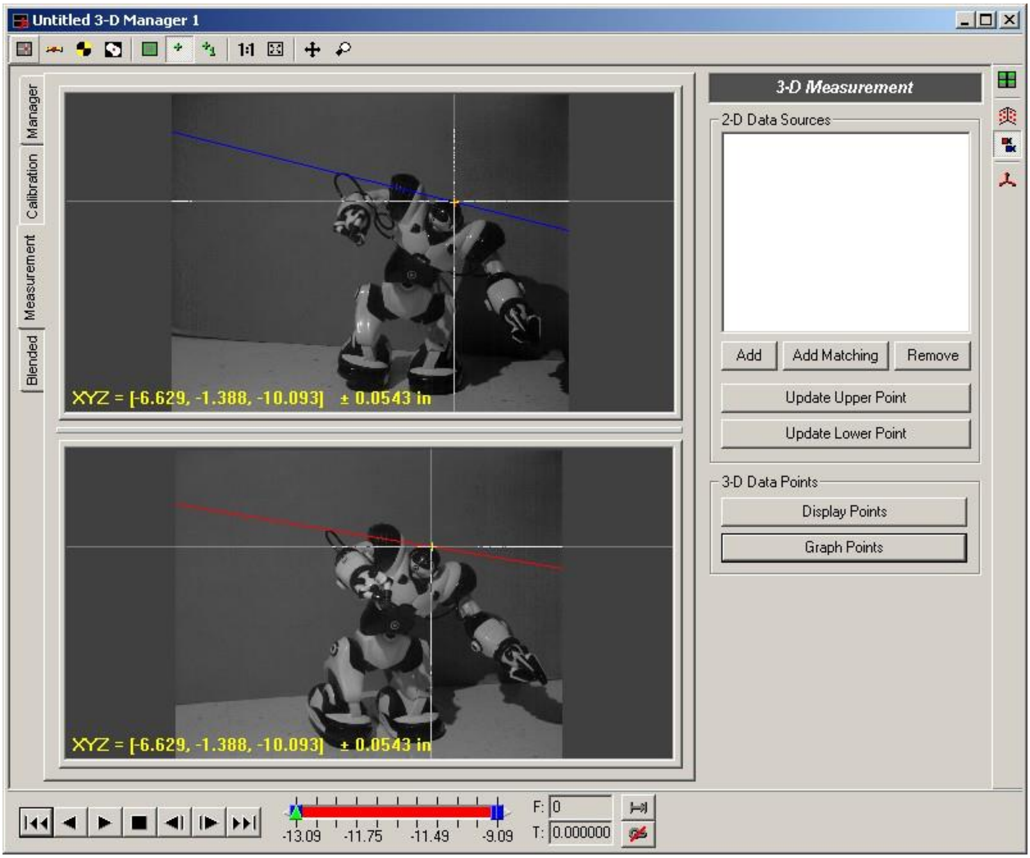
Computing 3-D Coordinates and Verifying Calibration

After the cameras have been calibrated, for every point that you click on in the top image, an "epipolar line" will be drawn in the bottom image and vice versa. The epipolar line indicates which points in the bottom image could correspond with the point that you have clicked on in the top image.

The current point in the top image is shown with a red plus symbol. The corresponding epipolar line in the bottom image is shown as a red line. The current point in the bottom image is shown with a blue plus symbol. The corresponding epipolar line in the top image is shown with a blue line.



If the calibration were perfect, the red plus would lie exactly on the blue line in the top image and the blue plus would lie exactly on the red line in the bottom image. The pluses and lines may not exactly intersect due to lens distortion, poor calibration, or difficulties in locating fix- ture points.

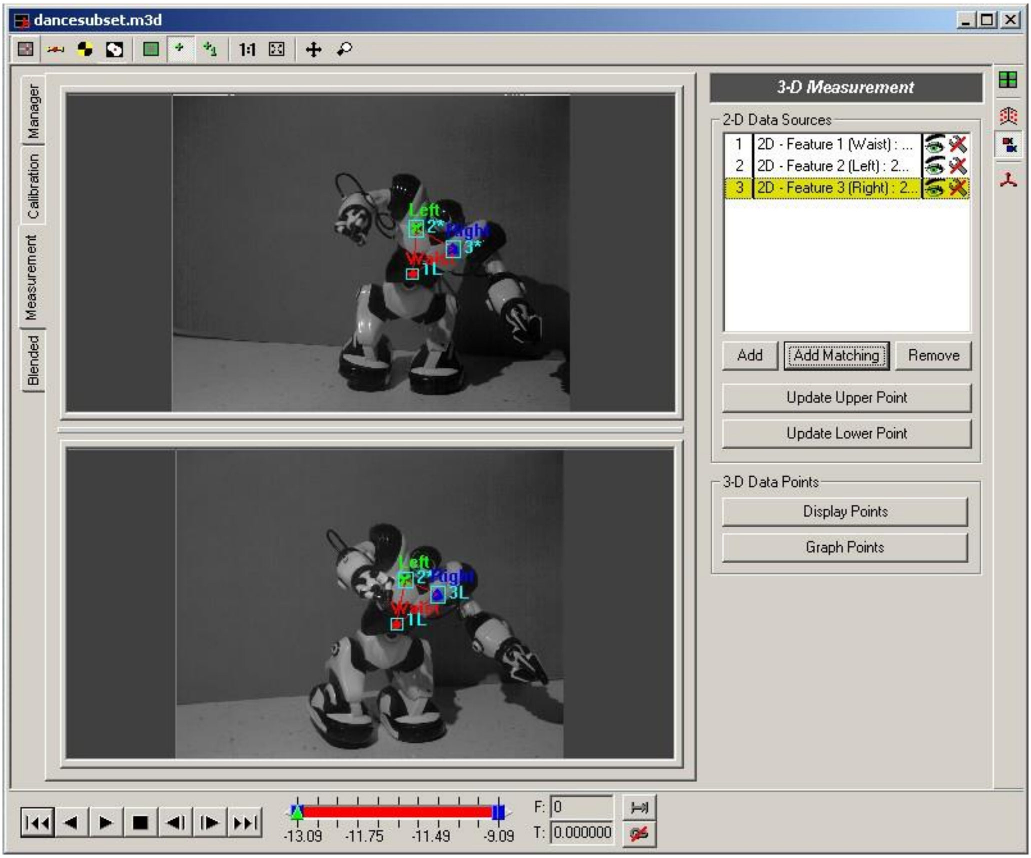


The red and blue lines represent images of two rays coming from each camera. Since they may not exactly cross, the midpoint of the shortest distance between the two lines is shown with a yellow plus symbol in both the top and bottom views. The distance from the yellow plus to the red and blue lines is the uncertainty in the position estimate. Information along the bottom of each view indicates the 3-D coordinates of the midpoint and the uncertainty associated with the 3-D coordinates.

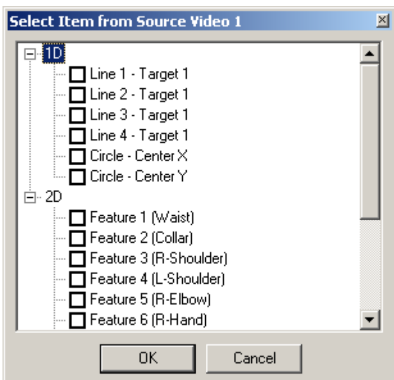
The uncertainty information displayed at the bottom of each of the images provides valuable feedback in determining if your calibration is valid. If you click on corresponding points in the top and bottom images, the uncertainty displayed at the bottom of the images should be within acceptable levels. If the uncertainty is too large, you must re-calibrate. This verification of the calibration should be done for every 3-D Manager document.

Measurement Panel

Each feature that you wish to compute 3-D coordinates for must be added to the 3-D Manager document. Each feature that is added uses the tracking information from one of the 2-D analysis toolkits. When each feature is added, the program will ask you to specify the source of the tracking information for the top and bottom videos. These sources can be a line from 1-D Line Tracking or a feature from 2-D Feature Tracking.



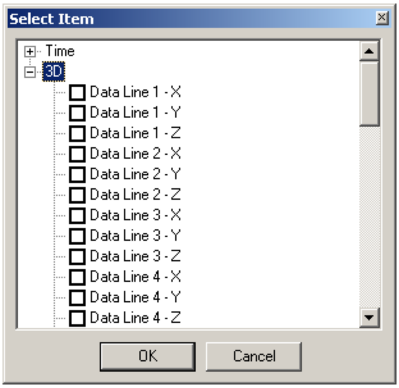
Add — Add a new data item. The tracking information source for the top and bottom videos must be specified. A dialog window will appear listing all available data sources for each of the two measurement videos.



Add Matching — If the same features are analyzed in the same manner in both videos, this button will automatically add data lines for each line or feature tracked in each video. For instance, if one Line Tracking target and three Feature Tracking targets are tracked in each of the two videos, this button will automatically pair the first Line Tracking target from the top video with the first Line Tracking target from the bottom video and also the first Fea- ture Tracking target from the top video with the first Feature Tracking tar- get from the bottom video, etc.

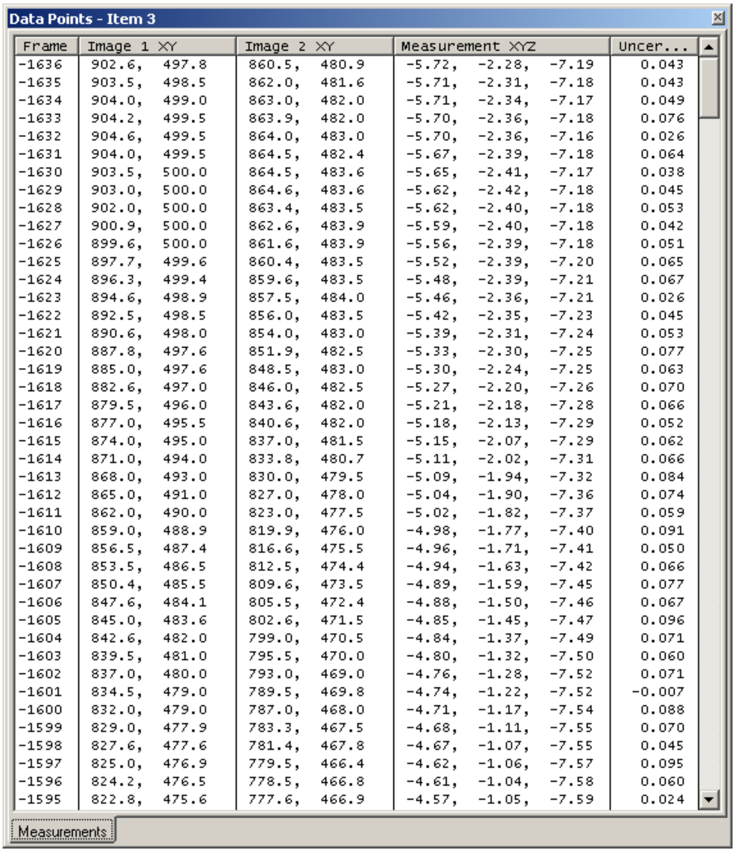
Remove — Select a data item from the list that you wish to remove, and then click this button to remove it.

Each data item that is added to this list then becomes available for graphing in the 2-Axis or 3-Axis graphing windows. When selecting a source for the graph, select your current `*.m3d` file from the source video list, then select the X, Y, or Z item from the 3D list.



Verifying and Updating Points

After the data items have been added, the 2-D coordinates from the Line Tracking or Feature Tracking sources are used to compute X, Y, and Z coordinates for each item for each frame. There will be some uncertainty resulting from the calculation of 3-D coordinates. The X, Y, and Z coordinates and the corresponding uncertainty for each point can be viewed by clicking on the Display Points button.



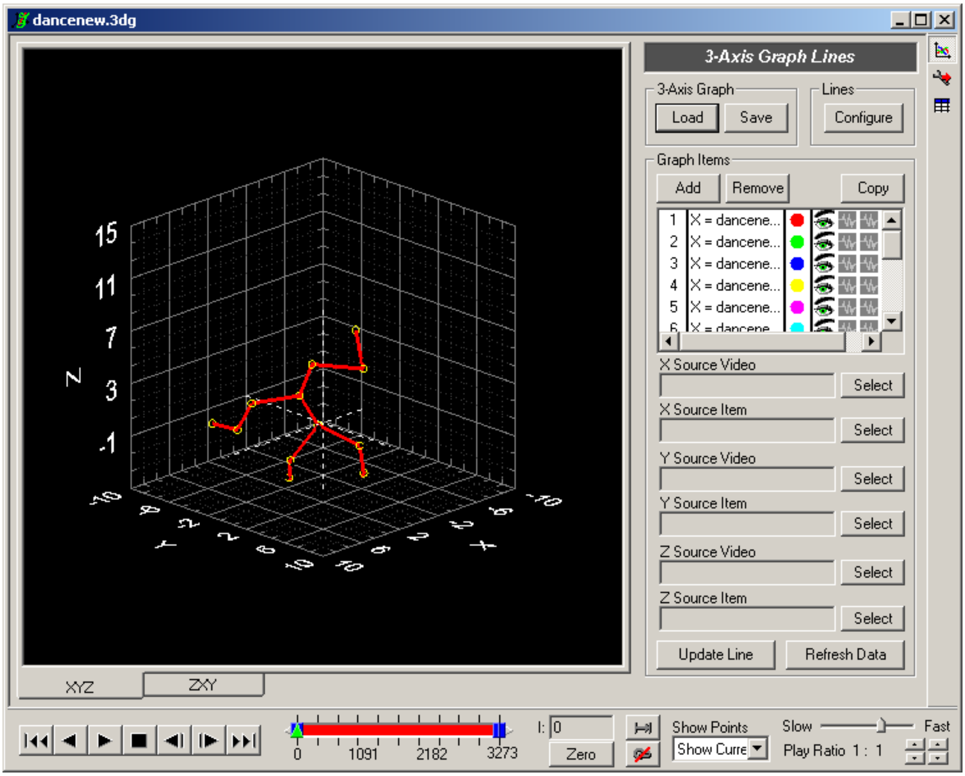
Frame	Image 1 XY	Image 2 XY	Measurement XYZ	Uncer...
-1636	902.6, 497.8	860.5, 480.9	-5.72, -2.28, -7.19	0.043
-1635	903.5, 498.5	862.0, 481.6	-5.71, -2.31, -7.18	0.043
-1634	904.0, 499.0	863.0, 482.0	-5.71, -2.34, -7.17	0.049
-1633	904.2, 499.5	863.9, 482.0	-5.70, -2.36, -7.18	0.076
-1632	904.6, 499.5	864.0, 483.0	-5.70, -2.36, -7.16	0.026
-1631	904.0, 499.5	864.5, 482.4	-5.67, -2.39, -7.18	0.064
-1630	903.5, 500.0	864.5, 483.6	-5.65, -2.41, -7.17	0.038
-1629	903.0, 500.0	864.6, 483.6	-5.62, -2.42, -7.18	0.045
-1628	902.0, 500.0	863.4, 483.5	-5.62, -2.40, -7.18	0.053
-1627	900.9, 500.0	862.6, 483.9	-5.59, -2.40, -7.18	0.042
-1626	899.6, 500.0	861.6, 483.9	-5.56, -2.39, -7.18	0.051
-1625	897.7, 499.6	860.4, 483.5	-5.52, -2.39, -7.20	0.065
-1624	896.3, 499.4	859.6, 483.5	-5.48, -2.39, -7.21	0.067
-1623	894.6, 498.9	857.5, 484.0	-5.46, -2.36, -7.21	0.026
-1622	892.5, 498.5	856.0, 483.5	-5.42, -2.35, -7.23	0.045
-1621	890.6, 498.0	854.0, 483.0	-5.39, -2.31, -7.24	0.053
-1620	887.8, 497.6	851.9, 482.5	-5.33, -2.30, -7.25	0.077
-1619	885.0, 497.6	848.5, 483.0	-5.30, -2.24, -7.25	0.063
-1618	882.6, 497.0	846.0, 482.5	-5.27, -2.20, -7.26	0.070
-1617	879.5, 496.0	843.6, 482.0	-5.21, -2.18, -7.28	0.066
-1616	877.0, 495.5	840.6, 482.0	-5.18, -2.13, -7.29	0.052
-1615	874.0, 495.0	837.0, 481.5	-5.15, -2.07, -7.29	0.062
-1614	871.0, 494.0	833.8, 480.7	-5.11, -2.02, -7.31	0.066
-1613	868.0, 493.0	830.0, 479.5	-5.09, -1.94, -7.32	0.084
-1612	865.0, 491.0	827.0, 478.0	-5.04, -1.90, -7.36	0.074
-1611	862.0, 490.0	823.0, 477.5	-5.02, -1.82, -7.37	0.059
-1610	859.0, 488.9	819.9, 476.0	-4.98, -1.77, -7.40	0.091
-1609	856.5, 487.4	816.6, 475.5	-4.96, -1.71, -7.41	0.050
-1608	853.5, 486.5	812.5, 474.4	-4.94, -1.63, -7.42	0.066
-1607	850.4, 485.5	809.6, 473.5	-4.89, -1.59, -7.45	0.077
-1606	847.6, 484.1	805.5, 472.4	-4.88, -1.50, -7.46	0.067
-1605	845.0, 483.6	802.6, 471.5	-4.85, -1.45, -7.47	0.096
-1604	842.6, 482.0	799.0, 470.5	-4.84, -1.37, -7.49	0.071
-1603	839.5, 481.0	795.5, 470.0	-4.80, -1.32, -7.50	0.060
-1602	837.0, 480.0	793.0, 469.0	-4.76, -1.28, -7.52	0.071
-1601	834.5, 479.0	789.5, 469.8	-4.74, -1.22, -7.52	-0.007
-1600	832.0, 479.0	787.0, 468.0	-4.71, -1.17, -7.54	0.088
-1599	829.0, 477.9	783.3, 467.5	-4.68, -1.11, -7.55	0.070
-1598	827.6, 477.6	781.4, 467.8	-4.67, -1.07, -7.55	0.045
-1597	825.0, 476.9	779.5, 466.4	-4.62, -1.06, -7.57	0.095
-1596	824.2, 476.5	778.5, 466.8	-4.61, -1.04, -7.58	0.060
-1595	822.8, 475.6	777.6, 466.9	-4.57, -1.05, -7.59	0.024

If any of the points have too large of an uncertainty value, the coordinates of the tracked points in the top and bottom views can be manually updated. Select the data point that you wish to update. You can update the coordinates of the track point in the upper image or the lower image or both. To update the coordinates in the upper image, click on the correct point in the upper image and then click on the Update Upper Point button. To update the coordinates in the lower image, click on the correct point in the lower image and then click on the Update Lower Point button.

Note that updating points actually updates the points in the Line Tracking or Feature Tracking files for the corresponding measurement videos. When you are done updating points, be sure to save the corresponding Line Tracking or Feature Tracking files so that the changes you have made are saved. The changes are *NOT* saved in the 3-D Manager document.

Graphing Points

A 3-Axis graph containing all the data items can be automatically generated. Click on the Graph Points button to generate a 3-Axis graph.



The normal configuration options for the 3-Axis graph can be used to configure the graph display as desired. See the section called "3-Axis Graphing" for more information.

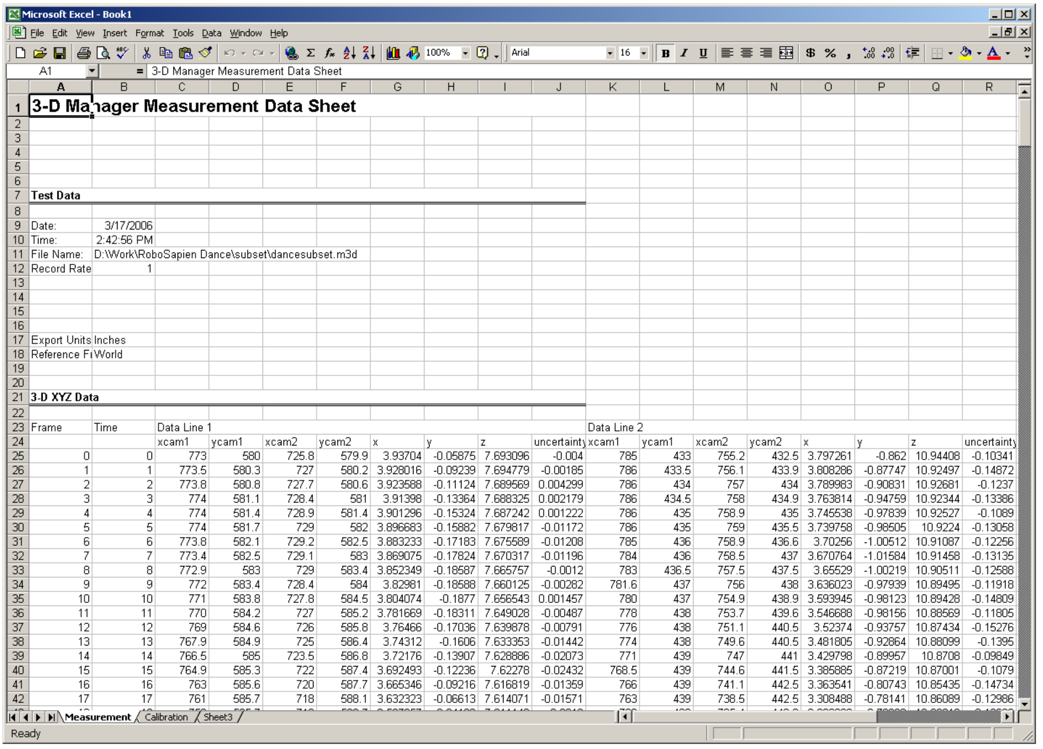
Saving, Loading, and Exporting

Saving and loading is accomplished through the Manager panel of the 3-D Manager window.

Load	Load calibration, measurement, and world reference information to a 3-D Manager file (`*.m3d`).
Save	Save all calibration, measurement, and world reference information to a 3-D Manager file (`*.m3d`).
Import Calibration	Import calibration information from a 3-D Calibration file (`*.cal3d`). This allows you to use the same calibration for multiple 3-D Manager documents.
Export Calibration	Export calibration information to a 3-D Calibration file (`*.cal3d`).
Import World Reference	Import world reference frame information from a 3-D World Reference file (`*.w3d`). This allows you to use the same world reference frame for multiple 3-D Manager documents.
Export World Reference	Export world reference frame information to a 3-D World Reference file (`*.w3d`).

In addition to saving and loading, the entire set of measurement and calibration results can be exported to Text, Excel or Excel Template. The measurement coordinates and the uncertainty values can also be exported to a C3D file. Calibration results are not included in a C3D export file. To export, select the units and output format in the Units & Export Results section of the panel and then click on the Export button.

When exporting to Excel, the measurement information is exported to the first sheet and the calibration information is exported to the second sheet. When exporting to Text, the measurement information is written to the text file first, followed by the calibration information.



3-D Manager Measurement Data Sheet

Test Data

Date:	3/17/2006
Time:	2:42:56 PM
File Name:	D:\Work\RoboSapien Dance\subset\dancesubset.m3d
Record Rate	1
Export Units	Inches
Reference Fr	World

3-D XYZ Data

Frame	Time	Data Line 1								Data Line 2							
		xcam1	ycam1	xcam2	ycam2	x	y	z	uncertainty	xcam1	ycam1	xcam2	ycam2	x	y	z	uncertainty
0	0	773	580	725.8	579.9	3.93704	-0.05875	7.693096	-0.004	785	433	755.2	432.5	3.797261	-0.862	10.94408	-0.10341
1	1	773.5	580.3	727	580.2	3.928016	-0.09239	7.694779	-0.00185	786	433.5	756.1	433.9	3.808286	-0.87747	10.92497	-0.14872
2	2	773.8	580.8	727.7	580.6	3.923588	-0.11124	7.689569	0.004299	786	434	757	434	3.789983	-0.90831	10.92681	-0.1237
3	3	774	581.1	728.4	581	3.91398	-0.13364	7.688325	0.002179	786	434.5	758	434.9	3.763814	-0.94759	10.92344	-0.13386
4	4	774	581.4	728.9	581.4	3.901296	-0.15324	7.687242	0.001222	786	435	758.9	435	3.745538	-0.97839	10.92527	-0.1089
5	5	774	581.7	729	582	3.896683	-0.15882	7.679817	-0.01172	786	435	759	435.5	3.739758	-0.98505	10.9224	-0.13058
6	6	773.8	582.1	729.2	582.5	3.883233	-0.17183	7.675589	-0.01208	785	436	758.9	436.6	3.70256	-1.00512	10.91087	-0.12256
7	7	773.4	582.5	729.1	583	3.869075	-0.17824	7.670317	-0.01196	784	436	758.5	437	3.670764	-1.01584	10.91458	-0.13135
8	8	772.9	583	729	583.4	3.852349	-0.18587	7.665757	-0.0012	783	436.5	757.5	437.5	3.65529	-1.00219	10.90511	-0.12588
9	9	772	583.4	728.4	584	3.82981	-0.18588	7.660125	-0.00282	781.6	437	756	438	3.636023	-0.97939	10.89495	-0.11918
10	10	771	583.8	727.8	584.5	3.804074	-0.1877	7.656543	0.001457	780	437	754.9	438.9	3.593945	-0.98123	10.89428	-0.14809
11	11	770	584.2	727	585.2	3.781669	-0.18311	7.649028	-0.00487	778	438	753.7	439.6	3.546688	-0.98156	10.88569	-0.11805
12	12	769	584.6	726	585.8	3.76466	-0.17036	7.639878	-0.00791	776	438	751.1	440.5	3.52374	-0.93757	10.87434	-0.15276
13	13	767.9	584.9	725	586.4	3.74312	-0.1606	7.633353	-0.01442	774	438	749.6	440.5	3.481805	-0.92864	10.88099	-0.1395
14	14	766.5	585	723.5	586.8	3.72176	-0.13907	7.628886	-0.02073	771	439	747	441	3.429798	-0.89957	10.8708	-0.09849
15	15	764.9	585.3	722	587.4	3.692493	-0.12236	7.62278	-0.02432	768.5	439	744.6	441.5	3.385885	-0.87219	10.87001	-0.1079
16	16	763	585.6	720	587.7	3.665346	-0.09216	7.616819	-0.01359	766	439	741.1	442.5	3.363541	-0.80743	10.85435	-0.14734
17	17	761	585.7	718	588.1	3.632323	-0.06613	7.614071	-0.01571	763	439	738.5	442.5	3.308488	-0.78141	10.86089	-0.12986

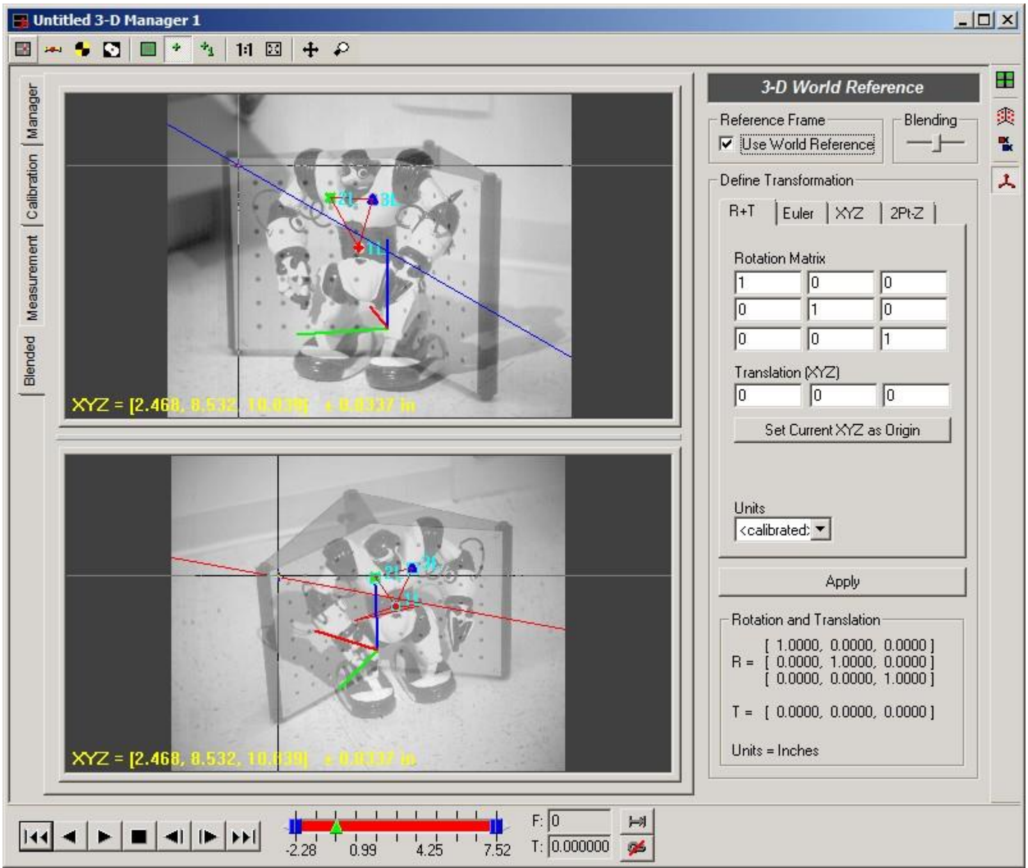
3-D World Reference

All 3-D coordinates produced by the 3-D Manager are given in the coordinate frame defined by the calibration fixture. The current Calibration Reference Frame is shown in the image with the red, green, and blue lines. The red line represents the X axis. The green line represents the Y axis. The blue line represents the Z axis. The 3-D coordinates may be transformed into a differ- ent coordinate frame. This new coordinate frame will be referred to as the World Reference Frame (in contrast to the Calibration Reference Frame defined by the calibration fixture).

World Reference Frame Panel

If a world reference frame is necessary, click on the Use World Reference checkbox at the top of the panel. To disable use of the world reference frame, uncheck this box. The world refer- ence frame information will not be lost if the box is unchecked.

There are currently four possible methods for entering information about the world reference frame: direct rotation and translation, euler angles, points on the XYZ axes, or specifying two points on the Z-axis.

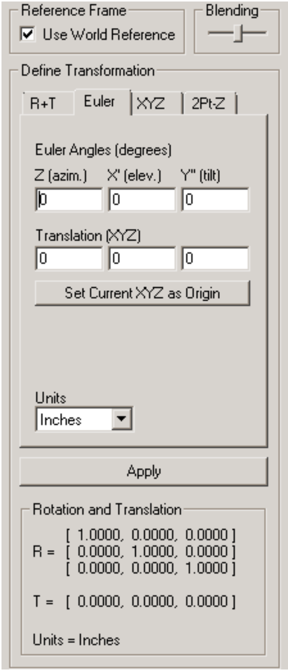


Rotation and Translation (R+T)

To use this method of input, select Rotation and Translation and enter the rotation matrix and translation vector used to transform calibration coordinates to world coordinates and click Apply. All 3-D coordinates will be multipled by this rotation matrix and then the translation vector will be added.

Euler Angles (Euler)

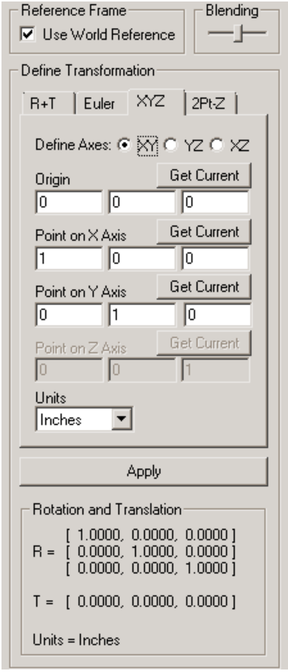
To use the second method, select the Euler tab. This method requires three Euler angle values to compute a new rotation matrix. All values should be entered in degrees. The order of rota- tions proceeds from left to right. The first rotation is about the Z axis. The second rotation is applied along the newly rotated X axis. The final rotation is about the doubly-rotated Y axis. In addition to the three Euler angles, a translation of the origin can also be supplied. After the sys- tem is calibrated, click on a point in the top image that lies at the desired origin. Click on the corresponding point in the bottom image. Since the system is calibrated, the 3-D coordinates of this point are now known. Click on Set Current XYZ as Origin button and the XYZ coordinates will appear in the edit boxes.



Click on Apply after the appropriate angles and origin have been selected. Using this information, the program will calculate the correct rotation matrix and translation vector that will achieve the desired transformation. You will note that the rotation matrix and translation vector from the Rotation and Translation section will be filled in with the newly computed values.

XYZ

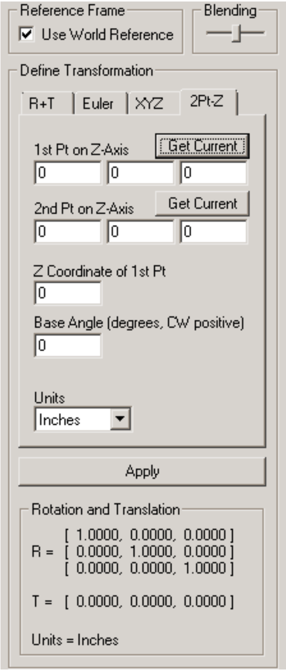
To use the third method, select the XYZ tab. This method requires the origin to be identified, plus a point on any of two of the three axes. Determine which axes you will select points for and click on the appropriate radio button for XY, YZ, or XZ. After the system is calibrated, click on a point in the top image that lies at the desired origin. Click on the corresponding point in the bottom image. Since the system is calibrated, the 3-D coordinates of this point are now known. Click on Get Current next to the Origin label and the XYZ coordinates of the origin will appear in the edit boxes. Do the same procedure for the points on the X, Y or Z axes and click on Get Current next to each label. The point that you select can be anywhere along the particular axis. Points farther from the origin will produce better results than points located very close to the origin.



Click on Apply after the appropriate points have been selected. Using the point information, the program will calculate the correct rotation matrix and translation vector that will achieve the desired transformation. You will note that the rotation matrix and translation vector from the Rotation and Translation section will be filled in with the newly computed values.

Two Points on Z-Axis (2Pt-Z)

To use the fourth method, select the 2Pt-Z tab. This method requires the 3-D coordinates of two points in the calibration frame that lie on the Z-axis. After the system is calibrated, click on a point in the top image that lies on the desired Z-axis. Click on the corresponding point in the bottom image. Since the system is calibrated, the 3-D coordinates of this point are now known. Click on Get Current next to the First Point label and the XYZ coordinates will appear in the edit boxes. Do the same procedure for a second point that lies on the desired Z-Axis and click on Get Current next to the Second Point label. Finally, specify the Z coordinate of the first point and the base angle (rotation about Z-axis).



Click on Apply after the appropriate points have been selected. Using the point information, the program will calculate the correct rotation matrix and translation vector that will achieve the desired transformation. You will note that the rotation matrix and translation vector from the Rotation and Translation section will be filled in with the newly computed values.

Blending

There are occasions where you may wish to define your world reference frame using points from either the calibration images or the measurement images. The blending feature allows you to see both the calibration and the measurement images blended together. The slider controls the blending factor. If the slider is moved to the left, the calibration image is shown. If the slider is moved to the right, the measurement image is shown.

The blending feature can also be used to verify that the cameras have not been moved between when the calibration images were acquired and when the measurement images were acquired. If there are features in the background that are visible in both the calibration and the measure- ment images, these features should remain in the same position in both images. If these back- ground features have shifted, then this can indicate that the camera has been shifted. In this case, new calibration images must be acquired and the system re-calibrated.

Saving and Loading

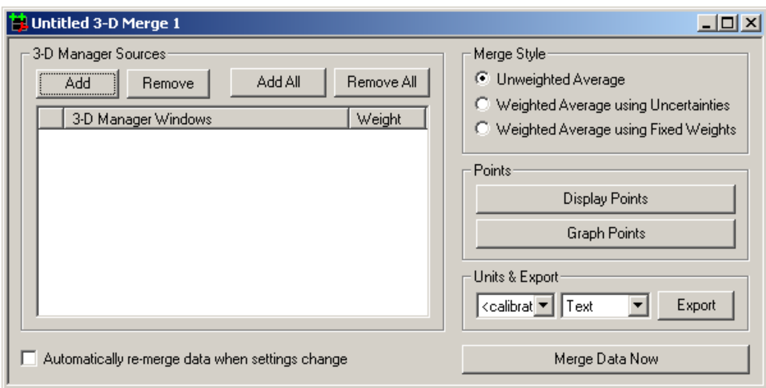
Saving and loading is accomplished through the Manager panel of the 3-D Manager window. When the 3-D Manager file is saved, the world reference frame information is also saved with it. The world reference frame information can be saved independently of the 3-D Manager file. This is useful if you wish to use the same world reference frame for multiple events. The world reference frame can be exported and then imported to any number of other 3-D Manager win- dows.

Import World Reference	Import world reference frame information from a 3-D World Reference file (`*.w3d`).
Export World Reference	Export world reference frame information into a 3-D World Reference file (`*.w3d`).

3-D Merge

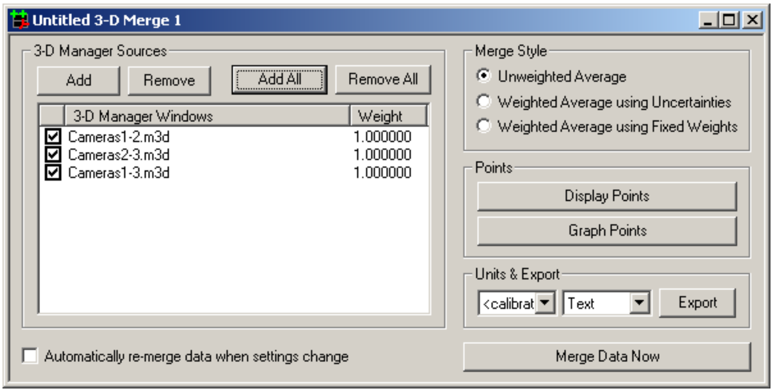
Overview

The 3-D Merge Window allows for the combination of data from multiple 3-D Manager Windows (the section called "3-D Manager"). Using this window, more than two cameras can be used to capture an event and perform 3-D analysis. When using more than two cameras, measurements can be made for every pair of cameras using a standard 3-D Manager window. The targets of interest may only be visible by a subset of cameras for a portion of the event and by another subset of cameras for another portion of the event. The 3-D Merge Window will intelligently combine the data from multiple 3-D Manager windows and produce a complete data set for every target.



Adding Sources

Consider an example where you have three cameras observing an event. For each pair of cameras, you would perform a calibration and measurement using the 3-D Manager. Three 3-D Manager files would be produced: Camera 1 + Camera 2, Camera 2 + Camera 3, and Camera 1 + Camera 3. When all three 3-D Manager files are open, click on the Add All button in the 3-D Merge Window.



This will add all currently open 3-D Manager windows to the list of sources.

Data will be combined from all 3-D Manager windows listed in the list of sources. If you wish to keep a 3-D Manager window in the list, but not incorporate the data into the result, uncheck the checkbox next to the name of the 3-D Manager file in the list of sources.

The targets of interest need not be visible to all cameras in every frame. However, all the 3-D Manager windows must have the same numbering for the targets of interest. For example, if only cameras 1 and 2 see the first target for the entire event and only cameras 2 and 3 see the second target for the entire event, then the 3-D Manager Window for cameras 1 and 2 must have an empty item entry for the second target and the 3-D Manager Window for cameras 2 and 3 must have an empty item entry for the first target (the section called “Measurement Pan- el”).

Merge Styles

There are currently three different styles provided for merging the data from the various 3-D Manager sources. All three styles perform a weighted average calculation. The difference between the various styles is in the determination of the weight values to use.

Unweighted Average	This style uses equal weights for all sources.
Weighted Average using Uncertainties	This style uses weights based on the reported uncertainties for each measurement from each 3-D Manager source. Data with large uncertainties are weighted less than data with small uncertainties.

Weights

This style allows you to manually specify fixed weights for each of the 3-D Manager sources. When this option is selected, you can double-click on the weight value displayed in the list of sources in order to change the value.

Only valid data points are used when computing the weighted average for a given item in a given frame. If a given 3-D Manager source does not have valid data for an item in a given frame, that source is not used in the weighted average calculation for that item in that frame. If no 3-D Manager sources have valid data for a given item in a given frame, then the result is left empty.

Merging Data

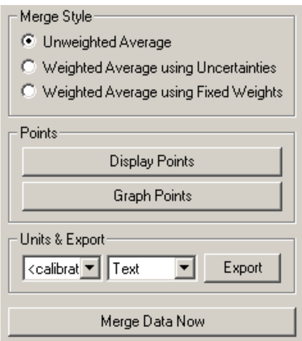
Whenever the data from any of the 3-D Manager sources is changed, the data must be re- merged using the 3-D Merge Window. It is therefore advised that all measurements be com- pleted first in all 3-D Manager sources before performing a merge operation.

Whenever the list of sources, merge style, or weight values are changed, the data must be re-merged. Because the merge operation could take some amount of time, the merging is not performed automatically. To perform a merge, click on the Merge Data Now button. If you prefer the merge to occur automatically whenever one of the settings is changed within the 3-D Merge window, check the "Automatically re-merge data when settings change" checkbox. Please note that this will only re-merge the data when the settings in the 3-D Merge window change. They will not know to re-merge the data if the measurements within one of the 3-D Manager source windows have changed.

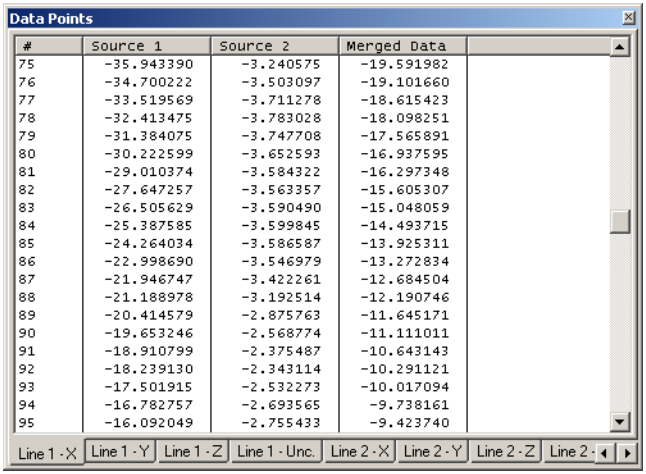
After merging the data in the 3-D Merge window, any graphs that display the merged data must also be refreshed (the section called “3-Axis Graphing”).

Viewing and Graphing the Merged Data

The resulting merged data can be viewed in tabular format or graphed in a 3-Axis graph.



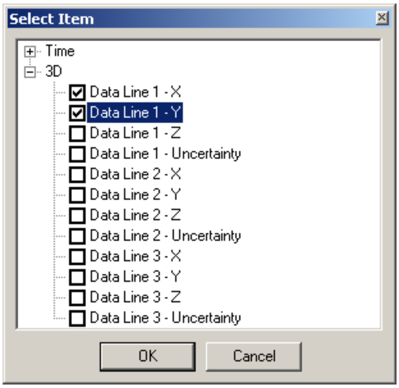
To view the data in a tabular display, click on the Display Points button.



#	Source 1	Source 2	Merged Data
75	-35.943390	-3.240575	-19.591982
76	-34.700222	-3.503097	-19.101660
77	-33.519569	-3.711278	-18.615423
78	-32.413475	-3.783028	-18.098251
79	-31.384075	-3.747708	-17.565891
80	-30.222599	-3.652593	-16.937595
81	-29.010374	-3.584322	-16.297348
82	-27.647257	-3.563357	-15.605307
83	-26.505629	-3.590490	-15.048059
84	-25.387585	-3.599845	-14.493715
85	-24.264034	-3.586587	-13.925311
86	-22.998690	-3.546979	-13.272834
87	-21.946747	-3.422261	-12.684504
88	-21.188978	-3.192514	-12.190746
89	-20.414579	-2.875763	-11.645171
90	-19.653246	-2.568774	-11.111011
91	-18.910799	-2.375487	-10.643143
92	-18.239130	-2.343114	-10.291121
93	-17.501915	-2.532273	-10.017094
94	-16.782757	-2.693565	-9.738161
95	-16.092049	-2.755433	-9.423740

To automatically generate a 3-Axis graph, click on the Graph Points button.

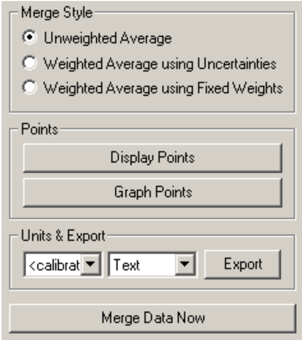
The merged data can also be graphed in a 2-Axis or 3-Axis graph. The 3-D Merge Window will appear in the list of data sources, similar to the 3-D Manager Window or any video window. Select the desired items to graph from the list of available items.



Saving, Loading, and Exporting

The 3-D Merge window may be saved using the File -> Save As... menu option. The 3-D Merge Window saves to a `*.m3m` file. A 3-D Merge file may be opened using the File -> Open Video/Data... menu. All necessary 3-D Manager source files will be opened.

The merge data may be exported by selecting the desired units and export format and clicking on the Export button.



The data may also be exported via the 3-Axis Graph export capabilities (the section called “3-Axis Graphing”).

Notes

Opening multiple 3-D Manager windows simultaneously requires many video files to be opened (4 videos per 3-D Manager window). Since a 3-D Merge Window requires multiple 3-D Manager windows to be open, this often leads to a problem with resource allocation inside of Microsoft Windows. Opening many video files (15+) simultaneously inside of ProAnalyst appears to consume a large amount of the Desktop Heap in Microsoft Windows. When this oc- curs, attempts to open additional windows will result in a *"Failed to create dialog."* error mes- sage. If you encounter this message, it is recommended that you increase the size of your Desktop Heap. Please refer to Microsoft's Knowledge Base article: ht- tp://support.microsoft.com/kb/126962/. You can use the Modify System Limits tool under the Help menu in ProAnalyst to adjust your system limits.

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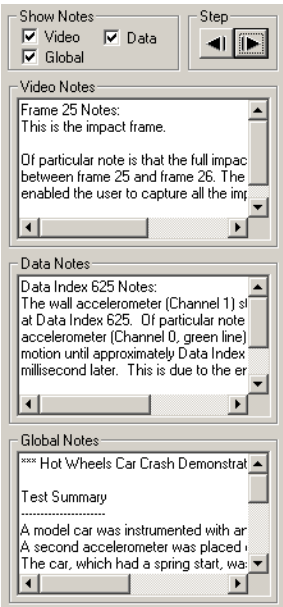
Chapter 5. Annotations

Video and Data Notes

Overview

The Notes control panel allows you to enter comments for each video frame and each data point in an event. It also allows for one global comment for the entire event. These comments are stored in a binary file along with other data such as GPS/IRIG information. This file is loaded automatically whenever the video is opened.

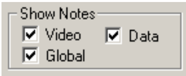
The Notes control panel is composed of five sections:



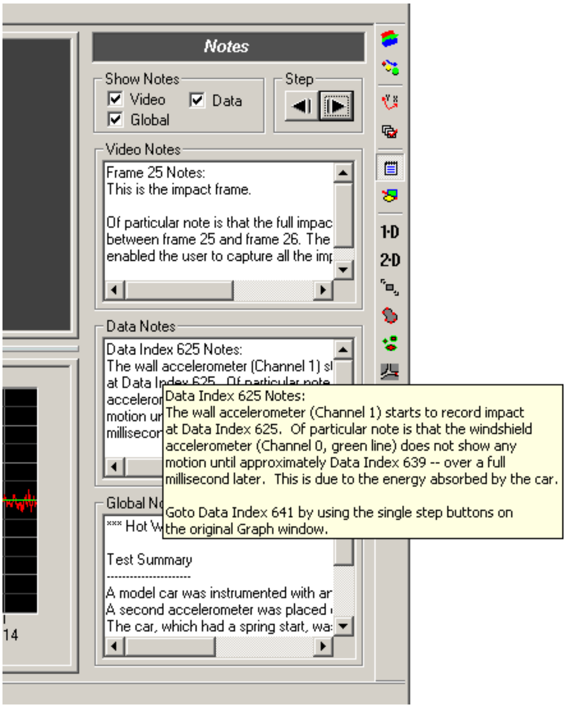
Video notes	These comments are saved for each frame of video.
Data notes	These comments are saved for each data point in the data sequence.
Global notes	These comments are free form - not assigned to any particular frame or data point.
Step	Step to the previous or next video or data comment in the sequence.
Show Notes	Check boxes to selectively display the video, data or global comment fields.

Showing Individual Sections

The notes control panel will typically display two text boxes (video and global) for events that only contain video and all three text boxes (video, data, and global) for events that contain video and data. Each of these boxes can be selectively displayed or hidden so that the remain- ing boxes have more room to display their contents. To enable or disable display of each item, check the checkbox next to each type.



For comments that are larger than the text box, tooltips are also provided. When the mouse is moved over each of the boxes, a tooltip window will appear displaying the full contents of the text box.



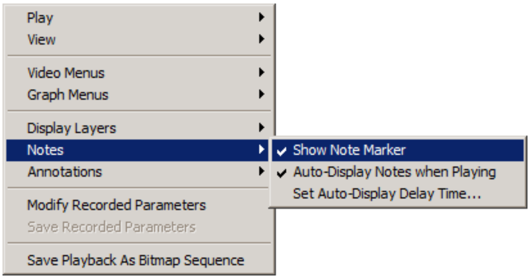
Stepping Through Notes

To review comments saved with an image sequence or with a data sequence, simply click on the left arrow button or right arrow button. You will be automatically advanced to the next se- quential comment (video or data). The corresponding video frame or data point will automatic- ally be displayed.

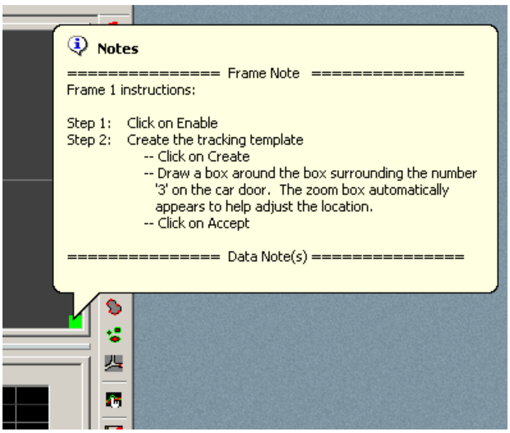
This provides an easy mechanism for stepping through your measurement to find all frames and data points that have been marked with notes.

Note Marker in Video Display

If enabled, a note marker will be displayed over the video image if the current video frame (or corresponding data points) contain a note. To enable note markers in the video display, right-click on the video and select Show Notes Marker from the View menu.



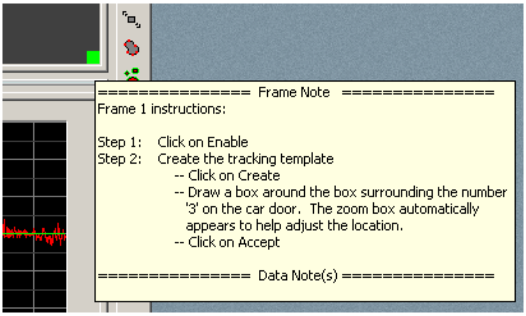
When enabled, a green box will be drawn in the lower left corner of the video image if a note is present. Moving the mouse over the green box will display the associated video, data, and global notes. The global note is only shown on the first frame of the video.



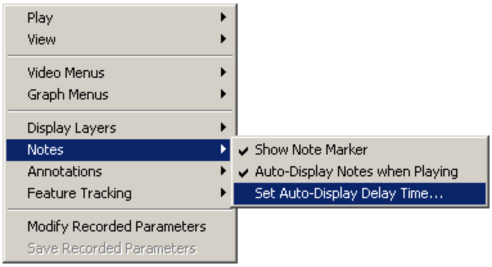
This feature can also be used to view Notes from within the Viewer version of the program, since the Notes panel is not accessible in the Viewer.

Auto-Display of Notes During Playback

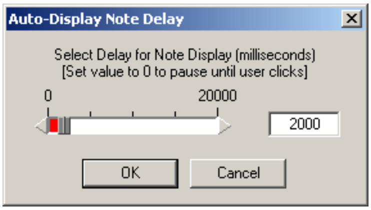
Notes can be automatically displayed during video playback. This feature is useful for creating a narrated presentation of your analysis whenever the video is played back. During playback, when a video note or data note is encountered, a popup window containing the note will be dis- played. If a global note is present, it is shown on the first video frame.



To enable this option, check the appropriate box in the Window dialog of the Program Options (the section called "Window") or right-click to access the context menu and select Auto-Display Notes when Playing in the Notes menu. The popup window can be displayed for a finite amount of time or an infinite amount of time. To set the delay time, right-click to access the context menu and select Set Auto-Display Delay Time.



The display delay time must be specified in milliseconds. If the delay time is set to 0, the user must click on a note in order to continue with playback.

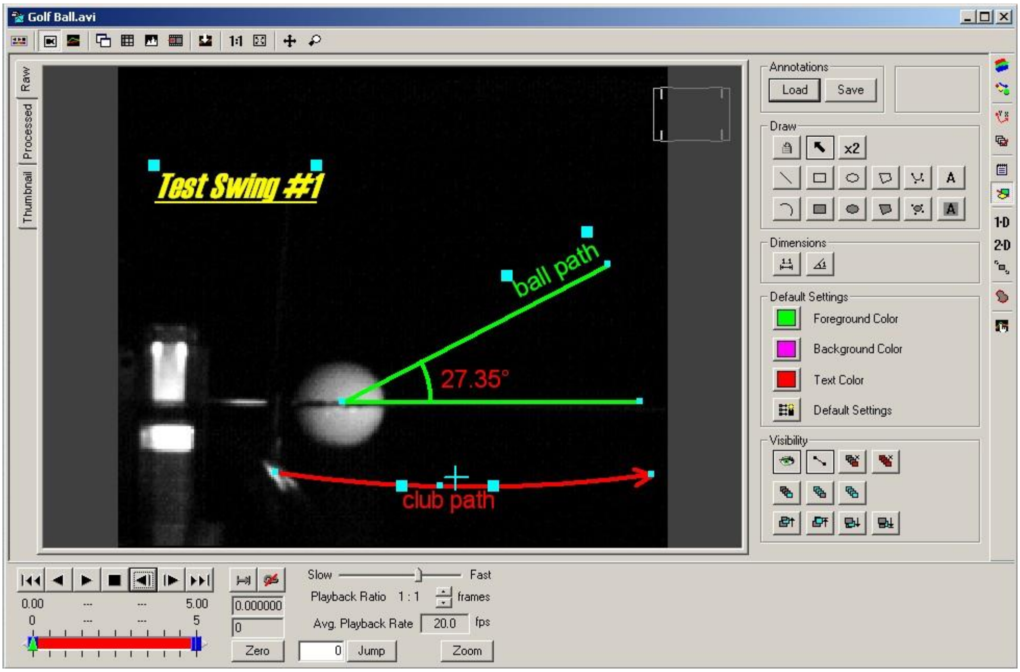


Graphical Annotations

Overview

Graphical annotations allow you to draw lines and text and other objects directly on the video images. These annotations can be made so that they only display on specific frames or they can be set to always display on all frames. The annotations are saved by default to a file with the same prefix as the video and with a `'ant'` extension. This file is loaded automatically whenever the video is opened.

The annotations controls are available on the application toolbar (see the section called “Annotation Toolbars”) or in the Annotations control panel in the Measurement window as shown.



Standard Annotations

In this section, the standard annotations, settings, and visibility tools are documented. There are also two special annotations that can be used to perform static length and angle measurements. These are discussed in the section called “Static Measurements”. The standard annotations available are:

Lock Annotations
: Lock annotations so that they cannot be modified.

Select Annotations
: Mouse clicks will select and drag any existing annotations. This is the default mode. Select Lock Annotations to prevent any mouse interactions from modifying existing annotations. Select any of the other buttons to create new annotations.

Duplicate Annotation
: Create a duplicate of the selected annotation. The duplicate

copy is created slightly offset from the original.

Draw Line — Start drawing a line in the video window. Holding down the **Control** key while dragging the mouse will constrain the line to be drawn horizontally or vertically.

Draw Arc — Start drawing a three-point arc in the video window. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Rectangle — Start drawing a rectangle in the video window. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Filled Rectangle — Start drawing a filled rectangle in the video window. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Ellipse — Start drawing an ellipse in the video window. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Filled Ellipse — Start drawing a filled ellipse in the video window. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Polygon — Start drawing a polygon in the video window. Each mouse click will add another point to the polygon. End the polygon by right-clicking on the last point. Points may be added and removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

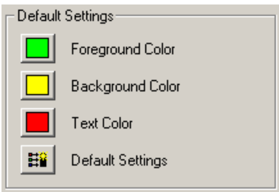
Draw Filled Polygon — Start drawing a filled polygon in the video window. Each mouse click will add another point to the polygon. End the polygon by right-clicking on the last point. Points may be added or removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Draw Spline — Start drawing a spline in the video window. Each mouse click will add another point to the spline. End the spline by right-clicking on the last point. Points may be added or removed from a polygon by using the **Insert** and **Delete** keyboard keys

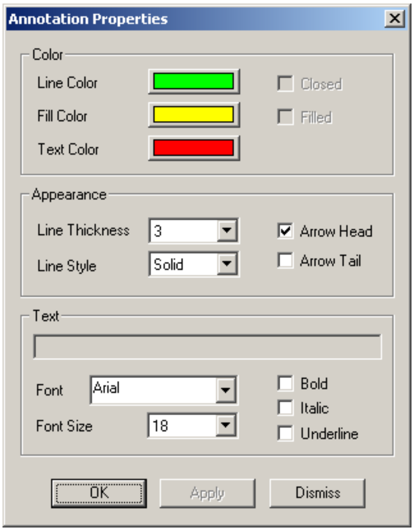
	when the mouse is over a drag handle. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.
Draw Filled Spline	Start drawing a filled spline in the video window. Each mouse click will add another point to the spline. End the spline by right-clicking on the last point. Points may be added or removed from a polygon by using the **Insert** and **Delete** keyboard keys when the mouse is over a drag handle. Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.
Draw Text	Start drawing text in the video window at the location of the next mouse click.
Draw Filled Text	Start drawing text with a filled background at the location of the next mouse click.

Default Settings

The default settings for newly created annotations can be set using the Default Settings portion of the control panel.



Foreground Color	Sets the default foreground color for all new annotations. Click on the colored button to display a color selection popup window.
Background Color	Sets the default background color for all new annotations. Click on the colored button to display a color selection popup window.
Text Color	Sets the default text color for all new annotations. Click on the colored button to display a color selection popup window.
Default Settings	Displays a default settings dialog where the default colors, line styles, and font styles may be set for all new annotations. To modify the settings of an existing annotation, double-click on the annotation in the video window.



Visibility Settings

The visibility settings for the selected annotation or all annotations can be set using the Visibility portion of the control panel.

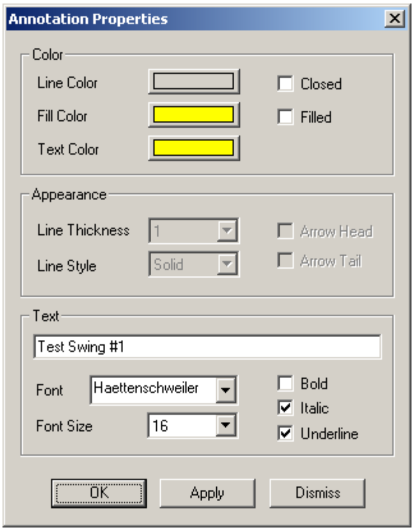
Show or Hide Annotations	Shows or hides all annotations for the active video.
Show or Hide Drag Handles	Shows or hides the square drag handles used to modify annotations.
Show in Current Frame	Set the currently selected annotation to display only in the current frame.
Show in Current Frame Forward	Set the currently selected annotation to display in the current frame forward.
Show in All Frames	Set the currently selected annotation to display in all frames.
Bring Forward	Move the currently selected annotation forward in the display order.
Bring to Front	Move the currently selected annotation to the top of the display order.

Send Backward	Move the currently selected annotation backward in the display order.
Send to Back	Move the currently selected annotation to the back of the display order.
Delete Annotations in Current Frame	Delete all annotations for the current frame only. Does not delete annotations that are set to display in all frames.
Delete All Annotations	Delete all annotations for the active video.

Editing Annotations

Properties

If you double-click on an existing annotation, the annotation properties dialog will appear.



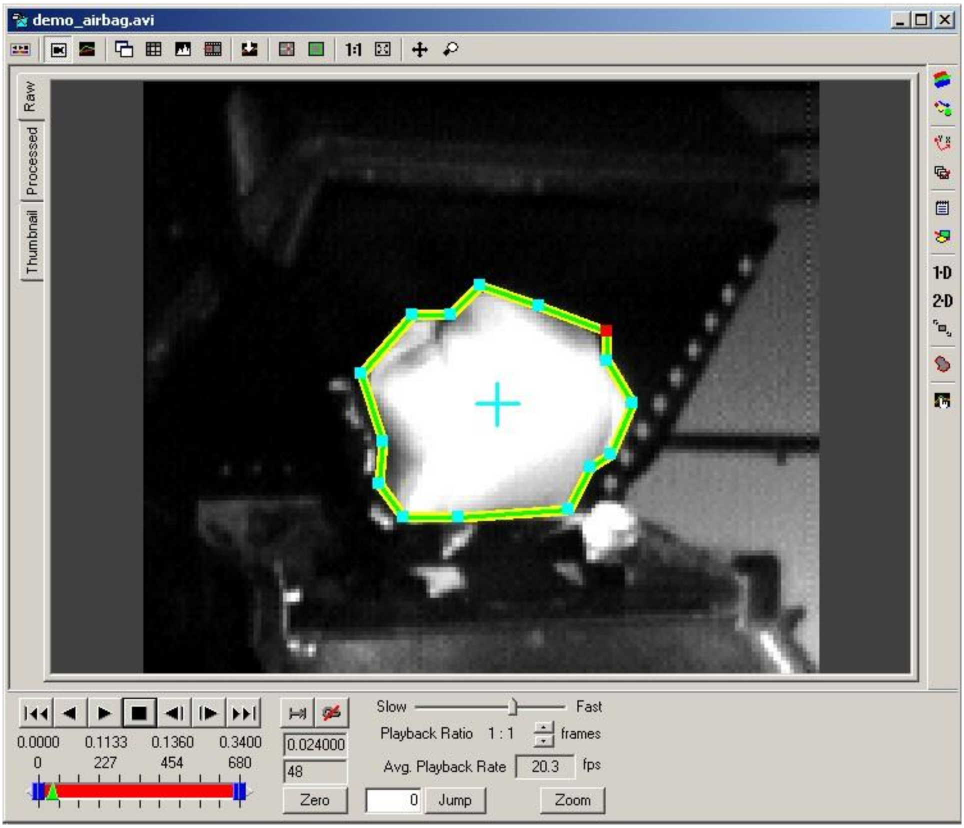
For different types of annotations, different properties will be available to be modified. Make the desired changes and click Apply to apply them to the drawing. Click on OK when you are satisfied, or Cancel to cancel your changes.

Deleting Annotations

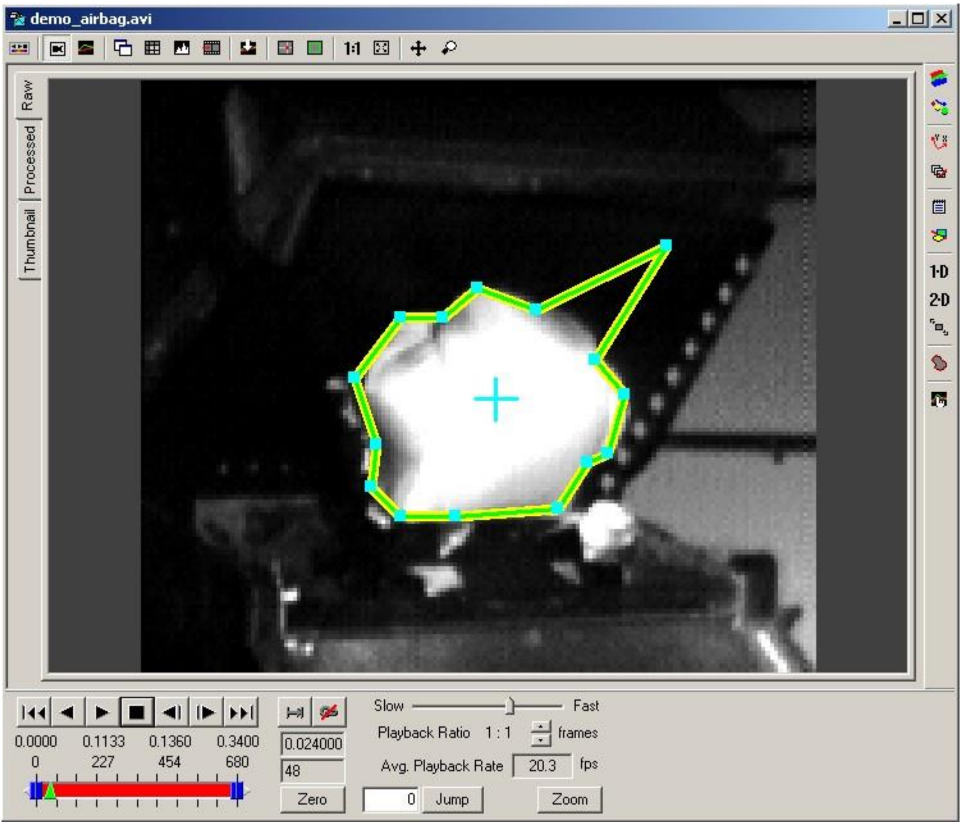
Click on the annotation that you wish to delete. The annotation should be highlighted in yellow. Press the **Delete** key on the keyboard and the annotation will be deleted.

Moving and Adding/Removing Points

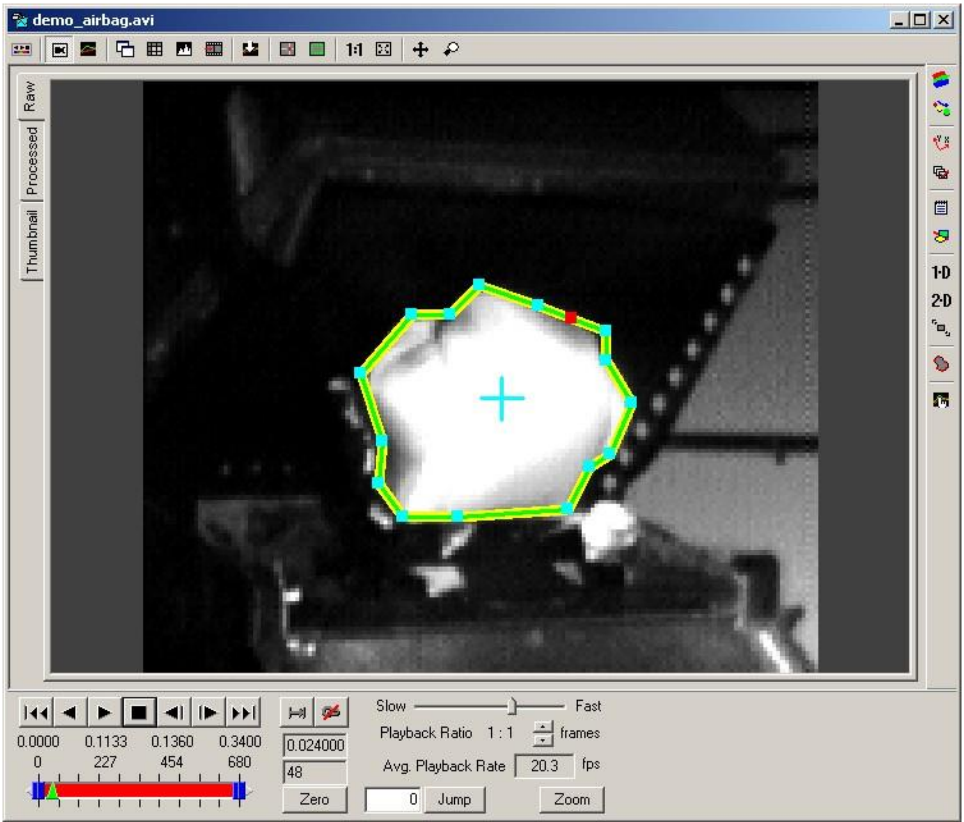
Every annotation has "handles". You can modify the location of these handles to change the shape or location of each annotation. When the mouse passes over a handle, the handle should become highlighted in red.



Click and drag the handle to move it to another location.

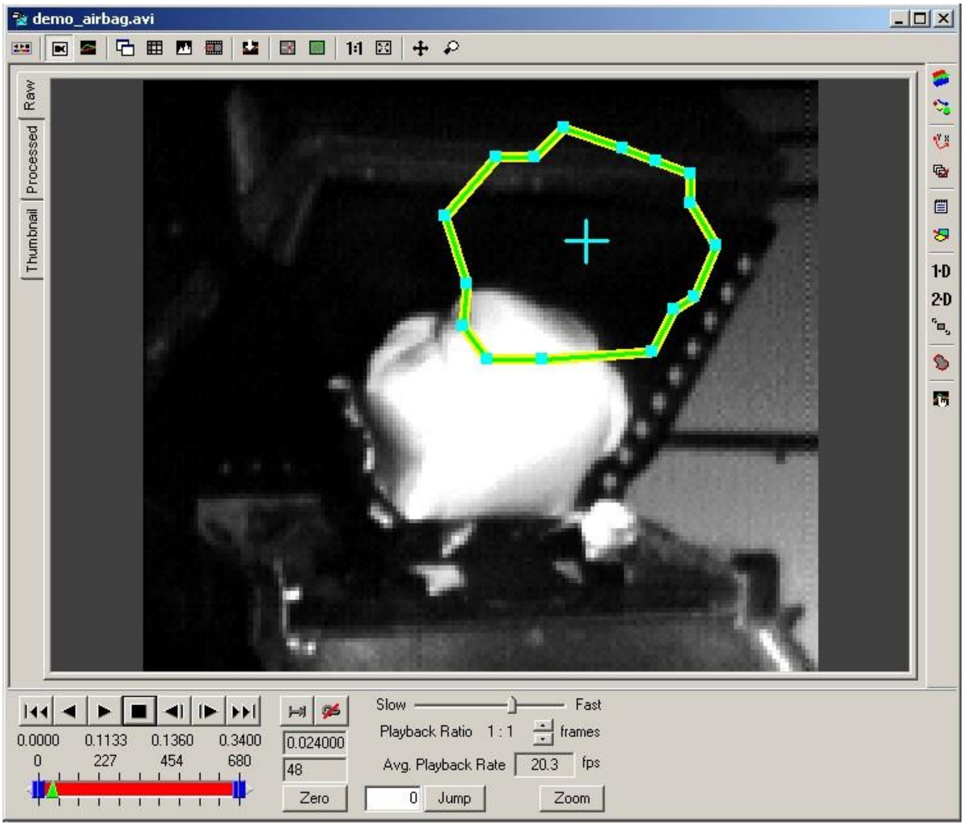


For annotations that support an arbitrary number of points (polygons, splines), new points can be added by selecting the annotation (click on it) and pressing the **Insert** key on the keyboard.



A new point (handle) will be added on the segment that is closest to the current mouse location. To remove a point, move the mouse over the point (handle) that you wish to remove. Make sure that it is highlighted in red, then press the **Delete** key. Be careful, this only works for poly- gons and splines and only if a drag handle is highlighted. If you press **Delete** for any other type of annotation or not over a highlighted drag handle, the whole annotation will be deleted.

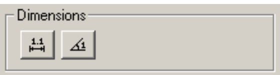
If you click and drag the annotation with the mouse far from all the drag handles, then the annotation itself will move.



Static Measurements

Overview

There are two special types of annotations that perform basic dimensioning functions. These are the length and angle dimension annotations. They are located in the middle of the Annota- tions control panel and on the Annotations toolbar (see the section called "Annotation Tool- bars").

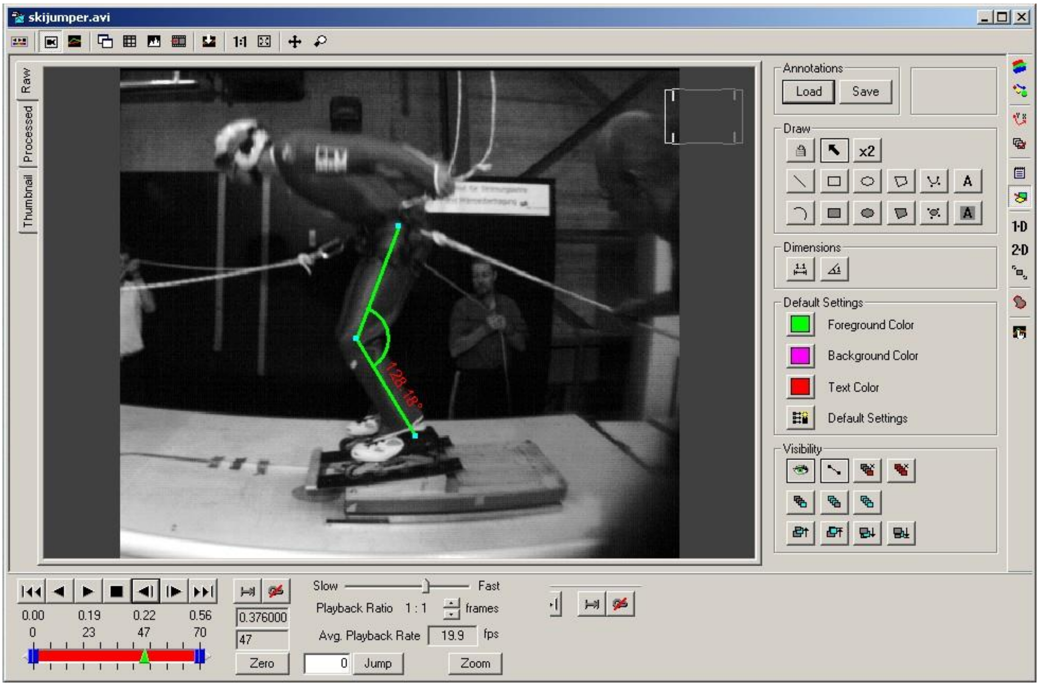


Draw Length Dimension	Start drawing a static length dimension in the video window. The length dimension will be shown in the units that the video was calibrated in (see the section called "Multi-Plane Calibration"). If no calibration has been applied, the length dimension is shown in pixels.
Draw Angle Dimension	Start drawing an angle dimension in the video window. The

angle is defined by the location of the next three mouse clicks in the video window. The angle measurement is shown in degrees and is the angle between the lines connecting the first and last point to the middle point.

Angle Dimension

The angle dimension annotation provides a simple means for measuring an angle in the video image. The units for the angle dimension are always given in degrees.



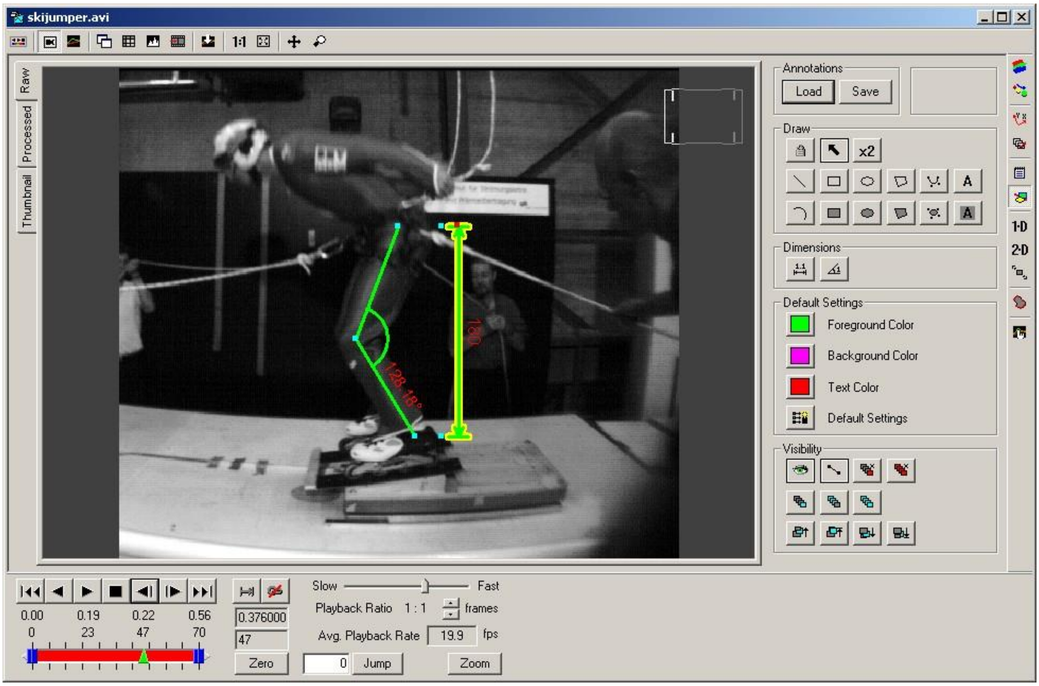
To draw an angle dimension:

1. Click on the Draw Angle Dimension button on the annotation toolbar or control panel.
2. Click on the first point in the image (ankle).
3. Click on the second point in the image which will be the center of the angle (knee).
4. Click on the third and final point in the image (hip).
5. Click and drag any of the drag handles to fine tune the location of the angle dimension.
6. Double-click on the new angle dimension and modify any settings if necessary.

Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.

Length Dimension

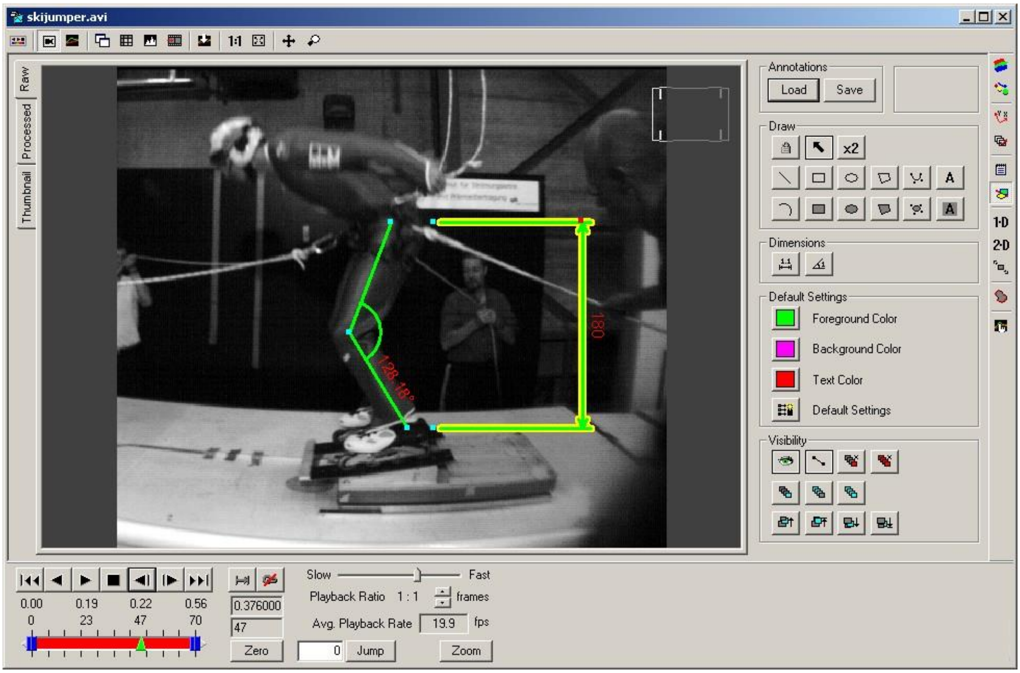
The length dimension annotation provides a simple means for measuring a length in the video image. The units for the length dimension will be given in the same units that were used for calibration (see the section called "Multi-Plane Calibration"). If no calibration has been done, the length dimension will be given in units of pixels.



To draw a length dimension:

1. Click on the Draw Length Dimension button on the annotation toolbar or control panel.
2. Click and hold down the mouse button starting at one end point of the length you wish to dimension.
3. Drag the mouse and release at the other end point of the length you wish to dimension.
4. Click on the additional drag handle at the end of the dimensioning line (shown in red here) and drag the dimensioning line to the desired position.
5. Click and drag any of the drag handles to fine tune the location of the length dimension.
6. Double-click on the new length dimension and modify any settings if necessary.

Holding down the **Control** key while dragging the mouse will constrain the current point to be drawn horizontally or vertically from the previous point.



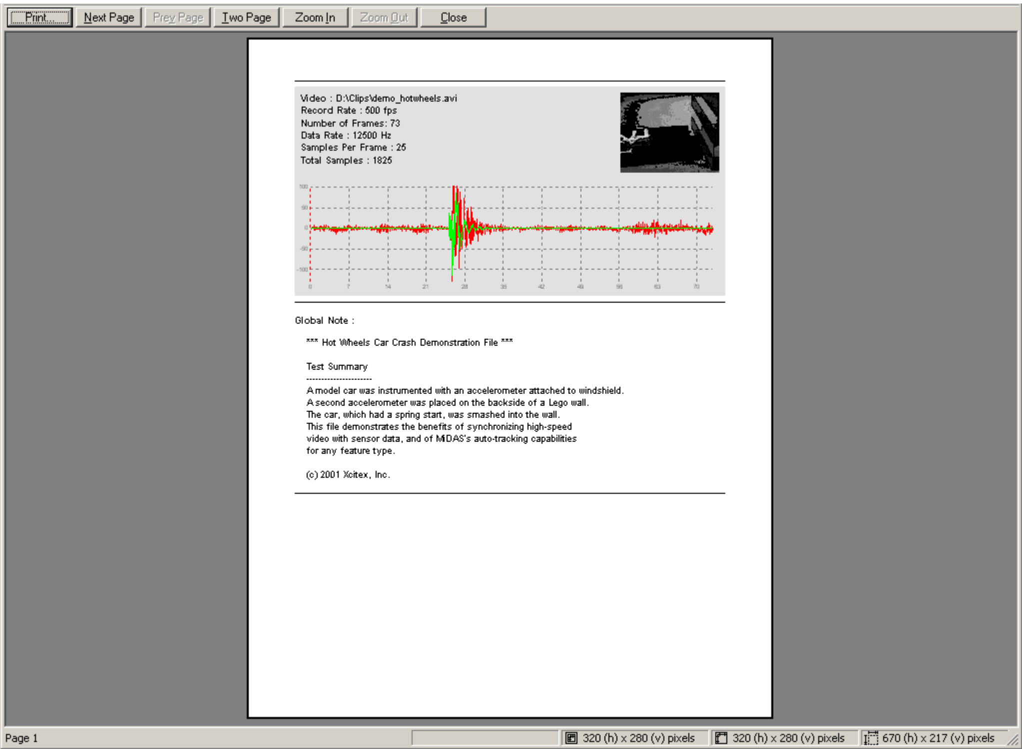
Chapter 6. Report Generation

Report Overview

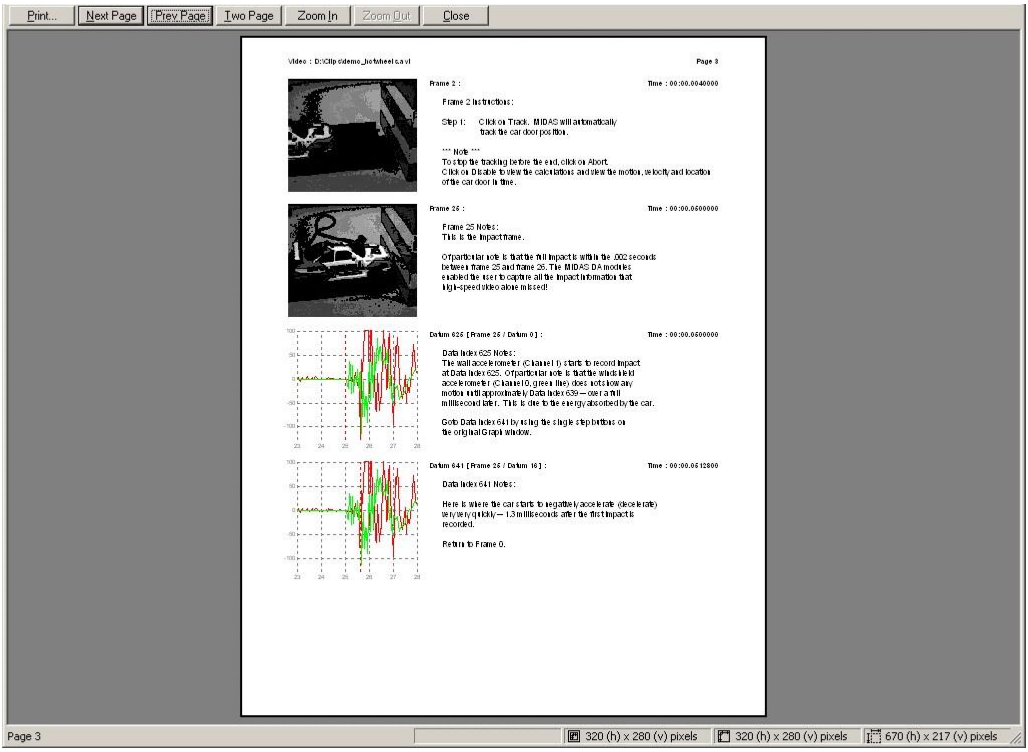
Report Contents

Automatically generated reports obtain their content from the video, data, analysis, notes, and annotations. These are assembled and output in a structured format suitable for printing or web distribution. The Print and HTML formats have essentially the same options and are built from the same content material. The PowerPoint format is new, and some options do not apply to PowerPoint reports.

Reports are composed of a cover page, which displays video and data information, an image of the first video frame, a data graph of the acquired data if present, and the global note associated with a video.



All subsequent pages are composed of blocks of video images and comments or data plots and comments.



Blocks are added to the report and formatted according to the guidelines specified in the Report Options (see the section called “Report Options”).

Adding Content

Any frame that contains a comment or annotation will automatically be included in the generated report unless specified otherwise in the Report Options. In addition, the Report Options can be changed to include other frames that do not have comments or annotations.

The content that is displayed in the report comes from many sources:

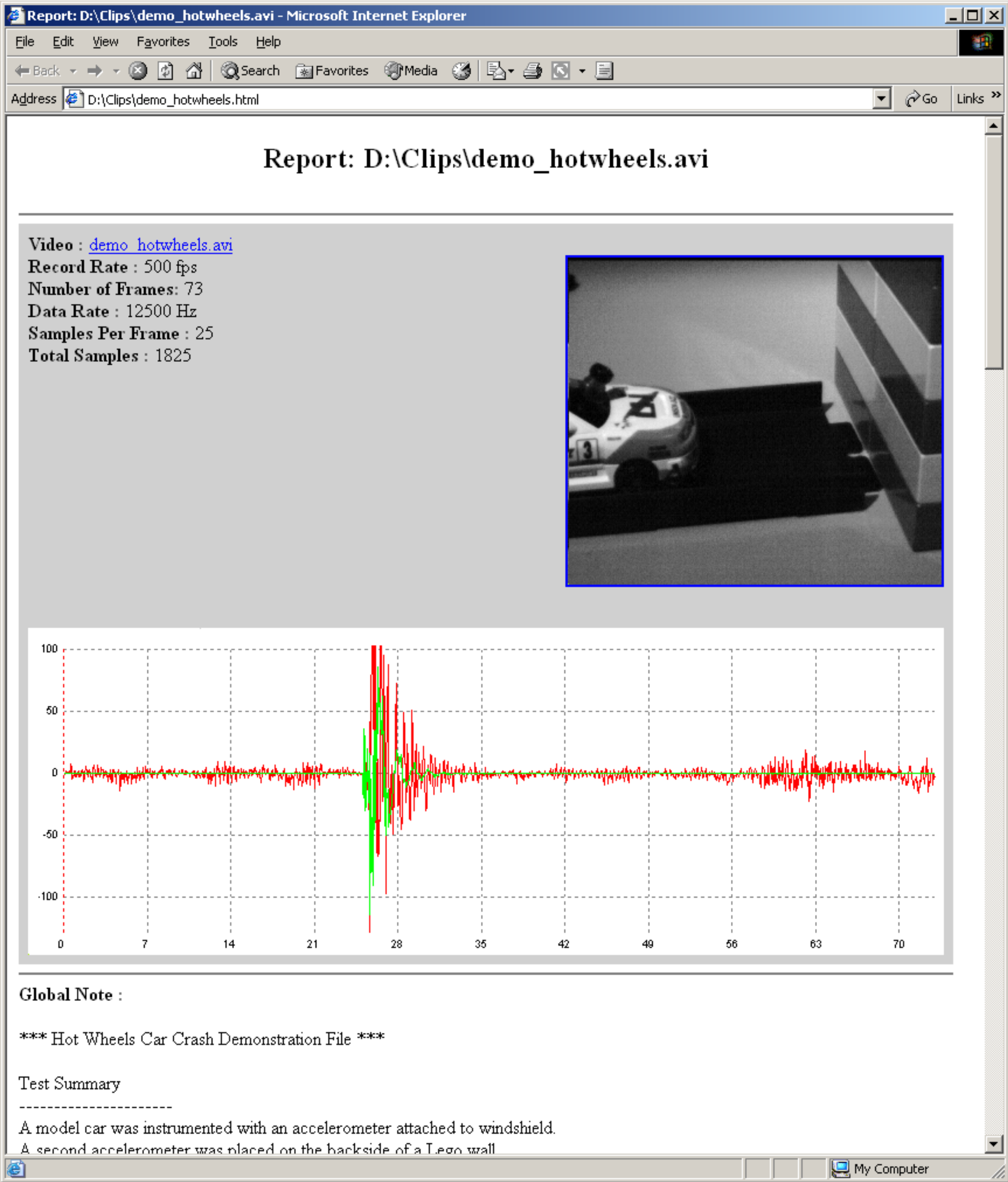
- To add video or data comments, use the Notes control panel (see the section called “Video and Data Notes”). Comments can be added for each video frame, each data point, or for the entire video.
- To add annotations, use the Annotations control panel (see the section called “Graphical Annotations” and the section called “Static Measurements”) or toolbars (see the section called “Annotation Toolbars”) to draw annotations over the video images. Annotations can be set to appear in a single frame or in all frames. Annotations that appear in a single frame will cause that frame to be included in the report generation. Annotations that appear in all frames will not force every frame to be included in the report.
- Changes to the image appearance using Image Processing (see the section called “Image Processing”) or Image Filtering (see the section called “Image Filtering”) will be visible in the report if the "Processed" tab (see the section called “Video”) is selected in the Measure-

ment Window when the report is generated. If the "Raw" tab is selected in the Measurement Window, then the raw video images will be used in the report.

- All visible analysis results that are shown in the Measurement Window will also be shown in the report (unless disabled in the Report Options).

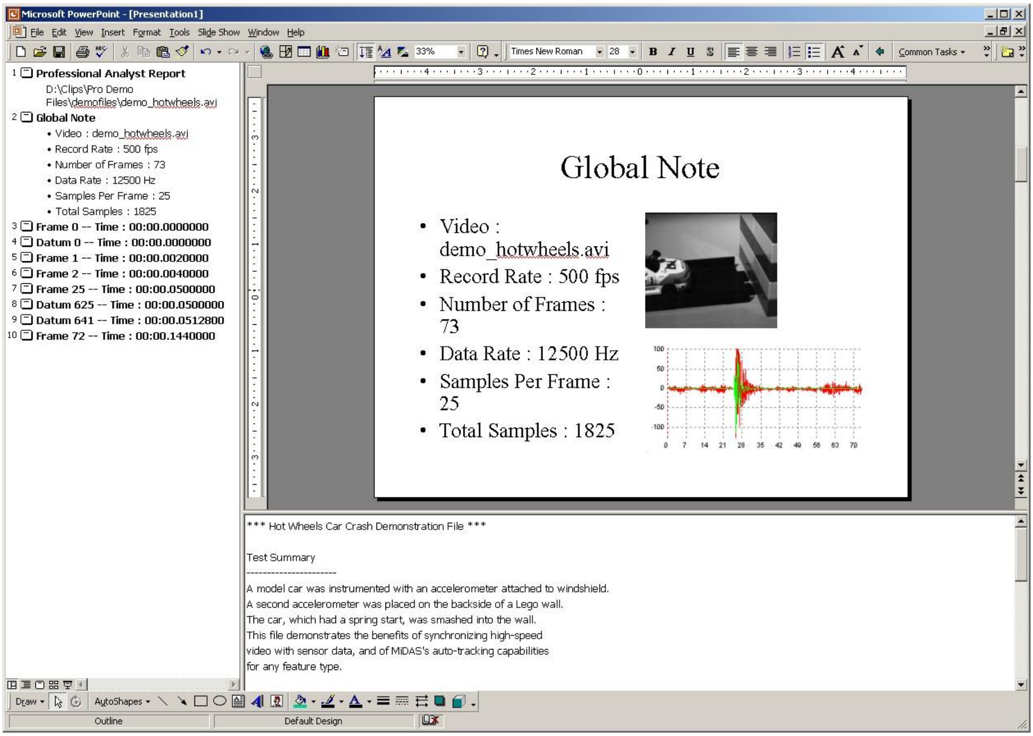
Using the Report

The results from the Report Generator can be used to supply content to a wide variety of productivity applications. HTML versions of the report can be imported into other typical word processing applications such as Microsoft Word. HTML versions can also be saved as plain text files using standard web browsing applications. These text files combined with the set of image files automatically generated with the report can be incorporated into a wide variety of word processing or presentation applications.



HTML reports are output to a single HTML file that is specified in the Report Options. The video images and the data plots are created as bitmap files that are stored in an images direct- ory. The image directory is located in the same directory as the HTML file. The directory is named after the video filename with a "`_imgs`" appended to it. For example, for the `demo_hotwheels.avi` video, the HTML file was named `demo_hotwheels.html` and the image directory was named `demo_hotwheels_imgs`.

PowerPoint reports generate a single slide for each frame or data point. The title is set to the time information for the given frame or data. The slide includes an image of the video and of the data (if present).



Because the associated frame or data notes could potentially be very lengthy, the notes are placed in the Notes section for each slide instead of within the slide itself.

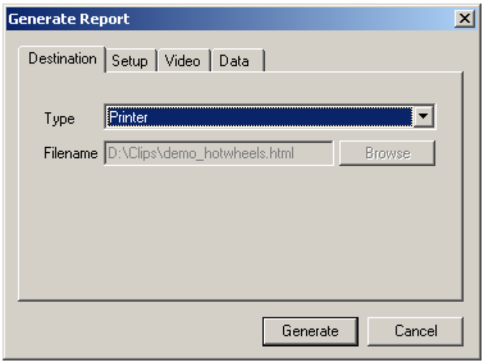
Report Options

Options Dialog

When the report generator is started, an initial options dialog window is displayed. The various configurable options for the report generator are described in this section.

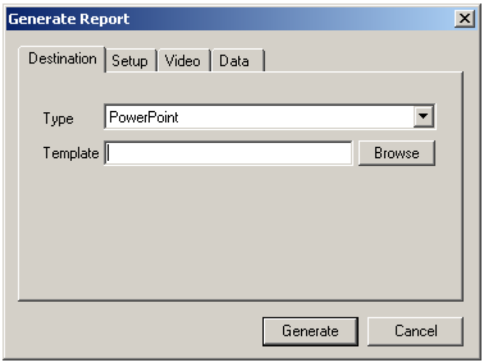
Destination

Select the type of output for the report: Printer will send directly to a printer, Print Preview will display a preview window, HTML generates an HTML page and associated images, and PowerPoint generates a PowerPoint presentation.



The HTML type will request an output filename. For your convenience, the filename will default to the video name with the `.html` file extension.

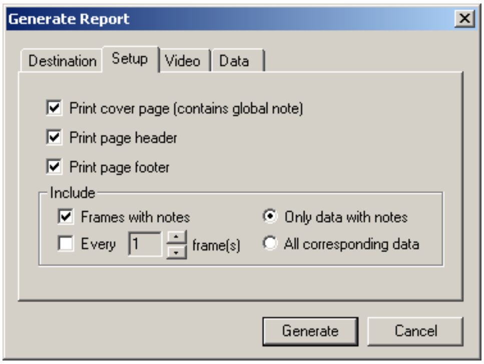
The PowerPoint type will allow you to specify a PowerPoint template file (`*.pot`) to be used for the resulting presentation. If this is left blank, no template will be used. For your convenience, the program will remember the last PowerPoint template used. To clear the template, either erase the Template field, or click Browse and then click Cancel in the browse window.



Depending upon the type that is selected on this tab, the contents of the Setup, Video, and Data tabs will change appropriately.

Setup

The setup options allow you to configure the overall format of the report.



Print cover page	The cover page provides a summary of the video and data. It includes an image of the first video frame, a graph of the complete data, and the contents of the global note if present. Select this checkbox to include the cover page.
Print page header	The page header includes the name of the file and the page number. Select this checkbox to include a header on every page.
Print page footer	The page footer includes the application name and the date and time. Select this checkbox to include a footer on every page.

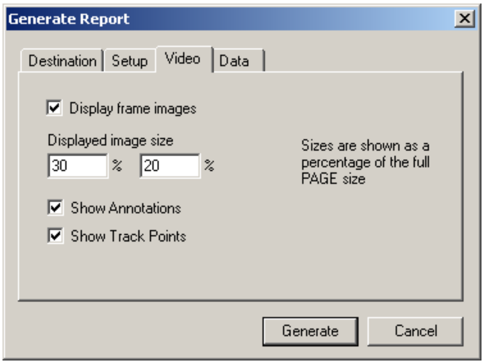
After the cover page, the remaining document is composed of blocks of frames with notes or data with notes. In the default setting, only frames or data that contain notes or annotations will be included in the generated report. Additional frames that do not contain notes can also be included in the report by modifying the Include options.

Frames with notes	Check this box to include every frame that contains a note or annotation.
Every [x] frame(s)	Check this box and specify an interval to automatically include equally spaced frames throughout the entire video.
Only data with notes	Select this option to only include data graphs if the data has an associated data comment.
All corresponding data	Select this option to include the associated data graph that corresponds with a video frame that is displayed regardless of whether the data itself has an associated data comment.

Future versions will have greater flexibility in what is included in the generated report.

Video

The video options control how the video frames are displayed in the generated report.

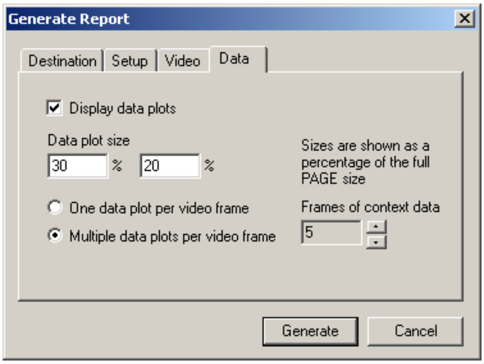


Display frame images	Check this box to include frame images. If this box is not checked, video images will not be included in the generated report.
Displayed image size	Specify the maximum image size on the page. For the Print and Print Preview destinations the size is given as a percentage of the total page size. The image will be resized to fill the specified size while maintaining the same aspect ratio. The image width cannot exceed 50 percent of the page size in order to leave room for user comments. For the HTML destination, the size is given as dimensions in pixels.
Show Annotations	Check this box to include annotations in the frame images that are displayed. The annotations must be visible in order to be displayed.
Show Track Points	Check this box to include analysis track results in the frame images that are displayed. Analysis must have been completed and visible in order to be displayed.

Frame images are displayed in the raw or processed form depending upon which tab is cur- rently selected in the Measurement Window when the report is generated. If the Raw tab is se- lected, the raw frames will be incorporated. If the Processed tab is selected, the processed frames will be incorporated.

Data

The data options control how the data graphs are displayed in the generated report.



Display data plots	Check this box to include data plots. If this box is not checked, data plots will not be included in the generated report.
Data plot size	Specify the data plot size. For the Print and Print Pre- view destinations the size is given as a percentage of the total page size. The image width cannot exceed 50 per- cent of the page size in order to leave room for user com- ments. For the HTML destination, the size is given as dimensions in pixels.
One data plot per video frame	A single video frame may contain multiple data points that have associated user comments. A single data plot can be generated for this video frame or multiple data plots can be generated for each data point that has an associated user comment. Select this option to generate a single data plot per video frame.
Multiple data plots per video frame	A single video frame may contain multiple data points that have associated user comments. A single data plot can be generated for this video frame or multiple data plots can be generated for each data point that has an associated user comment. Select this option to generate separate data plots for each data point that has an associated comment.
Frames of context data	For every data point that is plotted, a range of data points before and after the point of interest is included in the data plot. The amount of data shown before and after the data point of interest can be specified here. The amount is given as the number of frames worth of data to be dis- played in each graph. For instance, if the data is sampled at 10 samples per frame, 5 frames of context data would generate plots that have 50 data points each.

Only data that was acquired with the video is included in the data plots. Graphing of analysis results is not included in the generated report. Future versions will incorporate analysis graphing in the report generation.

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Chapter 7. Saving, Importing and Exporting

Saving Video Files

Overview

Video files that this program operates upon may be from one-time events or require complex conditions to setup. Therefore, our software always avoids modifying pixels in an image, so that they are always identical to what was acquired. All the analysis, image processing, and oth- er operations create separate data files so that they do not require overwriting or rewriting the video image.

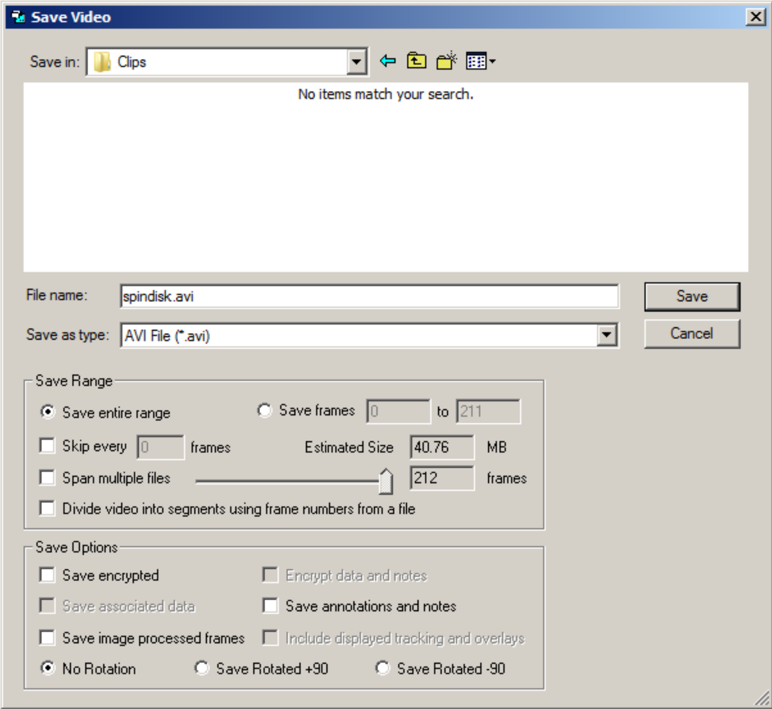
There are occasions where the video itself will need to be saved to another file, for instance:

- Saving a subset of frames to a new file.
- Splitting a long recording into smaller pieces.
- Changing the save format from AVI to bitmap files or any other format conversion.
- Saving processed results to another file for easier processing.
- Saving processed videos with all overlays (tracking, annotations, etc.).
- Saving a sub-region of the video images.

In all these operations, the original file is kept intact and a new file is created with the modified images and information.

Save Dialog

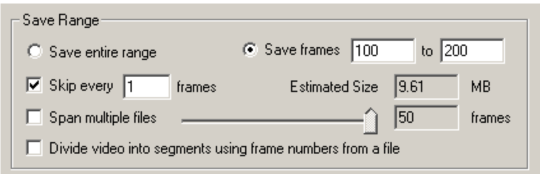
The Save Video dialog is similar to the standard Windows save dialog, with additional options beneath the standard controls. The Save Video dialog can be brought up in many different ways. Click on the Save button  on the main toolbar when the active window is a Measurement Window or use the main File menu and select Save As... or use the keyboard shortcut **Ctrl+S**.



Select the directory to save in and enter the filename to save as in the upper sections of the dialog. The lower sections of the dialog provide advanced save options that are explained below.

Saving Subset of Frames

To shorten a video or to focus on one section of the video, you can save a subset of frames or skip frames.



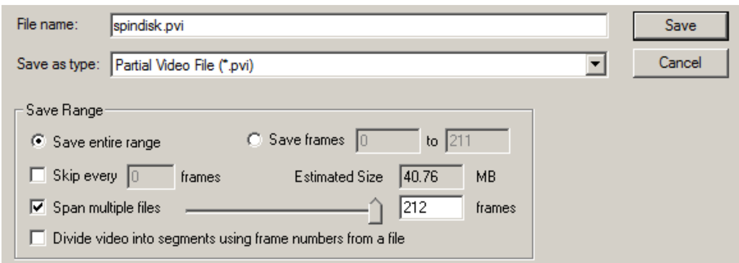
Save entire range	This option will save the entire set of frames from the original video. This is the default behavior.
Save frames	A range of frames between a start and end frame can be specified. The start and end frame must be valid frames in the video.
Skip every [x] frames	A reduced set of frames can be saved by skipping some frames. A skip value of 1 would save every other frame. A skip value of 2 would save one frame, skip 2, save the

	next frame, and so on. The default is to save all frames (skip value of 0). Skipping frames is not recommended in general unless you know what you are doing since this will alter the apparent frame rate of the video.
Estimated Size	Displays the estimated size of the total resulting video file(s).
Span multiple files	This option can be used to split the video into separate video pieces that can be loaded seamlessly as if they were one video.
Divide video into segments using frame numbers from a file	This option can be used to divide the video into separate video files using frame numbers contained in a text file.

Spanning Multiple Files

The standard Microsoft AVI file format supports up to a maximum of 2GB per file (with some extensions that can go to 4GB). Occasionally you may need to save a video in smaller pieces to save to a CD-ROM or other device. You can save sub-ranges using the Save Range portion of the Save dialog, or you can use the spanning functionality of this software.

This software will automatically span a video file into smaller pieces of a specified size. The resulting files will be reloaded as if they were one single video file. These partial pieces will be given the PVI file extension.



To save a video to a spanned set of files:

1. Check the Span multiple files checkbox in the Save dialog.
2. Drag the slider until the desired Estimated Size for each partial video file appears in the dialog.
3. Or type in the desired size for each partial video file in the Estimated Size edit box and press **Tab** to update the slider and number of frames.
4. Or type in the desired number of frames for each partial video file in the frames edit box and press **Tab** to update the slider and Estimated Size.
5. Click the Save button to execute the save operation.

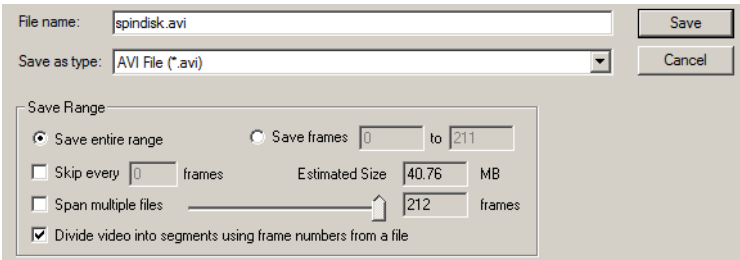
To load a spanned PVI file, click on any of the PVI portions in the Load dialog and all portions will be automatically identified and loaded.

Dividing Video Files

Occasionally you may need to divide a large video into smaller segments.You can create a text file containing the starting and ending frame numbers for each segment, and ProAnalyst will save the video in separate parts. You can also create a new project containing all the segments of the divided video.

Format the text file as shown below. The first line should be a comment beginning with a per-cent sign.

```
% frame numbers
-825, -665
-664, -506
-505, -347
```



To divide a video into segments:

1. Check the Divide video into segments using frame numbers from a file checkbox in the Save dialog.

2. Enter a filename and click Save.

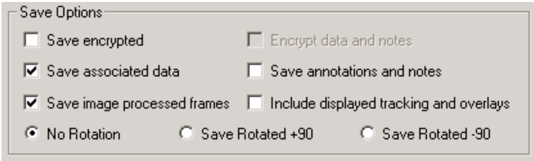
3. Navigate to the text file containing the frame numbers and click **Open**.

4. A dialog appears asking if the first frame is number 0, ignoring any zero/trigger frame number. Click Yes or No, depending on the frame numbers of your video. ProAnalyst saves the video in parts and also creates a new project containing all the segments of the divided video. The names of the segments will be composed of the filename and _Part01, _Part02, etc.

5. Click the Save button to save the new project.

Saving Processed Video

To speed up playback of processed video, a video can be saved with the processed settings applied to it. The original file should be left on the hard drive. The save processed operation is not reversible.



Save encrypted
: A user supplied pass-phrase can be used to encrypt the video frames of the new video. Anyone wishing to view the encrypted video will be required to type in the identical pass-phrase. Use this option carefully, if the pass-phrase is forgotten, the original video images can- not be retrieved. See the section called "Viewing En- crypted Video" for information on decrypting an encryp- ted video.

Encrypt data and notes
: Along with the video frames, the associated data and notes, if present, can also be encrypted with the same pass phrase.

Save associated data
: If acquired data is present in the current video, this data can be saved with the new video or it can be ignored. Check this box to save a copy of the current data with the new video.

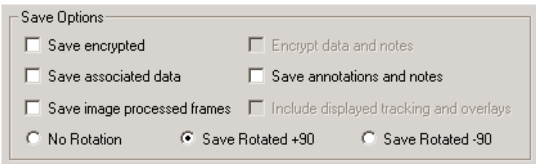
Save annotations and notes
: The annotations and notes associated with the current video can also be saved to the new video. Check this box to save a copy of the current annotations and data with the new video.

Save image processed frames
: The Image Processing and Image Filtering settings can be applied to the video and the results saved in the new video file. Normally the Image Processing settings and the Image Filtering settings are stored in separate files. These settings are loaded and applied to the video image every time the video image is drawn. The original video file is not modified and the Image Processing and Image Filtering settings can be turned off at any time. When saving with processing, the newly created file will have the current Image Processing and Image Filtering settings permanently applied. This saves computation time when the new processed video is loaded, however the changes cannot be turned off for the new video. Note that this process is not reversible. You cannot obtain the original file back from the resulting processed file. This option must be checked in order to select the next option,

	Include displayed tracking and overlays.
Include displayed tracking and overlays	This option is only available if "Save image processed frames" is selected. This option will save any overlays that are drawn on top of the video image as displayed on the screen. This includes any analysis track points, annotations, captions, etc. Note that this process is not reversible. You cannot obtain the original file back from the resulting processed file. The resulting overlays are drawn into the video image, however, they are limited by the resolution of the video itself. Therefore, the resulting output may appear more pixelated than what is seen on the screen.

Saving Rotated Video

Video frames can also be saved rotated +90 degrees or -90 degrees. To save a rotated video, select the appropriate rotation option in the Save dialog.



To save a video rotated 180 degrees, use the flip vertical and flip horizontal image processing filters and then save the processed video.

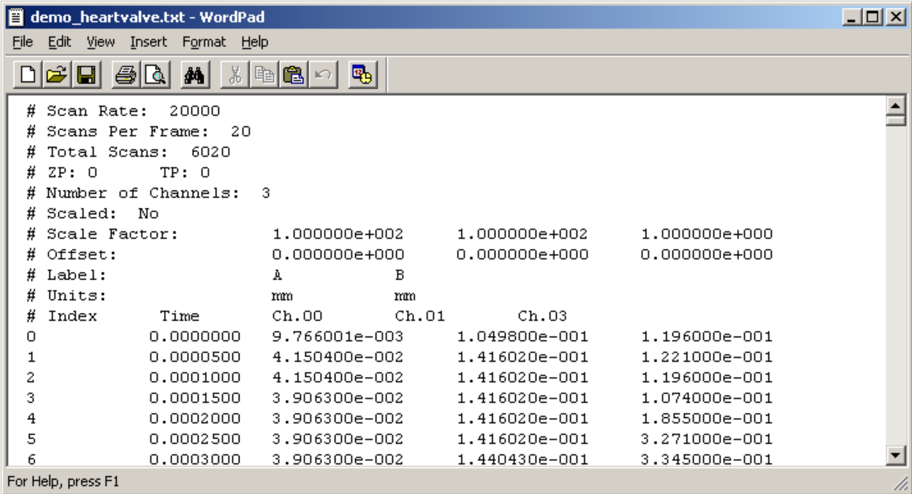
Saving Sub-Regions of Video

Using the zoom window, a sub-region of the video image can be saved to a separate video file. This can reduce the size of the resulting video and remove background sections that are unnecessary. For more information on saving sub-regions of video, see the section called “Zoom Window”.

Importing Data

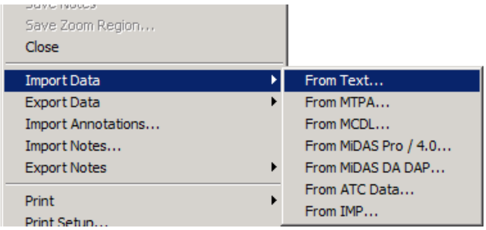
Overview

Data from external sources can also be imported and aligned to video sequences. The external data must be contained in a text file where each line contains one set of data. The text file may also contain comment lines. These comment lines should be indicated by having a special character at the start of each comment line. Blank lines are ignored. All other non-comment lines should contain the same number of values. These values can be separated by spaces, tabs, commas, or any other delimiter. Below is shown an example of a suitable text file. In this file, comments are indicated by the '#' character and each uncommented line contains five values separated by tabs.

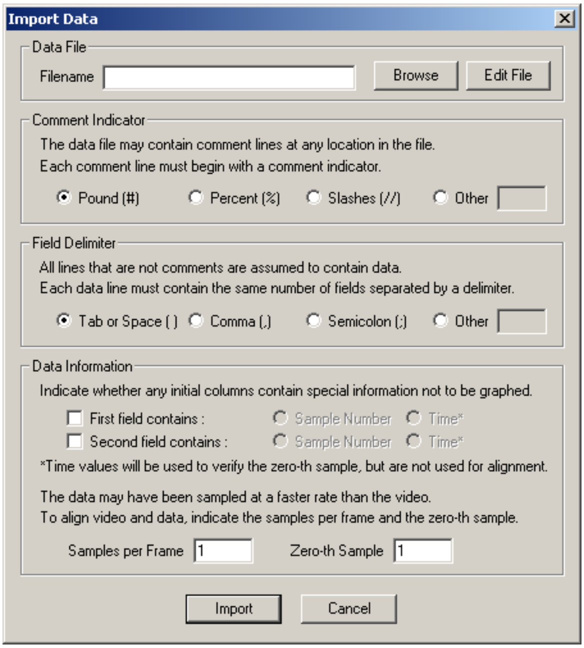


Importing from Text

To import data, use the Import Data menu in the main File menu.



The Import Data dialog will appear.



Enter the name of the text file to load the data from by typing in the name in the Filename box or by clicking on Browse to select a file. If you would like to review the contents of the file you have selected, click on the Edit File button, and the file will be opened with WordPad.

In order to properly interpret the contents of the text file, information about the formatting of the file must be provided.

1. Specify the Comment Indicator used in the text file. Typical characters are listed for convenience. You may use one of these or you may enter your own character(s) by selecting Other and typing in the correct value.

2. Specify the Field Delimiter used in the text file. This is the character(s) used to separate data values on each line. Typical values are listed for convenience. You may use one of these or you may enter your own character(s) by selecting Other and typing in the correct value.

3. Often data files contain special data in the first few columns that should be treated differently than the other columns. If the first and/or second column contains information that should not be graphed, then check the appropriate box and indicate what is contained in that column. Note that these values are not used to perform alignment. The Time value will be used to verify the zero point, but otherwise, these values are discarded.

4. In order to properly align the data to the video, information about the sampling rate and zero position of the data must be provided. The data must have been sampled at an integer multiple of the video rate in order to align properly. Enter in the number of data samples that correspond to one video frame in the Samples per Frame box. For instance, if the data was sampled at 1000 Hz and the video was recorded at 100 fps, then enter a value of 10 for samples per frame.

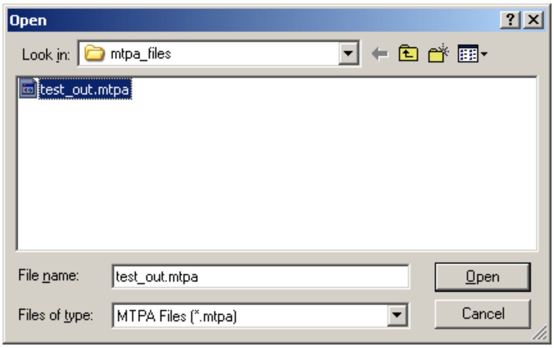
5. Next, specify the number of the data line that should be used as the zero-th sample. This data sample will be aligned with the zero frame of the video. For instance, if the 100th data line in the text file represents the zero point, enter 100 in the Zero-th Sample box. If the first or second field was specified to be a Time value and the data line where the Time value is zero differs from the value you have entered for the zero-th sample, you will be asked which value to use in alignment.

If the data does not align as you had expected, try importing the file again with different samples per frame and zero-th sample values until you achieve the desired alignment.

Importing from MTPA

To import data from an MTPA file, use the Import Data menu in the main File menu and select From MTPA....

A file open dialog will appear, select the desired `*.mtpa` file to load.



When importing from an MTPA file, it is critical that the video have the proper video frame rate specified. The frame rate can be set using the Modify Recorded Parameters command (see the section called “Setting Frame Rate, Shutter Speed, and Zero”). If no frame rate is specified, a default value of 1 frame per second will be used.

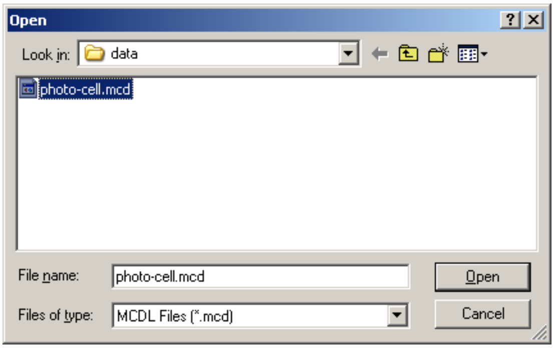
The data rate and zero-th sample will be read from the MTPA file. The video rate and the data rate must be compatible in order for the data to be loaded successfully. The rates are compat- ible if the data rate is an integer multiple of the video rate. If the rates are not compatible, the following message will be displayed.

Check that you have specified the proper video rate and selected the correct MTPA file.

Importing from MCDL

To import data from an MCDL file, use the Import Data menu in the main File menu and select From MCDL....

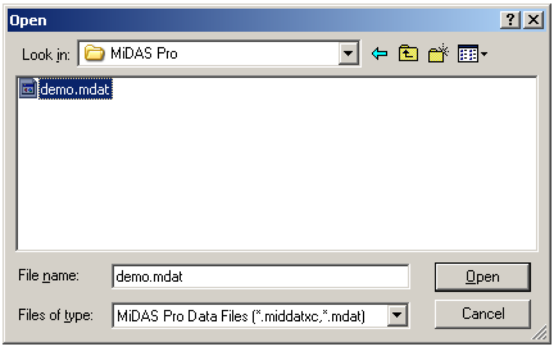
A file open dialog will appear, select the desired `*.mcd` file to load.



Importing from MiDAS Pro / 4.0

To import data from an MiDAS Pro / 4.0 file, use the Import Data menu in the main File menu and select From MiDAS Pro / 4.0....

A file open dialog will appear, select the desired `*.middatxc` or `*.mdat` file to load.

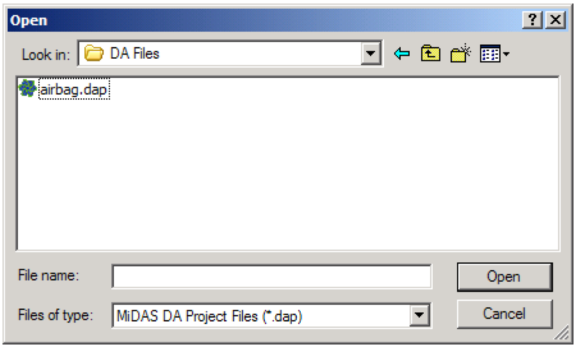


Note that the MiDAS Pro / 4.0 data file is automatically loaded when a similarly named video is opened. This option to import data from a MiDAS Pro / 4.0 file is only required if the base- name (filename without extension) of the data file does not match the basename of the video file.

Importing from MiDAS DA DAP

To import data from a MiDAS DA DAP file, use the Import Data menu in the main File menu and select From MiDAS DA DAP....

A file open dialog will appear, select the desired `*.dap` file to load.

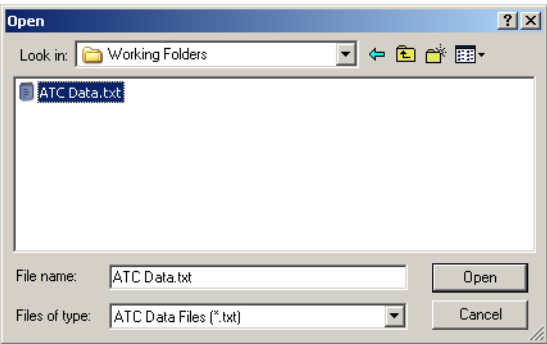


Note that MiDAS DA DAP files are normally automatically recognized by ProAnalyst. If a video file is opened that was referenced in a MiDAS DA Project, the associated data is auto- matically loaded. This option to import data from a MiDAS DA DAP file is only required if a DA DAP file was not loaded properly or you wish to load data from a specific DA DAP file ex- plicitly.

Importing from ATC Data

To import data from an ATC Data file, use the Import Data menu in the main File menu and select From ATC Data....

A file open dialog will appear, select the desired `*.txt` file to load.

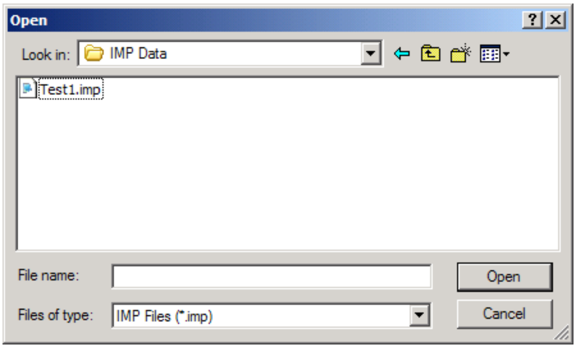


When importing from an ATC file, it is critical that the video have the proper video frame rate specified. The frame rate can be set using the Modify Recorded Parameters command (see the section called “Setting Frame Rate, Shutter Speed, and Zero”). If no frame rate is specified, a default value of 1 frame per second will be used.

Importing from IMP

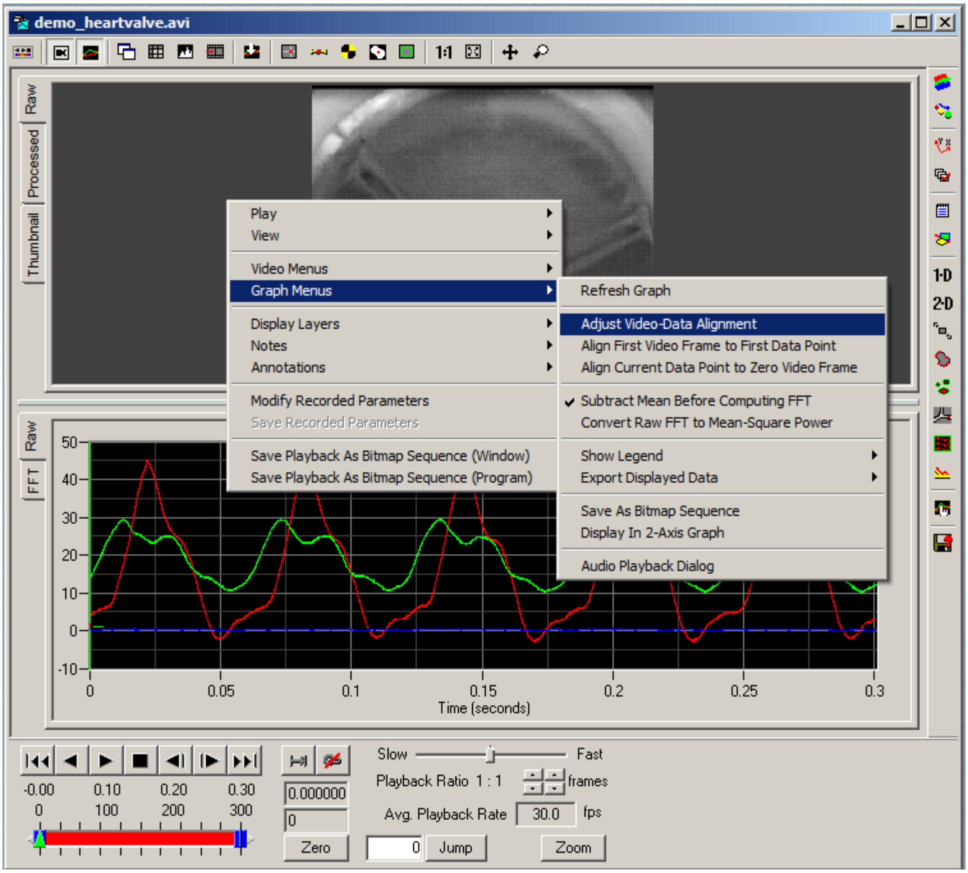
To import data from an IMP Data file, use the Import Data menu in the main File menu and select From IMP....

A file open dialog will appear, select the desired `*.imp` file to load.

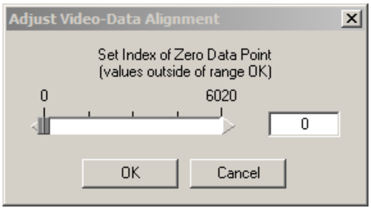


Adjusting Data Alignment

After data has been imported, you may wish to fine tune the alignment of data and video. To adjust the video data alignment, right-click in the Measurement Window and select Adjust Video-Data Alignment under Graph Menus in the context-menu.



A dialog will appear in which you can specify the index of the zero data point. Whichever data point you assign to be the zero data point will be aligned with the zero video frame.



To force alignment of the first video frame to the first data point, right-click in the Measure- ment Window and select Align First Video Frame to First Data Point under Graph Menus in the context-menu.

To adjust alignment so that the current data point is shifted to align with the zero video frame, right-click in the Measurement Window and select Align Current Data Point to Zero Video Frame under Graph Menus in the context-menu.

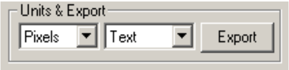
Exporting Data or Analyses

Overview

Data and analysis results can be exported to multiple file formats: Text, Excel (with or without a template), or Diadem. This selection of export formats was chosen to try to support the widest variety of customer's needs. Using one of these formats, it should be possible to directly, or with a small amount of modification, load the data or analysis results into most popular graph- ing or data analysis software packages.

To export data, use the Export Data menu in the main File menu.

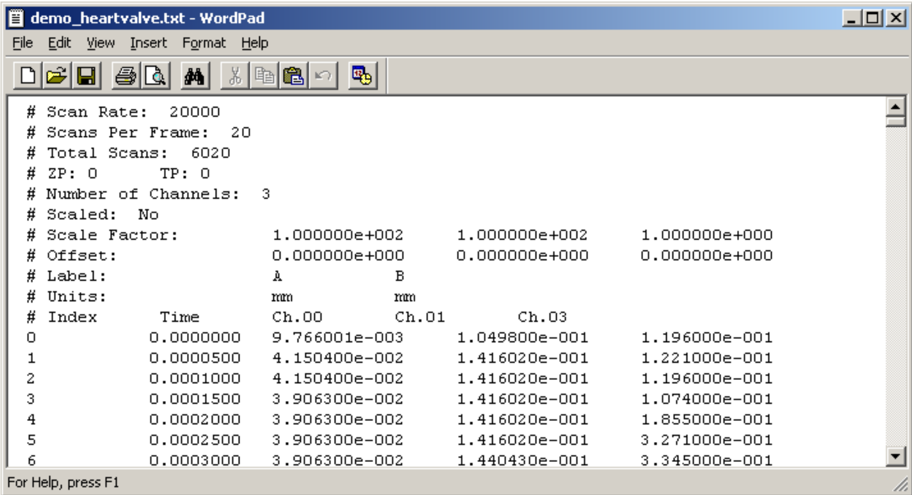
To export analysis results, use the Export section of each analysis control panel, if present. Only analysis toolkits that support exporting will have this section present on the lower portion of their control panel.



Exporting to Text

Text files are suitable for loading into any program that can load data in a comma delimited format (e.g. Matlab or Excel). Some small formatting may be required to have the text files load properly depending upon the application you are using to load. Lines in the text file that do not contain the explicit data are prefaced with a # to indicate that the line is a comment or information line rather than a data line.

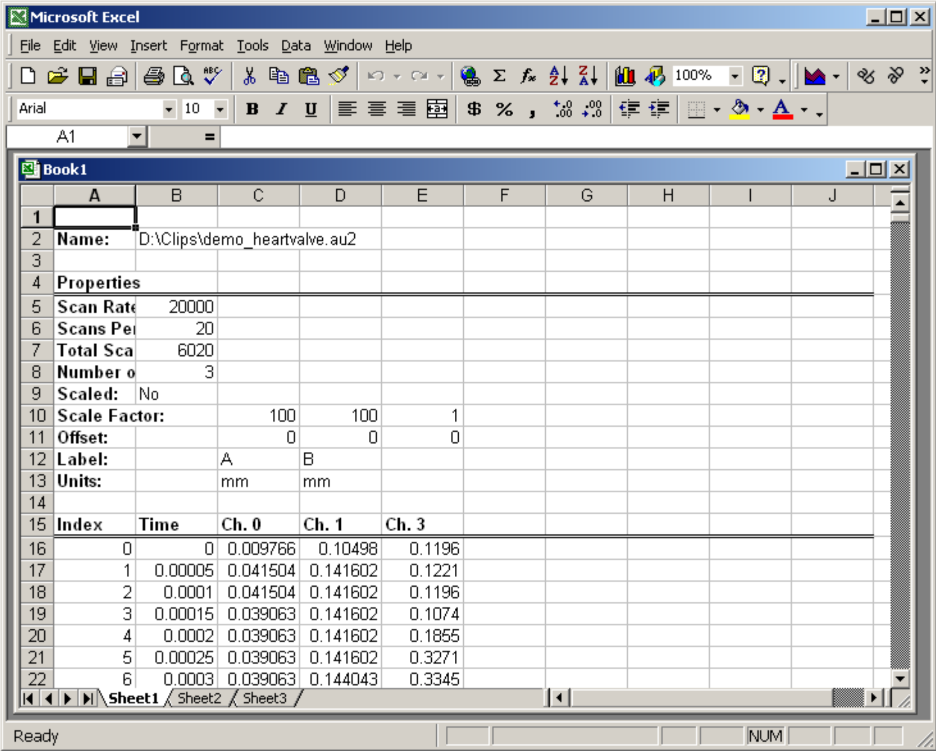
When exporting to Text, Wordpad is opened with the newly created file.




```
# Scan Rate:  20000
# Scans Per Frame:  20
# Total Scans:  6020
# ZP: 0       TP: 0
# Number of Channels:  3
# Scaled:  No
# Scale Factor:         1.000000e+002     1.000000e+002     1.000000e+000
# Offset:               0.000000e+000     0.000000e+000     0.000000e+000
# Label:                A           B
# Units:                mm          mm
# Index       Time      Ch.00       Ch.01       Ch.03
0           0.0000000   9.766001e-003     1.049800e-001     1.196000e-001
1           0.0000500   4.150400e-002     1.416020e-001     1.221000e-001
2           0.0001000   4.150400e-002     1.416020e-001     1.196000e-001
3           0.0001500   3.906300e-002     1.416020e-001     1.074000e-001
4           0.0002000   3.906300e-002     1.416020e-001     1.855000e-001
5           0.0002500   3.906300e-002     1.416020e-001     3.271000e-001
6           0.0003000   3.906300e-002     1.440430e-001     3.345000e-001
```

Exporting to Excel

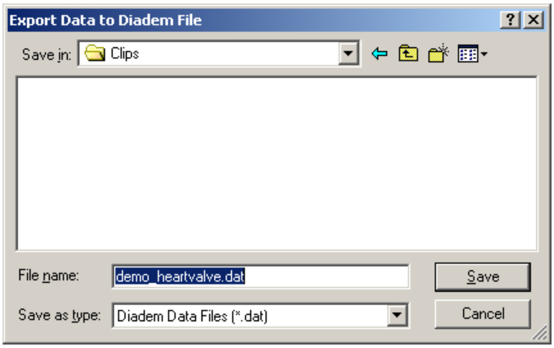
For exporting to Excel, Excel must be installed on the computer in order for this operation to complete. An instance of Excel is launched and the data is directly written into the Excel spreadsheet. In order to save the results, you must save the resulting spreadsheet from inside of Excel. To export to a blank Excel sheet, use the Excel Blank option for export format.



You can also export to Excel with a template file. When using a template file, Excel creates a new document that contains everything that is in the template file. The portion of the Excel sheet(s) that normally contain the exported data is overwritten. All graphs and formulas that are based on the exported data will automatically be redrawn and computed using the newly exported values. This is an easy way to reproduce any graphs or calculations made in Excel when doing similar tests. To export to Excel using a template, use the Excel Template option for export format.

Exporting to Diadem

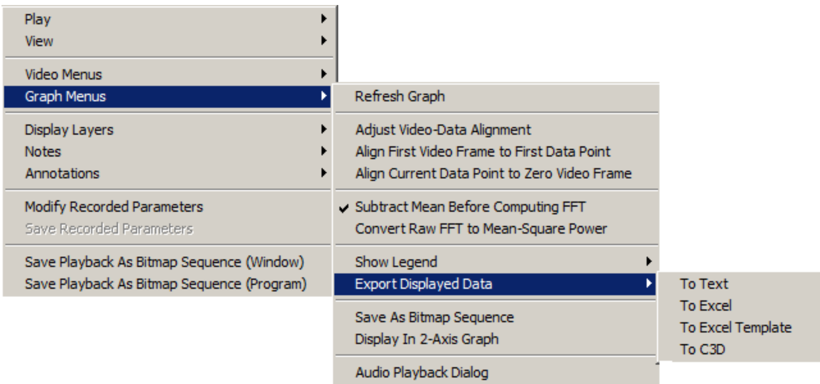
For exporting to Diadem, Diadem is not required for exporting. Two data files are generated when exporting to Diadem, one has the `R64` file extension and the other has the `DAT` extension. When exporting to the Diadem format, you will be asked to specify the `DAT` file and the `R64` file will be named with the same base filename, but with the `R64` extension. Both files are required for loading into Diadem.



An instance of Diadem is not launched when exporting.

Exporting Displayed Data

The actual data that is displayed in the graph window can be exported to a Text, Excel, or C3D file. This is useful when the data or analysis results have been filtered and you wish to manipulate the filtered results in an external application. To export the data exactly as it is displayed, right-click in the graph window and select Export Displayed Data from the context menu.



Managing Files and Packing Projects

Saving Your Work

One of the most important aspects of this software is the ability to save and load all the components of your work. The following information may be saved (and later reloaded):

- Video
- Data

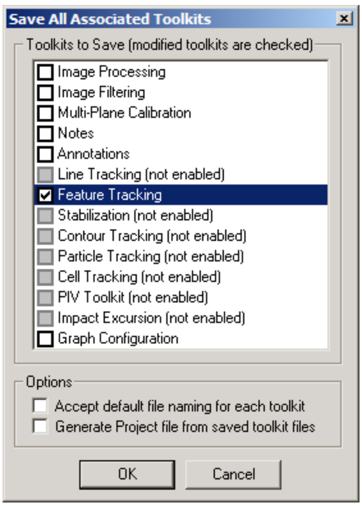
- Motion Analysis
- Image Processing
- User Notes and Annotations
- Calibration Information
- GPS/IRIG Timing Data

This software uses a video-centric file naming convention. That is, you name the video file during the save procedure and all the other files are saved with the same filename, but different suffix. During the Save As... process, you are asked for one filename. All the various pieces of your test are named this filename with a different 3-letter suffix (e.g. filename.avi, file- name.cfg, filename.ant, etc.). A complete listing of file extensions is provided in the section called "File Extensions".

Image processing settings, calibration information, analyses, and most other saved files can be saved and reloaded independently through their respective control panels. For more information on saving and reloading saved settings, consult the corresponding sections of this guide.

Saving All Toolkits

To simplify saving your work, a Save All Toolkits option is provided in the Measurement Window. It is the last button on the right toolbar (see the section called "Control Panels"). Click on this button and a dialog will appear showing all the open and modified toolkits for the current video. Greyed checkboxes indicate the toolkit is not currently enabled.

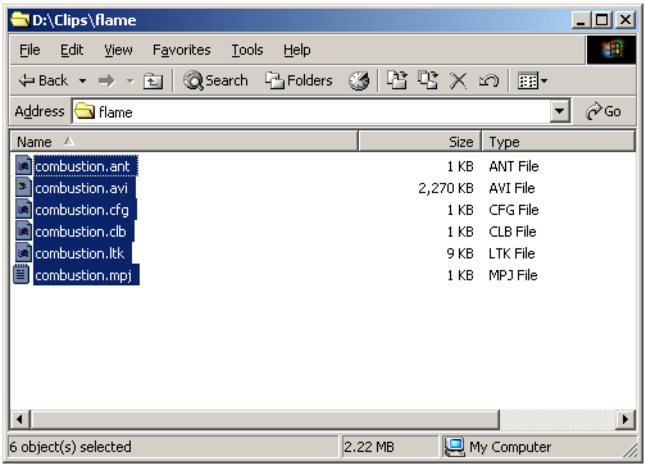


For each toolkit that is checked, the program will execute the save routine for that toolkit when the OK button is pressed. There are options which affect the behavior of the save routine:

toolkit	Checking this option will bypass the file save dialogs that prompt you for the destination filename for each toolkit. The save routine will use the default file name for each toolkit. The default filename is the filename of the video with the file extension replaced with the exten- sion of the corresponding toolkit. Note that this will overwrite any existing file with the same name.
Generate Project file from saved toolkit files	if this option is checked, after all the toolkit files have been saved, a new project wil be created that contains the current video file and all toolkit files that were just saved.

Moving Files

When copying or moving files, it is very important to move all files of the same name. Critical information or user-added content may not appear if all files are not moved together.



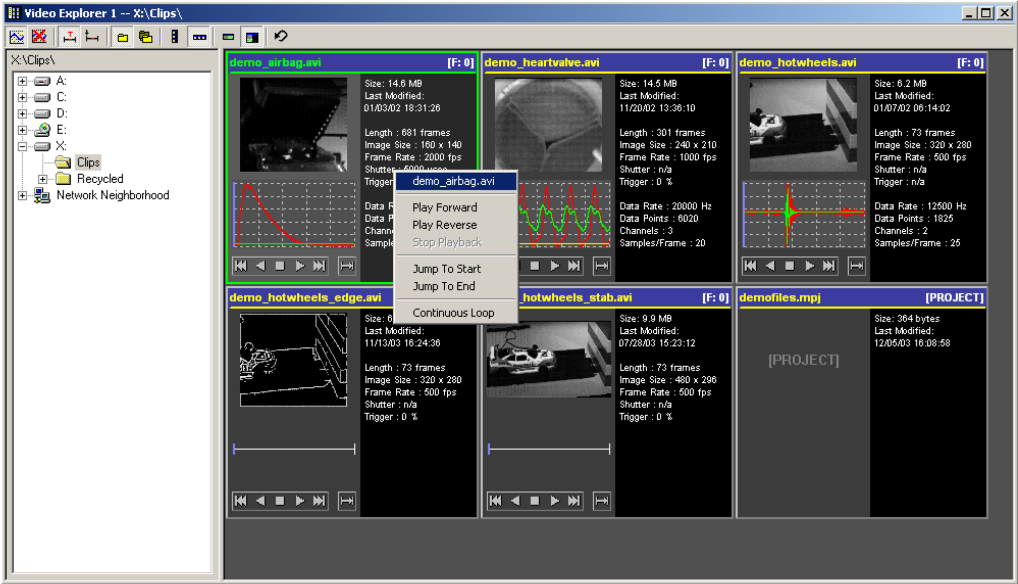
Also, be aware of projects that many contain references to a video you are moving. If you move the videos without moving or changing the contents of a project, the project will no longer be able to locate the video.

Packing and Unpacking Projects

A useful mechanism for managing, archiving, and distributing your work is the Pack Project feature. To use this feature, you must organize your work inside of project files. For more information about packing and unpacking projects, see the section called “Packing Projects” and the section called “Unpacking Projects”.

Browsing Through Files

A quick and easy way to browse through video files is to use the Video Explorer Window.



This window allows you to see and interact with thumbnail versions of the video and data for each recording in a directory or in sub-directories. See the section called "Video Explorers" for more details on using the Video Explorer Window.

File Extensions

Many different files are created to store various portions of your measurement and analysis. A complete listing of possible file extensions and their contents is provided here.

3DG	3-Axis Graph file. Contains a listing of all data display and filtering settings from the 3-Axis Graph window.
ASF, WMV, MOV, MPG, CIN, CINE, HSV, REC, IXV, TIF, MP4	Additional video file formats that are supported for reading only.
AVI, BMP, TIF, JPG, PNG	Standard save formats for video files. Either saved as a single video file (AVI) or as a sequence of images (BMP, TIF, JPG, PNG).
ANT	Annotations file. Contains all annotations associated with the video. This file is loaded automatically if present when the video is loaded.
AU2	Data file for acquisitions done with MiDAS software. This file is loaded automatically if present when the video is loaded.
AU3	Binary data file for MiDAS software. Contains user notes, GPS/IRIG time information, and other per frame information. This file is loaded automatically if present

	when the video is loaded.
C3D	C3D file. A standard file format, typically used for 3-D biomechanics. Information for this format can be found at C3D.ORG. This type of file is one of the export op- tions from the 3-D Manager and some graph windows. This file extension was previously used for the 3-D Cal- ibration file, which has now been changed to have the cal3d extension.
CAL3D	3-D Calibration file. The 3-D toolkit must be licensed in order to open this file. This type of file previously had the c3d extension. If you have older calibration files that use the c3d extension, these files can still be loaded by the 3-D Manager window.
CFG	Configuration file for MiDAS software. Contains record rate, shutter speed, zero frame and other record settings for a video. This file is loaded automatically if present when the video is loaded. Values in this file can be changed by modifying the recorded parameters (see the section called “Setting Frame Rate, Shutter Speed, and Zero” [51]).
CLB	Calibration file. Contains the calibrations settings saved via the Calibration panel.
CLR	Bayer Color Coefficients file. Contains color coefficients for decoding Bayer formatted video files. This file is loaded automatically if present when the video is loaded.
CTR	Contour Track file. Contains the settings and results for the Contour Tracking panel.
DAP	MiDAS DA DAP File. Data file saved from the MiDAS DA application. Automatically loaded by ProAnalyst. Can be explicitly imported using the Import Data menu item.
DAR	MiDAS DA Reference File. This file is saved by MiDAS DA to associate a video file with a DA Project. This file contains a reference to a DA DAP file that should be loaded when the video is opened.
FTK	Feature (2-D) Tracking file. Contains the settings and analysis results for the Feature Tracking panel.
GFC	Graph Configuration file. Contains a listing of all data display and filtering settings from the Graph Configura- tion panel.
IET	Graph Filter List file. Contains a list of filters saved from the Filtering sub-panel of the Graph Configuration panel.

IET	Impact Excursion file. Contains the settings and analysis results for the Impact Excursion panel.
IER	Impact Excursion Reference file. Contains the settings and configuration information for the reference markers used in the Impact Excursion Toolkit.
IMP	Image Filtering file. Contains the list and settings of the chain of image filters to apply to a video from the Image Processing panel.
IMP (data file)	Instron Data file. These files can be imported using the Import Data feature in the File menu.
LCF	Line Configuration File. This file contains feature line configuration information generated using Feature Tracking, Line Tracking, or 2 or 3 Axis graphing.
LTK	Line (1-D) Tracking file. Contains the settings and analysis results for the Line Tracking panel.
LUT	Image Processing file. Contains the brightness, contrast, gamma, and other LUT settings from the Image Processing panel.
M3D	3-D Manager file. The 3-D toolkit must be licensed in order to open this file.
M3M	3-D Merge file. The 3-D toolkit must be licensed in or- der to open this file.
MCDL	MCDL Data file. These files can be imported using the Import Data feature in the File menu.
MCL	Multi-Plane Calibration file. Contains the calibrations settings saved via the Multi-Plane Calibration panel.
MDAT	MiDAS Pro Data File. Data file saved from the MiDAS Pro application. Can be imported using the Import Data menu item.
MIDDATXC	MiDAS Pro Data File. Data file saved from the MiDAS Pro application. Can be imported using the Import Data menu item.
MPJ	Project file. Contains a listing of all video and associated files contained in the project.
MWK	Workspace file. Contains a list and layout of various windows in a workspace.
MTPA	MTPA Data file. These files can be imported using the Import Data feature in the File menu.

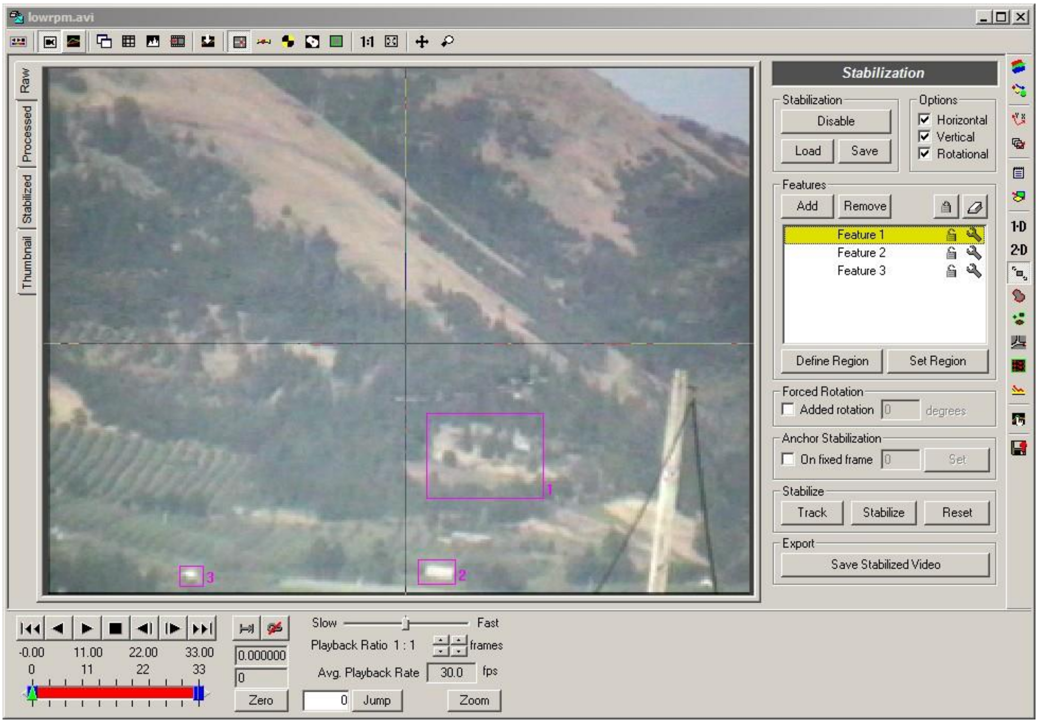
PBR	Particle Tracking file. Contains the settings and results for the optional Particle Tracking toolkit.
PFL	Cell Tracking file. Contains the settings and results for the optional Cell Tracking toolkit.
PPJ	Packed Project file. Contains the packed contents of a project file for distribution or archiving.
PVI	Partial Video file. This file is an AVI file that is a portion of a larger video consisting of sequentially named PVI files. These files load seamlessly as one large video file.
R64, DAT	Diadem Data files. These files are generated when exporting to Diadem using any of the analysis toolkits or the data export features.
STB	Stabilization file. Contains the settings used to stabilize a video using the Stabilization panel.
TXT	Text file. This file is a plain text file and is generated when exporting to Text using any of the analysis toolkits or the data export features.
W3D	3-D World Reference file. The 3-D toolkit must be licensed in order to open this file.
XLS	Excel Spreadsheet file. This file is generated when exporting to Excel using any of the analysis toolkits or the data export features.
XPV	PIV Toolkit file. Contains the settings and analysis results for the PIV Toolkit panel.
XYG	2-Axis Graph file. Contains a listing of all data display and filtering settings from the 2-Axis Graph window.

Chapter 8. Optional Toolkits

Image Stabilization

Overview

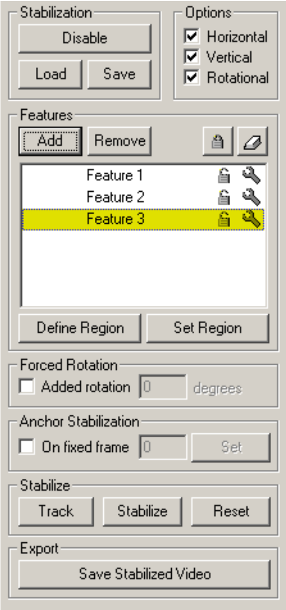
The Stabilization toolkit is used to stabilize shaky video by locating features in the video that should be stationary, tracking these features, and then computing the shift and rotation necessary to maintain the features in the fixed location. Stabilization can be done for any combination of horizontal direction, vertical direction, or rotation.



Many of the features of the Stabilization toolkit are similar to the Feature (2-D) Tracking toolkit (see the section called "Feature (2-D) Tracking"). The Stabilization toolkit uses the same automatic tracking algorithms in order to track features throughout the video.

Stabilization Panel

The Stabilization Panel follows the standard layout of analysis toolkits.



Brief summary of the controls on this panel:

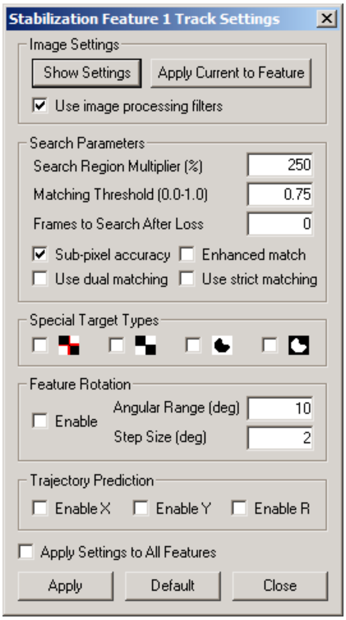
Enable/Disable	The first step in any Stabilization is clicking the Enable button in the upper left of the panel. This initializes memory and sets up configuration information. This must be done for each video that you wish to analyze. When you are done with the stabilization, you can press this button again to disable the Stabilization and free the associated memory.
Load	Saved Stabilization files can be loaded using this button. All feature settings and stabilization configuration will be reloaded from the saved file. Stabilization files are saved with the `STB` file extension.
Save	Save Feature Track analysis configuration and results to a file. All feature settings and stabilization configuration will be saved to the file. Stabilization files are saved with the `STB` file extension.
Options	Select the directions for stabilization, any combination of Horizontal, Vertical, and Rotational can be selected. Any of these items can be unchecked and the Stabilize button clicked to apply the changes to the stabilized video.
Add	Add a new feature to the analysis. Use the Define Region and Set Region buttons to define a template for the feature.
Remove	Remove a feature from the analysis. Select the feature to

	remove by clicking on the appropriate row in the properties section. Then click the Remove button.
Toggle Lock on All Features	Lock or unlock all features in the analysis. If the majority of features are currently unlocked, all features will be locked. If the majority of features are locked, all features will be unlocked.
Clear Selected Feature(s)	Clears all currently selected features. A message box will appear to confirm that you wish to clear all selected features.
Define Region	Click on this button to define a region for a feature. Click and drag a rectangle in the image to be used as a tem- plate for a feature. After dragging a rectangle, it may be repositioned by clicking and dragging it in the image. Click on the Set Region button when you are satisfied with the region you have defined, or click on Define Re- gion again to redraw another rectangle.
Set Region	Click on Set Region when you are satisfied with the feature region you have defined after clicking Define Region.
Forced Rotation	Enable this option to manually add a fixed rotation into the stabilized video output. For example, if the camera was not level when the original video was shot, you can perform tracking and stabilization functions and then correct the final video by adding a fixed rotation of a specific number of degrees. To add a fixed rotation, check the Added rotation checkbox. Enter the rotation angle value and click Stabilize to produce the rotated output.
Anchor Stabilization	Enable this option to manually set the anchor frame for the stabilization. The anchor frame is the frame that shows the features in the desired position and orienta- tion. Stabilization will attempt to modify every other frame of the video so that the resulting position and ori- entation of the features after stabilization match that of the anchor frame. By default, the anchor frame is set to the first frame of the video that contains a tracked point for all features. To manually set the anchor frame to a different frame, check the On fixed frame checkbox. Ad- vance to the desired frame, and then click on Set.
Track	Track the unlocked features from the current frame forward. When tracking is in progress, you can click this button again to Abort tracking.
Stabilize	After the location of the features in all frames is satisfactory, click this button to produce a stabilized video, displayed in the Stabilized tab. The options for stabiliza-

	tion direction can be changed and this button click again without having to do another tracking.
Reset	Resets any results from the Stabilize button. After hitting Reset, the video in the Stabilized tab will look identical to the original video.
Save Stabilized Video	Save the stabilized video to a new video file.

Track Settings

The Track Settings dialog can be displayed by clicking on the Settings icon  or by double-clicking on the feature number in the feature properties listing. The Track Settings dialog is where parameters can be set that control how tracking is performed. This dialog is nearly identical to the Feature (2-D) Tracking settings dialog.



Show Settings	Each feature can maintain its own set of Image Processing (see the section called “Image Processing”) settings. These LUT settings are typically the settings that were active when the feature was added. Click on this button to display the image using the image processing (LUT) settings associated with this feature.
Apply Current to Feature	This button allows the image processing (LUT) settings for a given feature to be changed to whatever settings are currently active. In order to change the LUT settings as-

sociated with a feature, change the LUT settings so that the desired appearance is achieved (see the section called “Image Processing”), and then press this button.

Use image processing filters
: While each feature can have its own set of Image Processing settings, all features share the single set of Image Filters (see the section called “Image Filtering”) defined for the video. However, each feature can be set to use the image processing filters or to not use them. Check this box to have the image processing filters applied to the video for this particular feature when analyzing.

Search Radius Multiplier
: Configure how large of an area to search for template matches. This is a percentage of the initial region size that was defined for this feature. A value of 100 (%) in- dicates that the algorithm should search in a region as large as the initial region size. Larger values will result in larger search areas, which will take a longer time to search. A typical value for this parameter is 300. The search region can be shown in the video image through the context-menu (right-click) in the video image.

Matching Threshold (used to be called Threshold Tolerance)
: Configure the sensitivity of the matching algorithm. The tracking algorithm assigns a value between 0 and 1 is given to all points within the search region indicating how well they match the template region. All values be- low a set threshold are ignored. A threshold value of 1.0 indicates that only a perfect match will be accepted. Lower this value if the tracking algorithm fails to track a feature. A typical value for this parameter is 0.75. This value is also used to determine a threshold intensity value when using the third or fourth Special Target Type option described below.

Frames to Search After Loss
: Configure if the tracking algorithm should continue to try searching for a match beyond a frame where the feature was lost. This parameter sets how many frames the algorithm should continue beyond the frame where it lost the feature. If the feature is found again, the tracking will continue as normal.

Sub-pixel accuracy
: Enabling sub-pixel accuracy attempts to estimate the best fit match to the template at a sub-pixel level. This option is typically always enabled, however, if only pixel accuracy is preferred, uncheck this option.

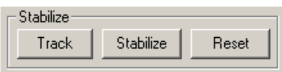
Enhanced match
: Enabling enhanced matching attempts to improve the matching by enhancing the template image and search region. This option is only available if sub-pixel accur- acy is also enabled. Enabling this option will increase the processing required for tracking and may result in a noticeable increase in the time required for tracking. Using this option with the third or fourth Special Target type

	will automatically set the threshold to assume that the background is perfectly white (255) or perfectly black (0) when calculating the center of the blob.
Use dual matching algorithm	Enable this to use a two-pass dual matching algorithm to avoid false matches. This technique will be more able to distinguish features that have both dark and light features. Enabling this option will result in a marginal increase in processing required.
Use strict matching algorithm	Enable this to use a stricter matching algorithm to avoid false matches. Note that this may lead to more frequent loss of targets during tracking. To compensate for this, you can lower the tolerance or increase the Frames to Search After Loss.
Special Target Types	Enable this if your target is one of the special targets shown. The first and second checkerboard targets can be used for a quad-target, checkerboard, or bow-tie pattern. When enabled, these options will use special algorithms to locate the selected target. Only the size and the initial location of the feature region is used to initiate tracking. The special algorithms automatically compensate for target rotation, so all rotation options are disabled if these options are enabled. When using a special target type, define the region so that it is just large enough to enclose the target. Do not make the region larger than necessary. The first special target type with the red lines uses a line fitting algorithm to detect the lines dividing the white and black regions and then returns the intersection of these lines. The second special target type uses an ideal- ized template composed of pure white and pure black values to initiate tracking. The third and fourth special target types are designed to locate the center of mass of a black blob or a white blob respectively. These last two special target types will return the center of the largest continuous black or white area found within the search region. The Matching Threshold value is used as a threshold on the image prior to performing blob detec- tion. For example, when locating white blobs, a Match- ing Threshold value of 0.75 would apply a threshold of 0.75*255=191 to the search region before locating blobs.
Enable (Feature Rotation)	Enable feature rotation when tracking. The algorithm will try comparing rotated versions of the template with the search region to find a match. The best match over all the rotation range will be returned as the final match.
Angular Range	The rotation range in degrees to search for matches. The template will be rotated plus or minus this value in degrees in intervals of the step size.
Step Size	The step size to use over the rotation range to search for

	matches. For example, a rotation range of 10 degrees with a step size of 1 will examine the range of -10 to 10 degrees in 1 degree increments.
Enable X Trajectory Prediction	Enable trajectory prediction in the horizontal direction. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Enable Y Trajectory Prediction	Enable trajectory prediction in the vertical direction. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Enable R Trajectory Prediction	Enable trajectory prediction for rotation. The trajectory is predicted using an estimated velocity and acceleration of the previous track points. The search area is then centered on the predicted location (rather than the last location). Enabling prediction will allow you to reduce the search radius multiplier for faster searching.
Apply Settings to All Features	Check this box to apply the above settings to all currently defined features.
Apply	Apply the settings to the feature. Changes will not be applied unless this button is clicked.
Default	Load the default settings for the feature properties into this dialog. The settings are not applied until the Apply button is clicked.
Dismiss	Close the dialog. Settings will not be applied unless the Apply button was clicked.

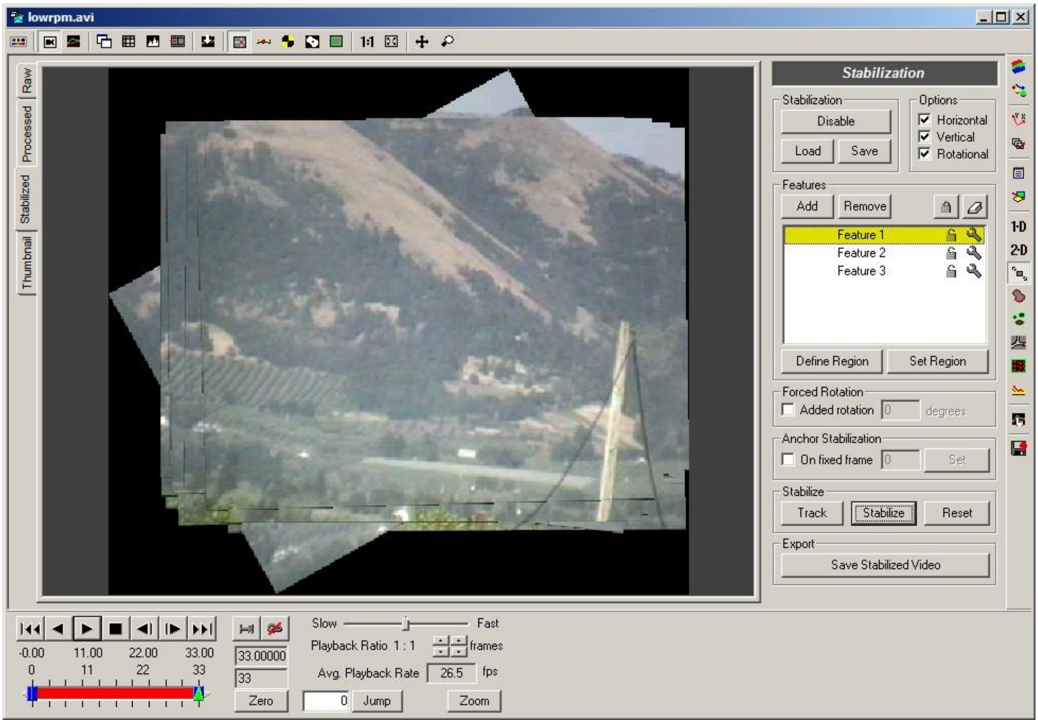
Stabilizing

Once the features have been defined and the track settings have been specified, you are ready to track the features and then stabilize.



The Track button starts tracking all unlocked features from the current frame forward. If features are lost during tracking, you can reset the template in the frame where the feature was lost and click Track again. All points need not be automatically tracked. If only a few points have been mistracked or lost, you can manually set those track points by using the Define Region and Set Region buttons in the frame where the points were mistracked or lost. If more than a few points were mistracked, try adjust the image appearance using the Image Processing or Fil- tering features or adjust the track settings until the feature can be tracked successfully.

When you are satisfied with the locations of the tracked points in all frames, click the Stabilize button. The stabilized video will appear in a new video tab of the Measurement Window.



The Stabilized tab shows what the resulting stabilized video will look like. The video can be played, panned and zoomed, but you cannot perform any other image manipulation or analysis operations on the video in the Stabilized tab. Once you are satisfied, you can save the stabilized video. When you open the stabilized video, all the normal image manipulation and analysis operations can be done with that video.

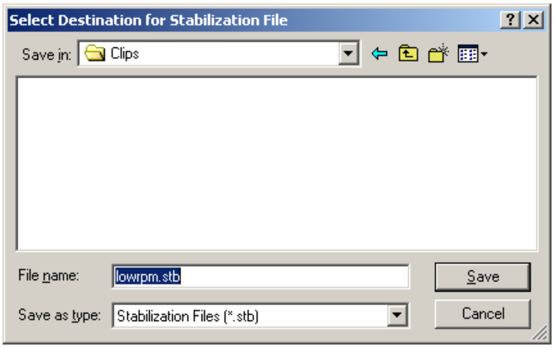
The Reset button clears the computations done by the Stabilize button so that the result in the Stabilized tab of the main window will be identical to the original video.

By default, the location of the features in the first frame of the video are used as the anchor location and orientation of the points in the resulting stabilized video. If the features are not tracked in the first frame of the video, the first frame in the video containing all tracked features is automatically used. You can override the frame in which the feature points are anchored by specifying a specific anchor frame. Advance the video to the frame that shows all features in the desired stabilized position and orientation. Click on the On Fixed Frame checkbox in the Anchor Stabilization section of the panel. Then click on Set to use the currently displayed frame as the anchor frame.

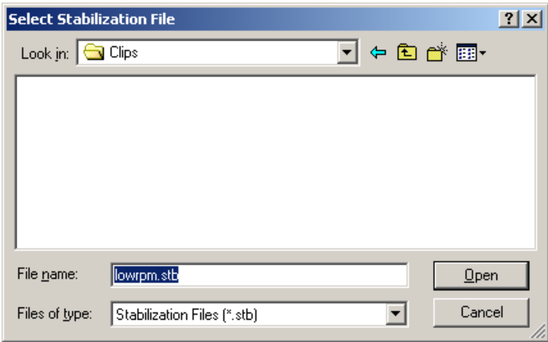
Saving and Loading

The Save and Load buttons in the Stabilization tab save and load the stabilization settings, not the stabilized video. Use the button in the Export section of the Stabilization panel to save the stabilized video. The stabilization settings are the number and location of the features, the track settings for each of the features, and the automatic feature extraction settings.

To save the stabilization settings, hit the Save button and the save dialog will appear. Stabilization files are saved with the `STB` file extension.

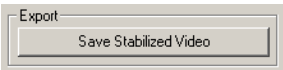


To load stabilization settings from a file, hit the Load button.

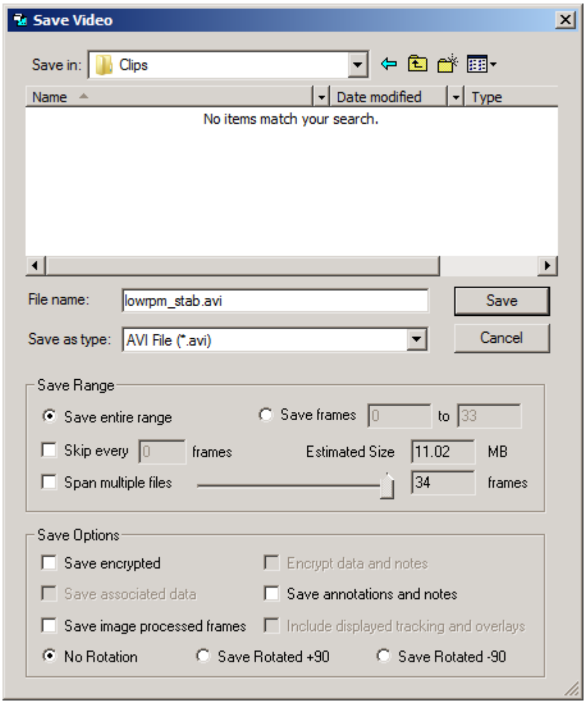


Exporting the Stabilized Video

The results of the Stabilization toolkit is a stabilized version of the original video. So the export section of the control panel provides the option to save the stabilized video.



The video must have been tracked and stabilized before it can be exported. After stabilizing, click this button and the standard Save dialog will appear.

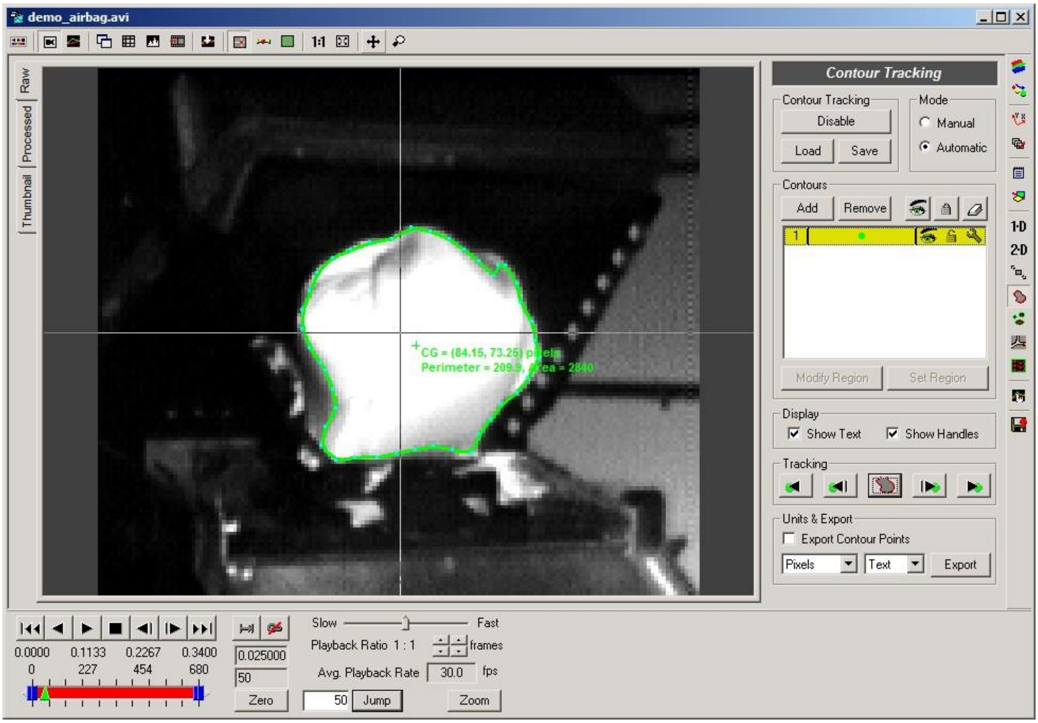


The original filename will be appended with "`_stab`" to differentiate it from the original video. The save options are identical to the standard video save options. See the section called “Saving Video Files” for more details on the Save Video dialog.

Contour Tracking

Overview

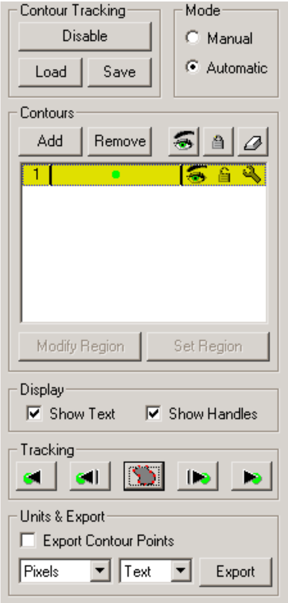
The Contour Tracking toolkit allows you to track the outline of deformable objects. A spline is generated using control points that are fit to the contour of the deformable object. Statistics such as the location of the center of gravity, the length of the spline (perimeter of the contour), and the area contained within the spline are automatically calculated.



The resulting contour statistics can be graphed in the main window. The contour statistics and the contour points themselves can be exported to Text or Excel for further analysis.

Contour Tracking Panel

The Contour Tracking Panel follows the standard layout of analysis toolkits.



Brief summary of controls on this panel:

Enable/Disable

The first step in any Contour Tracking is clicking the Enable button in the upper left of the panel. This initializes memory and sets up configuration information. This must be done for each video that you wish to analyze. When you are done with this toolkit, you can click this button again to disable Contour Tracking and free the as- sociated memory.

Load

Saved Contour Tracking files can be loaded using this button. All settings and tracking results will be reloaded from the saved file. Contour Tracking files are saved with the `CTR` file extension.

Save

Save Contour Tracking configuration and results to a file. All settings and tracking results will be saved to the saved file. Contour Tracking files are saved with the `CTR` file extension.

Mode

Specify the mode of operation for this toolkit. For this specific toolkit, there is no significant different between Manual and Automatic modes. Most operations for this toolkit are automatic. Switching to Manual mode allows you to manually modify regions that have been located using the automatic tracking feature. When in Manual mode, the Modify Region and Set Region buttons will become enabled.

Contours

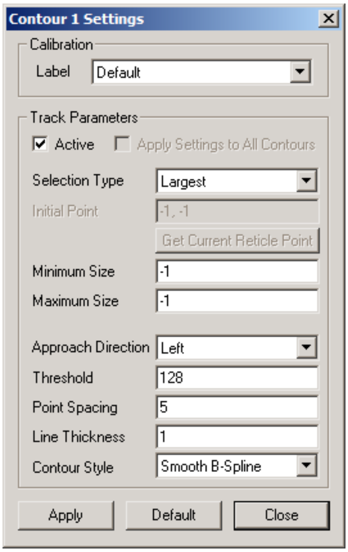
This section displays a list of current contours that have

	been added. To add more contours, use the Add button. To remove existing contours, use the Remove button. To clear the tracking results for any of the contours, use the Clear Selected Contour(s) button. The listing shows the contour number, contour color, visibility, active status, and the settings button. Double-clicking on the color allows you to change the color. Clicking on the visibility or active status will toggle those settings. Clicking on the settings icon will bring up the Contour Settings dialog.
Toggle Visibility of All Contours	Show or hide all contours in the analysis. If the majority of contours are currently visible, all contours will be hidden. If the majority of contours are hidden, all contours will be shown.
Toggle Lock on All Contours	Lock or unlock all contours in the analysis. If the majority of contours are currently unlocked, all contours will be locked. If the majority of contours are locked, all contours will be unlocked.
Clear Selected Contour(s)	Clears all analysis results for the selected contours. A message box will appear to confirm that you wish to delete the contour data.
Modify Region	This button is only active when in Manual mode. Clicking this button allows you to drag and drop handle points to manually modify a contour.
Set Region	This button is only active when in Manual mode. Click this button to save your changes after you have finished manually modifying a contour.
Show Text	Show or hide the text information drawn in the video for each contour.
Show Handles	Show or hide the handles along the contour that can be used to manually modify the contour when in manual mode.
Process Current Frame	Uses the settings for each of the active contours to locate the contour outlines in the current frame only.
Step Backward/Step Forward	Advances to the previous or next frame and then processes the next frame.
Track Backward/Track Forward	Continuously processes the current frame backward or forward until the first or last frame of the video is reached.
Export Contour Points	Check this item if you wish the export to contain the locations of the points that are used to construct the contour splines in each frame. Note that this will produce much larger export files.

Units	Select the units that are used in the video display of the contour statistics, the graph display, and the export of data. To select non-pixels units, the video must be calibrated. See the section called “Multi-Plane Calibration” for more information on calibration.
Export Format	Select the format of the output of the export command: Text, Excel Blank, or Excel Template.
Export	Export the current tracking results. See the section on Units and Exporting below for more information.

Contour Settings

A number of settings can be modified to change the behavior of the Contour Tracking toolkit. Each contour may have its own unique settings.



Summary of the Contour Settings:

Calibration	Each contour can use its own calibration (see the section called “Multi-Plane Calibration”) settings. The list of currently defined calibrations is shown in the drop down box. Select the specific calibration label to be used with this contour, or select Default to use whichever calibration is set as the default calibration.
Active	Check this to enable or disable tracking for this contour. This checkbox is the same as the active status icon in the Contours list in the Contour Tracking Panel. When a contour is not active, the tracking results cannot be modi-

fied.

Selection Type

If multiple potential targets are located in an image, one target must be selected. There are different techniques that may be used to select the desired target. These op- tions are: Largest, Includes Initial Point, Closest to Initial Point, Closest to Last Center. Largest selects the largest target. Note that if you have multiple contours that use the Largest Selection Type, unless Threshold, Minimum or Maximum size differ, the contours may select the same target. Includes Initial Point selects the target that contains the Initial Point Specified. Closest to Initial Point selects the target that has a center of gravity closest to the Initial Point specified. Closest to Last Center se- lects the target that has a center of gravity closest to the center of gravity of the contour from the previous frame.

Initial Point

For selection types that require an initial point, specify the initial point coordinates here. These coordinates are in pixels, with the origin in the upper left corner of the image. You can also specify the initial point by placing the reticle at the desired location and then clicking the Get Current Reticle Point button.

Get Current Reticle Point

This button obtains the current reticle coordinates and places them in the Initial Point edit box.

Minimum Size

Specify a minimum size required for a target to be selec- ted. Units are in pixels. A value of -1 allows any minim- um size value.

Maximum Size

Specify a maximum size required for a target to be selec- ted. Units are in pixels. A value of -1 allows any maxim- um size value.

Approach Direction

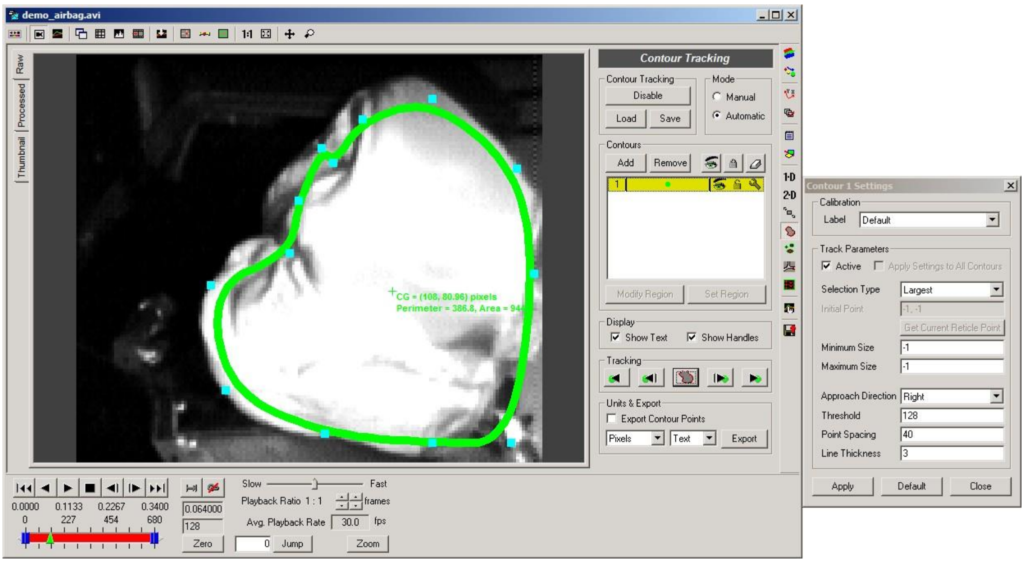
When fitting a contour to a target, an initial starting point is used to assist in fitting the contour. There may be times where an incomplete contour is fit to a target be- cause the target has a pinch point (a location where the target width reduces to 1 pixel). In order to avoid this confusion, try using a different approach direction to force the contour to capture a larger portion of the target. You may also wish to adjust the threshold value so that there are no pinch points in your target.

Threshold

Set the threshold value that is used to identify targets. Pixel values that are above this threshold value will be identified as targets. You may also use all the Image Pro- cessing and Image Filtering functions to modify your im- age so that a suitable threshold value can be used to identify your targets reliably. See the section called “Image Processing” and the section called “Image Filter- ing” for more information.

Point Spacing	Select the approximate spacing between nodes of the contour. A larger value will produce a less precise contour that uses fewer nodes. A smaller value will result in a more precise contour that uses more nodes (and more memory).
Line Thickness	Specify the thickness of the line that is used to represent the contour. This value affects the display of the results only.
Contour Style	Specify whether the contour should be rendered using a Smooth B-Spline between the contour points or using straight lines to form a polygon. This setting affects the area, perimeter, and center calculations since the statistics will match the rendering of the contour, whether it be curved or straight.

To illustrate the effect of point spacing, the original summary image used a point spacing of 5. The image below uses a point spacing of 40. Selection of the point spacing will directly influence the accuracy of the center of gravity, length, and area calculations.

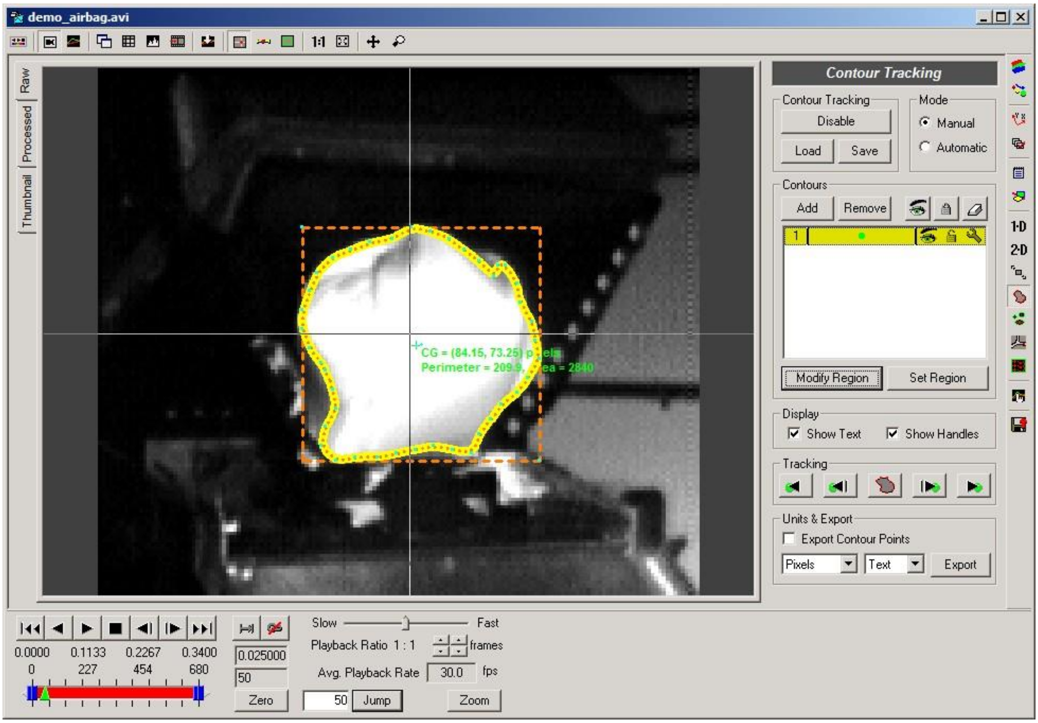


Tracking

Once you have adjusted the settings for each contour to your satisfaction, it is recommended that you use the Process Current Frame button first to verify that your desired target is identi- fied properly. Next, use the Step Forward button to process the next frame and verify that the desired target is identified properly. Once you are comfortable with the target identification, you may click the Track Forward button to process the remaining frames in the video.

Manual Adjustment of Contours

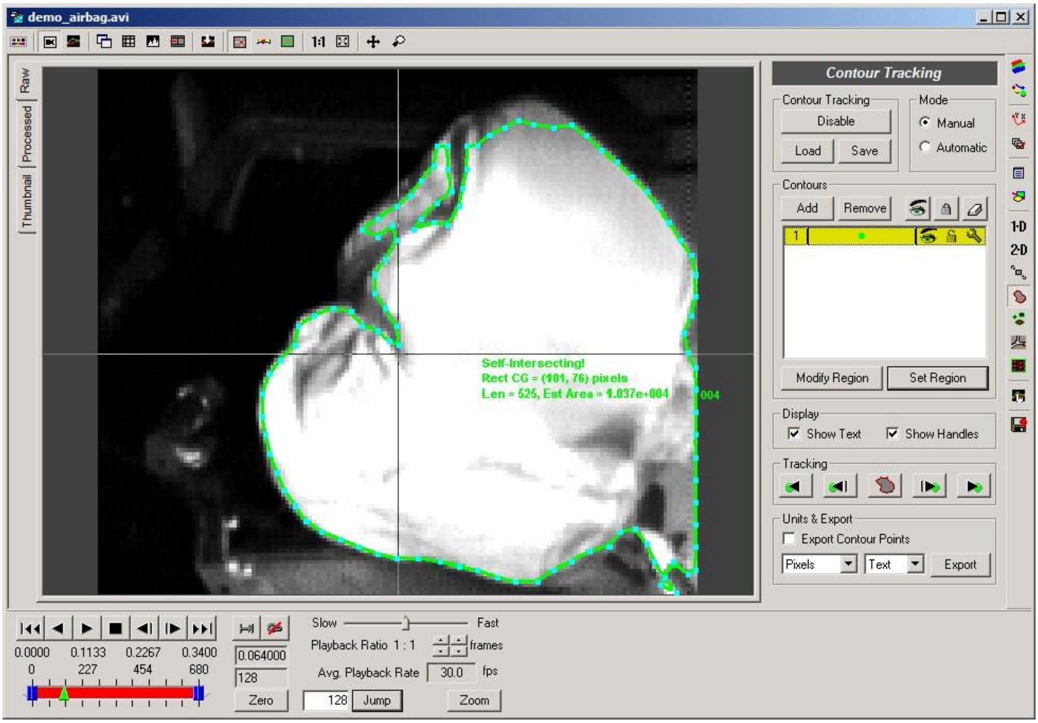
If you are unable to obtain a desired contour result from the automatic tracking, you can manually modify the contour region by switching to Manual mode and then clicking the Modify Region button.



You can click and drag any of the nodes to a new location. You can also drag the bounding rectangle to rescale the entire contour. Self-intersecting contours will not be accepted. If you drag the nodes such that the contour intersects with itself, when you click the Set Region but- ton, the program will automatically attempt to correct the intersection.

Handling Self-Intersecting Contours

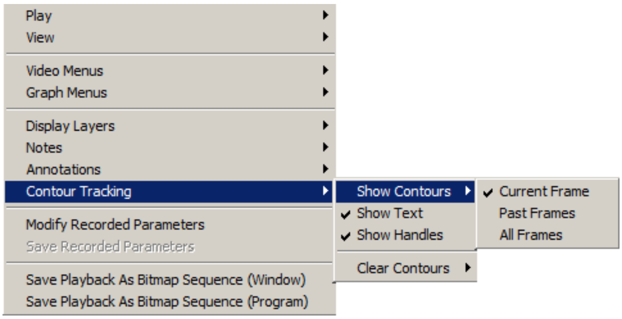
There may be rare occasions where the automatic tracking procedure will produce self-intersecting contours. This is an undesirable state because the center of gravity computation cannot be performed (the center of the bounding rectangle is displayed instead) and the area calculation is only an estimate that may be incorrect. If a contour is self-intersecting, it will be indicated in the main video window.



Correcting a self-intersecting contour may be as simple as clicking Modify Region and then Set Region. This reapplies the automatic self-intersection correction. If this corrects the issue, then the information display should update. If this does not correct the issue, you must look for where the self-intersection occurs and correct it by dragging some of the nodes. In this case, the intersection is in the lower right corner of the image.

Displaying Results

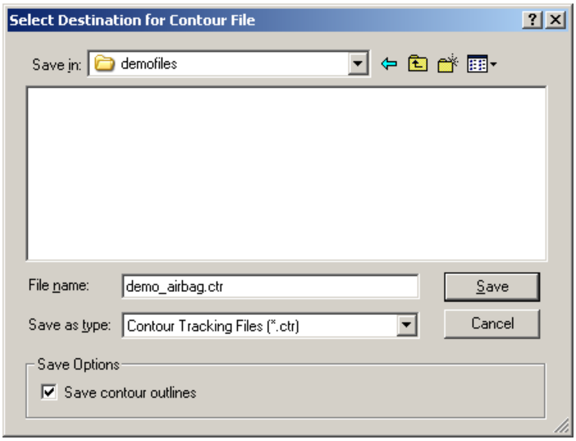
The summary text and contour nodes can be shown or hidden for each contour. In addition, the contours can be show for the current frame, past frames, or all frames. You can specify these options by right-clicking on the video to access the context menu.



Note that showing Past Frames or All Frames for contours may result in sluggish response, depending upon the speed of your computer. Many contour points are being drawn when these options are selected, placing a greater load on your system.

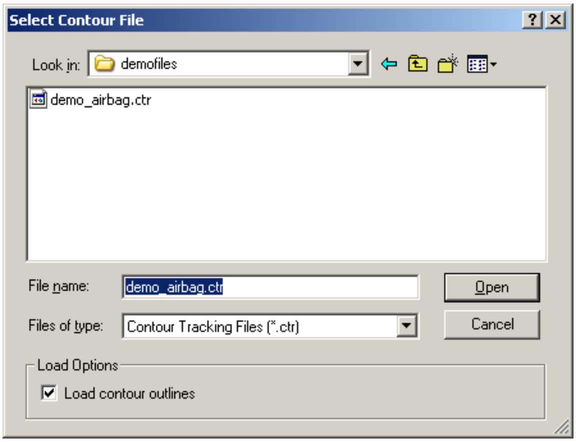
Saving and Loading

All Contour Tracking parameters and results can be saved to a file for later viewing. To save the parameters and results, click the Save button at the top of the control panel. Contour Track- ing parameters and results are stored to files with the CTR file extension.



You can choose to Save contour outlines to the file in the Save Options section of the dialog window. If you choose not to save the contour outlines, the resulting file will be smaller, however, the contour outlines will not be shown when the file is loaded unless you reprocess each frame.

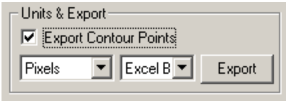
To load a saved Contour Tracking file, click the Load button at the top of the control panel.



Uncheck the Load contour outlines option if you do not want to load the contour outlines stored in the file.

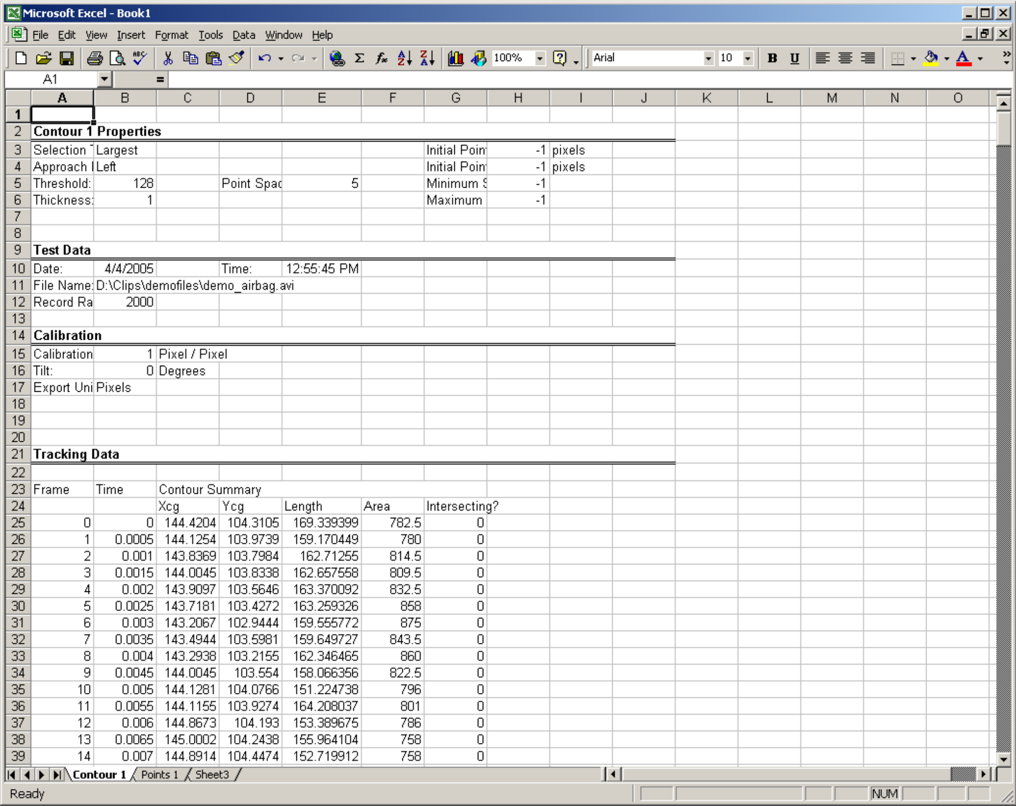
Units and Exporting

After you have completed analyzing your video, you can export the results to a variety of formats to perform any additional custom analysis or graphing.



Export Contour Points	Check this option if you wish to also export all the node points that are used to generate the contour for each frame. If this is not checked, only the statistics of each contour for each frame are exported.
Units	You can select what set of units to use for exporting the results. If no calibration has been done on this video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.
Export Format	You can select what format to export to: Text, Excel Blank, or Excel Template. Exporting to Excel Blank and Excel Template export the same data. However, Excel Template exports the data into an existing Excel file that is used as a template. You can place any formulas and graphs into the template file and these will be recomputed and regenerated when the data is exported into it.
Export	When you are satisfied with your results, select the desired units and format, and then click this button to export the results.

Shown below is an example of contour statistics exported using Pixels and Excel Blank.



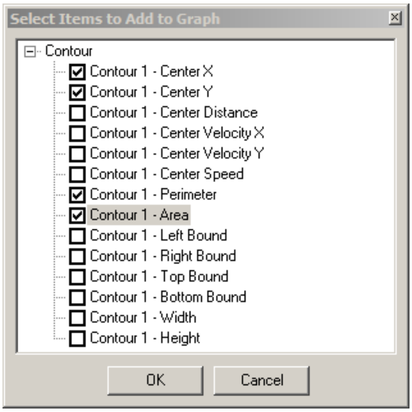
	A	B	C	D	E	F	G	H	I
1									
2	**Contour 1 Properties**								
3	Selection 1	Largest					Initial Poin	-1	pixels
4	Approach I	Left					Initial Poin	-1	pixels
5	Threshold:	128		Point Spac	5		Minimum S	-1	
6	Thickness:	1					Maximum	-1	
7									
8									
9	**Test Data**								
10	Date:	4/4/2005		Time:	12:55:45 PM				
11	File Name:	D:\Clips\demofiles\demo_airbag.avi							
12	Record Ra	2000							
13									
14	**Calibration**								
15	Calibration	1	Pixel / Pixel						
16	Tilt:	0	Degrees						
17	Export Uni	Pixels							
18									
19									
20									
21	**Tracking Data**								
22									
23	Frame	Time	Contour Summary						
24			Xcg	Ycg	Length	Area	Intersecting?		
25	0	0	144.4204	104.3105	169.339399	782.5	0		
26	1	0.0005	144.1254	103.9739	159.170449	780	0		
27	2	0.001	143.8369	103.7984	162.71255	814.5	0		
28	3	0.0015	144.0045	103.8338	162.657558	809.5	0		
29	4	0.002	143.9097	103.5646	163.370092	832.5	0		
30	5	0.0025	143.7181	103.4272	163.259326	858	0		
31	6	0.003	143.2067	102.9444	159.555772	875	0		
32	7	0.0035	143.4944	103.5981	159.649727	843.5	0		
33	8	0.004	143.2938	103.2155	162.346465	860	0		
34	9	0.0045	144.0045	103.554	158.066356	822.5	0		
35	10	0.005	144.1281	104.0766	151.224738	796	0		
36	11	0.0055	144.1155	103.9274	164.208037	801	0		
37	12	0.006	144.8673	104.193	153.389675	786	0		
38	13	0.0065	145.0002	104.2438	155.964104	758	0		
39	14	0.007	144.8914	104.4474	152.719912	758	0		

Note that the Excel export is limited in how many columns can be filled. Normally this does not create any difficulty; however, if you are exporting contour points, the number of coordin- ates may exceed the number of columns that may be written. In this case, the values will be wrapped onto subsequent rows in the Excel sheet. A message box will indicate when the wrap- ping has occurred.

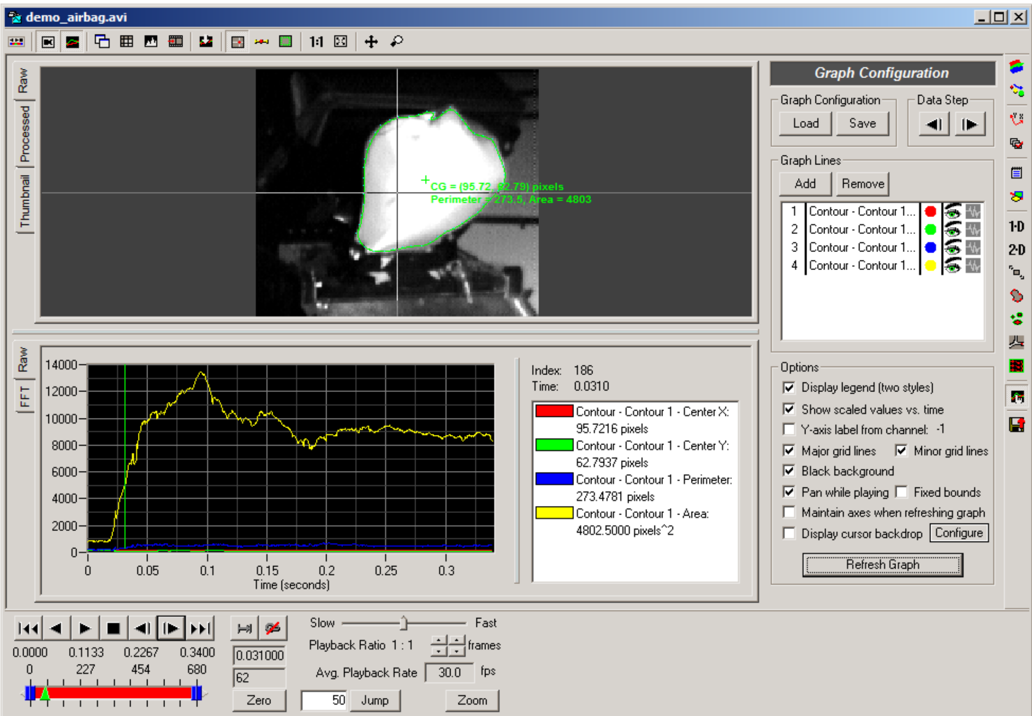
See the section called "Exporting Data or Analyses" for additional details regarding exporting.

Graphing

The statistics resulting from the Contour Tracking toolkit may be graphed in the main graph window. Select Add from the Graph Configuration panel and expand the Contour branch.



The coordinates of the center of gravity, the length of the contour perimeter, and the area enclosed by the contour are shown selected. In addition, the distance from the center to the origin, center X and Y velocity, center speed, and the width, height, and left, right, top, and bottom bounds of a bounding rectangle can be graphed.

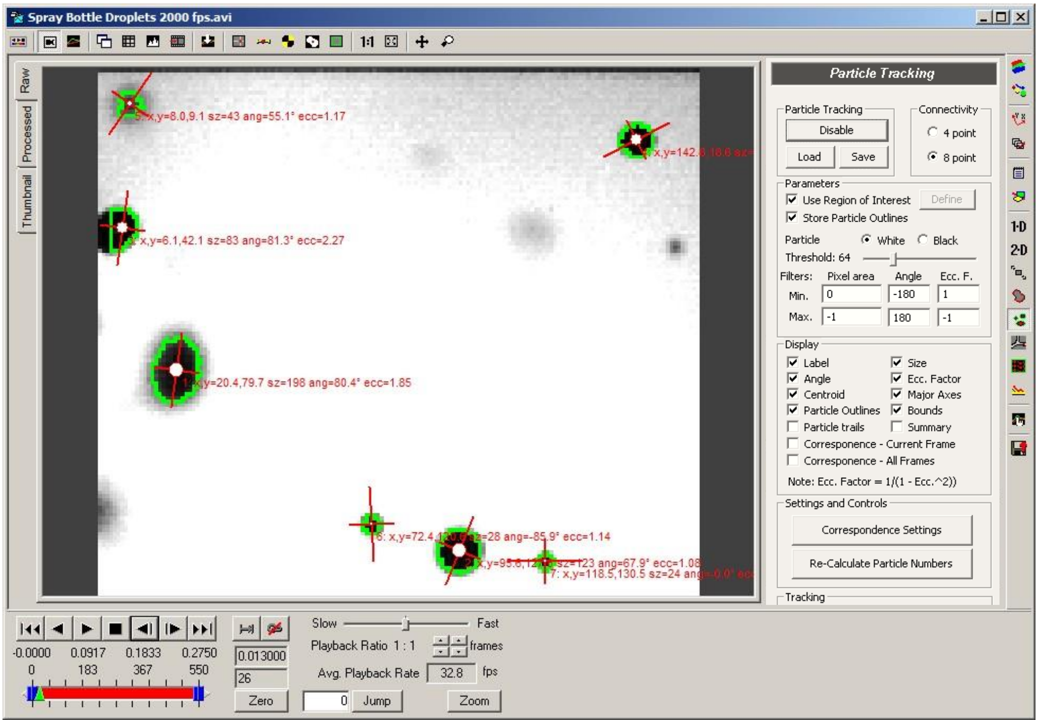


For more details on the options available for graphing, see the section called “Display Settings”.

Particle Tracking

Overview

The Particle Tracking toolkit is intended for statistical analysis of particle flows. The toolkit can identify the location, size, orientation, and eccentricity factor of white or black particles in each video frame. A summary of the total particle count, average, minimum, and maximum size, orientation, and eccentricity factor for each frame can be displayed or graphed. The average speed, direction, and x and y velocities can also be plotted or exported.

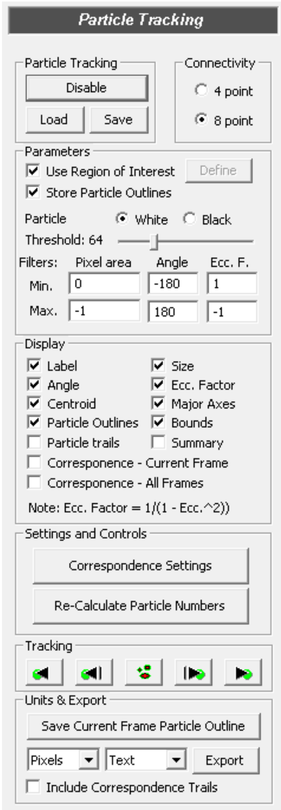


The particles are identified using an adjustable intensity threshold value. The displayed results can be selectively narrowed down using filters on the range of acceptable sizes, orientations, or eccentricities. The value of -1 is recognized as a wildcard by the software and it can be used to set the min/max values to positive or negative infinity.

The Particle Tracking toolkit will use the current default calibration. Particle sizes are displayed in units of pixels.

Particle Tracking Panel

The Particle Tracking Panel follows the standard layout of analysis toolkits.



Brief summary of controls on this panel:

Enable/Disable

The first step in any Particle Tracking is clicking the En- able button in the upper left of the panel. This initializes memory and sets up configuration information. This must be done for each video that you wish to analyze. When you are done with this toolkit, you can click this button again to disable Particle Tracking and free the associated memory.

Load

Saved Particle Tracking files can be loaded using this button. All settings and tracking results will be reloaded from the saved file. Correspondence trail numbers will be recalculated automatically. Particle Tracking files are saved with the `PBR` file extension.

Save

Save Particle Tracking configuration and results to a file. All settings and tracking results will be saved to the saved file. Correspondence trail numbers will be recalculated automatically. Particle Tracking files are saved with the `PBR` file extension.

Connectivity

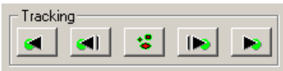
Set the connectivity mode that is used when locating particles. Four point connectivity requires that adjacent pixels must be to the left, right, top, or bottom of a given pixel in order for the adjacent pixel to be considered a part of the same particle. Eight point connectivity also allows adjacent pixels that are located along the diagonals to also be considered part of the same particle. Whenever this setting is changed, you must redo the tracking in order for the setting to be applied.

Use Region of Interest	Click the checkbox to define a region of interest for particle tracking. Click the Define button, then click in the measurement window and drag to draw a rectangle. After dragging the rectangle, it may be repositioned by clicking and dragging it in the image. Click the Set but- ton when you are satisfied with the region you have defined.
Store Particle Outlines	Specify whether you are interested in storing particle outline information. Unchecking this box will allow for analysis of a greater number of frames.
Particle Color	Specify whether you are interested in white particles or black particles.
Threshold	Set the threshold that is used to isolate the particles from the background. If you are looking for white particles, the intensity of the pixel must be above this threshold in order to be identified. If you are looking for black particles, the intensity must be below 255 minus the threshold in order to be identified.
Filters	The set of particles that are identified after threshold can be further reduced by filtering based upon the size, ori- entation, or eccentricity factor of the particles. If the particle falls outside of the minimum and maximum range in any of these properties, then the particle is removed from the set of identified particles. Size refers to the number of pixels that comprise the particle. Angle refers to the orientation of the major axis of the particle relative to horizontal. Eccentricity factor is the ratio of the length of the particle along the major and minor axes. A circular particle would have an eccentricity factor of 1.0 and a long and thin particle would have an eccentricity factor much greater than 1.0.
Display	These checkboxes determine what information is displayed in the video image. Check each item to display additional information in the video image.
Process Current Frame	Use the current parameter set to locate particles in the current frame. The status bar will show a percentage value indicating the progress of each step of the process.
Step Backward/Forward	Use these buttons to advance to the previous/next frame, apply the current parameter set, and then process the frame.
Track Backward/Forward	Use these buttons to continuously advance to the previ- ous/next frame, apply the current parameter set, and then

	process the frame until the start/end of the video is reached.
Save Current Frame Particle Outline	The particle outline is shown in green in the video image. The particle outline image containing only the outlines of the identified particles can be saved to a bitmap file by clicking this button and selecting the filename to save as.
Export	The tracking results, including the location, size, orientation, and eccentricity factor of each particle in each frame of the video can be exported to a Text or Excel document.

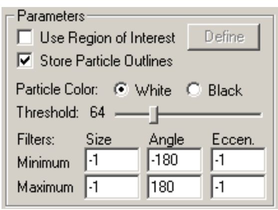
Tracking

There are three methods for initiating tracking. The most basic is Process Current Frame. Finding a good set of parameters for a given video is often an iterative process. By using the Process Current Frame button, you can verify that your set of parameters accurately identifies your particles of interest in a single frame, before proceeding with the rest of the video.

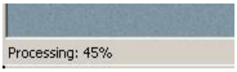


When you are comfortable that the parameters are correct for the current frame, you can apply the same parameter set and process the previous frame or the next frame by using the Step Backward or Step Forward buttons respectively. If the parameter set accurately identifies your particles in the next frame, then you can continue stepping through the video using the Step Backward or Step Forward buttons. Or you can automatically proceed through the entire video by using the Track Forward or Track Backward buttons.

It is important to note that the parameter set can be different for each frame of the video. Whenever the Step buttons or the Track buttons are used, the parameter set for the current frame is automatically applied to the any additional frames that are processed. If the parameters need to be adjusted for a single frame, simply go to that particular frame, make the changes to the parameters, and then click Process Current Frame. The new parameter set will only be applied to the current frame. If you wish to use your new parameters for the next frame also, click Step Forward. If you wish to use your new parameters for all subsequent frames, click Track Forward.

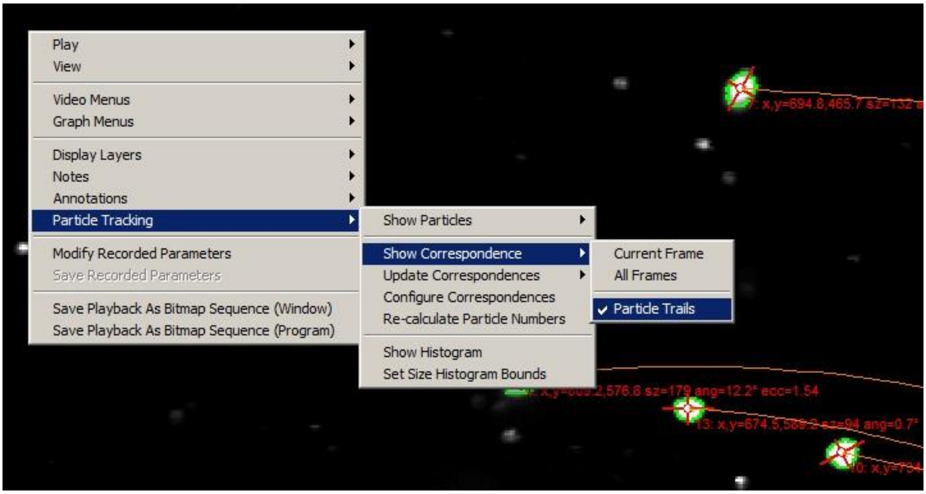


The processing of a frame may take some time if the frame is large or if there are many particles. The program will display a percentage in the lower left corner of the status bar so that you can monitor the progress.



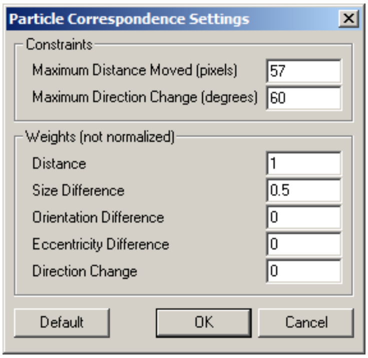
Correspondence

In order for the Particle Toolkit to estimate the path of particles or estimate the velocity of particles, correspondences between particles tracked in one frame to particles tracked in the next frame must be made. Functionality has been added to establish correspondences between particles tracked in each frame. To show, update, and configure correspondences, right-click in the video window to display the context-menu.



Select Particle Tracking -> Show Correspondence to show the frame-by-frame correspondence between tracked particles. If Current Frame or All Frames is selected, purple arrows are drawn between particles showing frame-by-frame correspondences. If Particle Trails is selected, brown lines are shown indicating the entire estimated trail for each visible particle. Note that some particles may disappear, in which case the trail will end, and new particles may appear, in which case new trails will begin. Enabling Particle Trails from the context-menu is equivalent to clicking the Correspondence Trails checkbox in the Display section of the Particle Tracking panel. The beginning of each particle trail will initially show a "?". The "?" is a placeholder for the particle number. The software cannot determine the particle number until all particle trails are numbered sequentially from the start of the video. This numbering is only performed when an export including correspondence trails is done. In order to see actual particle numbers, check the option to Include Correspondence Trails and click the Export button in the bottom of the Particle Toolkit panel.

To configure how correspondences are calculated, select Configure Correspondences from the Particle Tracking context-menu.



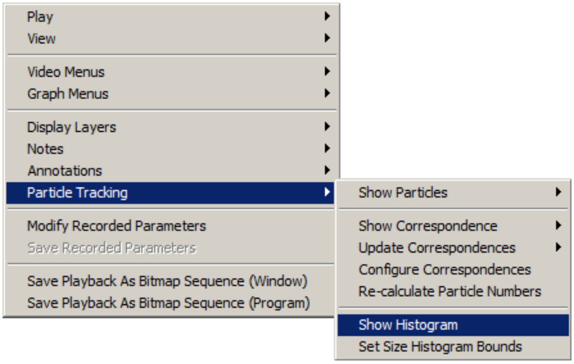
The software will attempt to match particles that are located in one frame with particles that were located in the previous frame. It uses a weighted distance measure to determine the best match for any given particle. The Particle Correspondence Settings dialog shows some of the weights used in calculating a distance quantity. In the upper portion of the dialog are maximum values that are used to eliminate impossible match candidates. If a particle location in the previ- ous frame is greater than the Maximum Distance Moved from a particle location in the current frame, then it is ignored. If the direction a particle was moving in the previous frame is greater than the Maximum Direction Change away from the direction that would result from the loca- tion of a particle in the current frame, then it is ignored. For the remaining particles from the previous frame that are within the Maximum Distance and Maximum Direction values, the quantities listed in the lower portion of the dialog are calculated, weighted, and summed. The particle with the lowest sum is then considered a match. ProAnalyst will attempt to match all particles in the current frame with particles from the previous frame. Any unmatched particles from the previous frame are considered to have disappeared. Any unmatched particles in the current frame are considered to have newly appeared.

After the correspondence settings have been changed (or if the correspondences were never calculated before), right-click on the context menu and select Particle Tracking -> Update Correspondences -> All Frames.

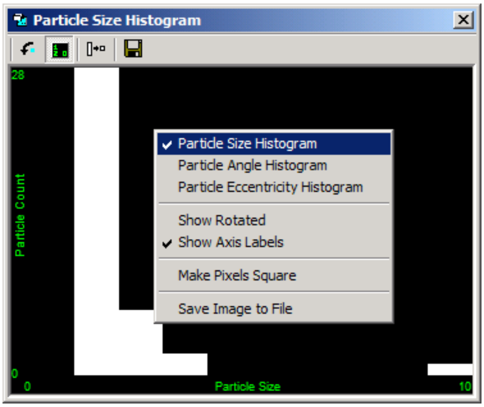
To recalculate the particle trail numbers (if the correspondences were calculated before), right-click on the context menu and select Particle Tracking -> Re-calculate Particle Numbers.

Histogram

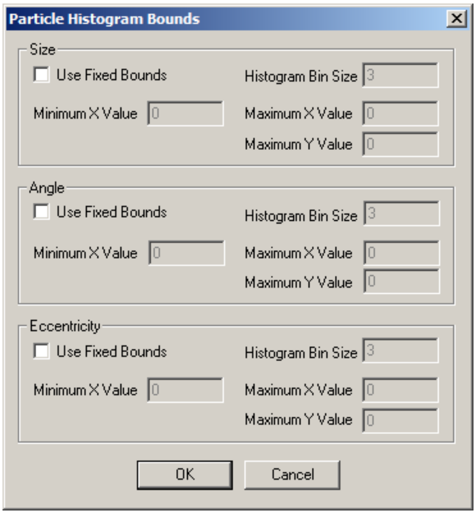
The Particle Tracking toolkit also has rudimentary histogram graphing capabilities. To display the Histogram window, right-click in the video window and select Particle Tracking -> Show Histogram.



The Histogram window draws a simple histogram of the data for the current frame. As the video is played, the histogram contents should change to reflect the tracking data for the current frame. If no tracking has been performed, no data will be displayed. There are multiple histo- grams that can be displayed. Right-click in the Histogram window to see the various options.



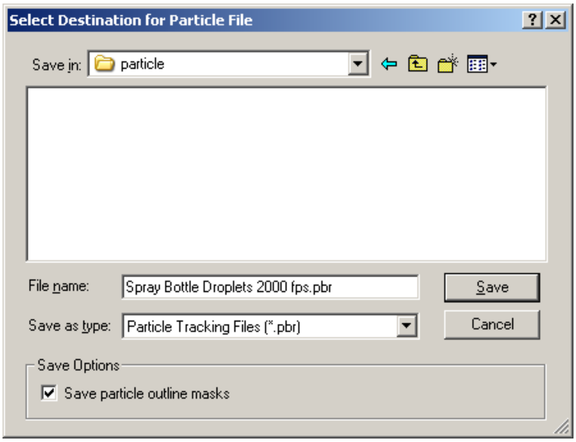
The size of the bins and the bounds of each histogram can be adjusted from the context-menu of the video window. From the context-menu of the video window, select Particle Tracking -> Set Size Histogram Bounds.



The Particle Histogram Bounds window allows you to specify fixed bounds for the X and Y axes of the histogram. In addition, you can specify the bin size of the accumulator. This has the effect of adjusting the resolution of the X axis of the histogram.

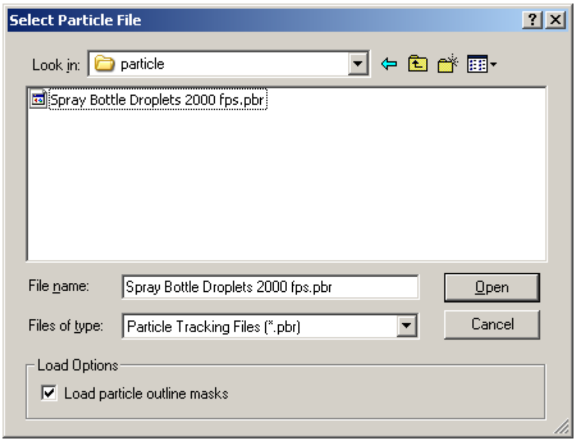
Saving and Loading

All Particle Tracking parameters and results can be saved to a file for later viewing. To save the parameters and results, click the Save button at the top of the control panel. Particle Tracking parameters and results are stored to files with the `PBR` file extension.



You can choose to Save particle outline masks to the file or not in the Save Options section of the dialog window. If you choose not to save the particle outlines, the resulting file will be smaller, however, the green outlines will not be shown when the file is loaded unless you process each frame again.

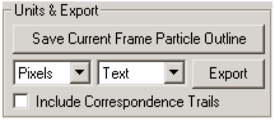
To load a saved Particle Tracking file, click the Load button at the top of the control panel.



Uncheck the Load particle outline masks option if you do not want to load the particle outlines stored in the file.

Units and Exporting

After you have completed analyzing your video, you can export the results to a variety of formats to perform any additional custom analysis or graphing.



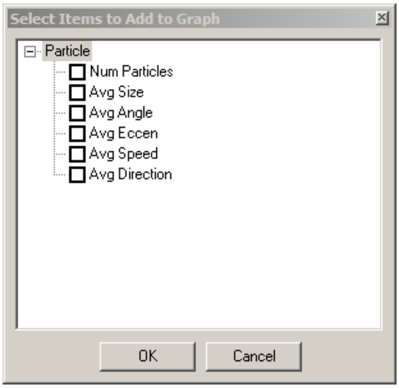
Save Current Frame Particle Outline	You may wish to export the particle outline masks to a file for analysis in an external program. For each frame of the video, you can save the outline mask to a bitmap file by using this button.
Units	You can select what set of units to use for exporting the results. If no calibration has been done on this video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.
Format	You can select what format to export to: Text, Excel Blank, or Excel Template. Exporting to Excel Blank and Excel Template export the same data. However, Excel Template exports the data into an existing Excel file that is used as a template. You can place any formulas and graphs into the template file and these will be recomputed and regenerated when the data is exported into it.

Export	When you are satisfied with your results, select the desired units and format, and then click on this button to export the results.
Include Correspondence Trails	Check this option to include Correspondence Trail information in the export file. If this option is checked, all particles are numbered sequentially from the start of the video and the X, Y coordinates of the trails of each particle is exported. Once the export has completed, the particle numbers shown in the video are updated. The "?" at the beginning of each Correspondence Trail will now show the particle number. This particle number can be used to find the corresponding X, Y coordinates in the exported file.

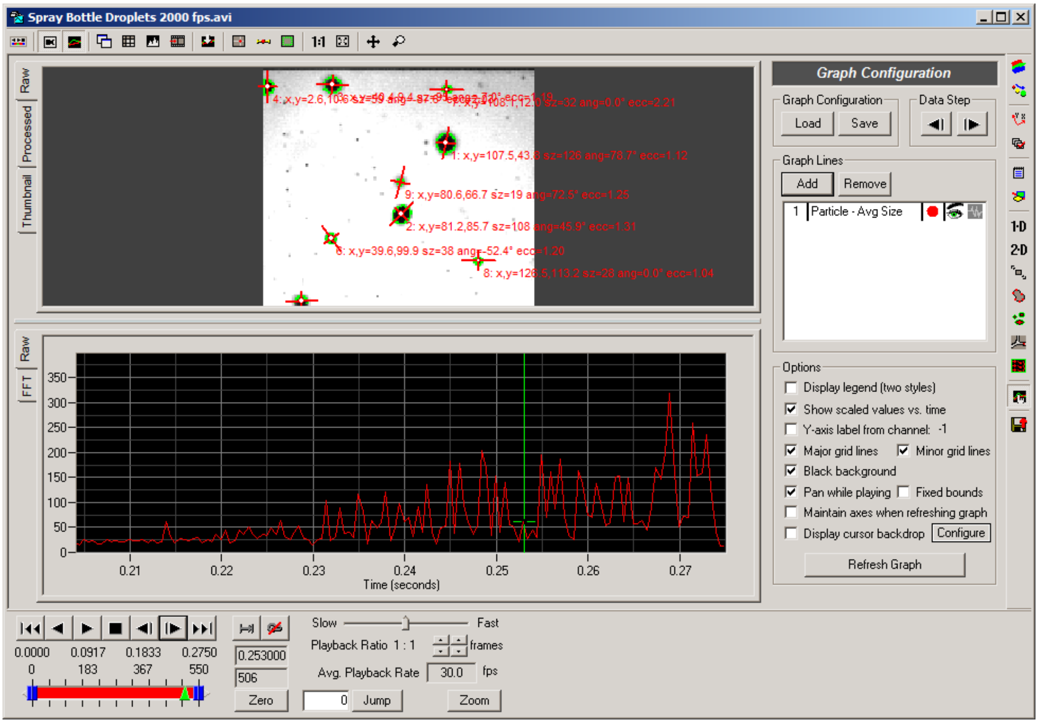
See the section called “Exporting Data or Analyses” for additional details regarding exporting.

Graphing

Various statistics resulting from the Particle Tracking toolkit may be graphed in the main graph window. Select Add from the Graph Configuration panel and expand the Particle branch.



The number of particles, average size, orientation angle, eccentricity factor, speed, and direction for each video frame can be graphed.

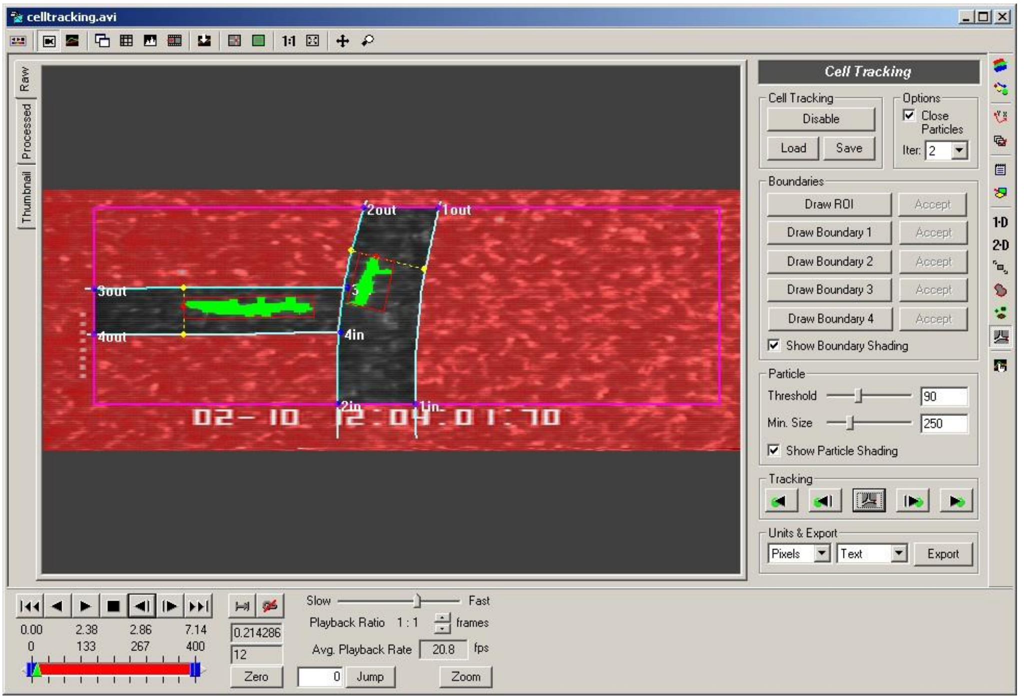


For more details on configuring the other options in the Graph Configuration panel, see the section called "Display Settings".

Cell Tracking

Overview

The Cell Tracking toolkit is designed to track particles that are flowing within user defined channels. The leading edge of the particle, size of the particle, and distance to each of the boundary walls is computed for every particle for every frame of a video. The results can be exported to a text file or to an Excel spreadsheet for further analysis.



The Cell Tracking toolkit will use the current default calibration. If the current default calibration is a Perspective calibration, particle sizes cannot be computed in real-world units. Therefore, sizes will be displayed in units of pixels when a Perspective calibration is used.

User Defined Channels

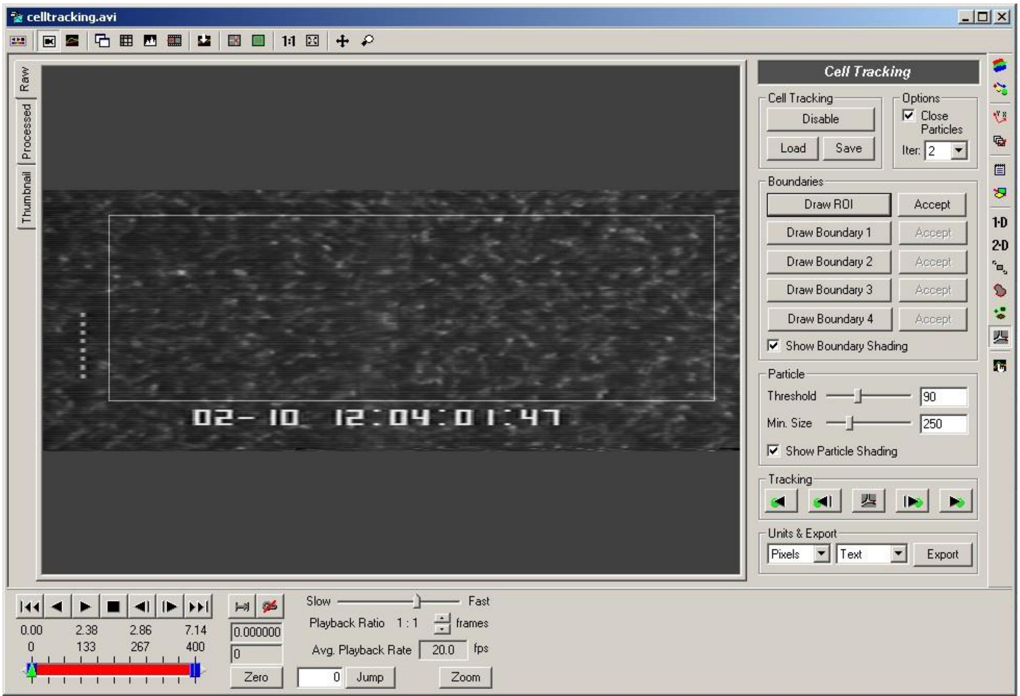
The user defined channels specify the location of the INPUT and OUTPUTs, the locations of the boundary walls, and which portions of the video can be safely ignored. The channels are specified using a region of interest (ROI) and two pairs of channel boundaries.

Region of Interest

The user must define a rectangular ROI in the video image. All activity outside of the ROI is ignored. This feature is primarily used to enable the software to ignore time stamps on the video image or any other extraneous markings.

To define the ROI:

1. Click on the Draw ROI button.
2. Click on the upper left corner of the desired ROI. Drag the mouse to the lower right corner of the desired ROI.
3. If you need to redraw the ROI, go back to step 1.
4. When you are satisfied with the ROI, click on the Accept button.



Channel Boundaries

The toolkit is configured to handle a primary channel and a secondary channel that branches off from the primary channel. One end of the primary channel is the INPUT, the other end of the primary channel and the end of the secondary channel are the OUTPUTs. Particles are expected to flow from the INPUT to one of the two OUTPUTs.

Each channel is defined by two boundary walls. These walls are defined using B-splines with an arbitrary number of nodes. The B-splines are defined by clicking on multiple points in the video image for each boundary. The first node point is considered the INPUT end and the last node point is the OUTPUT end.

To draw a boundary:

1. Click on the Draw Boundary # button for the boundary you wish to draw. Boundaries 1 and 2 form the primary channel. Boundaries 3 and 4 form the branching secondary chan- nel.

2. If you are defining a boundary for the primary channel (1 or 2), click on the video image, outside of the ROI, to place the first point of the boundary. The first point needs to be outside the ROI because the intersection of the boundary and the ROI will be used to determine the location of the INPUT.

3. If you are defining a boundary for the secondary channel (3 or 4), click on the video image just inside of the primary channel to place the first point of the boundary. The first point must be on the inside of the primary channel because the intersection of the boundary and the primary channel will determine the location of the branch. Do not place the point too

far into the primary channel, otherwise the boundary spline will obstruct portions of particles flowing in the primary channel.

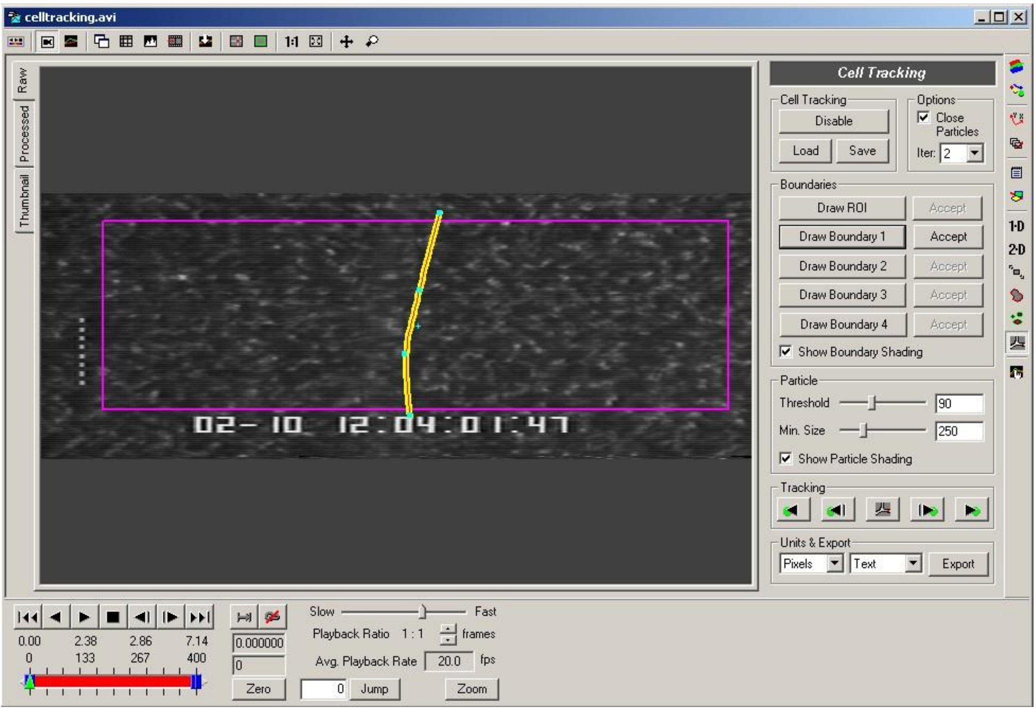
4. Continue to place points that define the boundary by clicking on the video image.

5. Make sure that the final point of the boundary lies outside of the ROI. The final point must be outside the ROI because the intersection of the boundary and the ROI will be used to determine the location of the OUTPUT.

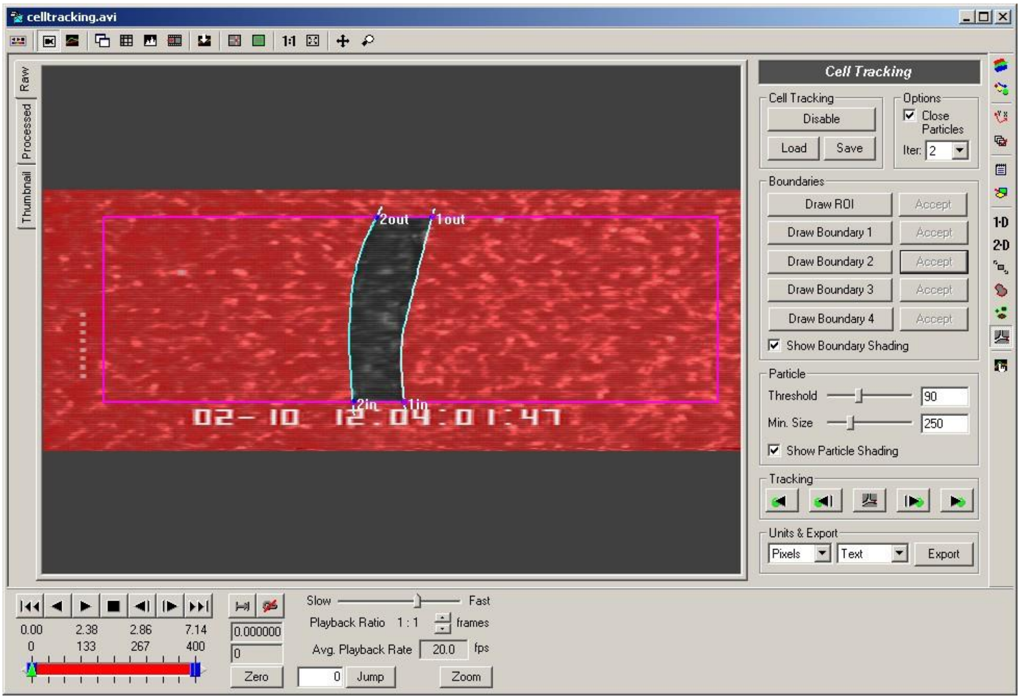
6. If you wish to modify the locations of any nodes, click on the node and drag it to the desired location.

7. If you wish to redraw the entire boundary, go back to step 1.

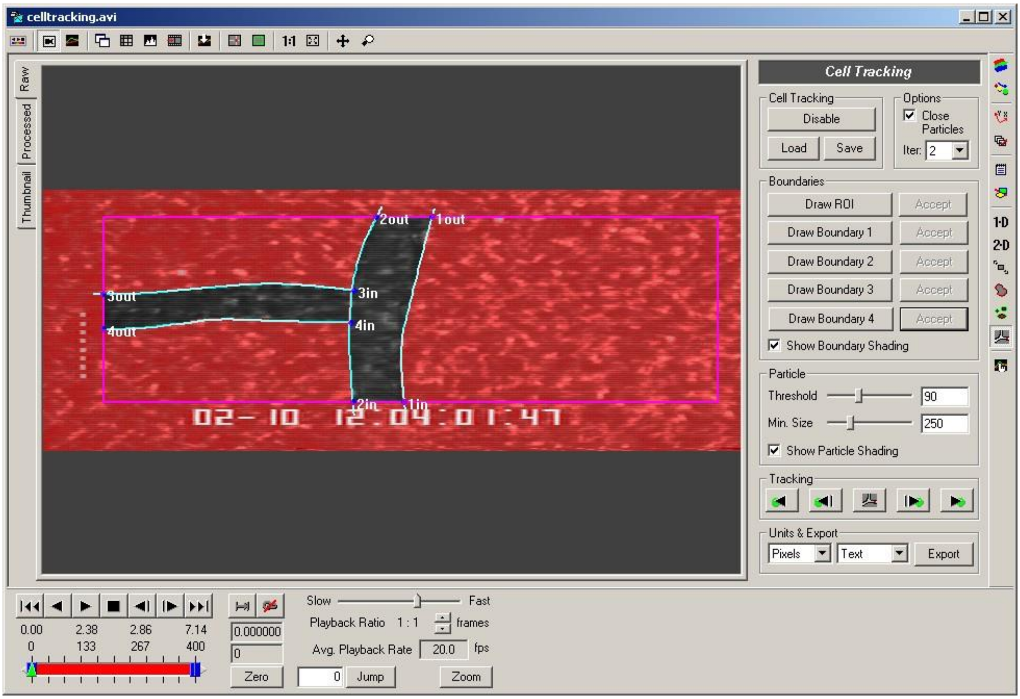
8. Once you are satisfied with the boundary, click on the Accept button.



After you have defined the primary channel, a red shading will be drawn over portions of the video that will be ignored during processing. The intersections of the boundaries and the ROI will also be marked to indicate the boundary number and whether it is an INPUT (in) or an OUTPUT (out).

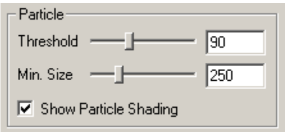


After the secondary channel has been defined, another portion of the image within the secondary channel should become unshaded. If this does not occur, most likely the input points for boundary 3 or 4 do not intersect with the boundary of the primary channel. In this case, try redrawing the boundaries for the secondary channel until it becomes unshaded.



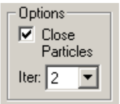
Configuring Processing

There are two primary tools used to locate particles of interest. These are thresholding and size filtering. A third tool is provided in the Options section of the panel that allows for small gaps between pieces of the same particle to be filled by closing particles.



The Threshold value indicates what level of brightness is required for a pixel to be considered a part of a particle of interest. The value can range between 0 and 255. Ideally, this value should be set somewhere above the brightest value considered to be background and below the darkest value considered to be a particle. In this case, use trial and error to determine a value that captures most of the particle while ignoring most of the background.

The Minimum Size value is intended to compensate for small bright spots in the background that might mistakenly be considered a particle. Any particle that is fewer than the minimum size will be ignored. Adjust this value as necessary to ignore smaller particles.



Closing particles allows for small gaps between particles and holes inside of particles to be filled. This is especially helpful if your videos are noisy, causing portions of particles to fall be- low the threshold, effectively dividing the particle. In this case, the single particle may be coun- ted as two separate particles or the portion of the particle that has been separated may fall be- low the minimum size and be ignored. The number of iterations controls how large of a gap may be filled. Set the number of iterations to roughly half the size of the largest gap that needs to be filled.

Processing and Tracking

After all parameters have been configured, the video can be processed. During processing, all particles within the channels, above the specified threshold, and greater than the minimum size will be located.

The center of the leading edge of these particles will be determined and marked with a red dot. The distance from the center of the leading edge to both boundaries will be computed and indicated with a yellow dotted line. A bounding box that encloses the entire particle will be drawn in red. For the most recent frame that has been processed, a green shading will be drawn over the portions of the video where particles have been detected.

Note that the primary channel and the secondary channel are treated completely independently. A particle that is partially in one channel and partially in another will be detected as two particles, one in each channel. This must be done so that there is no confusion regarding the leading edge and size of the particle due to the odd shape of the particle while it is near the branch. The appearance of a particle in the secondary channel, while a simultaneous particle is near the branch point in the primary channel, can readily be seen in the resulting exported data. This should ensure that this case can be handled properly.

There are five buttons for initiating tracking.

The center button processes only the current frame. This button is useful if you are tuning the threshold and minimum size parameters to ensure that the particles of interest are being correctly detected. Click on this button after each change to see the results.

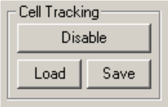
The next two buttons advance one frame backward or forward and then processes that frame. These buttons are useful for stepping through a video while verifying that the tracking is operating as desired.

The outer two buttons track forward or track backward. These buttons will automatically track from the current frame to the beginning or the end of the video. A processing window will be displayed which will show the current progress. To abort the tracking, click on the Cancel button in the processing window.

Saving and Loading

The current ROI, boundaries, settings, and all tracking information can be saved to file. The resulting file can be reloaded for the current video to perform additional analysis, or the file can be loaded for any similar video to perform the same analysis without having to redefine ROIs and boundaries.

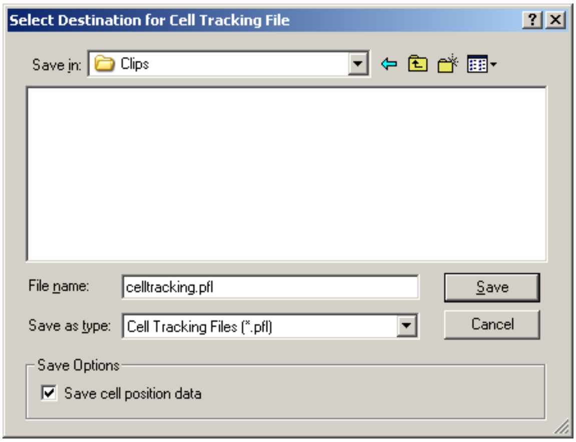
To save and load files, use the Save and Load buttons at the top of the panel.



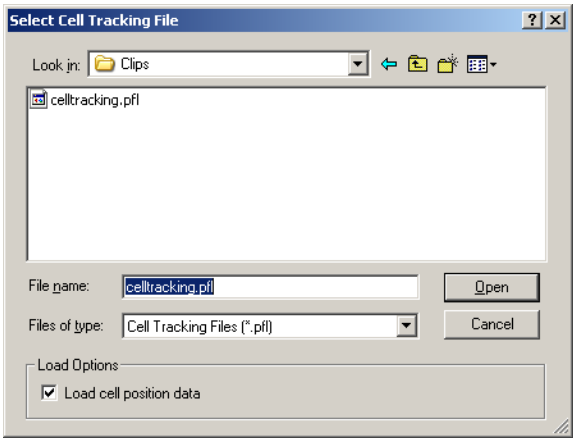
When saving, you have the option to save the tracking results (cell position data). If you wish to use the saved file as a basis for doing tracking on a different video, then there is no need to save the tracking results. If you wish to reload the file into the same video for viewing or addi- tional processing, then you should save the particle data (default behavior).

The non-particle data that is stored in the file includes the location of the ROI and the boundaries, the threshold and minimum size settings, and the close particle setting and number of iterations.

The particle data that is stored is the location of the leading edge, the bounding box, and the distance to each of the boundary walls for each particle in every frame.

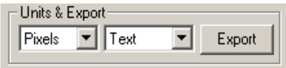


When loading, you also have a similar option to either load the tracking results (cell position data) or to choose to ignore it if present.



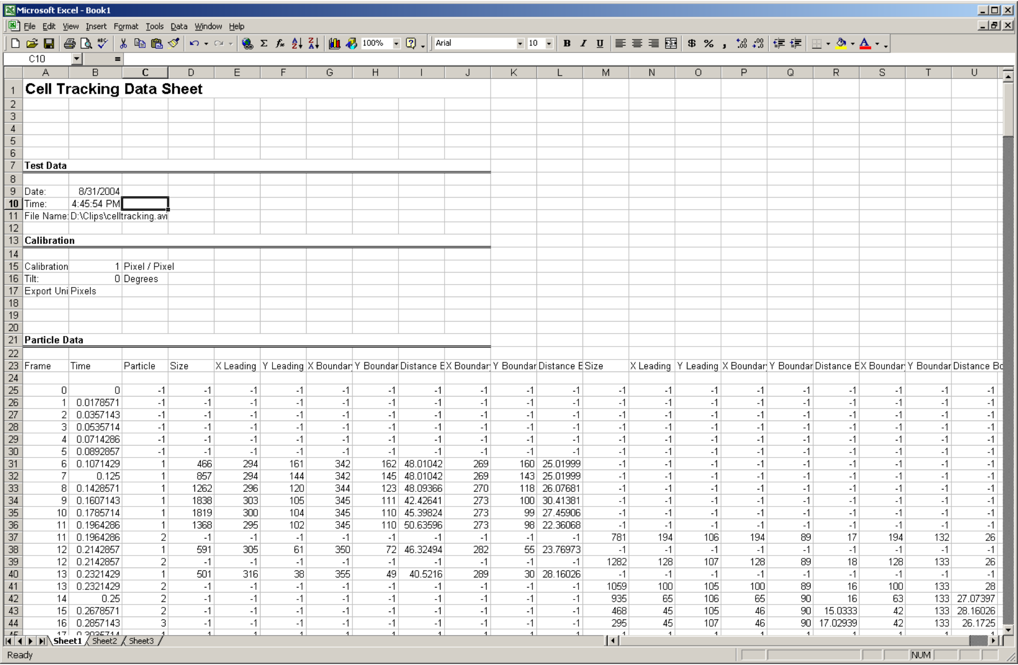
Units and Exporting

The tracking results can be exported to multiple formats for additional processing. To export results, select the units for exporting and the export format and then click the Export button.



In order to select non-pixel units, the video must be calibrated first. See the section called "Multi-Plane Calibration" for additional details regarding calibrating the video.

The format of the exported results for both Text and Excel are very similar, therefore, we will only show the Excel export here.



Cell Tracking Data Sheet

Test Data

Date: 8/31/2004
Time: 4:45:54 PM
File Name: D:\Clips\celltracking.avi

Calibration

Calibration 1 Pixel / Pixel
Tilt: 0 Degrees
Export Uni Pixels

Particle Data

Frame	Time	Particle	Size	X Leading	Y Leading	X Boundar	Y Boundar	Distance E	X Boundar	Y Boundar	Distance E	Size	X Leading	Y Leading	X Boundar	Y Boundar	Distance E	X Boundar	Y Boundar	Distance Bo
0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
1	0.0178571	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2	0.0357143	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3	0.0535714	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
4	0.0714286	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
5	0.0892857	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
6	0.1071429	1	466	294	161	342	162	48.01042	269	160	25.01999	-1	-1	-1	-1	-1	-1	-1	-1	-1
7	0.125	1	857	294	144	342	145	48.01042	269	143	25.01999	-1	-1	-1	-1	-1	-1	-1	-1	-1
8	0.1428571	1	1262	296	120	344	123	48.09366	270	118	26.07681	-1	-1	-1	-1	-1	-1	-1	-1	-1
9	0.1607143	1	1838	303	105	345	111	42.42641	273	100	30.41381	-1	-1	-1	-1	-1	-1	-1	-1	-1
10	0.1785714	1	1819	300	104	345	110	45.39824	273	99	27.45906	-1	-1	-1	-1	-1	-1	-1	-1	-1
11	0.1964286	1	1368	295	102	345	110	50.63596	273	98	22.36068	-1	-1	-1	-1	-1	-1	-1	-1	-1
11	0.1964286	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	781	194	106	194	89	17	194	132	26
12	0.2142857	1	591	305	61	350	72	46.32494	282	55	23.76973	-1	-1	-1	-1	-1	-1	-1	-1	-1
12	0.2142857	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	1282	128	107	128	89	18	128	133	26
13	0.2321429	1	501	316	38	355	49	40.5216	289	30	28.16026	-1	-1	-1	-1	-1	-1	-1	-1	-1
13	0.2321429	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	1059	100	105	100	89	16	100	133	28
14	0.25	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	935	65	106	65	90	16	63	133	27.07397
15	0.2678571	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	468	45	105	46	90	15.0333	42	133	28.16026
16	0.2857143	3	-1	-1	-1	-1	-1	-1	-1	-1	-1	295	45	107	46	90	17.02939	42	133	26.1725

The upper portion of the data sheet shows information about the video that has been processed, including any calibration that has been performed.

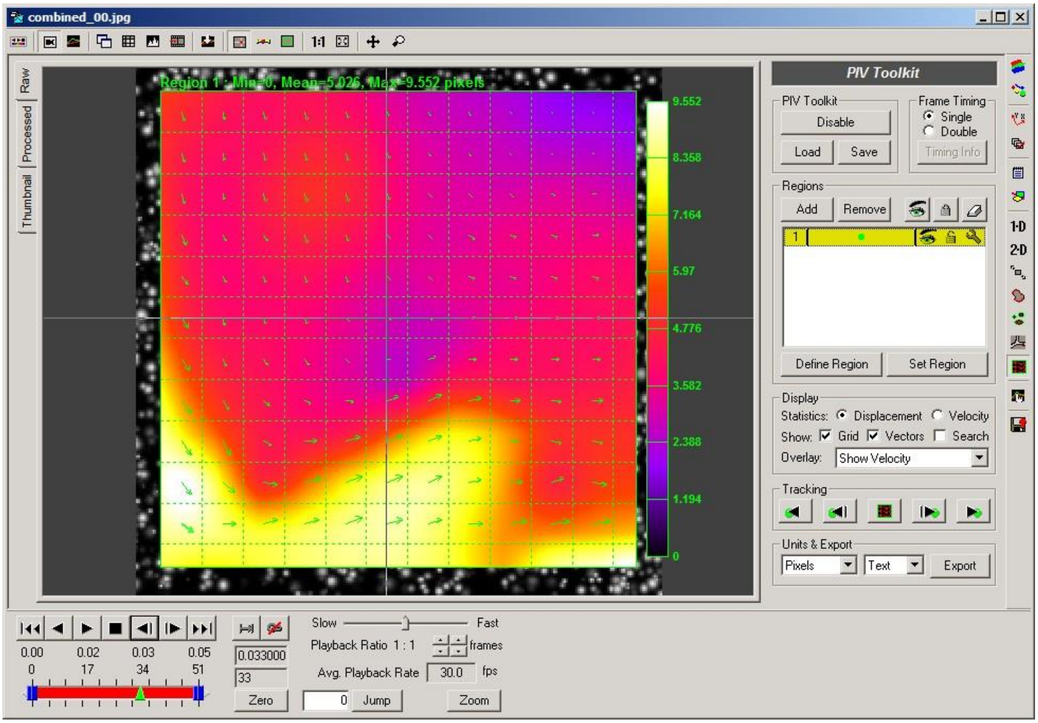
The lower tabular data contains the tracking results. For each frame of the video, each particle is listed. Columns D-L list information about particles in the primary channel. Columns M-U list information about particles in the secondary channel. Values of all -1 indicate that no particle was found for that frame and channel. In some frames, multiple particles will be found within each channel. These particles will be listed sequentially.

See the section called “Exporting Data or Analyses” for additional details regarding exporting.

PIV Toolkit

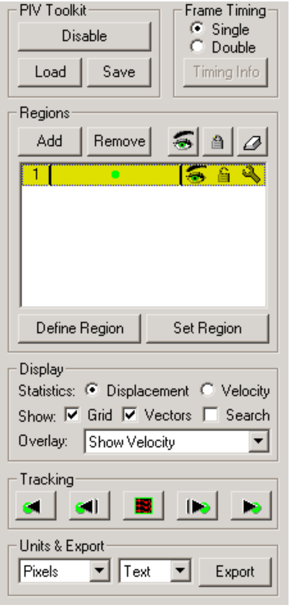
Overview

The PIV Toolkit is designed to perform Particle Image Velocimetry (PIV) analysis on a video source. The toolkit provides estimates of flow vectors across multiple user-defined regions. The flow vectors are calculated on a grid that spans each region. The grid sizing and spacing can be configured by the user. The resulting flow vector field is drawn on top of the image and can also be rendered as a colorized contour map.



PIV Toolkit Panel

The PIV Toolkit panel follows the same general layout as the other toolkit panels.



Each of the controls in the panel is briefly described below:

Enable/Disable

Click on the Enable button in the upper left of the panel to start the PIV Toolkit. Clicking this button initializes memory and sets up initial configuration information. This must be done for each video that you wish to analyze. When you are done with this toolkit, you can click this button again to disable the PIV Toolkit and free the associated memory.

Load

Load configuration and results from a PIV Toolkit file. All settings and tracking results will be reloaded from the saved file. PIV Toolkit files are saved with the `XPV` file extension.

Save

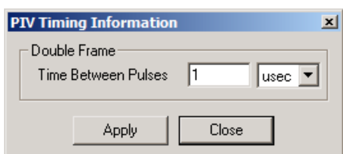
Save PIV Toolkit configuration and results to a file. All settings and tracking results will be saved to the saved file. PIV Toolkit files are saved with the `XPV` file exten- sion.

Frame Timing

The video source can either be a traditional video file or a "double-frame" video file. For a traditional video, the timing between all frames in the video is a constant value. For a double-frame video, the actual timing between every pair of images is precisely controlled us- ing a double-pulsed laser. When the frame timing is set to Single, the software will use the frame rate set for the video to determine the time scale for velocity calcula- tions and all the flow vectors for all frames are estimated (e.g. 1-2, 2-3, 3-4, etc.). When the frame timing is set to Double, the exact timing between the double-pulses of the laser must be specified using the Timing Info button and only every pair of images are analyzed (e.g. frames 1-2, 3-4, 5-6, etc.).

Timing Info

This button is only enabled if the Frame Timing mode is set to Double. Click this button to set the exact time between laser pulses used to generate the double-frame pairs in the video.



Regions

This section displays a list of current regions that have been added. Each region can be configured with different parameters and analyzed independently from other re- gions. To add more regions, use the Add button. To remove existing regions, use the Remove button. The listing shows the region number, region color, visibility, active status, and the settings button. Double-clicking on the color allows you to change the color. Clicking on the visibility or active status will toggle those settings. Clicking on the settings icon will bring up the Region Settings dialog.

Toggle Visibility of All Regions — Show or hide all regions in the analysis. If the majority of regions are currently visible, all regions will be hidden. If the majority of regions are hidden, all regions will be shown.

Toggle Lock for All Regions — Lock or unlock all regions in the analysis. If the majority of regions are currently unlocked, all regions will be locked. If the majority of regions are locked, all regions will be unlocked.

Clear Selected Region(s) — Clears all analysis results for the selected regions. A message box will appear to confirm that you wish to delete the analysis data.

Modify Region — Click on this button to specify the rectangle in the image associated with the currently selected region in the list of regions. After clicking this button, use your mouse to move to the upper left corner of the desired rectangle, then click and hold the left mouse button and drag the mouse to the lower right corner of the desired rectangle. If the rectangle was not drawn in the proper location, you can move the center of the rectangle by clicking in a dif- ferent location in the image. If you wish to resize the rectangle, click Modify Region again and repeat the above steps.

Set Region — When you are satisfied with the size and location of the rectangle that was drawn after clicking Modify Region, click this button to set the rectangle for the currently selected region.

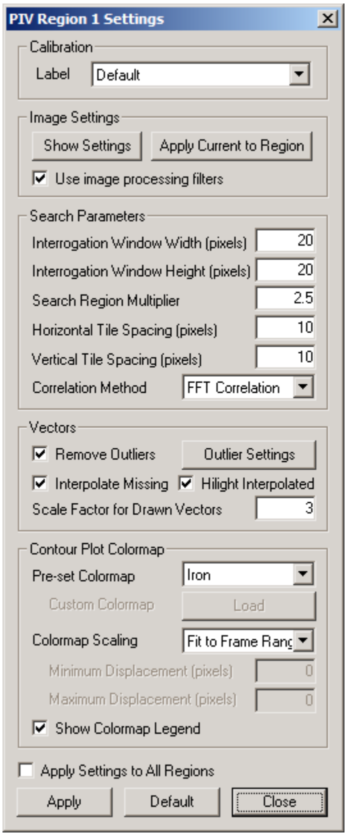
Statistics: Displacement — Above each region in the video image, basic statistics for the estimated vectors are displayed for each frame. These statistics can either be displayed as displacement values or velocity values. Selection Displacement to show the statistics as displacement values. This setting also controls whether displacement or velocity values are exported when clicking the Export button.

Statistics: Velocity — Above each region in the video image, basic statistics for the estimated vectors are displayed for each frame. These statistics can either be displayed as displacement values or velocity values. Selection Velocity to show the statist- ics as velocity values that incorporate the frame timing. This setting also controls whether displacement or velo-

	city values are exported when clicking the Export button.
Show Grid	Show or hide the horizontal and vertical spacing gridlines in the video for each region. See Display Settings below for more information.
Show Vectors	Show or hide the estimated flow vectors in the video for each region. See Display Settings below for more information.
Show Search	Show or hide a sample of the interrogation window size and the search region size in the video for each region. See Display Settings below for more information.
Overlay	Show or hide the contour map in the video for each region. The contour map can render Velocity, Diffusion, or Vorticity data. See Display Settings below for more information.
Track Forward/Backward	Continuously processes the current frame backward or forward until the first or last frame of the video is reached.
Track Single Step Forward/Backward	Advances to the previous or next frame and then processes the next frame.
Analyze Current Frame	Uses the settings for each of the active regions to estimate the vector field in the current frame only.
Units	Select the units that are used in the video display of the PIV statistics, the graph display, and the export of data. To select non-pixels units, the video must be calibrated. See the section called “Multi-Plane Calibration” for more information on calibration.
Export Format	Select the format of the output of the export command: Text, Excel Blank, or Excel Template.
Export	Export the current tracking results. See the section on Units and Exporting below for more information.

Region Settings

Clicking on the settings button (wrench icon) in the list of regions will cause the Region Settings dialog to appear. This dialog exposes all the settings that can be used to change the behavior of the toolkit for the analysis of a specific region.



Each of the settings is described briefly below:

Calibration	Each region can use its own calibration (see the section called “Multi-Plane Calibration”) settings. The list of currently defined calibrations is shown in the drop down box. Select the specific calibration label to be used with this region, or select Default to use whichever calibration is set as the default calibration.
Show Settings	Each region can maintain its own set of Image Pro- cessing (see the section called “Image Processing”) set- tings. These LUT settings are typically the settings that were active when the region was set. Click on this button to display the image using the image processing settings associated with this region.
Apply Current to Region	This button allows the image processing (LUT) settings for a given region to be changed to whatever settings are currently active. In order to change the LUT settings as- sociated with a region, change the LUT settings so that the desired appearance is achieved (see the section called “Image Processing”), and then press this button.

Use image processing filters	While each region can have its own set of Image Processing settings, all regions share the single set of Image Filters (see the section called “Image Filtering”) defined for the video. However, each region can be set to use the image processing filters or to not use them. Check this box to have the image processing filters applied to the video for this particular region when analyzing.
Interrogation Window Width (pixels)	This is the width of the interrogation window. The interrogation window is the size of the rectangle extracted from the video image that is used as a template to search in the next frame. The size of this window should be related to the density of particles in your video. The size should be set so that approximately 10-15 particles are typically contained within the interrogation window. A sample of the interrogation window and search region can be shown in the video image by clicking Show Search Region in the main PIV Toolkit panel.
Interrogation Window Height (pixels)	This is the height of the interrogation window. The interrogation window is the size of the rectangle extracted from the video image that is used as a template to search in the next frame. The size of this window should be related to the density of particles in your video. The size should be set so that approximately 10-15 particles are typically contained within the interrogation window. A sample of the interrogation window and search region can be shown in the video image by clicking Show Search Region in the main PIV Toolkit panel.
Search Region Multiplier	Configure how large of an area to search for template matches. This is a multiplier on the interrogation size. A value of 2.0 indicates that the algorithm should search in a region twice as large as the interrogation window size. Larger values will result in larger search areas and longer search times. A typical value for this parameter is 2.5. A sample of the interrogation window and search region can be shown in the video image by clicking Show Search Region in the main PIV Toolkit panel.
Horizontal Tile Spacing (pixels)	This value determines the horizontal spacing of points where flow vectors will be estimated. Smaller values will increase the density of flow vectors, but increase the processing time. A visual representation of the resulting tiles can be shown in the video image by clicking Show Grid in the main PIV Toolkit panel. The resulting grid lines show the boundaries of each tile. A flow vector will be estimated for the center of each tile.
Vertical Tile Spacing (pixels)	This value determines the vertical spacing of points where flow vectors will be estimated. Smaller values will increase the density of flow vectors, but increase the processing time. A visual representation of the resulting tiles

can be shown in the video image by clicking Show Grid in the main PIV Toolkit panel. The resulting grid lines show the boundaries of each tile. A flow vector will be estimated for the center of each tile.

Correlation Method
: The algorithm used to find the best match for each template region in the next frame can be set from the options in this drop-down list. There are currently three methods available to choose from: FFT Correlation, Direct Correlation, Absolute Difference. FFT Correlation returns the coordinates of the maximum correlation when calcu- lated using the FFT. This method is the fastest of the three methods. Direct Correlation returns the coordinates of the maximum correlation when calculated using a dir- ect equation for the correlation coefficient between two images. Absolute Difference returns the coordinates of the minimum normalized absolute difference between two images. This method is significantly slower than the other two methods.

Remove Outliers
: Check this option if you would like the toolkit to perform a check on the resulting flow vectors and remove outliers.

Outlier Settings
: Opens a dialog to configure the settings for determining which vectors are outliers. See the section called “Outlier Settings” for more information. This button is only enabled when Remove Outliers is checked.

Interpolate Missing
: Check this option if you would like the toolkit to interpolate any missing flow vectors using the neighboring flow vectors.

Hilight Interpolated
: Check this option if you would like interpolated vectors to be shown using a lighter color and thicker lines.

Scale Factor for Drawn Vectors
: Set the scale factor for the vectors drawn in the image. A value of 1.0 will draw the vectors as the exact length of the estimated displacement. A value of 2.0 will draw the vectors twice as long as the estimated displacement.

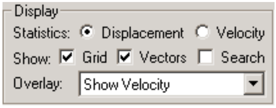
Pre-set Colormap
: Select from a list of pre-defined colormaps to use when the contour map is shown in the video. To use your own custom defined colormap, select Custom from the drop-down list. To enable rendering of a contour map, click on Show Contour Plot in the main PIV Toolkit panel.

Custom Colormap
: A custom colormap can be used if Custom is selected in the Pre-set Colormap drop-down list. A text file containing the custom colormap should be created and loaded by clicking on this button. The text file should contain 256 lines, with each line containing comma-separated R, G, and B values.

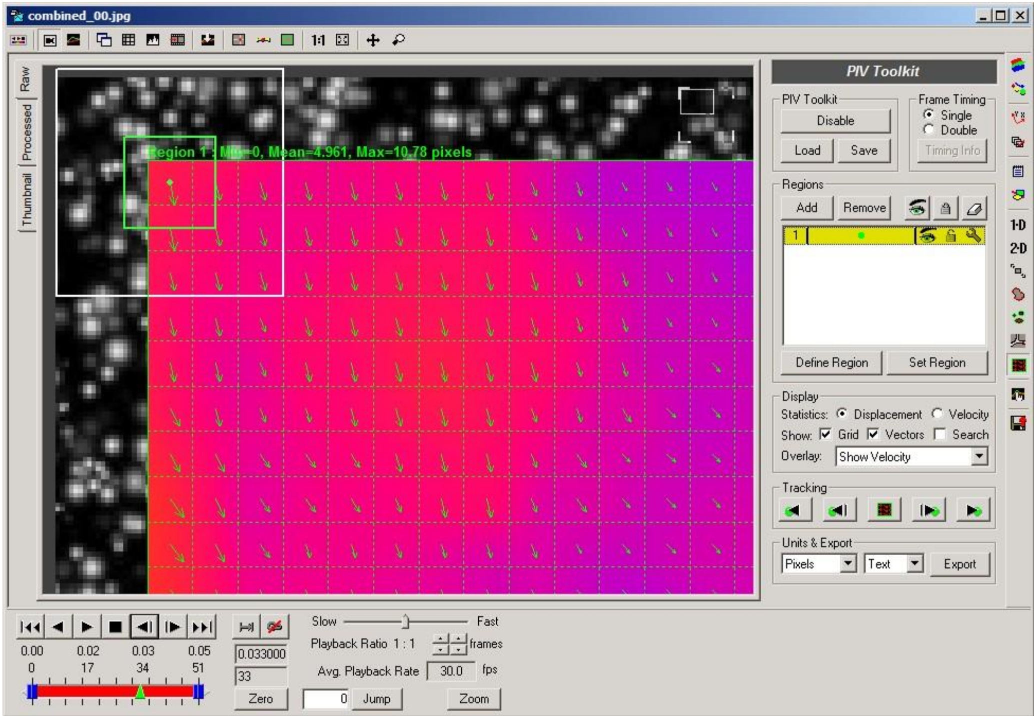
Colormap Scaling	The colormap can be scaled in five different methods: Fit to Total Range, Fit to Total Maximum, Fit to Frame Range, Fit to Frame Maximum, or Fixed Range. These options control the range of displacements over which the 256 colors of the colormap are assigned. Fit to Total Range calculates the minimum and maximum displacements over all frames of the video and then distributes the colors across the minimum-maximum range. Fit to Total Maximum calculates the maximum displacement over all frames of the video and then distributes the col- ors across the 0-maximum range. Fit to Frame Range calculates the minimum and maximum displacements for the current frame. The range is recalculated for every frame. Fit to Frame Maximum calculates the maximum displacement for the current frame. The range is recalcu- lated for every frame. Fixed Range uses user specified values for the minimum and maximum displacements. Fixed Range is the best option if you wish to compare contour plots from one region to another or one video to another.
Minimum Displacement (pixels)	Specify the minimum displacement in pixels to be used for colormap scaling. Displacement values less than or equal to this value will be assigned the first color in the colormap.
Maximum Displacement (pixels)	Specify the maximum displacement in pixels to be used for colormap scaling. Displacement values greater than or equal to this value will be assigned to the last color in the colormap.
Show Colormap Legend	Check this option to show a colormap legend on the right side of the region.
Apply Settings to All Regions	Check this box to apply the above settings to all currently defined regions.
Apply	Apply the settings to the region. Changes will not be applied unless this button is clicked.
Default	Load the system default values for the region settings into this dialog. The settings are not applied until the Apply button is clicked.
Close	Close the dialog. Settings will not be applied unless the Apply button was clicked.

Display Settings

A number of different items can be displayed over the video image. The settings that control what are displayed are located in the lower half of the main PIV Toolkit panel and also in the settings dialog for each region. The options in the main panel apply to all regions.



These options have been described briefly in an earlier section of this chapter. Below is a graphic showing all four options checked.



Statistics are shown above each region in the video image. The magnitudes of the minimum, mean, and maximum displacement or velocity is shown for each region for the current frame. If Displacement is selected, the values are shown as the magnitude of the displacement from one frame to the next. If Velocity is selected, the frame rate or the double-frame timing is used to calculate the magnitudes of the velocity from one frame to the next.

Show Grid renders the grid of tiles in all regions. The grid is the dashed horizontal and vertical lines that span the entire region. The grid lines are spaced horizontally and vertically according to the Horizontal Tile Spacing and Vertical Tile Spacing settings.

Show Search renders a sample of the interrogation window and the search region for the upper left tile in each region. A sample of one interrogation window is shown as the green rectangle in the upper left corner of the green region. Notice that the interrogation window size can be larger than the horizontal and vertical tile spacing. The interrogation window is always centered on each tile. The search region is shown as a white rectangle also centered on the center of the tile. This is the region in the next image where the software will attempt to find the best match for the interrogation window.

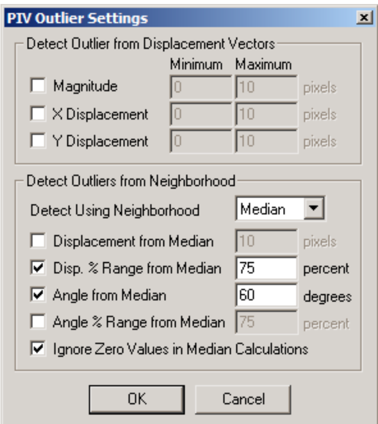
Show Vectors renders an arrow located at the center of each tile to represent the displacement of that point in the next frame. The length of the vector can be scaled up or down by setting the Scale Factor for Drawn Vectors setting in the Region Settings dialog.

Overlay renders the colorized contour map drawn in the background of the grid and vectors. The data shown by the contour map can be selected to be Velocity, Diffusion, or Vorticity. For Diffusion and Vorticity, the magnitude (absolute value) of the quantities can be shown or the signed values. The colormap used by the contour map can be selected in the Region Settings dialog.

Some of the above options and a few additional display settings can also be found in the PIV Toolkit context-menu. You can access this menu by clicking the right mouse button anywhere in the video image.

Outlier Settings

Multiple criteria can be used to determine whether an estimated displacement vector is an outlier. These criteria are grouped into two categories: magnitude-based or neighborhood-based. The PIV Outlier Settings dialog can be shown by clicking the Outlier Settings button from any PIV Region Settings dialog. The Remove Outliers option must be checked in order for these settings to have effect. Outliers are only removed when the video is being processed. Changing these settings will not change existing results. You must re-analyze your frame(s) in order for changes to be applied.



Each of the criteria is described below:

Magnitude

Check this box to enable outlier detection based upon the magnitude of the displacement vector. A minimum and maximum bound can be specified in pixels. If the magnitude of a vector is below the minimum or above the maximum, it will be removed during processing.

X Displacement

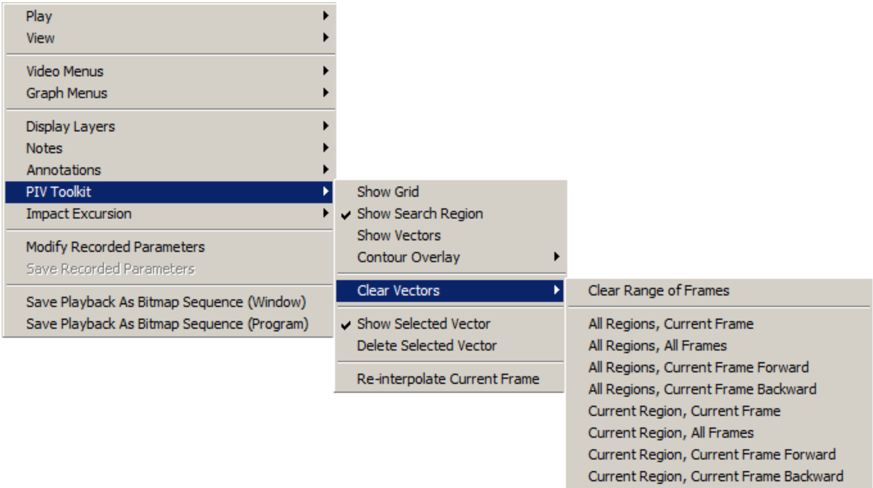
Check this box to enable outlier detection based upon the

	X displacement. A minimum and maximum bound can be specified in pixels. Note that this is a signed quantity, so the minimum and maximum can be negative values. If the X displacement is below the minimum or above the maximum, it will be removed during processing.
Y Displacement	Check this box to enable outlier detection based upon the Y displacement. A minimum and maximum bound can be specified in pixels. Note that this is a signed quantity, so the minimum and maximum can be negative values. If the Y displacement is below the minimum or above the maximum, it will be removed during processing.
Detect Using Neighborhood	For the outlier detection settings below, the variations can be calculated relative to the neighborhood Mean or Median. Select Mean or Median in the drop down box to choose which quantity to use.
Displacement from Mean/Median	Check this box to enable outlier detection based upon the difference between the magnitude of a vector and the mean/median magnitude of the surrounding vectors. Enter the maximum allowable pixel difference in the box on the right.
Disp. % Range from Mean/Median	Check this box to enable outlier detection based upon the difference between the magnitude of a vector and the mean/median magnitude of the surrounding vectors. The maximum allowable pixel difference is calcluated as a percentage of the range of magnitudes in the surrounding neighborhood. For instance, if the neighborhood of a vector contains magnitudes ranging from 2 pixels to 10 pixels, then the range is 8 pixels. If the percentage is 50%, then the maximum allowable difference between the magnitude and the mean/median would be 4 pixels.
Angle from Mean/Median	Check this box to enable outlier detection based upon the difference between the direction of a vector and the mean direction of the surrounding vectors. Enter the maximum allowable angle difference in degrees in the box on the right.
Angle % Range from Mean/Median	Check this box to enable outlier detection based upon the difference between the direction of a vector and the mean/median direction of the surrounding vectors. The maximum allowable angle difference is calcluated as a percentage of the range of directions in the surrounding neighborhood. For instance, if the neighborhood of a vector contains directions ranging from 20 degrees to 60 degrees, then the range is 40 degrees. If the percentage is 50%, then the maximum allowable difference between the direction and the mean/median would be 20 degrees.

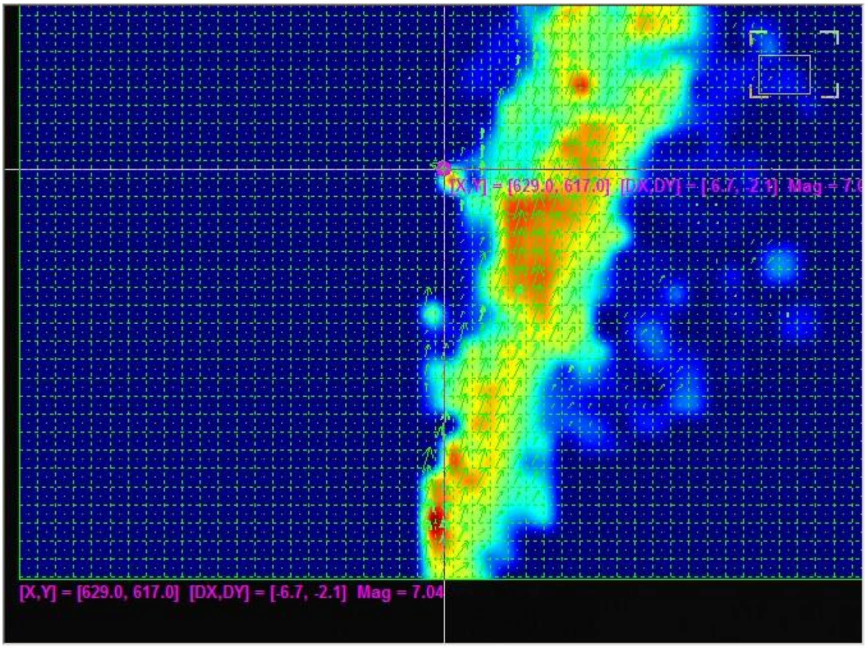
Ignore Zero Values in Mean/Median Calculations	Some locations may be found to exhibit no discernible motion, especially near the boundaries of the flow. These locations will contain displacement vectors of zero magnitude. Check this box to ignore these vectors when calculating neighborhood magnitude or angle mean/median values. If this box is unchecked, the zero values will be included in the mean/median calculations.

Clearing Vectors

There are multiple methods for clearing vectors that have been found during the analysis. The majority of these methods are accessed through the context-menu. You can access the context-menu by clicking the right mouse button in the video window.



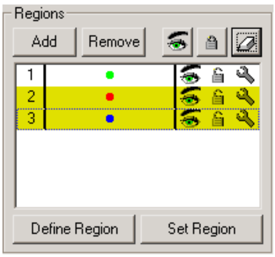
For removing a single vector, enable Show Selected Vector via the context-menu if it is not already enabled. When Show Selected Vector is enabled, clicking anywhere in the image will highlight the nearest flow vector and provide information about that vector at the bottom of the corresponding Region and also next to the vector as shown below. If the currently selected vector is an interpolated vector, an "[I]" will be shown at the end of the cursor information. If no motion could be determined for the currently selected vector position, an "[X]" will be shown at the end of the cursor information.



To remove the selected vector, click Delete Selected Vector from the context-menu. This will replace the selected vector with an empty vector that can be filled using interpolation. To fill in the deleted vector using an interpolated result, click Re-interpolate Current Frame from the context-menu.

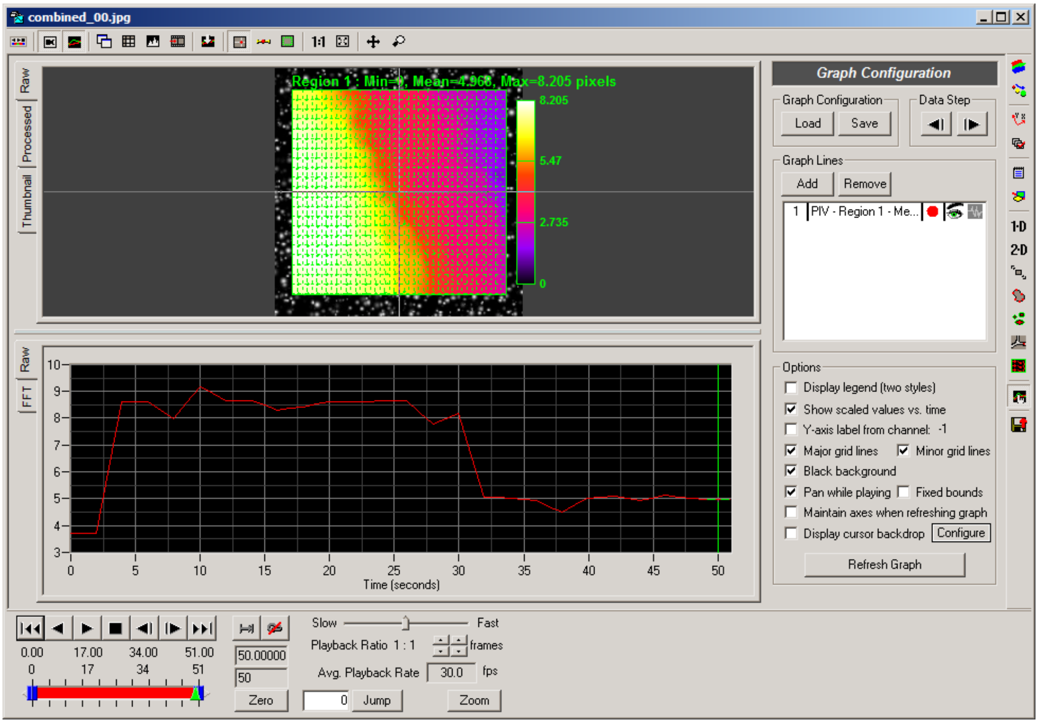
Entire frames or entire regions of tracking data can also be removed via the context-menu. Use the Clear Vectors menu to access a number of options to clear a range of frames or clear forward or backward from the current frame. These clearing operations can be performed for All Regions or only for the currently highlighted Region in the list of Regions.

To clear all vectors for one or more regions, you can also use the eraser button located at the top of the list of regions in the PIV Toolkit panel. Select the regions that you wish to clear, and then click the Clear Selected Region(s) button.

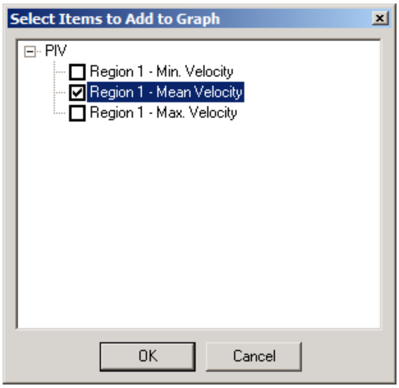


Graphing

Once your analysis is complete, a number of quantities can be graphed. Use the Graph Configuration control panel to add feature tracking results to the graph section.



After clicking on the Add button, a listing of available items to graph is presented. Select the items that you wish to graph and click on the OK button at the bottom of the dialog.



For more details on configuring the other options in the Graph Configuration panel, see the section called “Display Settings”.

Units and Exporting

After a successful analysis is completed, you can export the data to a variety of formats to perform any additional custom analysis or graphing.

Units You can select what set of units to use for exporting the tracking results. If no calibration has been done on the video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.

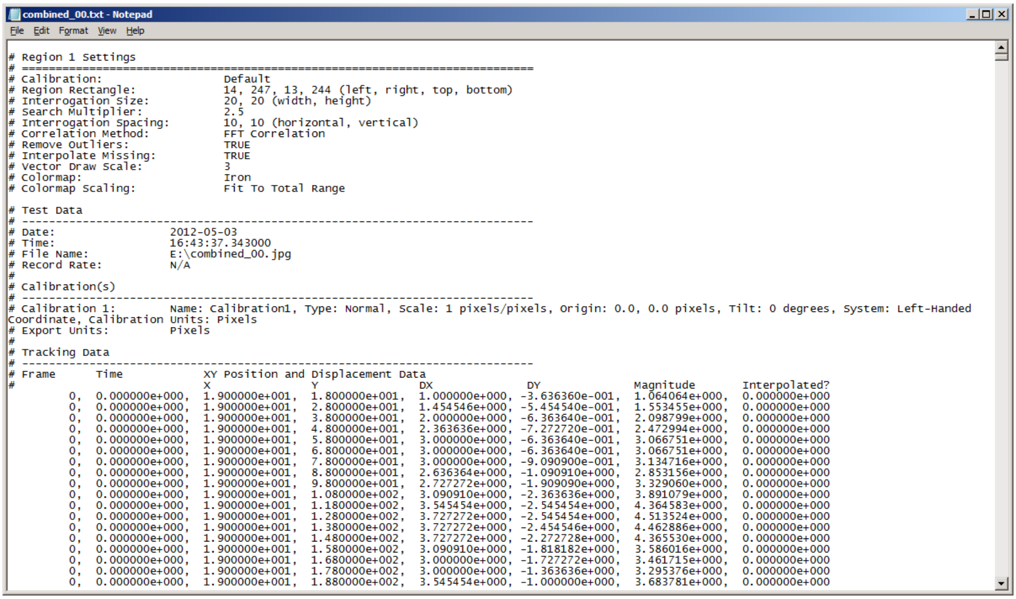
Format You can select what format to export to: Text, Excel Blank, or Excel Template.

The analysis data is composed of the following information: frame number, time (if we know the record rate of the video), the X and Y coordinates of each flow vector, the X and Y displacement or velocity of each flow vector, and a 0 or 1 indicating if the vector information is interpolated. Displacement is exported if Displacement is selected for Statistics in the Display section of the panel. Velocity is exported if Velocity is selected for Statistics in the Display section of the panel.

Exporting to Excel Blank and Excel Template export the same data. However, Excel Template exports the data into an existing Excel file that is used as a template. You can put in any formulas and graphs into the template file, and these will be recomputed and regenerated when the new data is exported into it.

Export When you are satisfied with your analysis results, and have selected your export units and format, click the Export button to export the results.

See the section called “Exporting Data or Analyses” for additional details regarding exporting. An example of a text export is shown below.

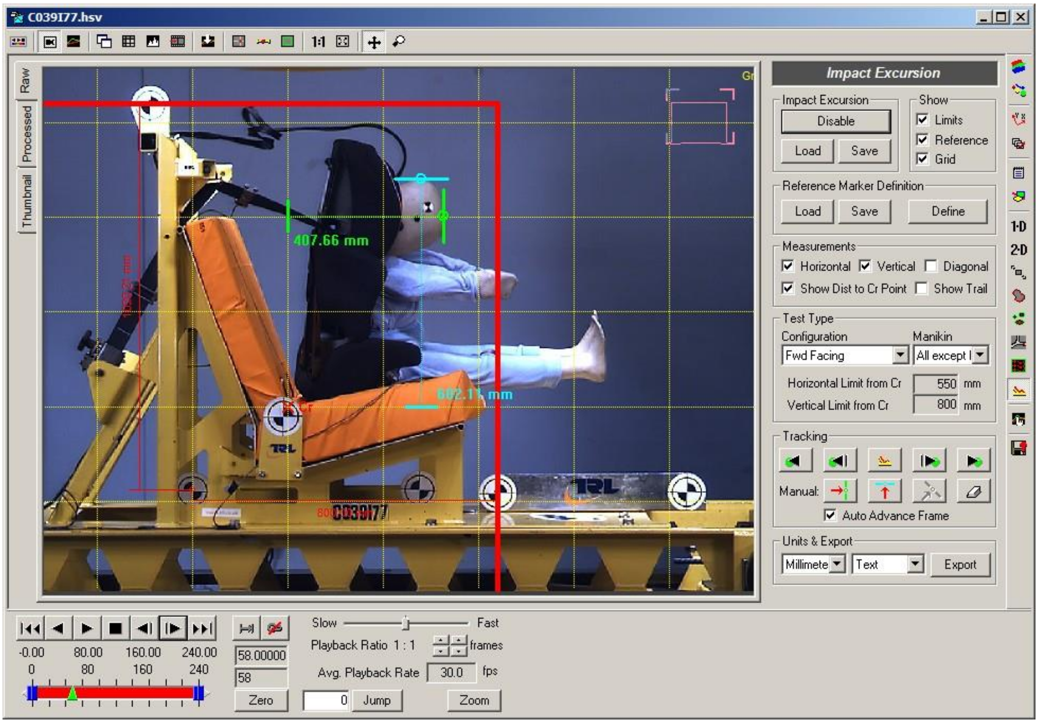


```
combined_00.txt - Notepad
File Edit Format View Help

# Region 1 Settings
# ===========================================================================
# Calibration:                  Default
# Region Rectangle:             14, 247, 13, 244 (left, right, top, bottom)
# Interrogation Size:           20, 20 (width, height)
# Search Multiplier:            2.5
# Interrogation Spacing:        10, 10 (horizontal, vertical)
# Correlation Method:           FFT Correlation
# Remove Outliers:              TRUE
# Interpolate Missing:          TRUE
# Vector Draw Scale:            3
# Colormap:                     Iron
# Colormap Scaling:             Fit To Total Range

# Test Data
# ---------------------------------------------------------------------------
# Date:                 2012-05-03
# Time:                 16:43:37.343000
# File Name:            E:\combined_00.jpg
# Record Rate:          N/A
#
# Calibration(s)
# ---------------------------------------------------------------------------
# Calibration 1:        Name: Calibration1, Type: Normal, Scale: 1 pixels/pixels, Origin: 0.0, 0.0 pixels, Tilt: 0 degrees, System: Left-Handed
Coordinate, Calibration Units: Pixels
# Export Units:         Pixels
#
# Tracking Data
# ---------------------------------------------------------------------------
# Frame      Time           XY Position and Displacement Data
#                           X              Y              DX             DY              Magnitude      Interpolated?
        0,   0.000000e+000, 1.900000e+001, 1.800000e+001, 1.000000e+000, -3.636360e-001, 1.064064e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 2.800000e+001, 1.454546e+000, -5.454540e-001, 1.553455e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 3.800000e+001, 2.000000e+000, -6.363640e-001, 2.098799e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 4.800000e+001, 2.363636e+000, -7.272720e-001, 2.472994e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 5.800000e+001, 3.000000e+000, -6.363640e-001, 3.066751e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 6.800000e+001, 3.000000e+000, -6.363640e-001, 3.066751e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 7.800000e+001, 3.000000e+000, -9.090900e-001, 3.134716e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 8.800000e+001, 2.636364e+000, -1.090910e+000, 2.853156e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 9.800000e+001, 2.727272e+000, -1.909090e+000, 3.329060e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.080000e+002, 3.090910e+000, -2.363636e+000, 3.891079e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.180000e+002, 3.545454e+000, -2.545454e+000, 4.364583e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.280000e+002, 3.727272e+000, -2.545454e+000, 4.513524e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.380000e+002, 3.727272e+000, -2.454546e+000, 4.462886e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.480000e+002, 3.727272e+000, -2.272728e+000, 4.365530e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.580000e+002, 3.090910e+000, -1.818182e+000, 3.586016e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.680000e+002, 3.000000e+000, -1.727272e+000, 3.461715e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.780000e+002, 3.000000e+000, -1.363636e+000, 3.295376e+000, 0.000000e+000
        0,   0.000000e+000, 1.900000e+001, 1.880000e+002, 3.545454e+000, -1.000000e+000, 3.683781e+000, 0.000000e+000
```

Impact Excursion

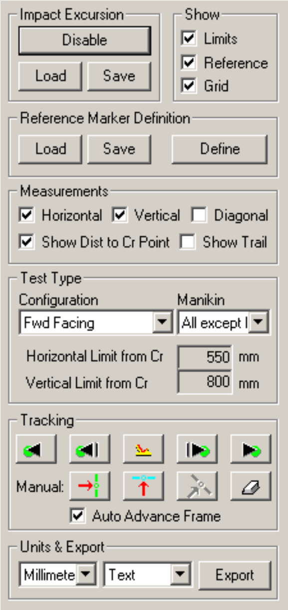
Overview

The Impact Excursion toolkit is designed to analyze the motion of a crash test dummy during an impact event. The toolkit is designed to handle side camera views and top-down camera views. The toolkit can handle both stationary and sled mounted cameras. The toolkit is de- signed for automatic tracking of user-defined reference markers placed on the impact sled. The locations of the reference markers are used to define horizontal and vertical calibration scales and excursion limits. Once the reference markers are successfully tracked, key points on the crash test dummy can be manually tracked to determine whether the motion of the crash test dummy exceeds the excursion limits. Horizontal, vertical, and diagonal distance measurements are calculated and can be displayed for each frame.



Impact Excursion Toolkit Panel

The Impact Excursion toolkit panel follows the same general layout as the other toolkit panels.



Each of the controls in the panel is briefly described below:

Enable/Disable	Click on the Enable button in the upper left of the panel to start the Impact Excursion toolkit. Clicking this button initializes memory and sets up initial configuration information. This must be done for each video that you wish to analyze. When you are done with this toolkit, you can click this button again to disable the Impact Ex- cursion toolkit and free the associated memory.
Load	Load configuration and results from an Impact Excursion Toolkit file. All settings and tracking results will be reloaded from the saved file. Impact Excursion toolkit files are saved with the `IET` file extension.
Save	Save Impact Excursion toolkit configuration and results to a file. All settings and tracking results will be saved to the saved file. Impact Excursion toolkit files are saved with the `IET` file extension.
Show: Limits, Reference, Grid	Select which overlays are drawn over the video image. If Limits is checked, the maximum excursion limits of the current test configuration are shown using bold red lines. If Reference is checked, the tracked locations of the reference markers and the associated calibration distances are shown. If Grid is checked, a yellow dotted grid is overlaid on the video image. The spacing of the grids can be modified by checking and unchecking the Grid checkbox and entering a new value in the dialog that appears. The origin of the grid is the Cr point.

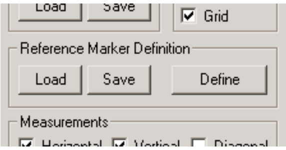
Reference Marker Definition	These controls are used for loading, saving, and defining reference marker arrangements. A different reference marker definition can be created for each type of sled, camera configuration, or testing conditions. Reference marker definitions are discussed in more detail in the following section.
Measurements: Horizontal	Check this option to enable tracking and display of horizontal excursion of the crash test dummy.
Measurements: Vertical	Check this option to enable tracking and display of vertical excursion of the crash test dummy.
Measurements: Diagonal	Check this option to enable tracking and display of diagonal excursion of the crash test dummy. The diagonal measurement is calculated as the distance from the tracked point to the diagonal line corresponding to the angled back of the sled chair.
Measurements: Show Dist to Cr Point	If this option is checked, the horizontal and vertical distances are calculated as distances from the Cr point. The location of the Cr point is defined in the Reference Marker definition, and corresponds to the location where the horizontal and vertical portions of the seat join. If this option is not checked, then the horizontal and vertic- al distances are calculated relative to the excursion limits for the current Test Configuration.
Measurements: Show Trail	If this option is checked, the tracked points for the crash test dummy are shown for the current frame and all past frames. If this option is not checked, then only the tracked points for the current frame are shown.
Test Type	Standard test configurations are shown in the drop-down list. Select the appropriate test configuration for your current test. Additional test configurations can be added upon request.
Track Forward/Backward	Continuously track the reference markers in the current frame backward or forward until the first or last frame of the video is reached.
Track Single Step Forward/Backward	Advances to the previous or next frame and then track the reference markers in the next frame.
Analyze Current Frame	Processes the current frame to track and locate the reference markers.
Manual Tracking	Once the reference markers have been tracked, the excursion of any portion of the dummy can be manually tracked. Click in the video image to place the reticle at the desired point, then click on the horizontal, vertical, or diagonal button to set the track point.

Clear Current Frame	Clears analysis results for the selected measurements in the current frame.
Auto Advance Frame	If this option is checked, the video will be advanced to the next frame automatically when all manual measurements have been placed. For example, if horizontal, vertical, and diagonal measurement options are checked, then after all three have been placed, the video will ad- vance to the next frame automatically.
Units	Select the units that are used in the video display of the Impact Excursion toolkit, the graph display, and the export of data. To select non-pixels units, the video must be calibrated. See the section called "Multi-Plane Calibration" for more information on calibration.
Export Format	Select the format of the output of the export command: Text, Excel Blank, or Excel Template.
Export	Export the current tracking results. See the section on Units and Exporting below for more information.

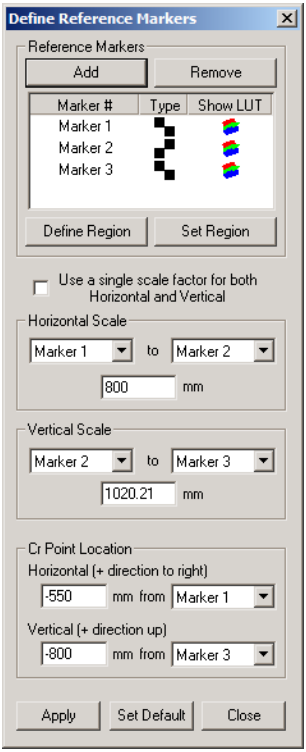
Reference Markers

Reference Markers are used to define the location of the origin (Cr point) and the horizontal and vertical calibration scales for the video. The reference markers should be bow-tie or quad- target markers that are placed on the moving sled in the same plane-of-motion as the desired measurements. The distances between the reference markers should be known. Different sets of Reference Marker configurations can be defined for different test sleds or testing conditions.

To define a Reference Marker configuration, click on the Define button in the Impact Excur- sion panel:



The following Define Reference Markers dialog will appear.



Use the Add and Remove buttons to create a list of the number of markers to be used for this test. You must define a region in the video for each marker. Advance your video to the first frame where all the markers are visible. For each marker in the list, click on the marker # to highlight it. Next, click on Define Region and click and drag a box around the marker in the video. Click on Set Region to set the region for the highlighted marker to the box shown in the video. If the box is not in the desired position, you can click on Define Region again and re- drag the box to the appropriate location. Repeat the same steps to define a region for each of the markers.

For each reference marker, click on the icon in the Type column until the icon matches the orientation and style of the actual marker in the video. For instance, if the marker in the video is white in the upper-left corner and black in the upper-right corner, click on the icon in the Type column until the icon that is shown is also white in the upper-left corner and black in the upper-right corner.

If the reference marker is difficult to track due to poor lighting or poor background contrast, image processing can be used to enhance the appearance of each reference marker. Different image processing settings can be used for each marker. To adjust the image processing settings for a given marker, go to the Image Processing panel, adjust the brightness, contrast, etc. as needed. Then come back to the Reference Marker definition dialog shown above and re-define and set the region. Whatever image processing settings are currently active when the Set Re- gion button is clicked will be stored with that reference marker. You can change the image pro- cessing settings for a different marker and then set the region for that marker. To see the image processing settings that have been stored for each marker, click on the icon in the Show LUT column in the list of markers.

Once the number of reference markers has been set, the distance between the markers must be input. These distances define the calibration that will be used to convert measurements from pixels to real-world units. Independent scales can be used for the horizontal and vertical directions if necessary. To define the horizontal scale, select a marker number in the left drop-down list and select a marker number in the right drop-down list. Then input the distance between the two markers in millimeters. To define the vertical scale, select a marker number in the left drop-down list and select a marker number in the right drop-down list. Then input the distance between the two markers in millimeters. To use a single length scale for both horizontal and vertical directions, check the Use a single scale factor for both Horizontal and Vertical check- box. This will disable the Vertical Scale section, and the single length scale can be input where the Horizontal Scale is normally defined.

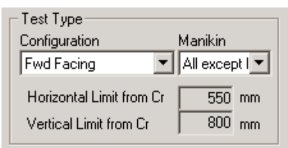
The origin of the coordinate frame is located where the vertical and horizontal portions of the seat join together. This point is referred to as the Cr point. The location of the Cr point is defined relative to the location of the reference markers. To set the horizontal position of the Cr point, enter the horizontal distance in millimeters and select the reference marker in the drop- down list. If the Cr point is to the left of the selected reference marker, enter a negative hori- zontal distance. To set the vertical position of the Cr point, enter the vertical distance in milli- meters and select the reference marker in the drop-down list. If the Cr point is below the selec- ted reference marker, enter a negative vertical distance.

After all settings are configured, click on Apply to apply the Reference Marker configuration to the Impact Excursion toolkit. In the Impact Excursion panel, click on Save in the Reference Marker Definition section to save the current Reference Marker configuration to a file. Reference marker configurations are stored to files with the `IER` file extension. Different configurations can be stored in different files and re-loaded to match the configuration being analyzed.

When the Impact Excursion toolkit is first enabled, an empty Reference Marker configuration is loaded. If a default Reference Marker configuration has been set, then the default configura- tion is loaded. To set the current configuration as the default, click on the Set Default button at the bottom of the Define Reference Markers dialog.

Test Type Configuration and Manikin Selection

After the Reference Markers have been defined, a test configuration and manikin must be selected. The list of configurations and manikins will increase as more standards are incorporated into the toolkit. The initial list of configurations and manikins contain values for the European Union R44 Safety Standard for child car seats. These standards include configurations for forward and rearward facing configurations and P10 or non-P10 manikins. Each of these configurations specifies the horizontal and vertical excursion limits which are displayed after the configuration is selected.



If you need additional configurations to be incorporated into the toolkit, please contact us with the appropriate information.

Top-Down Configurations

Top-down camera views are a special configuration for the Impact Excursion Toolkit. The typical test conditions have a side-view camera either fixed to the ground or moving with the sled. In some cases, users will use a top-down-view camera mounted on the ceiling in addition to the side-view camera. The Impact Excursion toolkit can also perform measurements using the top-down view.

In this configuration, since the camera is mounted above the crash test looking downward, typically a single scale factor is used for both the horizontal and vertical scales. In this case, when defining the Reference Markers, check the Use a single scale factor for both Horizontal and Vertical checkbox. Follow the same procedure to specify the other Reference Marker parameters.

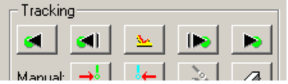
Under the Test Type Configuration in the Impact Excursion panel, be sure to select a Configuration that begins with "Top". When using a configuration beginning with "Top", the horizontal excursion tracking remains the same, but the vertical excursion tracking now becomes a second horizontal excursion measurement. The toolkit will now display the distance between the two horizontal tracked points for each frame. The diagonal measurements are disabled when using a top-down configuration.

User Defined Configurations

The User Defined and Top User Defined configuration selections allow you to enter values in the Horizontal Limit from Cr and Vertical Limit from Cr fields to create a custom configuration.

Automatic Tracking of Reference Markers

The Reference Markers must be tracked in order to define the calibration scales and to locate the Cr point. The Reference Markers are tracked automatically using the upper row of buttons in the Tracking section of the Impact Excursion panel.



To track the Reference Markers, advance to the first frame of the video where all reference markers are visible. When all Reference Markers are visible, click on the center button (icon showing a yellow sled and red chair) in the Tracking section of the panel. This will process the current frame of video and attempt to locate all defined Reference Markers. If all Reference Markers are found, the square regions will disappear and small circles will be placed on each Reference Marker, lines and distances between Reference Markers will be shown, the Cr point will be marked with an X, and horizontal and vertical excursion limits will be drawn with bold red lines.

To proceed with tracking the Reference Markers in future frames, click on the far right button in the Tracking section of the panel. This will continuously track the Reference Markers until you hit the button again to stop or when the end of the video is reached.

Manual Tracking of Crash Test Dummy Excursion

Once the Reference Markers have been automatically tracked, excursion data points can now be recorded. Since the appearance of the dummy and the background cannot always be con- trolled and portions of the dummy are often partially obscured, a reliable automatic scheme for determining the exact point of interest on the dummy is near impossible to create. Manual placement by an experienced user is the best method for reliable excursion measurement.

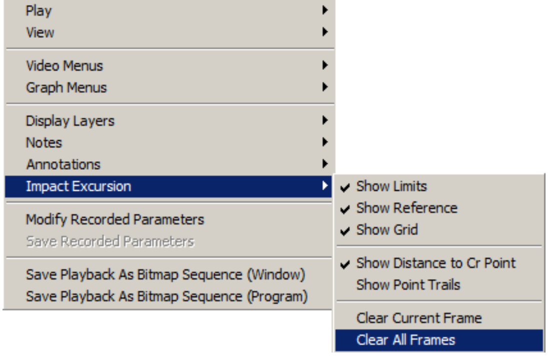
To manually track the crash test dummy excursion, use the play controls to move to the first frame of interest in the video. Place the reticle on the desired point on the crash test dummy where a measurement should be made and click on the first Manual button (red arrow with a vertical green line) shown below to place a horizontal measurement. Or click on the second button to place a vertical measurement (red arrow with a horizontal cyan line) or the third button to place a diagonal measurement (red arrow with a diagonal magenta line). The button icon colors match the colors that are used to draw the measurements in the video image.

The three Manual buttons are enabled or disabled according to the state of the corresponding checkboxes in the Measurements section of the Impact Excursion panel. If the Auto Advance Frame checkbox is checked, then when all the measurements are placed for a given frame, the video will automatically be advanced to the next frame.

There are keyboard shortcuts to place each of the three Manual measurements. After you have placed your reticle in the desired spot in the video, holding down **Control** + Left- Mouse-Button will set the horizontal measurement. Holding down **Control** + Right- Mouse-Button will set the vertical measurement. Holding down **ALT** + Left-Mouse-Button will set the diagonal measurement. With the Auto Advance Frame option checked, a user can quickly place all measurements for an entire video without moving the mouse outside of the video window.

Clearing Measurements

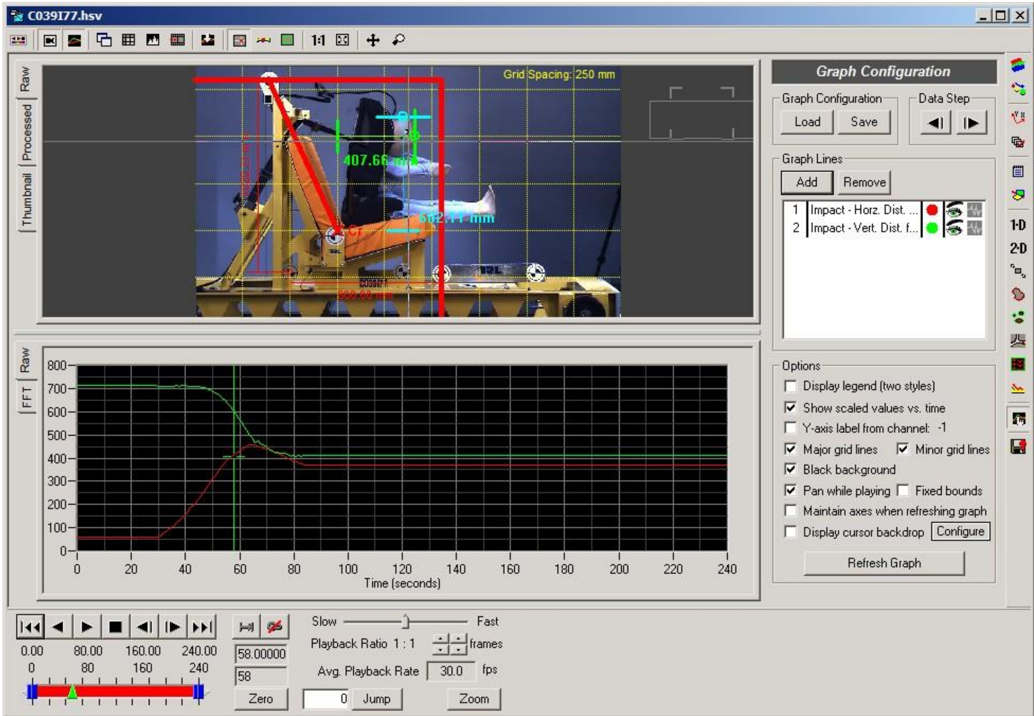
You can clear a single frame or all frames of measurements that have been produced by the analysis by using the context-menu. You can access the context-menu by clicking the right mouse button in the video window.



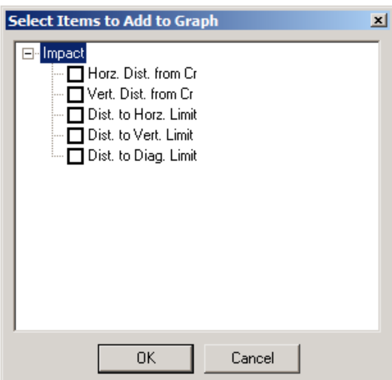
To clear tracked points and measurements from all frames of the video, select Clear All Frames from the context-menu. A dialog box will appear asking you to confirm your choice.

Graphing

Once your analysis is complete, a number of quantities can be graphed. Use the Graph Configuration control panel to add feature tracking results to the graph section.



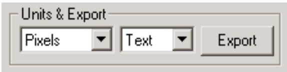
After clicking on the Add button, a listing of available items to graph is presented. Select the items that you wish to graph and click on the OK button at the bottom of the dialog.



For more details on configuring the other options in the Graph Configuration panel, see the section called “Display Settings”.

Units and Exporting

After a successful analysis is completed, you can export the data to a variety of formats to perform any additional custom analysis or graphing.



Units — You can select what set of units to use for exporting the tracking results. If no calibration has been done on the video, then this selection is ignored and the values are output in Pixels. If any graph lines are currently being displayed, they will be updated to use the newly selected units.

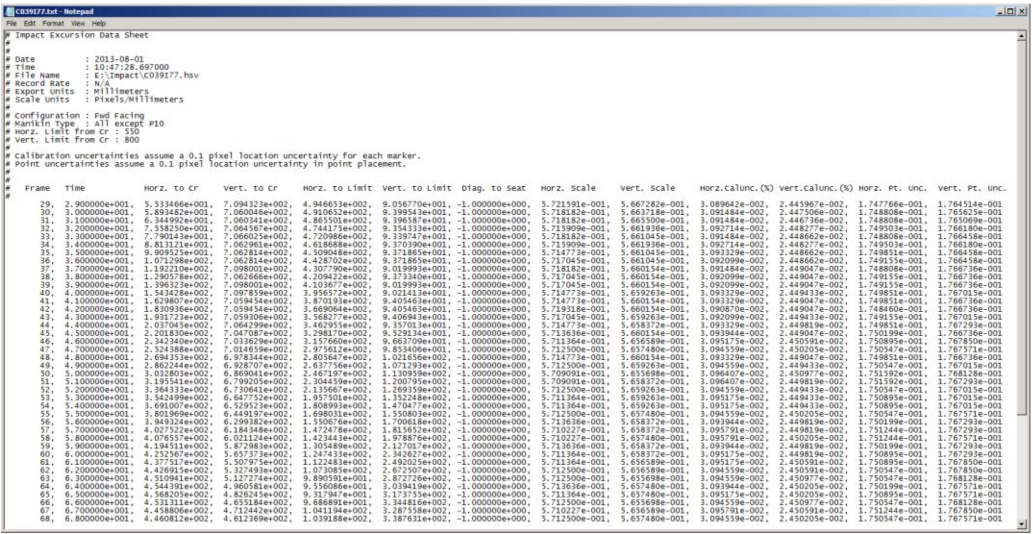
Format — You can select what format to export to: Text, Excel Blank, or Excel Template.

The analysis data is composed of the following information: frame number, time (if we know the record rate of the video), the horizontal distance to the Cr point, the vertical distance to the Cr point, the horizontal distance to the excursion limit, the vertical distance to the excursion limit, and the diagonal distance to the seat. In addition, the horizontal scale factor, the vertical scale factor, horizontal calibration uncertainty (%), vertical calibration uncertainty (%), horizontal point uncertainty, and vertical point uncertainty are displayed. If measurements for horizontal, vertical, and/or diagonal are not enabled, then -1 values are placed in those columns. The units for the distances are given by the Export Units shown in cell B13. The units for the scale factors are given by the Scale Units shown in cell B14. The calibration uncertainties are displayed as a percentage (0-100%). The units for the point uncertainties are given by the Export Units in cell B13.

Exporting to Excel Blank and Excel Template export the same data. However, Excel Template exports the data into an existing Excel file that is used as a template. You can put in any formulas and graphs into the template file, and these will be recomputed and regenerated when the new data is exported into it.

Export — When you are satisfied with your analysis results, and have selected your export units and format, click on the Export button to export the results.

See the section called “Exporting Data or Analyses” for additional details regarding exporting. An example of a text export is shown below.



C039I77.txt - Notepad

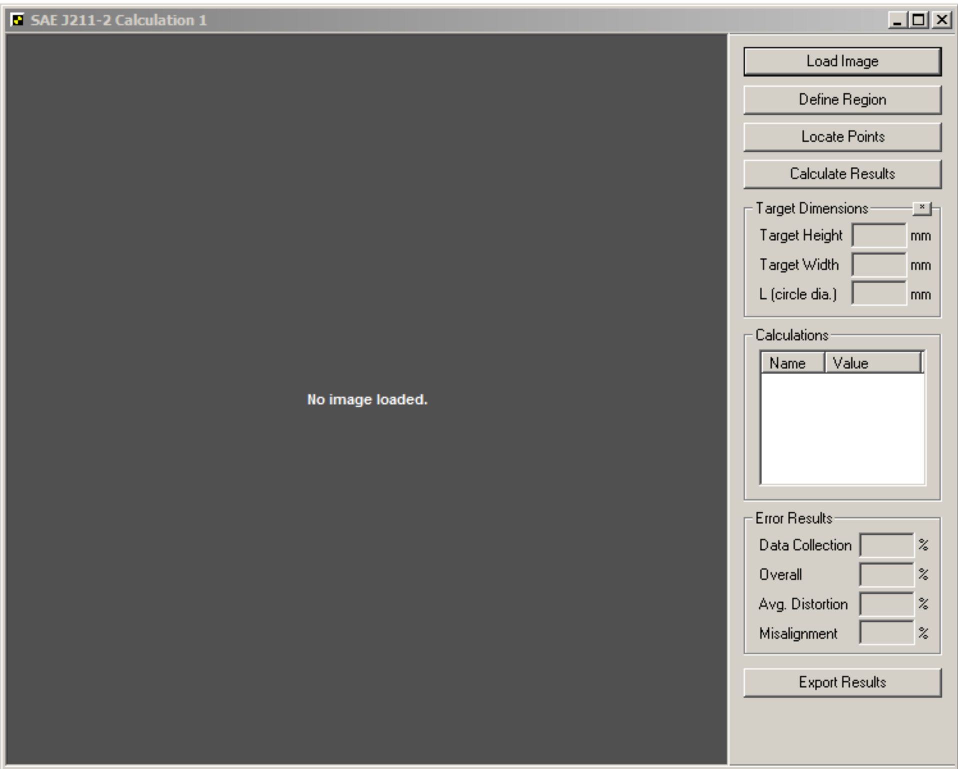
File Edit Format View Help

\# Impact Excursion Data Sheet
\#
\#
\# Date : 2013-08-01
\# Time : 10:47:28.697000
\# File Name : E:\Impact\C039I77.hsv
\# Record Rate : N/A
\# Export Units : Millimeters
\# Scale Units : Pixels/Millimeters
\#
\# Configuration : Fwd Facing
\# Manikin Type : All except P10
\# Horz. Limit from Cr : 550
\# Vert. Limit from Cr : 800
\#
\# Calibration uncertainties assume a 0.1 pixel location uncertainty for each marker.
\# Point uncertainties assume a 0.1 pixel location uncertainty in point placement.
\#
\#

Frame	Time	Horz. to Cr	Vert. to Cr	Horz. to Limit	Vert. to Limit	Diag. to Seat	Horz. Scale	Vert. Scale	Horz.CalUnc.(%)	Vert.CalUnc.(%)	Horz. Pt. Unc.	Vert. Pt. Unc.
29	2.900000e+001	5.533466e+001	7.094323e+002	4.946653e+002	9.056770e+001	-1.000000e+000	5.721591e-001	5.667282e-001	3.089642e-002	2.445967e-002	1.747766e-001	1.764514e-001
30	3.000000e+001	5.893482e+001	7.060046e+002	4.910652e+002	9.399543e+001	-1.000000e+000	5.718182e-001	5.663718e-001	3.091484e-002	2.447506e-002	1.748808e-001	1.765625e-001
31	3.100000e+001	6.344992e+001	7.060341e+002	4.865501e+002	9.396587e+001	-1.000000e+000	5.718182e-001	5.665500e-001	3.091484e-002	2.446736e-002	1.748808e-001	1.765069e-001
32	3.200000e+001	7.558250e+001	7.064567e+002	4.744175e+002	9.354333e+001	-1.000000e+000	5.715909e-001	5.661936e-001	3.092714e-002	2.448277e-002	1.749503e-001	1.766180e-001
33	3.300000e+001	7.790143e+001	7.066025e+002	4.720986e+002	9.339747e+001	-1.000000e+000	5.718182e-001	5.661045e-001	3.091484e-002	2.448662e-002	1.748808e-001	1.766458e-001
34	3.400000e+001	8.813121e+001	7.062961e+002	4.618688e+002	9.370390e+001	-1.000000e+000	5.715909e-001	5.661936e-001	3.092714e-002	2.448277e-002	1.749503e-001	1.766180e-001
35	3.500000e+001	9.909525e+001	7.062814e+002	4.509048e+002	9.371865e+001	-1.000000e+000	5.714773e-001	5.661045e-001	3.093329e-002	2.448662e-002	1.749851e-001	1.766458e-001
36	3.600000e+001	1.071298e+002	7.062814e+002	4.428702e+002	9.371865e+001	-1.000000e+000	5.717045e-001	5.661045e-001	3.092099e-002	2.448662e-002	1.749155e-001	1.766458e-001
37	3.700000e+001	1.192210e+002	7.098001e+002	4.307790e+002	9.019993e+001	-1.000000e+000	5.718182e-001	5.660154e-001	3.091484e-002	2.449047e-002	1.748808e-001	1.766736e-001
38	3.800000e+001	1.290578e+002	7.062666e+002	4.209422e+002	9.373340e+001	-1.000000e+000	5.717045e-001	5.660154e-001	3.092099e-002	2.449047e-002	1.749155e-001	1.766736e-001
39	3.900000e+001	1.396323e+002	7.098001e+002	4.103677e+002	9.019993e+001	-1.000000e+000	5.717045e-001	5.660154e-001	3.092099e-002	2.449047e-002	1.749155e-001	1.766736e-001
40	4.000000e+001	1.543428e+002	7.097859e+002	3.956572e+002	9.021413e+001	-1.000000e+000	5.714773e-001	5.659263e-001	3.093329e-002	2.449433e-002	1.749851e-001	1.767015e-001
41	4.100000e+001	1.629807e+002	7.059454e+002	3.870193e+002	9.405463e+001	-1.000000e+000	5.714773e-001	5.660154e-001	3.093329e-002	2.449047e-002	1.749851e-001	1.766736e-001
42	4.200000e+001	1.830936e+002	7.059454e+002	3.669064e+002	9.405463e+001	-1.000000e+000	5.719318e-001	5.660154e-001	3.090870e-002	2.449047e-002	1.748460e-001	1.766736e-001
43	4.300000e+001	1.931723e+002	7.059306e+002	3.568277e+002	9.406943e+001	-1.000000e+000	5.717045e-001	5.659263e-001	3.092099e-002	2.449433e-002	1.749155e-001	1.767015e-001
44	4.400000e+001	2.037045e+002	7.064299e+002	3.462955e+002	9.357013e+001	-1.000000e+000	5.714773e-001	5.658372e-001	3.093329e-002	2.449819e-002	1.749851e-001	1.767293e-001
45	4.500000e+001	2.201830e+002	7.047087e+002	3.298170e+002	9.529134e+001	-1.000000e+000	5.713636e-001	5.660154e-001	3.093944e-002	2.449047e-002	1.750199e-001	1.766736e-001
46	4.600000e+001	2.342340e+002	7.033629e+002	3.157660e+002	9.663709e+001	-1.000000e+000	5.711364e-001	5.656589e-001	3.095175e-002	2.450591e-002	1.750895e-001	1.767850e-001
47	4.700000e+001	2.524388e+002	7.014659e+002	2.975612e+002	9.853406e+001	-1.000000e+000	5.712500e-001	5.657480e-001	3.094559e-002	2.450205e-002	1.750547e-001	1.767571e-001
48	4.800000e+001	2.694353e+002	6.978344e+002	2.805647e+002	1.021656e+002	-1.000000e+000	5.714773e-001	5.660154e-001	3.093329e-002	2.449047e-002	1.749851e-001	1.766736e-001
49	4.900000e+001	2.862244e+002	6.928707e+002	2.637756e+002	1.071293e+002	-1.000000e+000	5.712500e-001	5.659263e-001	3.094559e-002	2.449433e-002	1.750547e-001	1.767015e-001
50	5.000000e+001	3.032803e+002	6.869041e+002	2.467197e+002	1.130959e+002	-1.000000e+000	5.709091e-001	5.655698e-001	3.096407e-002	2.450977e-002	1.751592e-001	1.768128e-001
51	5.100000e+001	3.195541e+002	6.799205e+002	2.304459e+002	1.200795e+002	-1.000000e+000	5.709091e-001	5.658372e-001	3.096407e-002	2.449819e-002	1.751592e-001	1.767293e-001
52	5.200000e+001	3.364333e+002	6.730641e+002	2.135667e+002	1.269359e+002	-1.000000e+000	5.712500e-001	5.659263e-001	3.094559e-002	2.449433e-002	1.750547e-001	1.767015e-001
53	5.300000e+001	3.542499e+002	6.647752e+002	1.957501e+002	1.352248e+002	-1.000000e+000	5.711364e-001	5.659263e-001	3.095175e-002	2.449433e-002	1.750895e-001	1.767015e-001
54	5.400000e+001	3.691007e+002	6.529523e+002	1.808993e+002	1.470477e+002	-1.000000e+000	5.711364e-001	5.659263e-001	3.095175e-002	2.449433e-002	1.750895e-001	1.767015e-001
55	5.500000e+001	3.801969e+002	6.449197e+002	1.698031e+002	1.550803e+002	-1.000000e+000	5.712500e-001	5.657480e-001	3.094559e-002	2.450205e-002	1.750547e-001	1.767571e-001
56	5.600000e+001	3.949324e+002	6.299382e+002	1.550676e+002	1.700618e+002	-1.000000e+000	5.713636e-001	5.658372e-001	3.093944e-002	2.449819e-002	1.750199e-001	1.767293e-001
57	5.700000e+001	4.027522e+002	6.184348e+002	1.472478e+002	1.815652e+002	-1.000000e+000	5.710227e-001	5.658372e-001	3.095791e-002	2.449819e-002	1.751244e-001	1.767293e-001
58	5.800000e+001	4.076557e+002	6.021124e+002	1.423443e+002	1.978876e+002	-1.000000e+000	5.710227e-001	5.657480e-001	3.095791e-002	2.450205e-002	1.751244e-001	1.767571e-001
59	5.900000e+001	4.194511e+002	5.872983e+002	1.305489e+002	2.127017e+002	-1.000000e+000	5.713636e-001	5.658372e-001	3.093944e-002	2.449819e-002	1.750199e-001	1.767293e-001
60	6.000000e+001	4.252567e+002	5.657373e+002	1.247433e+002	2.342627e+002	-1.000000e+000	5.711364e-001	5.658372e-001	3.095175e-002	2.449819e-002	1.750895e-001	1.767293e-001
61	6.100000e+001	4.377517e+002	5.507975e+002	1.122483e+002	2.492025e+002	-1.000000e+000	5.711364e-001	5.656589e-001	3.095175e-002	2.450591e-002	1.750895e-001	1.767850e-001
62	6.200000e+001	4.426915e+002	5.327493e+002	1.073085e+002	2.672507e+002	-1.000000e+000	5.712500e-001	5.656589e-001	3.094559e-002	2.450591e-002	1.750547e-001	1.767850e-001
63	6.300000e+001	4.510941e+002	5.127274e+002	9.890591e+001	2.872726e+002	-1.000000e+000	5.712500e-001	5.655698e-001	3.094559e-002	2.450977e-002	1.750547e-001	1.768128e-001
64	6.400000e+001	4.544391e+002	4.960581e+002	9.556086e+001	3.039419e+002	-1.000000e+000	5.713636e-001	5.657480e-001	3.093944e-002	2.450205e-002	1.750199e-001	1.767571e-001
65	6.500000e+001	4.568205e+002	4.826245e+002	9.317947e+001	3.173755e+002	-1.000000e+000	5.711364e-001	5.657480e-001	3.095175e-002	2.450205e-002	1.750895e-001	1.767571e-001
66	6.600000e+001	4.531311e+002	4.655184e+002	9.686891e+001	3.344816e+002	-1.000000e+000	5.712500e-001	5.655698e-001	3.094559e-002	2.450977e-002	1.750547e-001	1.768128e-001
67	6.700000e+001	4.458806e+002	4.712442e+002	1.041194e+002	3.287558e+002	-1.000000e+000	5.710227e-001	5.656589e-001	3.095791e-002	2.450591e-002	1.751244e-001	1.767850e-001
68	6.800000e+001	4.460812e+002	4.612369e+002	1.039188e+002	3.387631e+002	-1.000000e+000	5.712500e-001	5.657480e-001	3.094559e-002	2.450205e-002	1.750547e-001	1.767571e-001

SAE J211-2 Calculation Tool

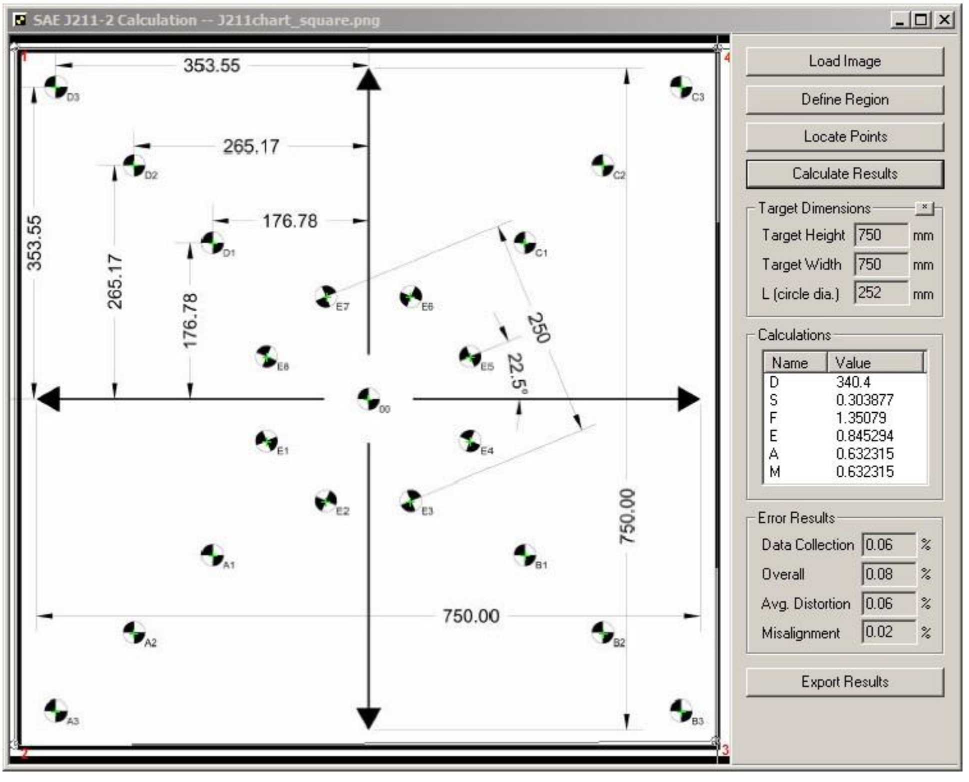
The SAE J211-2 Calculation Tool can be accessed from the main menu bar under Tools and then select SAE J211-2 Calculation.



To perform this calculation, an image of a J211-2 target pattern is required. The resulting calculations computed from this tool are only applicable to the SAE J211-2 target image that is loaded. If a different target image is used, another calculation must be performed.

To perform the calculation:

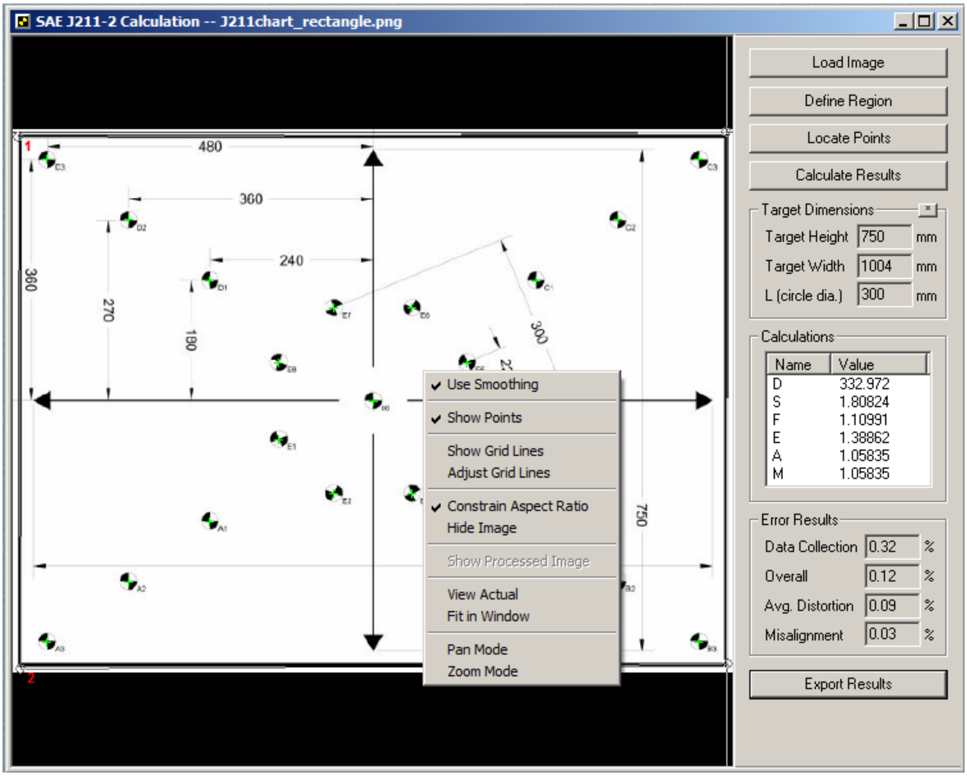
1. Capture an image of an SAE J211-2 target pattern that will be used in testing.
2. Click on Load Image and select the target pattern image file (PNG, BMP, TIFF, or JPEG).
3. Click Define Region and click the left mouse button on the four corners of the black rectangle that encloses the target pattern.
4. If you would like to redraw the region, click Define Region again and reselect the four points.
5. Click Locate Points. You will see a Processing message flashing in the lower left corner of the window. When processing is complete, green points are displayed at the target midpoints.
6. To calculate, click the Calculate Results button to display the target dimensions, calculations, and error results.



If you wish to override the computed target dimensions, click the button at the right side of the Target Dimensions panel. The Override Dimensions window appears, and you may enter new values for Target Height, Target Width, and Spacing. Click OK, then click Calculate Res- ults again to apply the new dimensions and display updated results.

The results of the calcuation can be exported to a text file for further reference. Click the Ex- port Results button.

If you encounter difficulties performing the calculation, there are a number of tools available via the context-menu.



Use Smoothing	Applies a smoothing filter on the image before attempting to locate targets.
Show Points	Show the green markers for the target midpoints.
Show Grid Lines	Show grid lines over the image. These lines can be used to manually set the target dimensions using trial and error. Lines that should be straight in the image can be compared to the grid lines to determine the effectiveness of the correc- tion.
Adjust Grid Lines	The grid lines that are displayed over the image can be ad-

	justed to produce an inclined, non-perpendicular set of lines. Select this option and then click the left mouse button and drag the mouse in the image to adjust the grid lines.
Constrain Aspect Ratio	The image is normally shown with the normal aspect ratio of the native image. The image can also be displayed with an unconstrained aspect ratio by checking this item. This option can be very useful in determining if a row of points is straight by adjusting the window size to produce a skinny and tall image or a short and wide image.
Hide Image	Check this option to hide the original image. This option is useful when you only wish to see the located and corrected point markers. This option is often used in combination with unconstraining the aspect ratio.
Show Processed Image	This option can be checked to show the processed image that is analyzed to locate the target midpoints. If you are having difficulty in locating corners, you can examine the processed image and see what portions of the image are creating difficulties for the automatic location scheme.
View Actual	Show the image at the actual image resolution.
Fit in Window	Set the zoom so that the entire image is shown.
Pan Mode	Select this mode to pan the image by clicking and dragging using the left mouse button.
Zoom Mode	Select this mode to zoom the image by clicking and dragging using the left mouse button.

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