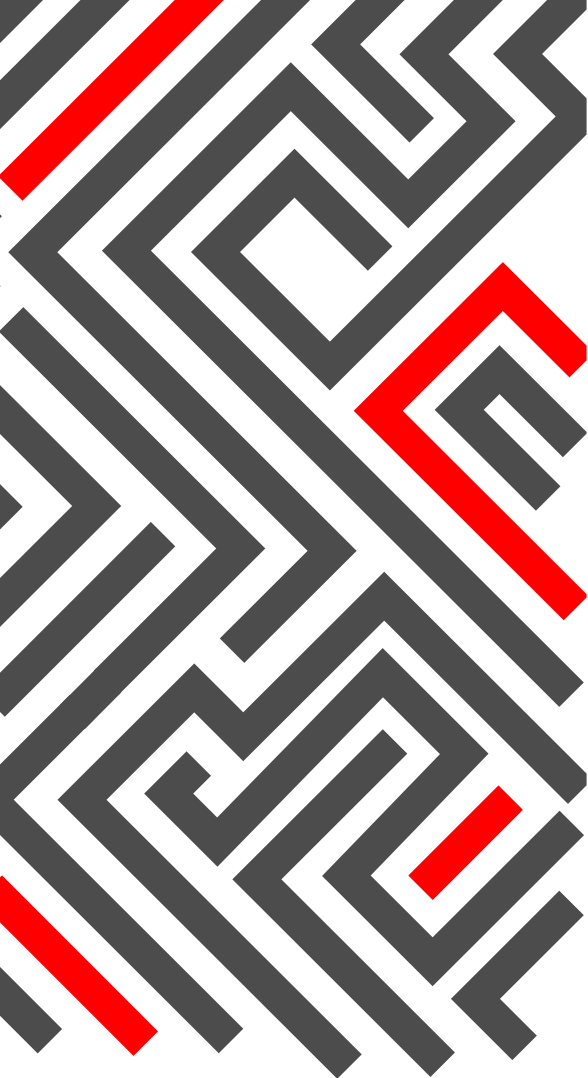




MERCURY RT

Reference Handbook

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1. BRIEF OVERVIEW

Welcome to MERCURY RT, your advanced solution for material property analysis through the cutting-edge DIC (Digital Image Correlation) method. MERCURY RT is designed to provide precise, contactless deformation measurements with both online data acquisition and processing capabilities.

MERCURY RT Core Features:

- ❖ **Material Testing:** Evaluate material properties with high precision.
- ❖ **Component Testing:** Analyze the behavior of various components under different conditions.
- ❖ **Finite Element Analysis (FEA) Validation:** Validate FEA results with real-world deformation data.
- ❖ **Flow/Motion Field Measurement:** Understand and visualize the flow or motion fields in your experiments.
- ❖ **Vibrography:** Study vibrations and oscillations in structures.
- ❖ **Test Rig Control:** Have control over your test rig for comprehensive experiments.

This manual delves into the details of the MERCURY RT contactless measuring system. If you're looking for a quick setup and getting started guide, we recommend checking out the "Getting Started" guide before diving into this comprehensive reference handbook.

2. MAIN WINDOW

The **main window** is used to visualise the calculated data using graphs and highlighted fields with numerical values. Other key features include real-time display of measurements on a connected test machine and controls for starting and stopping a measurement.

The **main menu** at the top of the main window provides essential project management functions such as creating, loading and saving projects, import and export options, as well as application specific tools, settings and help.

As shown in Figure 1, the main window consists of several distinct parts.

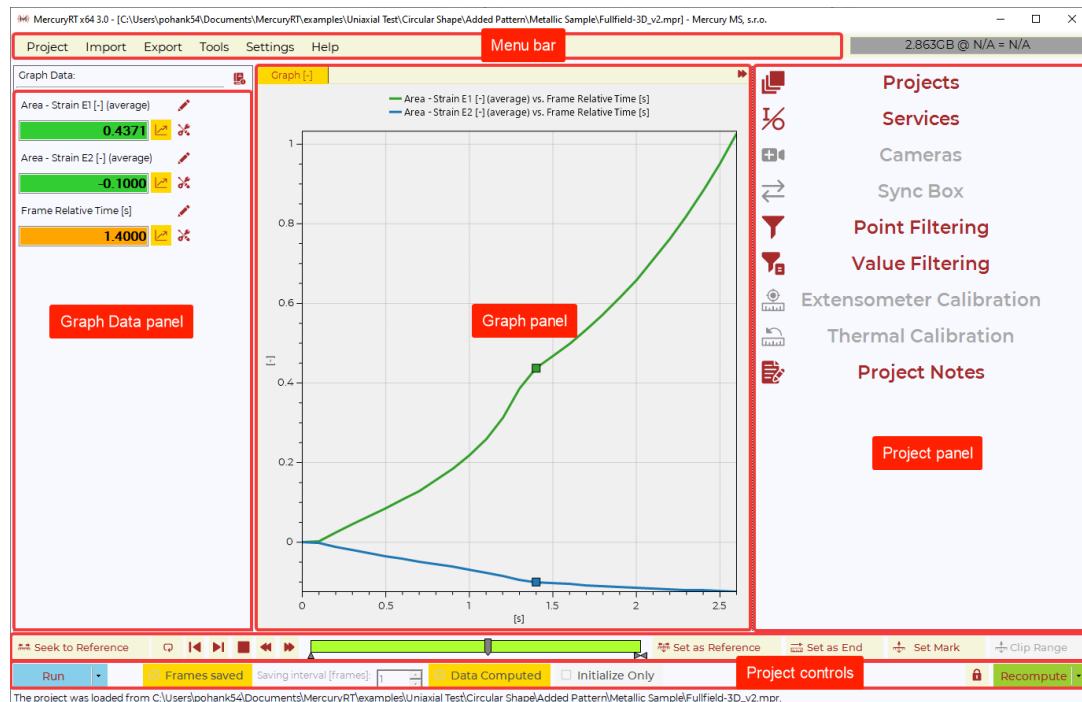


Figure 1: Main Window

2.1. MENU BAR

The **menu bar** is located at the top of the main window and contains the following items:

- ❖ **Project** – Offers a drop-down menu with **New**, **Load**, **Save**, **Save as**, **Close** and **Exit** options.
 - In the **New** tab, it is available to create either a **Real-time Measurement**, a **Real-time Extensometer Calibration**, a **Real-time Thermal Calibration**, and create a project From **Existing Images**, **Existing Video Files**, an **Existing Project Data Structure** or to create a **Testing Machine Controller** (when the testing machine is activated). A real-time measurement requires one or more connected cameras, whereas an offline measurement needs previously recorded images or videos. See section 2.2 for details.
 - **Load** – Loads a previously configured or recorded project from a specified directory.
 - **Save** – Saves the currently open project. This is also done automatically at several critical points, such as starting or stopping a measurement.

- **Save As** – Copies the currently open project to a different location. See 2.2.1 for details.
- **Close** – Closes the currently open project.
- **Recent Projects** – Lists the most recently opened projects.
- **Reinit Cameras** – Discards the information about the currently connected cameras and initialises them again the same way they are processed at program startup. This can be useful when the configuration of cameras changes or when some of them were in an invalid state during detection.
- **Exit** – Quits the application.
- ❖ **Import** – Imports data into the currently open project. A more detailed description can be found in chapter 4.
- ❖ **Export** – Exports a configurable amount of measured and computed data into files of various commonly used formats such as CSV, HDF5, PDF or STL. Further information can be found in chapter 5.
- ❖ **Tools** – Offers post-processing tools for **Vibrography**, **CAD/FEA** and **FLC/FLD** analyses. An option to **Create LiteView Shortcut** is also located here. See chapter 6 and Appendix A for detailed information.
- ❖ **Settings** – Contains a drop-down menu with access to the following sections:
 - **System** – Opens the window for the adjustment of settings applied regardless of the project currently open. See chapter 7.1 for details.
 - **Presentation** – Opens the window for the adjustment of settings, which are only related to the open project and set how the computed data are presented in the UI. See chapter 7.2 for details.
 - **Computation** – Opens the window for the adjustment of settings, which are only related to the open project and set how the data are computed. See chapter 7.3 for details.
 - **Change Password** – Opens the window for changing a password.
- ❖ **Help** – Offers a drop-down menu with these options:
 - **Examples** – Opens a browser of available examples demonstrating the capabilities of MERCURY RT. See chapter 8 for details.
 - **Check for Updates** – Checks for the latest version of the software.
 - **Request License** – Opens the window for requesting a new license.
 - **Upgrade License** – Allows loading a different license file.
 - **View Help** – Opens the reference handbook (this document) of the MERCURY RT.
 - **About** – The About dialogue is shown in Figure 2 and displays the information about the version of the software and the active license.

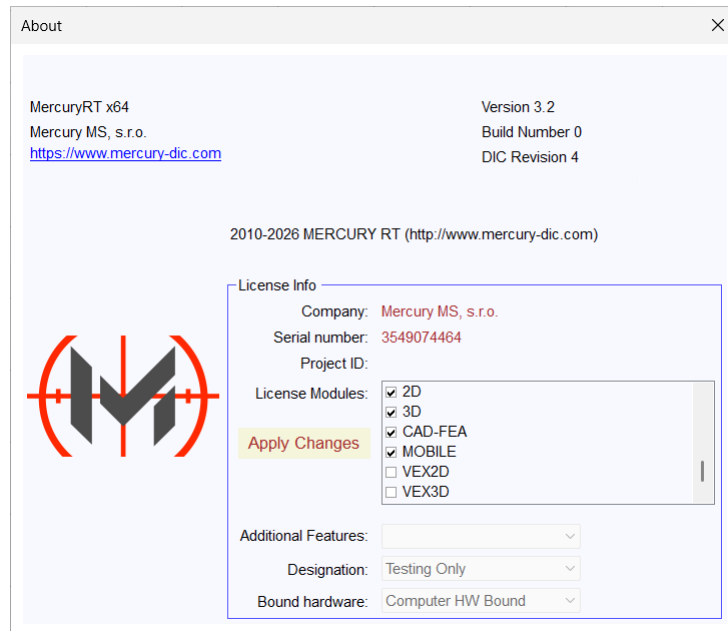


Figure 2: About Window

- ❖ **Disk space status viewer** – Situated in the upper-right corner of the main window, where it serves as an indicator of the disk space at the location of the stored data. Indicates the remaining space, the current data flow and the time left until there is no space available.

2.2. PROJECT CREATION

When preparing a new measurement, a new project needs to be created first. This is done by clicking **Project -> New** in the menu bar, as seen in Figure 3. From the drop-down menu, choose one of the available options. The project name and its location are set right afterwards.

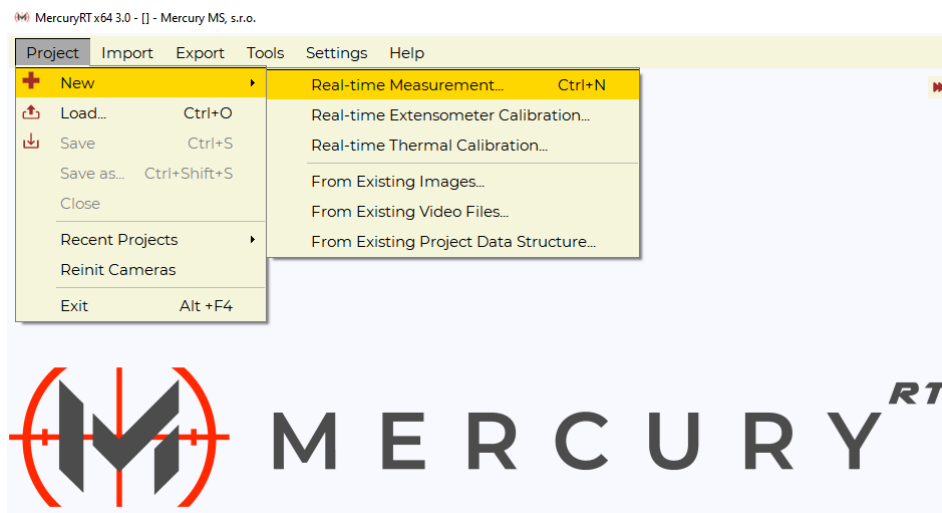


Figure 3: New Project Creation

The second dialogue offers a choice between the categories **Mono Cameras**, **Stereo Cameras**, **Stitched Mono Cameras** and **Stitched Stereo Cameras**, as seen in Figure 4. The scene layouts can be combined as desired, allowing, for example, a project with a single stereo and two mono cameras. When creating a project for a real-time measurement or an extensometer or thermal calibration, only the active cameras are available in the corresponding column. If the desired cameras are not visible, an adjustment needs to be made in **System Settings** under **Active Camera Libraries** (see 7.1.1).

By dragging the requested cameras to the right column, they are selected to comprise a layout for a new scene in the created project. The selected cameras may be deselected by dragging them to the bin in the bottom-right corner.

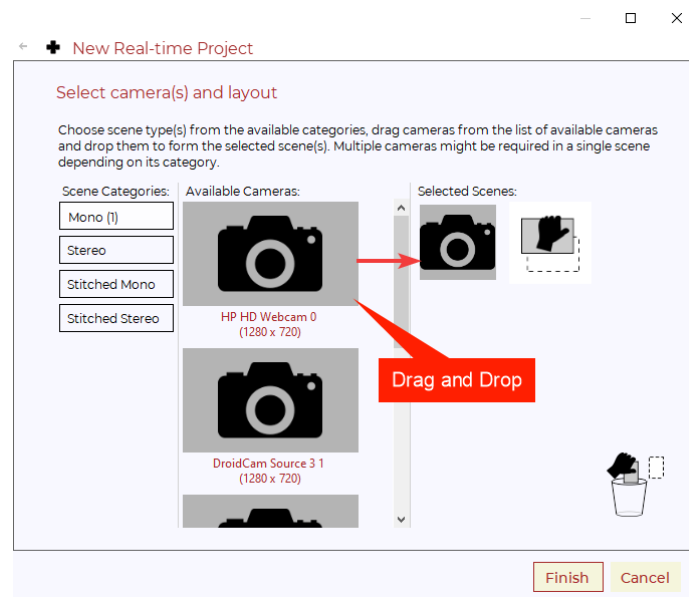


Figure 4: New Project window of real-time measurement

Concerning creating scenes, it is essential to note that when using **high-speed cameras**, it is not possible to combine them with other kinds of cameras in a single scene. Likewise, when using **thermal cameras**, it is only possible to create scenes with a single thermal camera in mono mode. The messages displayed by the wizard ensure the enforcement of these constraints. When multiple cameras are selected for a particular scene, an additional page appears in the wizard (see Figure 5). This dialogue is used for choosing blocking cameras. All blocking cameras run at the FPS of the slowest blocking camera and faster cameras may drop images if not synchronized. This option is typically used for measurements when all cameras have similar FPS. Unchecked (non-blocking) cameras do not slow down any other blocking or non-blocking cameras. Images from slower cameras may be repeated to keep consistency. This option is useful for non-measurement purposes.

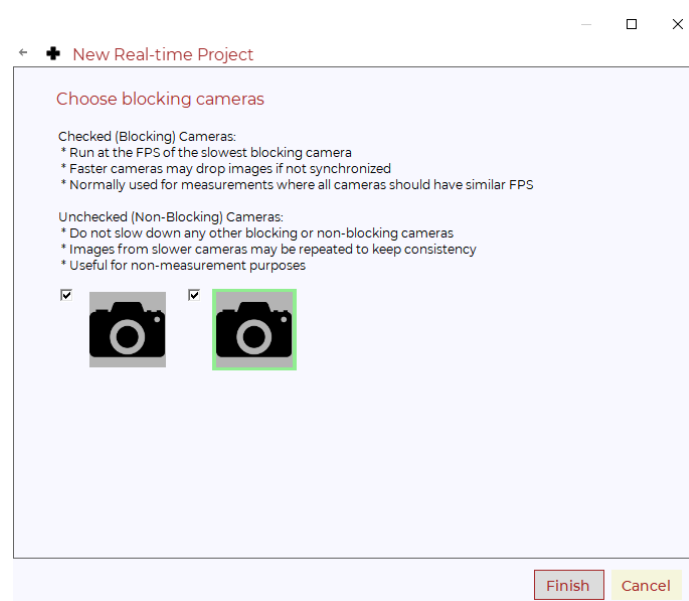


Figure 5: Choose blocking cameras page.

Additionally, when a stitched stereo scene is selected, another page appears at the end of the wizard, where the field of view of these cameras must be specified (see Figure 6). Further information is displayed right on the page itself. Connected cameras do not have to be of the same arrangement as presented in the images shown in Figure 6. It is only important that there should be pairs of neighbouring cameras, which share a field of view and may, therefore, be calibrated together. The setting of whether the cameras form a **Partial** or **Full Circle** is only important to specify to determine whether the last camera is neighbouring to the first or not.

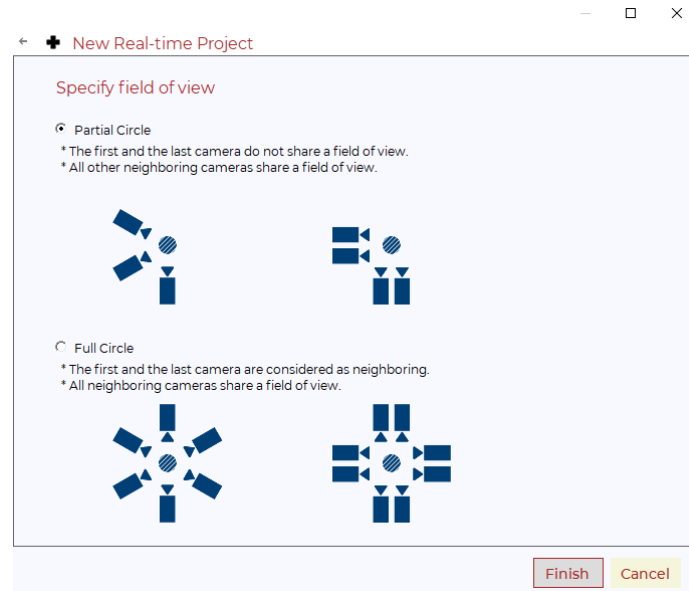


Figure 6: Specify field of View Page.

Provided that an offline measurement is required, images, videos or MERCURY RT projects are loaded from a specified directory. When one of the cases **From Existing Images.../From Existing Video files.../From Existing Data Structure...** is chosen, a dialogue similar to the one in Figure 7 opens, after saving the project file. This dialogue contains an additional **Browse** button shown in Figure 7, which is used to browse and select the required images, video files or an existing data structure. In the case of images, the entire directory containing image data is selected this way, but this behaviour can be changed by toggling the **Select specific images** option below. The other option **Copy Images to Project Directory** determines whether to keep the selected images only in their original location or to make a local copy for the new project. Once the images, video files or data structures are selected, new offline cameras are made available, and they can be manipulated similarly to online cameras.

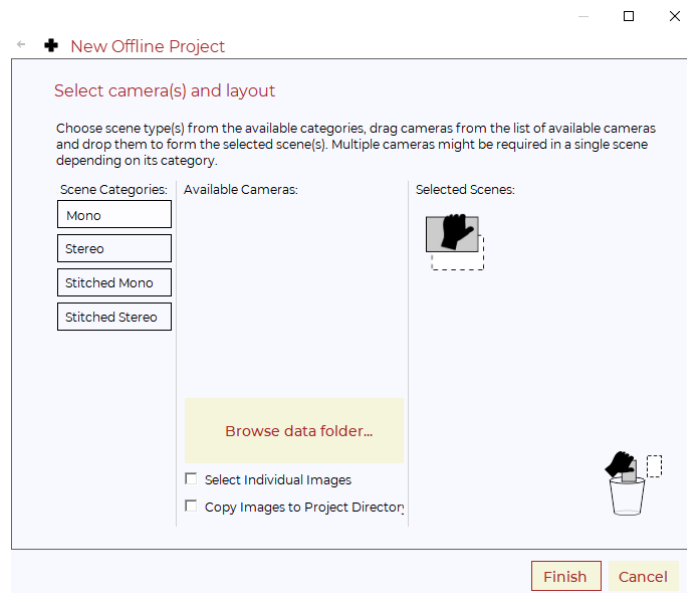


Figure 7: The Browse button with Options.

Whenever a new project from existing images, video files or data structure is being created, there is another additional page, which appears as displayed in Figure 8. It allows specifying the acquisition times of imported data by either inputting the FPS value with which the camera was running or by loading a MERCURY RT project file containing the exact acquisition times.

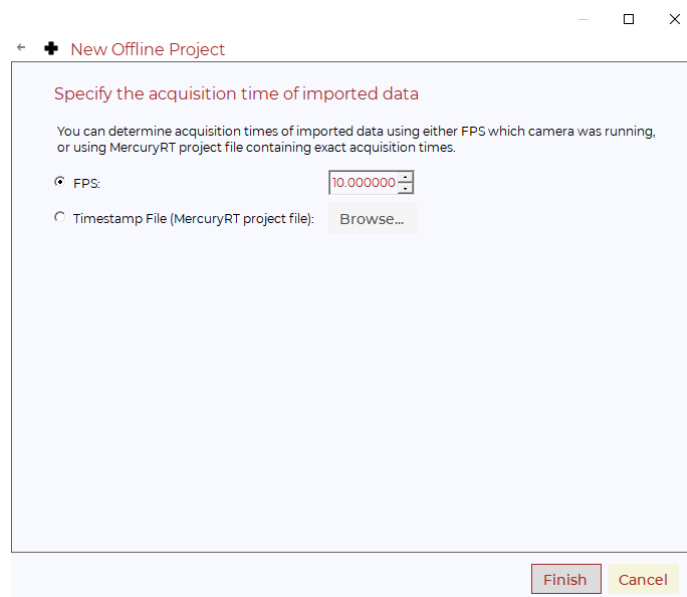


Figure 8: Second dialogue, creation of a new project from existing images.

2.2.1. Save As

By clicking the **Project/Save As** button, a dialogue window seen in Figure 9 opens, prompting a name of a new measurement. The recorded camera images in the open measurement can be reused in the new measurement. In this instance, the new measurement contains either the relative paths of the reused images (if they are located in the directory of the project or its subdirectory) or their absolute paths. The first option creates an empty measurement. All probes, calibrations, coordinate systems and other settings are copied to the new measurement in both cases. The same functionality is

available through the **Copy Project** button marked by the plus sign icon in the **Projects Panel** on the right of the main window.

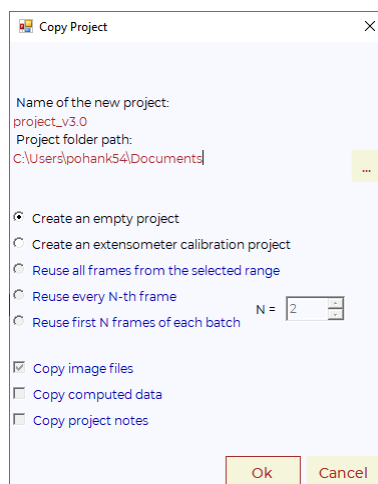


Figure 9: Copy Project dialogue.

2.3. PROJECT PANEL

The **project panel** is situated on the right of the main window, as seen in Figure 1. It provides the means of control over the current project as well as the configuration of external devices and such (Projects, Test. Machine, Services, Cameras, Sync Box, Point Filtering, Value Filtering, Extensometer Calibration, Thermal Calibration and Project Notes).

2.3.1. Projects

This menu in the Project panel primarily provides a list of projects associated with the current one due to being located in the same directory. Clicking on the items in this list switches the currently open project to the selected one. The current project also shows the number of captured frames, as well as the number of batches, among which these frames are logically distributed. Figure 10 describes three buttons for advanced project management located below this list. By using these buttons, projects may be copied, renamed and deleted. To copy a project represents the same functionality as **Project/Save As**.

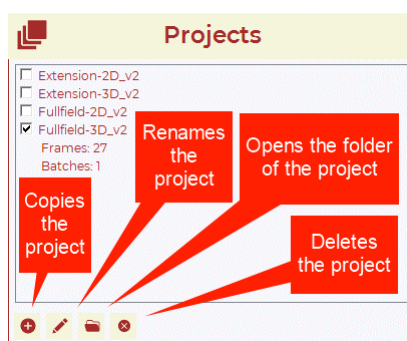


Figure 10: Projects tab in the Project Panel

2.3.2. Test. Machine

When Testing Machine is enabled, the Test Machine panel represents an option of the panel to control DOLI DoPE driven testing machines or just display data from analogue/digital inputs in the case of an absence of a testing machine. For a detailed description of the configuration of a testing machine and its control, see chapter 9.

2.3.3. Services

MERCURY RT is capable of receiving commands and sending specified values of measured quantities through various analogue and digital channels. The **I/O Services panel** handles the creation of **I/O services** and allows their management. See chapter 10 for more details.

2.3.4. Cameras

Contains a panel for control over camera synchronisation and access to a high-speed recording tool (where applicable). See chapters 13 and 14 for details.

2.3.5. Sync Box

Provides the real-time input of a camera synchronisation box if such a device is available. See chapter 13.3 for detailed information.

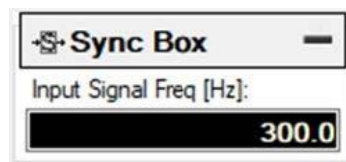


Figure 11: Sync Box tab in the Project Panel

2.3.6. Point Filtering

Enables the filtering of data during computation. The offered filter types are averaging, Gaussian smoothing, batches averaging and polynomial fitting (linear, quadratic or cubic). Batches averaging means that if data is recorded in batches, only the individual batches are averaged. The items contained in this panel are the same as the respective parameters in **Computation Settings** under **Point Filtering** (see 7.3.6).

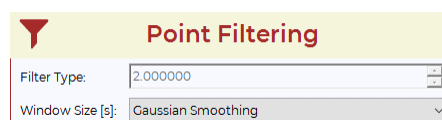


Figure 12: Point Filtering tab in the Project Panel

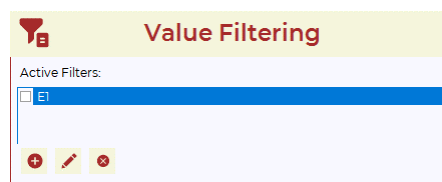


Figure 13: Value Filtering tab in the Project Panel

2.3.7. Value Filtering

Enables the filtering of data after the computation is done. The available functions are average, minimum, maximum, median and standard deviation. Any number of available values may be selected for filtering with the specified function, and the filter is created by clicking the **Accept** button below. The settings of a value filter are related to values with given names, so they are no longer valid when the corresponding probes or series are renamed. The created filters are available in all projects, but the configuration of which of

these are active in a project is saved with the project data. All filters are disabled in a new project.

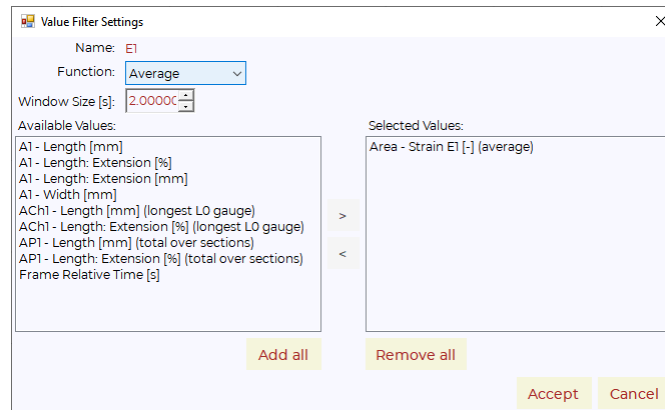


Figure 14: Value Filter settings dialog

2.3.8. Extensometer Calibration

Enables performing the correction of calibration through inputting values from an external gauge. This panel is only available in an extensometer calibration project. For detailed information, see chapter 11.

2.3.9. Thermal Calibration

Enables to assign the values of deformation to their corresponding temperatures retrieved by a thermal camera. This panel is only available in a thermal calibration project. For detailed information, see chapter 12.

2.3.10. Project Notes

Enables to insert of a custom description of samples and tests associated with the project. This does not have any effect on the computation, only serves for informational purposes and can also be included in generated reports.

2.4. PROJECT CONTROLS

The panel of project controls seen in Figure 15 provides the most necessary controls for data acquisition, performing computations with these data and browsing recorded data.

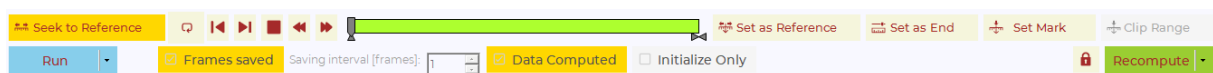


Figure 15: Panel of project controls with already recorded and computed data

The controls are explained as follows:

- ❖ **Project Seeker** (Figure 16) – Seeks in the recorded data. Changing the position of the current frame updates the image(s) displayed in the camera view(s) and causes the highlighting of measured values in graphs. The positions of the reference frame and the end frame are shown as vertical lines with arrow pointers. The green range shows the amount of computed data. The yellow range (not displayed in the picture) means that some of the frames were not computed although they are written to disk. The light-blue range, which may be overlapping with the green range, also specifies the range of frames for recomputation, the recording of video files (available through the corresponding control in the **camera view controls** of the **scene window**, see 3.1) and vibrography analysis (see 6).

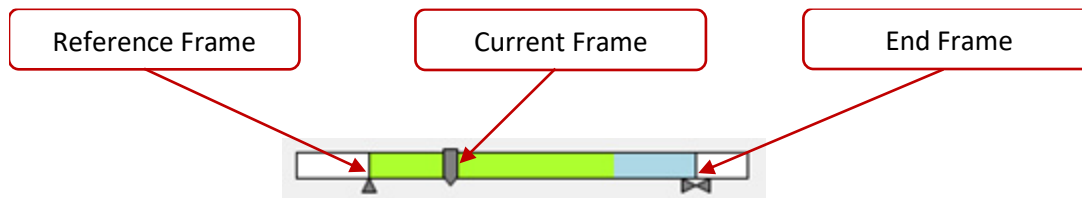


Figure 16: The Project Seeker

- ❖ **Seek to Reference** – Moves the seek slider to the position of the reference image(s) and displays it/them in the corresponding camera view(s). Pressing this button once again will instead move the slider to the position of the last displayed image(s).
- ❖ **Recorded Data Player** (Figure 17) – Plays the recorded data in different ways:
 - **Backplay / Pause** – Plays the recorded data backwards or pauses playing at the current frame.
 - **Play / Pause** – Plays the recorded data forward or pauses playing at the current frame.
 - **Stop** – Stops playing and steps to the reference frame.
 - **Loop** – Enables / disables looping during play. There are two kinds of a loop – circle and bidirectional. The circle loop continues playing by the reference frame when the end frame is reached. The bidirectional loop switches direction from forward to backwards when the end frame is reached and vice versa when the reference frame is reached.
 - **Previous Frame** – Steps to the previous frame.
 - **Next Frame** – Steps to the next frame.



Figure 17: The recorded data player. From the left to the right: loop, backplay, play, stop, previous frame and next frame.

- ❖ **Set as Reference** – Sets the currently displayed frame(s) determined by the current position of the seek slider as reference. If there are any computed data present, they will be erased on a prompt. A copy of the probes from the previous reference frame is used in the new one.
- ❖ **Set as End** – Sets the current position of the seek slider as the effective end of the record, the same way it would be set by moving the corresponding element of the seeker by mouse.
- ❖ **Set Mark** – Determines the moment in time with data, which serve as an input to various operations such as FEA and FLC analysis.
- ❖ **Run / Stop** – Launches or stops a new test, during which the recording of frames from the connected cameras takes place, as well as the recording of measured data from the connected testing machine and the computation of data for display in graphs. It is not possible to append new frames to the existing measurements, so permission to clear all recorded data is requested on consecutive presses of the **Run** button. The arrow on the right of the button opens a context menu with alternate modes of running a new test:
 - **Run with Timer** – Records data in batches of a length specified by the number of frames. The time between consecutive batches is also specified by the respective numeric control.

- **Run in Snap Mode** – In this mode, frames are not processed automatically as they arrive from the connected cameras, but only when the **Snap Frame(s)** button is pressed. It appears to the right of the Run button when this option is selected. The data recorded this way is logically stored within batches, whose length is specified by the respective numeric control.
- **Run without Recording** – The results are computed without saving both images and measured data altogether. This means that the memory demands are kept to a minimum, and as soon as the test is over, the project is in the same state as it was before the test.
- ❖ **Frames Saved** – Toggles the option to save the recorded images into the directory with project files. If disabled, it will not be possible to view the processed images after the test is stopped. This option is enabled by default.
- ❖ **Saving interval [frames]** – Restricts the number of frames, which are saved to drive during a live test. Specifies the interval between frames, which are saved and the rest will not be available to further recomputation.
- ❖ **Data Computed** – Toggles the option to compute data during a live test in addition to recording the frames. If unchecked, data are not computed, which is frequently used with checked **Frames Saved**. In that case, data can be recomputed later, e.g. when measuring with a high framerate. This option is enabled by default.
- ❖ **Initialize Only** – Toggles the option to wait until the system is ready for measurement after starting the test by using the **Run** button instead of proceeding with the entire measurement. The actual measurement begins only after the **Ready** button is pressed, which appears right next to **Run**. This helps to prevent gaps of not computed data from forming at the beginning of the measurement due to more computationally expensive operations, which happen with reference frames. Especially in stereo scenes, because the points need to be correlated between neighbouring cameras first.
- ❖ **Unlock reference**  – Unlocks the modification of probes in the reference frame, which is locked whenever a new test or recomputation is started. Some other controls, such as Computation Settings (see 7.3) are affected by this as well. **Mind that this operation deletes all computed data.**
- ❖ **Recompute / Stop** – Performs new computations using the recorded frames, beginning with the frame set as a reference and stopping either on request or when it reaches the frame set as the end of the record. It is, therefore, possible to have the computation proceed in either the forward direction or backwards, as determined by the relative position of the reference frame and the end frame. The difference is indicated in Figure 18. Please note that it is not possible to perform this action if saving frames functionality was disabled during the live test.

a)



b)



Figure 18: a) Forward and b) backward recomputation

- ❖ The arrow on the right of the **Recompute** button provides some additional options:

- **Post-Process** – Recomputes the project, but without performing any correlation again. Can be helpful when the data are already computed, but only the coordinate system is modified without unlocking the reference or such.
- **Recompute All Projects** – Run the recomputation on all projects in the directory of the currently open project, as seen in the Projects panel on the top right.

2.5. GRAPHS PANEL

Displays a selection of graphs for the computed quantities, which are distributed among their corresponding tabs according to the units in which they are measured. By default, there are graphs available for all kinds of units used through the program, with some of them, such as the units of millimetres, being separated between absolute and relative quantities for a better chance of comparison.

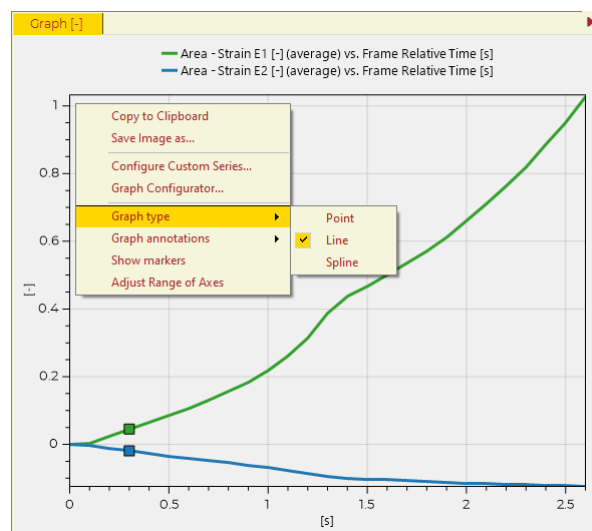


Figure 19: Graph with shown markers and an open context menu with additional options

A graph shows the values evaluated by using the selected probes of each camera. The graph panel has several tabs with different graphs according to various units of measurement. A graph can be zoomed in by using the mouse wheel or fit the window by using a double click of the left mouse button. Also, notice the possibility of zooming along either the vertical or the horizontal direction only (scroll on the individual axes). The visibility of each series can be changed by the corresponding control in the **Graph Data panel** on the left of the graphs panel.

The basic graph options can be modified using the context menu seen in Figure 19. The first available options are **Copy to Clipboard** and **Save Image as**, which assist with the creation of reports about the results of the measurement. Additionally, the **Configure Custom Series** and **Graph Configurator** options open the windows described in chapters 15 and 16, respectively. Finally, the appearance of the graph can be adjusted by the options **Graph type**, **Graph annotations** and **Show markers**. The possibility of a manual adjustment of the x-axis and y-axis scale is provided through the **Adjust Range of Axes** option and shown in Figure 20. Additional options are available in **Presentation Settings** under **Graph** (see 7.2.1).

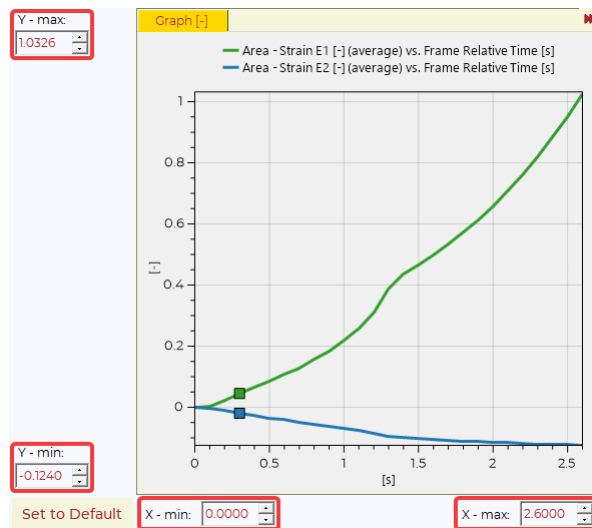


Figure 20: Manual adjustment of the x-axis and y-axis scale

2.6. GRAPH DATA PANEL

This panel includes all the data values available in the current project for display in graphs and output through I/O services. Their order in this panel is preserved when all values are sent to outputs that support such a feature. The colour of the boxes represents the origin of these values and can be one of the following. **Green** are values computed using probes and other measuring tools set in the camera displays. **Orange** are values measured by connected devices such as testing machine, sync box and cameras for timestamp retrieval (replaced by system time if not available). **Red** are values computed by custom expressions. **Blue** are values computed by value filtering.

As seen in Figure 21, every box has three buttons on the right side. The button right next to the name of the data value  can be used to change the name of the data value to the desired alias, which can be consequently used to input more straightforward custom series and so forth. Another button  hides or shows the corresponding data in the graph. The last button  contains the settings that allow to configure the output values through the configured I/O services, then to configure the visual alarms and triggers for each of the displayed values.

Graph Data:		
A1 - Length: Extension [mm]		
75.7458		
A1 - Length: Extension [%]		
20.0663		
Frame Relative Time [s]		
7.1000		

Figure 21: The Graph Data Panel

2.6.1. Output Values

For further information on I/O services, see 10.2 CONFIGURATION OF THE OUTPUT VALUES.

2.6.2. Visual Alarm

In the Visual Alarm tab of the Graph Data Settings dialogue, it is possible to configure the values in the Graph Data panel to change colour at specified key moments. This makes it easier to see the critical values when the user is at a greater physical distance from the screen. The specific parameters are defined as follows:

- ❖ **Show in Camera Displays** – Indicates whether the current value of this graph data unit should be displayed on all camera screens whenever it is available, regardless of whether the alarm is enabled or not. This also makes the value available for exported images and videos.
- ❖ **Alarm Enabled** – Specifies whether the visual signal is applied to the associated graph data series.
- ❖ **Normal Value Color** – The colouring of the corresponding display when the value is in its normal state.
- ❖ **Alarming Value Threshold** – The value of the threshold, when the associated graph data value is considered alarming. Must be different from the value of the critical threshold, because their relation to each other determines whether the associated graph data value is expected to be ascending or descending towards the critical value.
- ❖ **Alarming Value Color** – The colouring of the corresponding display when the value is in its alarming state.
- ❖ **Critical Value Threshold** – The value of the threshold, when the associated graph data value is considered critical. Must be different from the value of the alarming threshold, because their relation to each other determines whether the associated graph data value is expected to be ascending or descending towards the critical value.
- ❖ **Critical Value Color** – The colouring of the corresponding display when the value is in its critical state.

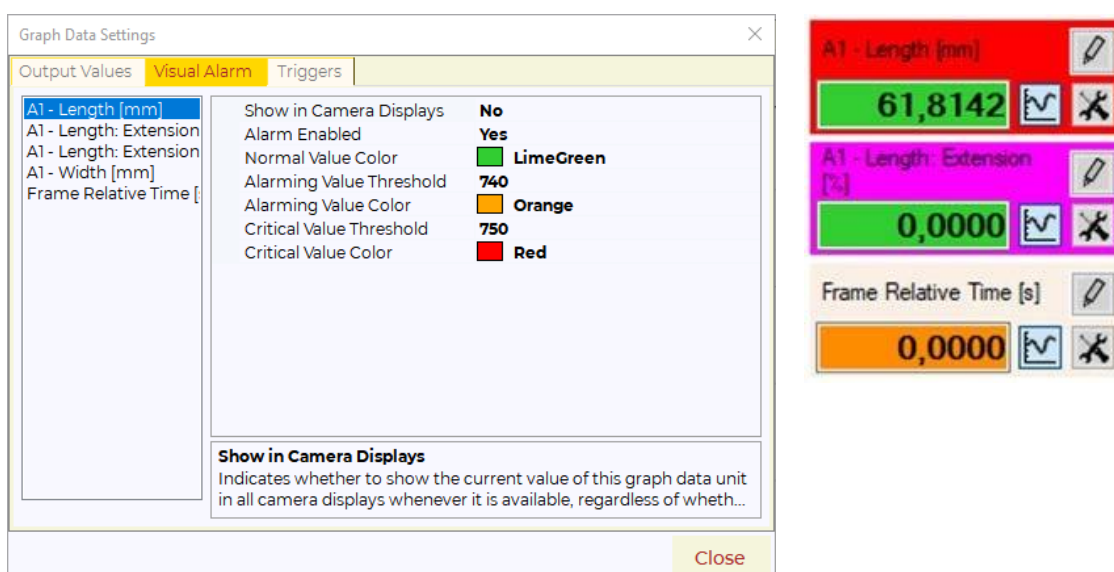


Figure 22: The Graph Data Settings dialogue showing the parameters of Visual Alarms

2.6.3. Triggers

In the **Triggers** tab of the Graph Data Settings dialogue box, data value thresholds can be configured to act as triggers for changing other specific parameters during a live test. The progress of such a live test can therefore be programmed to automatically respond to specific changes in data values by adjusting either the **FPS** setting of the connected cameras or the **Frame Saving Interval**. This can be useful both to reduce the amount of stored data during non-significant parts of the test and to increase the density of processed image data during significant parts of the test.

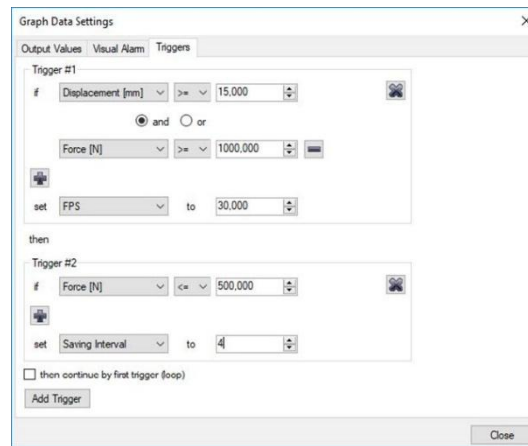


Figure 23: The Graph Data Settings dialogue showing the settings of Triggers

It is possible to configure an arbitrary number of consecutive Triggers by adding them with the **Add Trigger** button. Each of these represents a state change to a new configuration and consists of a **condition**, which must be met before the **effect** is applied to the current measurement and the following trigger can be considered in the same way. Each **condition** (following the word if) consists of a selected graph data value (among those present in the project), a comparer of $\geq$ (higher than or equal) or $\leq$ (less than or equal) and the threshold of the value in its units. There can be multiple conditions present in a single trigger as they are added by pressing the + button and removed by the – button. They can either be in an AND or an OR relation to each other, meaning that either all of these conditions must be met before the effect is triggered, or only one of them. There is only one **effect** per trigger and it consists of the name of the parameter to be adjusted and its target value. If the target needs to be applied to a specific scene (e.g. FPS), it is also specified by a box that appears next to it if necessary. After the last trigger has been applied during a test, it is possible to resume the process with the first trigger by selecting the "then continue by first trigger (loop)" option located after the last trigger.

3. SCENE WINDOW

The functionality of the scene window includes the preview of frames acquired by a live camera and the adjustment of its parameters, the display of imported or recorded images and the setup of tracking probes and the coordinate system, as well as the calibration of camera distortions. As shown in Figure 24, the scene window consists of the **camera view controls** on the left side, the **camera view** in the middle and the **control panel** on the right side of the scene window.

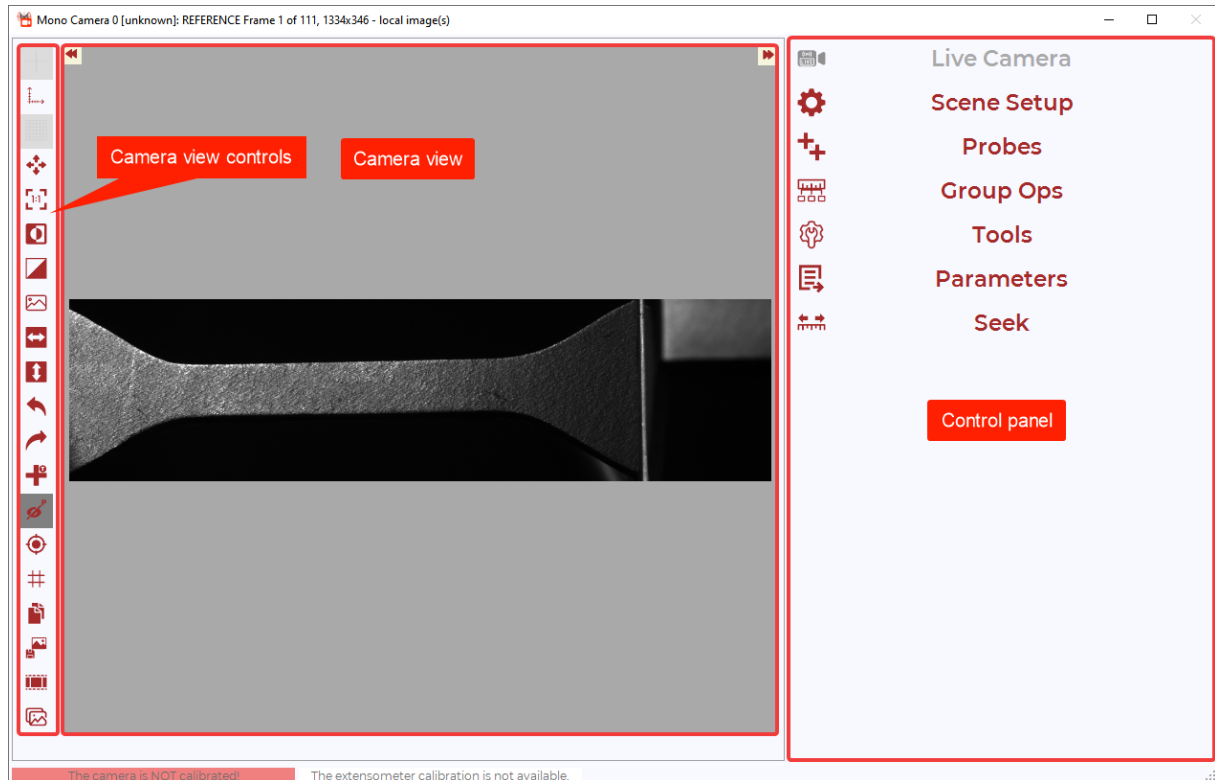


Figure 24: Scene window (mono scene mode)

It is allowed to organise the camera views to make a measurement or the processing of results arranged and clutter-free. As displayed in Figure 25, the individual scenes are docked in the desired places by drag-and-drop to a specific position of the cross in the center of the scene window.

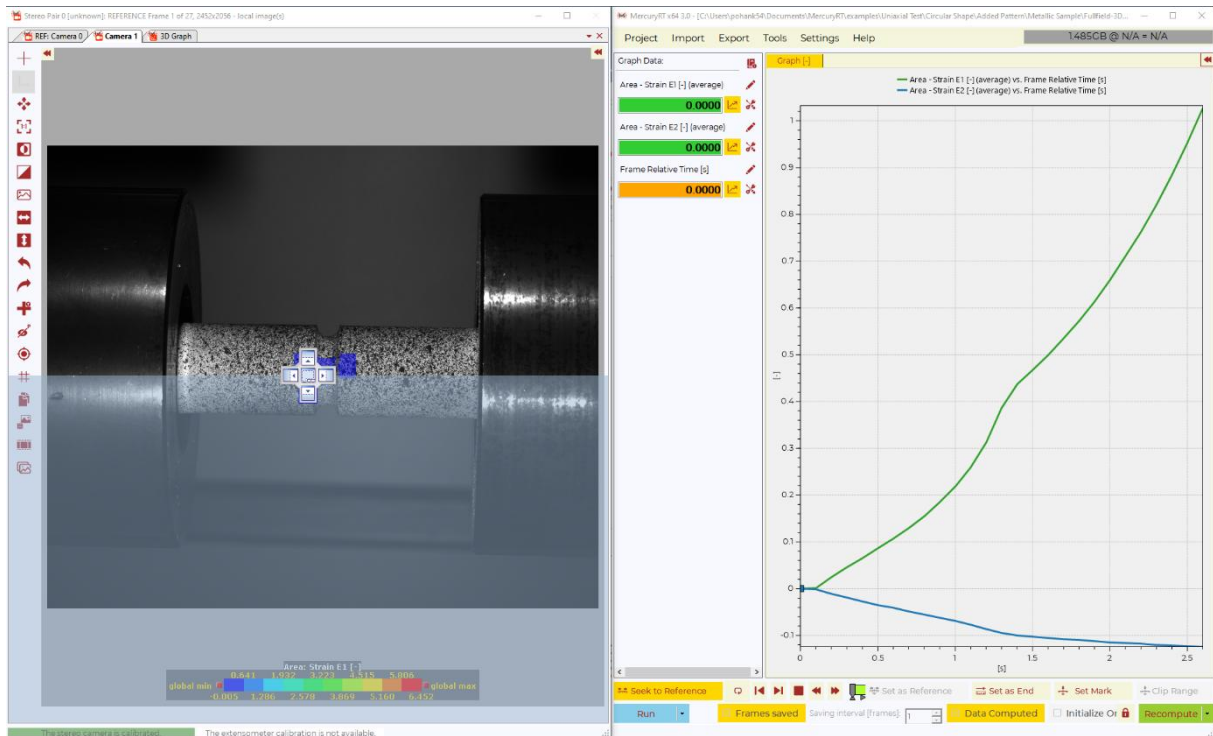


Figure 25: The Dockable window layout

3.1. CAMERA VIEW CONTROLS

The controls which affect the **camera view** of the associated scene window are grouped in the vertical panel on the left of the window and are as follows:

- ❖ **Show optical axis**  – Shows or hides the optical axis, as defined by the current camera calibration. If no such calibration is active, the axis is displayed at the center of the image to assist with the positioning of the calibration grid.
- ❖ **Show coordinate system**  – Shows or hides the coordinate system. In a stereo scene, this is only available after a custom coordinate system is enabled.
- ❖ **Show metrology tool**  – Shows or hides the metrology tool. It is only available in a 2D scene. This tool can be used to visually determine the physical distances within the scene. Its properties are defined by the currently set coordinate system and some additional parameters located in **Presentation Settings** under **Metrology tool** as described in chapter 7.2.3.
- ❖ **Fit to window**  – Fits the currently displayed image (camera frame) into the **camera view**. Zooming in disables this feature.
- ❖ **Zoom one-to-one**  – Sets the zoom to 100%, meaning that a pixel of the screen corresponds to a pixel of the image.
- ❖ **Invert colors (shortcut: I)**  – Inverts the colors of the displayed image. This feature does not affect the measured data.

- ❖ **Show Clippings and Histogram**  – Clippings mark the overexposed / underexposed areas with a red/blue color, as shown in Figure 26. Both overexposed and underexposed areas of the image cause loss of information and are therefore unsuitable for forming places upon which the measurements take place. The button also displays a histogram which is not shown in the figure below.

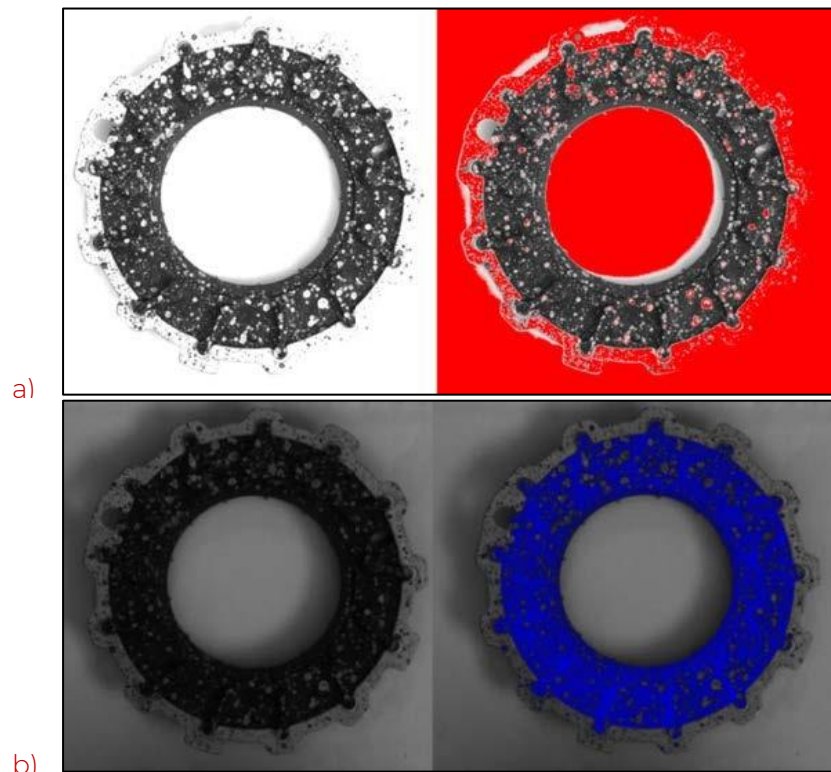


Figure 26: The colouring of a) overexposed areas, b) underexposed areas

- ❖ **Pseudo Colors**  – Converts a greyscale image to a colour image for more visual contrast. This does not affect the computed data in any way.
- ❖ **Flip Image Horizontally**  – Flips the currently displayed image around its vertical axis.
- ❖ **Flip Image Vertically**  – Flips the currently displayed image around its horizontal axis.
- ❖ **Rotate Image Left**  – Rotates the currently displayed image counter-clockwise by 90°.
- ❖ **Rotate Image Right**  – Rotates the currently displayed image clockwise by 90°.
- ❖ **Hide Labels**  – Hides labels from the camera view. This is suitable when they overlap too much, slow down the program or are undesired to be visible on captured screenshots.

- ❖ **Hide Probes**  - Hides all probes in the camera view. Can be helpful when they obscure the underlying image too much.

- ❖ **Focus Tool**  – Highlights places with green in the image which is sufficiently sharp to provide information as a template for correlation.

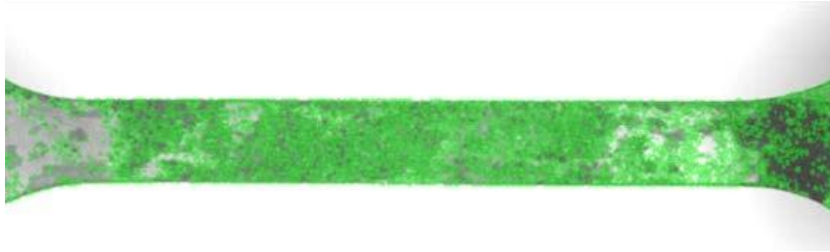


Figure 27: Focus Tool functionality

- Grid Tool**  – Toggles the display of four perpendicular lines to help with the alignment of the specimen.



Figure 28: Grid Tool functionality

- ❖ **Copy Camera View to Clipboard (shortcut: Ctrl + C)**  – Copies the currently displayed contents of the **camera** view to the clipboard. This includes the visible part of the displayed image as well as all other displayed components.
- ❖ **Save Image**  – Saves the image into the selected directory.
- ❖ **Save Video Sequence**  – Saves the recorded sequence of images into an AVI file. An additional dialogue window shown in Figure 29 is consequently opened for setting the parameters of the saved subsequence.

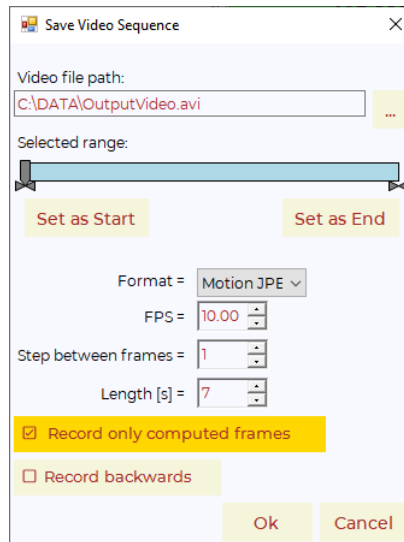


Figure 29: Save Video Sequence dialog box

- The **path to the output video** file can be selected in the topmost control. The Start and End marks of the subsequence are available under the included seeker – the movement of the two markers  selects the desired range on the time scale. The slider defines  the current image displayed in the camera view window and does not affect the resulting output. Its current position can be either **Set as Start** or **Set as End** for convenience. The **Format** can be set as either YUV 420 or Motion JPEG. The **FPS** value defines the exported speed of the video sequence in units of frames per second. Step between frames selects every n-th frame from the selected subsequence for capture. The Length value shows the expected length of the saved video file as specified by the other parameters in this dialogue. Changing this value automatically adjusts the FPS value to match the desired length. Two additional checkboxes **Record only computed frames** and **Record backwards** can be used to specify further which frames are saved and in which order.

- ❖ **Clip background in saved images**  – Can be toggled to automatically clip the grey background around the displayed frame when saving it to an image or video file. Beware as it might clip a part of the text and/or colour scale as well.

3.2. CONTROL PANEL

The panel is located on the right of the **scene window** and provides configuration of the associated camera(s), scene-related settings as well as the input of tracking probes, all of which are associated with the current project.

3.2.1. Live Camera

This panel provides control over the parameters of the camera and is accessible only when a live camera is present. The individual controls located in this panel are available only if the connected camera supports their associated features, and some of them may be available only if the associated camera is stopped. They are explained as follows:

- ❖ **Run/Stop Camera** – Runs/stops all live cameras associated with the current project. The background color of this button also indicates whether they are currently

running or not. Additionally, along with the FPS value, this is the only control in this panel, which is available even during the measurement.

- ❖ **Turn Light(s) On/Off** – This button makes it possible to switch the connected light on/off, which is also done automatically when a test is started or stopped. A precondition to this, however, is that a specific USB relay and lights must be connected to the computer and its parameters need to be specified correctly in **System Settings** under **USB Relay** (see 7.1.5).
- ❖ **Turn Laser On/Off** – This button activates and deactivates the laser pointer (no USB Relay is used, only a USB-TTL UART communication cable). The laser pointer is then automatically switched on and off within the application in the following situations:
 - When the Capture Image button is pressed (during calibration), the laser is switched off. After receiving the calibration image from the camera or after about 100ms, the laser pointer is switched on again.
 - The laser is automatically switched off when the Run button is clicked and is switched on again when the Stop button is pressed.
 - During Run in Snap it is only switched off for the duration of the image capture. The laser pointer is switched on again when the Stop button is pressed to end the measurement.
- ❖ **Shutter [ms]** – Adjusts the shutter speed of the associated camera. The higher the value, the brighter the image, but more prone to motion blur. Recommended shutter values for typical measurements are up to 20 ms depending on the amount of applied light and motion conditions.
- ❖ **Auto Shutter** – Toggles the option to adjust the value of the shutter automatically by analyzing the incoming images. This also makes it possible to change the value of the shutter even during a measurement, which is otherwise denied. In combination with the **Auto Function AOI** (area of interest) mentioned later in this list, it is possible to restrict the auto shutter to a specified rectangle in the image.
- ❖ **Gain** – Adjusts the sensor gain of the associated camera. The units in which it is specified differ from camera to camera, with the most common being a unit of dB.
- ❖ **Auto Gain** – See **Auto Shutter**, except it adjusts the value of the gain instead of the shutter. The **Auto Function AOI** (area of interest) mentioned later in this list works together with the Auto Gain functionality as well.

The screenshot shows a software interface for camera settings. At the top is a yellow header with a camera icon and the text 'Live Camera'. Below this is a grey bar with the text 'Stop Camera'. The main content area has a light blue background and contains several controls: 'Turn Light(s) On/Off', 'Turn Laser On/Off', 'Shutter [ms]:' with a value of 0.000, 'Auto Shutter:' with an unchecked checkbox, 'Gain:' with a value of 0, 'Auto Gain:' with an unchecked checkbox, 'FPS:' with a value of 1, and 'High SNR:' with a dropdown menu. Below these is a red bar with a plus icon and the text 'Advanced'. Under 'Advanced' are 'AOI Width:' with a value of 640 and 'AOI Height:' with a value of 480. At the bottom is a button labeled 'Select Image AOI'.

Figure 30: The panel with live camera settings

- ❖ **FPS** – Adjusts the frame rate of the associated camera in units of frames per second. This is the only parameter in this panel, which is allowed to change during the measurement. The change is however not immediate, because the camera needs to be stopped before the FPS is changed and then started again. It is possible to set FPS in integer numbers and when the FPS goes down under 1 FPS it is set to fractions. Possible FPS fractions are 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9, and 1/10.
- ❖ **High SNR** – Adjusts the number of consecutive frames which are taken as an input to optical data averaging. The output of such averaging is a single frame with a reduced amount of noise, which is then received instead of the original, unprocessed frames. The use of this feature decreases the real FPS.
- ❖ **Advanced** – Opens a window of advanced camera properties depending on the type of the associated camera.
- ❖ **AOI Width/Height** – Adjusts the size of the AOI (area of interest). In most cameras, decreasing the AOI increases the maximum allowed frame rate.
- ❖ **Select Image/Auto Function AOI** – Activates/applies the AOI selection in the associated camera. According to the selection toggled by the arrow on the right of the button, the selected AOI is then applied either to the entire image or just for **Auto Shutter** and **Auto Gain functions**. The selection is performed either by manual adjustment of the associated values or by moving the green border lines by mouse. The adjustment of the top-left corner of the AOI can only be made by dragging these lines. Activating the AOI selection also resets the maximum frame resolution.

3.2.2. Thermal Camera

Whenever a scene with a thermal camera is displayed, a panel for the adjustment of its properties shown in Figure 31 becomes available separately below the more generic Live Camera panel. Most of its controls are related to the calibration of the thermal sensor itself, but these are only available if the connected thermal camera supports this type of access to its parameters.

Figure 31: The panel with thermal camera settings

The controls are described as follows:

- ❖ **Temperature [°C]** – The range of temperatures that are mapped to the image data, which are retrieved from the camera. In units of degrees Celsius. **This parameter is always available when using thermal cameras.**
- ❖ **Emissivity** – The emissivity of the observed object.
- ❖ **Ambient Temperature [°C]** – The temperature of the environment surrounding the observed object in units of degrees Celsius.
- ❖ **Transmittance** – The transmittance of the intermediate atmosphere.

- ❖ **Air Temperature [°C]** – The temperature of the intermediate atmosphere in units of degrees Celsius.
- ❖ **Load Calibration File** – Loads an IR camera calibration file that corrects the measured temperatures. Its current status is displayed in the box located above the button.

3.2.3. Scene Setup

Provides the means of the calibration of the system, definition of the coordinate system, and other options. Its content is different according to whether the scene is 2D or 3D.

Mono Scene Setup

The panel depicted in Figure 32 contains controls for the camera calibration and the definition of the coordinate system in a mono mode. All of the included operations are only optional, yet necessary to maintain high precision of the performed measurements.

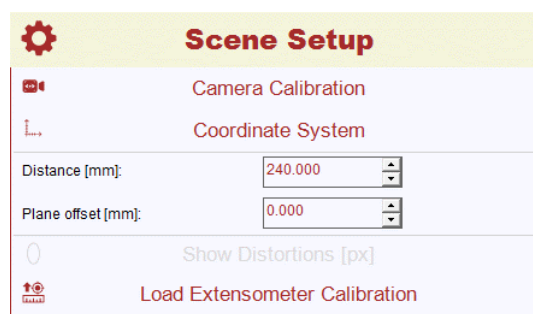


Figure 32: Mono Scene Setup tab

The explanations of the included controls are as follows:

- ❖ **Camera Calibration** – Opens a window for the calibration of the associated camera (see 3.2.4).
- ❖ **Coordinate System** – Opens a window for the configuration of the coordinate system (see Mono Coordinate System in 3.2.5).
- ❖ **Distance [mm]** – Show the distance between the Origin of the coordination system and Point X on the X-axis. To manually adjust the scale factor (px/mm) in mono scene use Scale Caliper Tool (see 3.2.9)

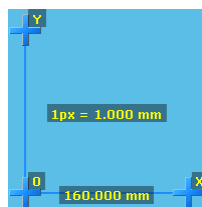


Figure 33: Distance of coordinate system

- ❖ **Plane offset [mm]** – Allows the measurement plane offset to be adjusted closer or further away from the camera (the camera must be calibrated in the required planes for accurate results).
- ❖ **Show Distortions [px]** – Shows a color map, which illustrates the magnitude of the calibrated distortions caused by the curvature of the used lens (tool only available when camera is calibrated).

- ❖ **Load Extensometer Calibration** – This allows loading a file containing an extensometer calibration, which was previously created in a specialized project (see 11).
- ❖ **Load Thermal Calibration** – Available in scenes with a thermal camera, allows loading a file containing a thermal calibration, which was previously created in a specialized project (see 12).

In addition to the previous options, right-clicking the coordinate system in the scene opens the context menu seen in Figure 34. This contains options like Distance [mm]. The distance (between two known points on the measuring plane in the scene) may be set this way instead of a calibration (but Scale Caliper Tool is recommended to specify this distance in mono scene – see 3.2.9). However, keep in mind that proper calibration with the use of a calibration grid is always more precise than this. Another function of the context menu is **Free Edit**, which further allows adjusting the coordinate system manually (without a calibration grid) either in a plane perpendicular to the camera or in a perspective view. The position of the coordinate system may also be locked by **Lock Position**, which is also done automatically when the coordinate system is set by detecting the points of a calibration grid or when performing a measurement.

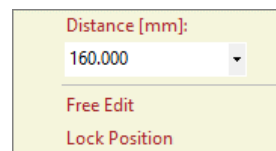


Figure 34: The context menu of the coordinate system in a mono scene

Stereo Scene Setup

The panel shown in Figure 35 replaces the previously described **Mono Scene Setup** panel in stereo mode. Unlike the camera calibration in a mono mode, the calibration of a stereo camera pair is necessary before performing any measurements. The definition of an optional custom 3D coordinate system is only allowed after the associated stereo pair is successfully calibrated. The controls in this panel are as follows:

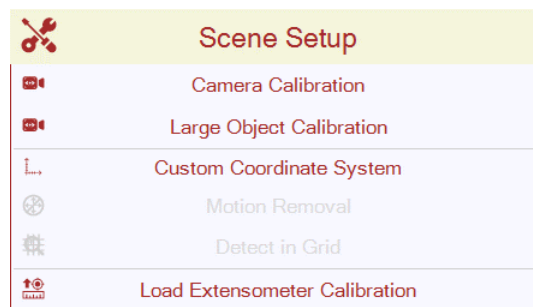


Figure 35: Stereo Scene Setup tab

- ❖ **Stereo Camera Calibration** – Opens a window for the calibration of the associated stereo pair (see 3.2.4).
- ❖ **Large Object Calibration** – Opens a tool for the calibration of large objects (see Stereo Scene)
- ❖ **Custom Coordinate System** – Activates the use of a custom 3D coordinate system (see Stereo Coordinate System).
- ❖ **Motion Removal** – Toggles the computation of displacement for the points of a custom coordinate system. Measured data is then computed relatively to the displaced coordinate system, effectively making the data unaffected by the motion (and rotation) of the object, on which the points of the custom coordinate system are positioned. This feature is available only if such a custom coordinate system is active.

- ❖ **Detect in Grid** – Sets the position and the rotation of the coordinate system using a calibration grid. The parameters of the calibration grid are requested first when the button is pressed. This feature is available only when a custom 3D coordinate system is active. Using this feature automatically locks the coordinate system, so it cannot be manipulated any further until the lock is disabled in the context menu of the coordinate system.
- ❖ **Load Extensometer Calibration** – Allows loading a file containing an extensometer calibration, which was previously created in a specialized project (see 11).

Stitched Mono Scene Setup

The panel represented in Figure 32 is also available in a stitched mono scene. Only the windows opened by the buttons located in this panel differ, with the camera calibration being done individually for two or more cameras and the definition of the coordinate system performed in all cameras at once. Also, unlike the plain mono scene, these steps are necessary to do before a measurement can provide any meaningful results because the spatial relationship between the stitched cameras is unknown until then.

Stitched Stereo Scene Setup

The **Scene Setup** panel available in a stitched stereo scene is a reduced version of the panel displayed in Figure 35. It only contains the **Camera Calibration** and the **Extensometer Calibration** buttons. Their function, however, remains the same as in the case of Stereo Scene Setup

3.2.4. Camera Calibration

The **Camera Calibration** window is used for the calibration of the distortions of the camera lens as well as the geometry of stereo camera pairs or chains of cameras in stereo with stitching. **Please note that some features require or depend on camera calibration; therefore, it is recommended to perform this calibration as the first step after opening the scene window.** Additionally, although **it is necessary to perform the calibration at full resolution**, it is still possible to change the calibration after the AOI is applied, but the new calibration needs to be already prepared as a separate file.

Each camera lens has its specific distortion, which negatively influences the measurement. In this case, it is necessary to perform a calibration to calculate this distortion so it can be removed later. Camera calibration is performed using a calibration grid. This grid is captured in various positions and angles in the entire field of view (Figure 36). The quality of camera calibration increases as more space is covered. Calibration instructions specific to different types of scenes are given in the following four sections.

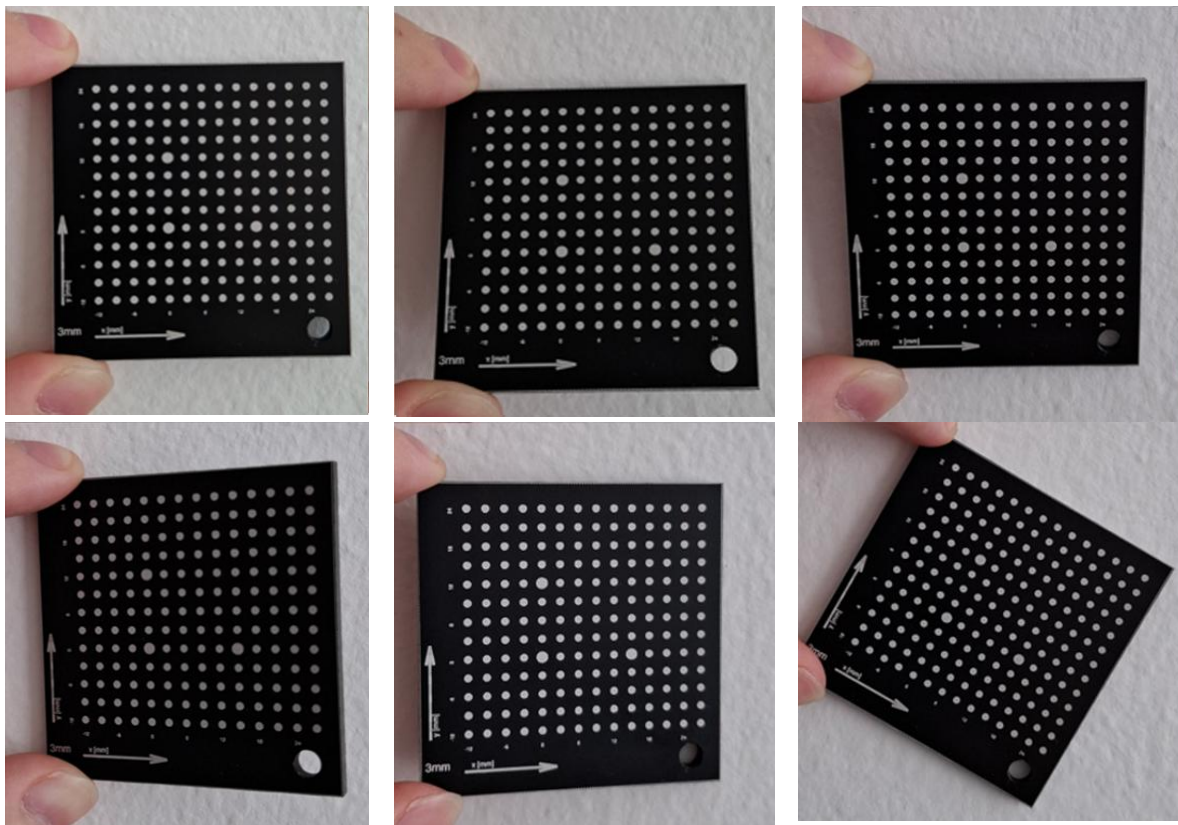


Figure 36: Stereo scene calibration - correct capturing of the calibration grid (turning in different angles)

Mono Scene Calibration

Take several pictures of the calibration grid in various positions and orientations but keep the calibration grid in the plane of the measured motion or deformation. Consider that reconstruction of the scene recorded by a single camera is highly sensitive to out-of-plane motion (i.e. motion along the line of sight of the camera) and this so-called mono scene setup is not suitable for measurements that include significant out-of-plane motion or deformation. A stereo setup should be used in such a case. This calibration determines only local distortions caused by camera lens imperfections. The second step calibrating real distances in the recorded scene is described in the Mono Coordinate System section later in this handbook.

Stitched Mono Scene Calibration

Calibration of stitched mono scene camera setup is performed for distortion of every camera separately, and so all considerations from the Mono Scene Calibration section above hold. Also, every single camera must see only one calibration grid during every frame capture. Calibration of real distances in XY plane and definition of standard coordinate system for the combined stitched scene is then done in the following step described in Stitched Mono Coordinate System section later in this handbook.

Stereo Scene Calibration

The stereo scene calibration process provides both all single cameras parameters calibration, camera relative position/ orientation calibration and coordinate system definition. Unlike the mono scene setup, stereo scene setup is not sensitive to out-of-plane motion as it provides full 3D scene reconstruction and thus stereo scene calibration should be done with a broad range of grid orientation relative to all axes in 3D. Both cameras should have a full view of the pattern on the calibration grid at the same time. The stereo scene calibration window helps with this by reporting whether the calibration algorithm

managed to detect the grid with both cameras. For the best precision of calibration, keep the center of the calibration grid in the expected position of a measured object.

Stitched Stereo Scene Calibration

Stitched stereo scene calibration is similar to stereo scene calibration, except that the calibration images have to be recorded in such a way that the algorithm can stitch the full 3D scene together.

This is achieved by recording the calibration grid in a way that every two neighboring cameras see the entire grid at some point during the calibration process. For example, if four cameras (1, 2, 3 and 4) are connected, 15-30 frames should be recorded, where at least cameras 1 and 2 see the full calibration grid and the same needs to be done for cameras 2 and 3 and cameras 3 and 4 (and also 4 and 1 when cameras form a full circle around the measured object).

Again, the calibration tool of MERCURY RT reports whether the calibration grid is detected by the calibration algorithm. It is better to provide an image where more cameras see the full calibration pattern, but it is not strictly necessary. Several images should be provided for every pair of neighboring cameras in the stitched chain.

To make sure that a stereo stitch is done correctly, follow these guidelines:

- ❖ The order in which the cameras are placed in the stitch stereo scene is important.
- ❖ The cameras should be connected and placed to the stereo scene from left to right. To make things easier, select one camera as the "primary" camera, cover the lens so that the image is blacked out, place it in the scene, remove the cover, and continue with the next camera on the right until all cameras are in the scene. This is necessary because the cameras in the Available Cameras (see 2.2) column are not in the correct order, and we need to be sure of the order in which the cameras are placed in a stereo stitched scene.

Stereo Scene Camera Calibration step-by-step:

To start a new camera calibration, click on the **Start New** button, which is highlighted in Figure 37. A dialogue window appears, containing the **Calibration Grid** parameters described in chapter 7.3.3. From here, it is possible to select the grid type, the detection method (either faster or more accurate), the number of radial distortion coefficients and input the unit distance of the calibration grid. **Detect from QR** function can be used in the case of a circular grid. When the OK button is clicked, the calibration is ready to start.

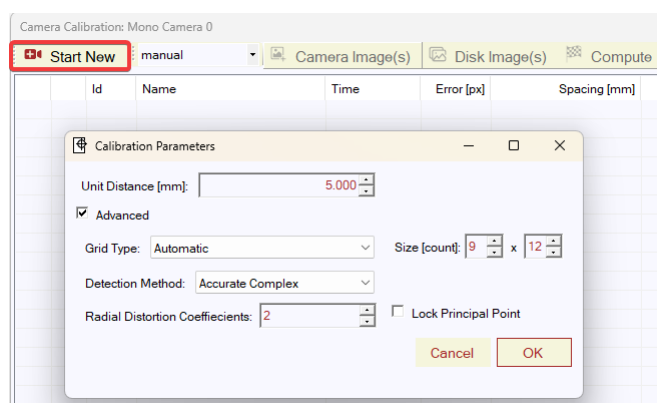


Figure 37: Start New Camera Calibration

The following points relates to Figure 38 and Figure 39.

1. First select a method for capturing camera images. **Manual** method requires clicking on a Camera Image(s) button to capture an image. The **Automatic** method automatically captures images at 1 second intervals when you click the Camera Image(s) button. To stop automatic capturing, press the Stop Capturing button.
2. Then capture (**Camera Image(s)** button) between 15 and 30 images. Pay attention to avoid over/ underexposed and blurry images. The more space of the image is covered by the grid, the higher the quality of the resulting calibration. Keep changing the angle of the grid slightly as you take pictures.
3. Click **Compute**.
4. Verify if there are some significantly higher error values than others.
5. If so, uncheck these higher error values and proceed with step 6. If not, click **Apply**.
6. Unchecked images are excluded from the calibration.
7. Click **Compute** again.
8. Verify the similarity of error values again.
9. If all the error values are similar and the average reprojection error is lower than 0.5 (sometimes the average reprojection error may reach almost 0.8), click **Apply**. At this moment, the calibration is done. If not, click **Start New** to clear all detected calibration grids (except for their corresponding locally stored image files) and start again.

Camera Calibration: Mono Camera 0 (CameraCalibration_0.0.0)

Start New automatic 1 Camera Image(s) 2 Disk Image(s) 3 Compute Load File Save File Save Info

	Id	Name	Time	Error [px]	Spacing [mm]
☒	1		15:53:23	0.584	5.000
☒	2		15:53:24	0.587	5.000
☒	3		15:53:25	0.589	5.000
☒	4		15:53:26	0.587	5.000
☒	5		15:53:27	0.591	5.000
☒	6		15:53:28	0.586	5.000
☒	7		15:53:29	0.588	5.000
☒	8		15:53:30	0.597	5.000
☒	9		15:53:31	0.606	5.000
☒	10		15:53:32	0.601	5.000
☒	11		15:53:33	0.738	5.000
☒	12		15:53:34	0.762	5.000
☒	13		15:53:35	0.760	5.000
☒	14		15:53:36	0.762	5.000
☒	15		15:53:37	0.766	5.000
☒	16		15:53:38	0.951	5.000
☒	17		15:53:39	0.760	5.000
☒	18		15:53:40	0.763	5.000
☒	19		15:53:41	0.762	5.000
☒	20		15:53:42	0.748	5.000

Camera 0 ####
 Focal length X [px]: 12,513.64 ± 354.76
 Focal length Y [px]: 12,513.64 ± 354.76
 Center X [px]: 205.99 ± 4.97
 Center Y [px]: 401.07 ± 10.17
 Radial distortion k1: -93.806 ± 1.054
 Radial distortion k2: 24,176.793 ± 126.616
 Radial distortion k3: 0.000
 Translation [mm]: (0.0, 0.0, 0.0)
 Rotation [deg]: (0.00, 0.00, 0.00)
 #### Other ####
 Number of grid positions: 20
 Reprojection error [px]: 0.7

Average Reprojection Error [px]: 0.685

Apply Close

Figure 38: Camera Calibration Step-by-Step – 1st part

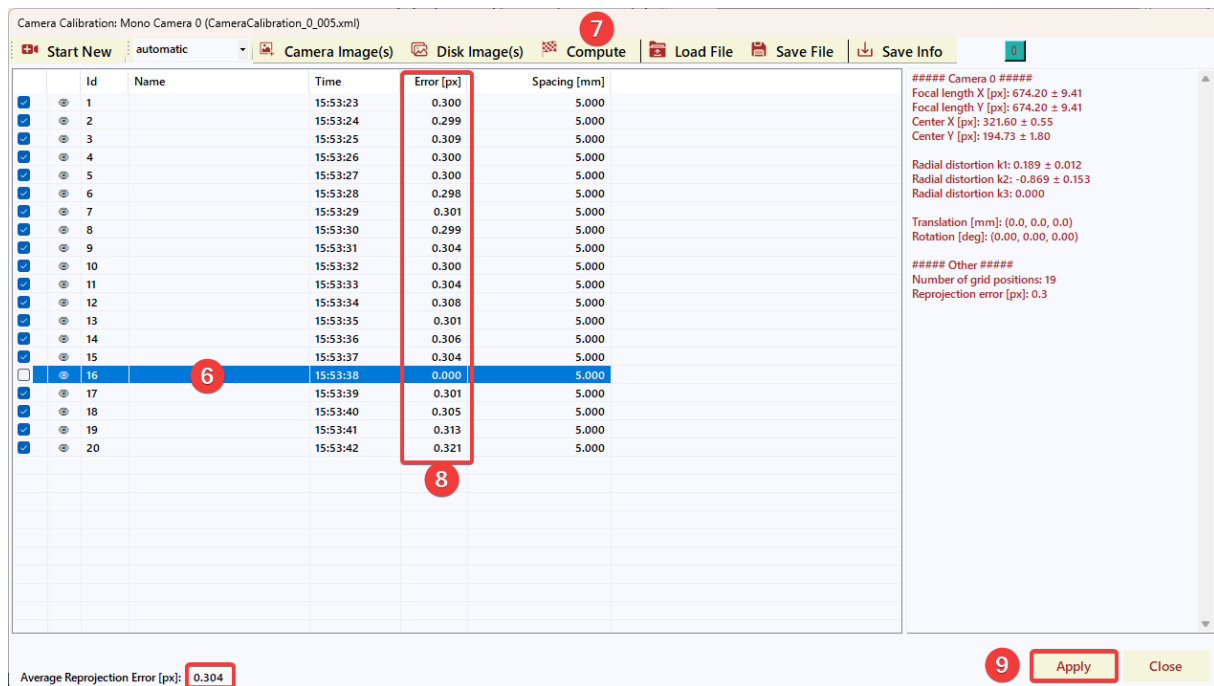


Figure 39: Camera Calibration Step-by-Step – 2nd part

The newly active calibration is indicated by the green status box at the bottom of the scene window.



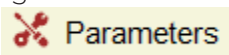
Figure 40: Indication of a calibrated camera

The other features of Camera Calibration window include:

Load File – Loads a camera calibration from a file. Can be used to load a camera calibration from a different project.

Save File – Saves the computed camera calibration to an XML file.

Parameters – In order to be able to correct the calibration grid unit distance, which can be produced with some variations in unit distance, it is possible to change the value of the

calibration grid unit distance by clicking on the Parameters button . This is useful if, during the verification measurement, the difference between the calibrated 3D system and the actual measurements differs. For example, if you move your testing machine or calibrator exactly 1mm and the result of measurement is 1.01mm, it is possible that the calibration grid unit distance is 1% higher than the designed 7.5mm. In this case the more accurate unit distance should be $7.5 \times 1.01 = 7.575\text{mm}$. In this way it is possible to correct the unit distance and recalculate the co-ordination system, thus obtaining a more accurate calibration of the stereo system.

3.2.5. Coordinate System Definition

A coordinate system is a tool for the conversion of computed values into physical units (mm). In mono mode, the coordinate system is set independently to the camera calibration, but in stereo mode, the coordinate system is already a part of the calibration of the stereo camera pair or chain (stitching). However, even in a stereo mode, a custom coordinate system may be enabled to allow a user-specified location of its origin and the alignment of its axes. The definition of a coordinate system in each of the different scene types is described below and can be performed regardless of the current AOI setting.

Mono Coordinate System

The Coordinate System window seen in Figure 41 is accessible through the **Scene Setup** panel in a mono mode and allows to detect coordinate system defined by a calibration grid or set the coordinate system using points of an image with a known location in physical units.

- ❖ **Using detection grid:** Click the Detect button if the scene displaces the calibration grid (Figure 41). The reference measuring plane (coordinate system) is set on the front plane of the calibration grid.
- ❖ **Mark critical points in a scene:** The user is given the option to mark the critical points in a sketch and then set their coordinates in a dialog box when clicking on Edit XY. Adding more points increases the accuracy of the coordinate system because the errors of individual points are statistically eliminated.

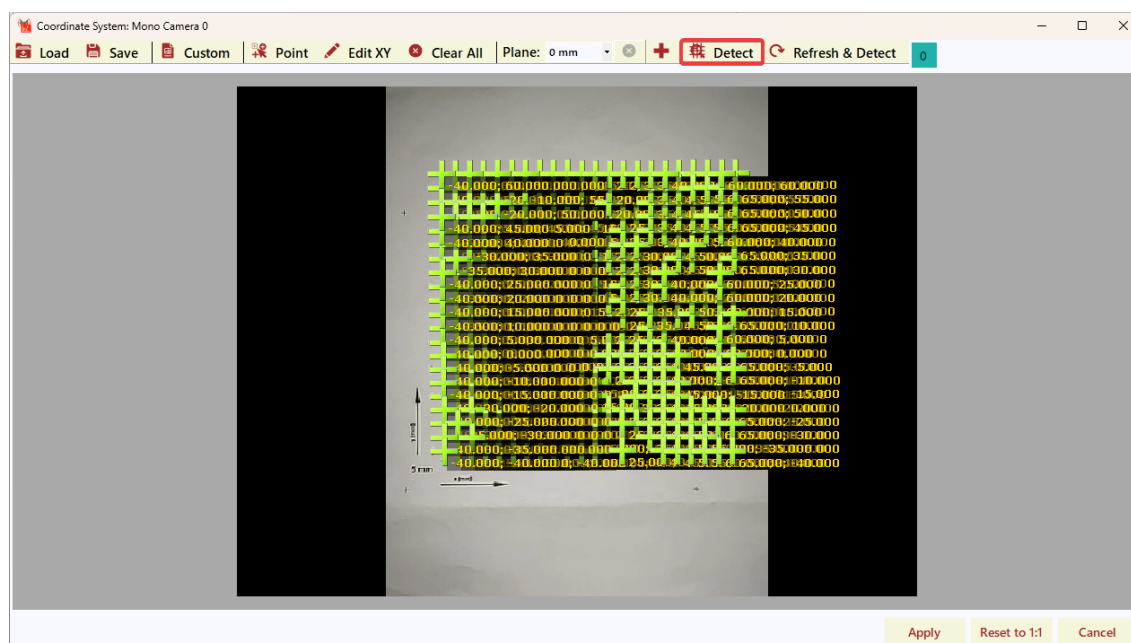


Figure 41: A calibration grid detected in the Coordinate system window

The controls located in this window are described as follows:

- ❖ **Load** – Loads coordinate system points from a specialized CSV file.
- ❖ **Save** – Saves coordinate system points to a specialized CSV file. This can be used to enter the coordinates of these points in an external program such as MS Excel, which allows the coordinate system to be defined only by a small number of points with a known location in 2D space.
- ❖ **Custom** – Loads a custom image to serve as a layout for coordinate system points.
- ❖ **Point** – Enables to add new coordinate points by mouse. Selecting the existing points while the Shift button is pressed removes them instead.
- ❖ **Edit XY** – Dialog box for specifying the position of selected points in physical units.
- ❖ **Clear All** – Clears all coordinate system data.
- ❖ **Plane [mm]** – Allows to define multiple coordinate systems and establish Plane Offsets for each measurement in mono scene. It is then possible to move the measurement plane in parallel to the reference plane set by a calibration grid. This feature is available only if the associated camera is calibrated. It is usually used when

the calibration grid is positioned on the surface of a measured object. In this case, the offset is equal to the negative value of the thickness of the calibration grid.

Here's a step-by-step guide on utilizing this feature:

- **Adding Coordinate Systems:** Click the plus button  to initiate the addition of a coordinate system. Specify the Plane Offsets for which you intend to create a coordinate system. Positive and negative numerical values are allowed. For each plane offset, ensure you detect a calibration grid. In the event that you forget to detect a calibration grid for any of the offsets, a dialog box will prompt you as a reminder. The more plane offsets are created in the measurement range, the more accurate the actual measurement will be if the correct plane offset is selected during measurement, as interpolation errors are eliminated.

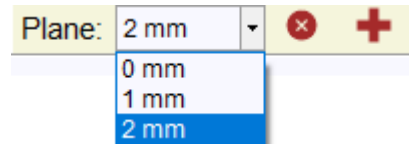


Figure 42: Plane Offset settings

- **Setting Plane Offset During Measurement:** Throughout the measurement process, you can dynamically set a desired plane offset by specifying its value. The software will intelligently interpolate the plane offset to align with the nearest coordinate system. This process allows you to tailor your coordinate systems with precision, enhancing the accuracy of your measurements.

A positive value means that the measurement plane is moved further from the camera from the reference plane set by a grid, as indicated in Figure 43. A negative value means that the measurement plane is moved closer the camera from the reference plane set by a grid, as indicated in Figure 43.

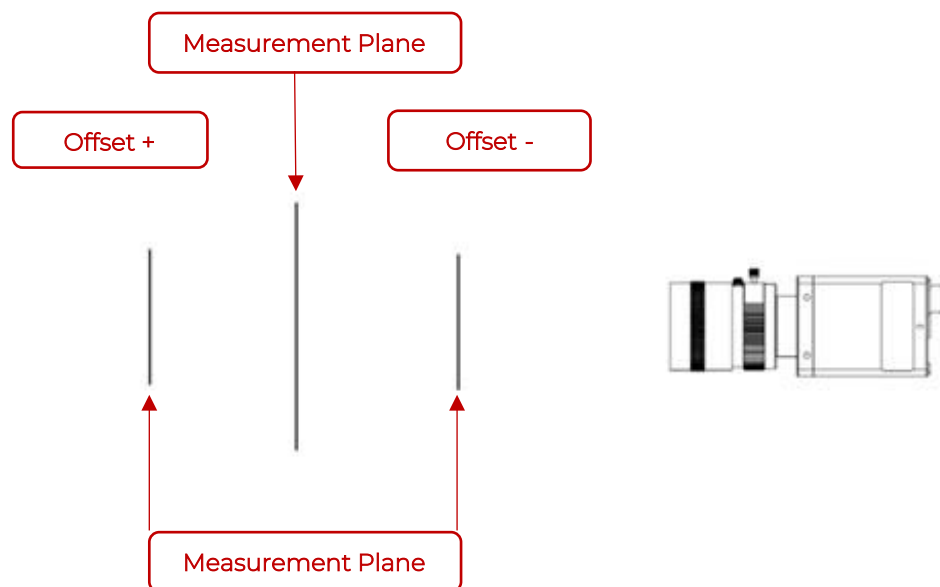


Figure 43: The adjustment of the plane offset (in parallel to the reference plane)

- ❖ **Detect** – Detects the points of a coordinate system using a calibration grid with parameters set through the dialogue displayed when opening the window.

- ❖ **Refresh Frame(s) and Detect** – Reloads the displayed image as the last displayed one from the corresponding camera view and runs a detection as if pressing the previous button.

When the coordinate system is set as desired, it can be put into use by pressing the **Apply** button at the bottom of the window. Oppositely, the **Reset to 1:1** button sets the coordinate system to its default values, where 1 pixel = 1 millimetre. Since the coordinate system is just an optional, yet recommended part of the calibration process in a mono scene, its state is indicated by the middle box located at the bottom of the scene view shown in Figure 44.

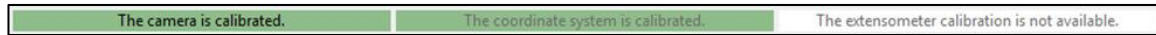


Figure 44: Status indication of the coordinate system in a mono scene

Stereo Coordinate System

In a stereo mode, the coordinate system which handles the conversion of computed values into physical units (mm) is already a part of the stereo camera calibration. Such a coordinate system is based on the left camera of the pair and has its center located inside the camera, X-axis going to the right of the camera, Y-axis going to the top of the camera and Z-axis going away from the camera. To align the coordinate system with known points located in the scene instead, a **Custom Coordinate System** feature is available and accessible through the **Scene Setup** panel (see Figure 35) once the associated stereo pair has been calibrated.

The visual representation of the custom coordinate system is made to closely resemble the coordinate system used for measurements in a mono mode and is displayed in Figure 45. The point labeled as “O” sets the origin of the custom coordinate system, the point labeled “X-axis” sets the direction of the X-axis and the point labeled “XY plane” sets the rotation of the XY-plane around the X-axis. The individual lines may also be decoupled from the origin of the coordinate system by dragging them instead of the points.

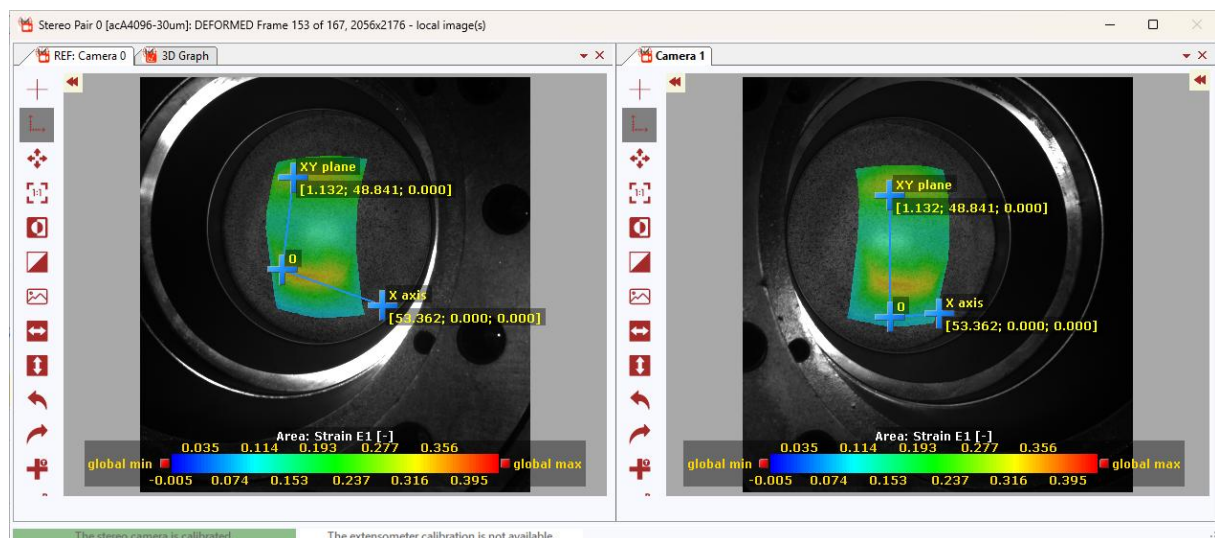


Figure 45: The custom coordinate system in a stereo mode

The custom coordinate system is set correctly only when the positions of all of its points in the left camera are detected in the right camera. This is indicated by a light blue color and a displayed location in physical units (mm) next to the “X axis” and “XY plane” labels. As with tracked probes, the points in the right camera may be dragged to their corresponding positions to increase their likelihood of being successfully detected. If the condition of their proper setting is not met, starting a new test or recomputation is not possible and will result in a warning message. To avoid this, either set the custom coordinate system properly or disable it in the **Scene Setup** panel (see Figure 35). Notice that although the custom coordinate system may be hidden using the corresponding button in the **camera**

view controls panel (see chapter 3.1), this does not disable it nor change the detection status of its points in any way.

Stitched Mono Coordinate System

The stitched mono mode is used to extend the field of view when performing a 2D measurement. As opposed to a mono mode, the probes are allowed to cross between the stitched cameras if there is a proper overlap, as illustrated in Figure 46. Usually, the stitched mono mode is useful when testing hyperelastic materials with considerable deformation or when measuring long specimens.

The process of adjustment of the coordinate system in a stitched mono scene is mostly different from a stereo or a mono scene. The following requirements are necessary to perform the definition of the coordinate system correctly. First of all, a **special calibration grid** for this purpose must be used, as illustrated in Figure 46. This calibration grid differs in the way that it includes two origins of the coordinate system marked with thicker dots. These origins are highlighted in Figure 46 by red rectangles. Keep in mind that **each of these individual origins highlighted in red must be seen in its own camera**, as illustrated in Figure 46. Ensure that no camera views both origins at the same time. The green and blue rectangles signify the fields of view of the two cameras. The overlap of the cameras represents another essential thing. This **overlap** ensures a smooth crossing of probes between the cameras. The recommended size of the overlap is approximately twice as big as the size of the correlation template. If the crossing of probes between the cameras is not accounted for, the overlap is not necessary.

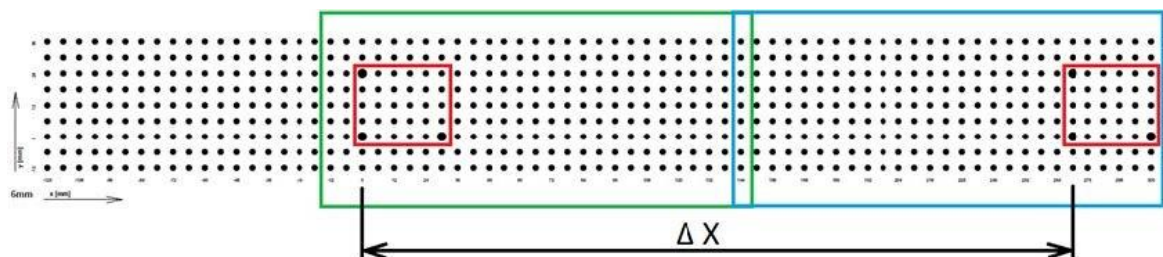


Figure 46: The adjustment of the coordinate system in a stitched mono mode with a special calibration grid

Notice the buttons for switching cameras in the right top corner of Figure 47 (highlighted in orange). The measurement grid must be detected through the button **Refresh Frame(s) And Detect** shown in Figure 47 for each camera individually. Afterward, as highlighted in red in Figure 46 and green in Figure 47, it is necessary to specify the location of the origin of the coordinate system. Specifically, it means manually entering values of individual coordinates into the boxes below (origin position). In the most common case, only the ΔX value should be entered as the X-coordinate, leaving the Y-coordinate at 0. The plus or minus sign depends on the relative positions of the cameras and possibly some individual requirements of the measurement.

It is highly recommended to compare, e.g. a distance between two points in two cameras by a caliper tool with the real distance to make sure about the correctness of the calibration. As depicted in Figure 48, an overlap between cameras is colored yellow.

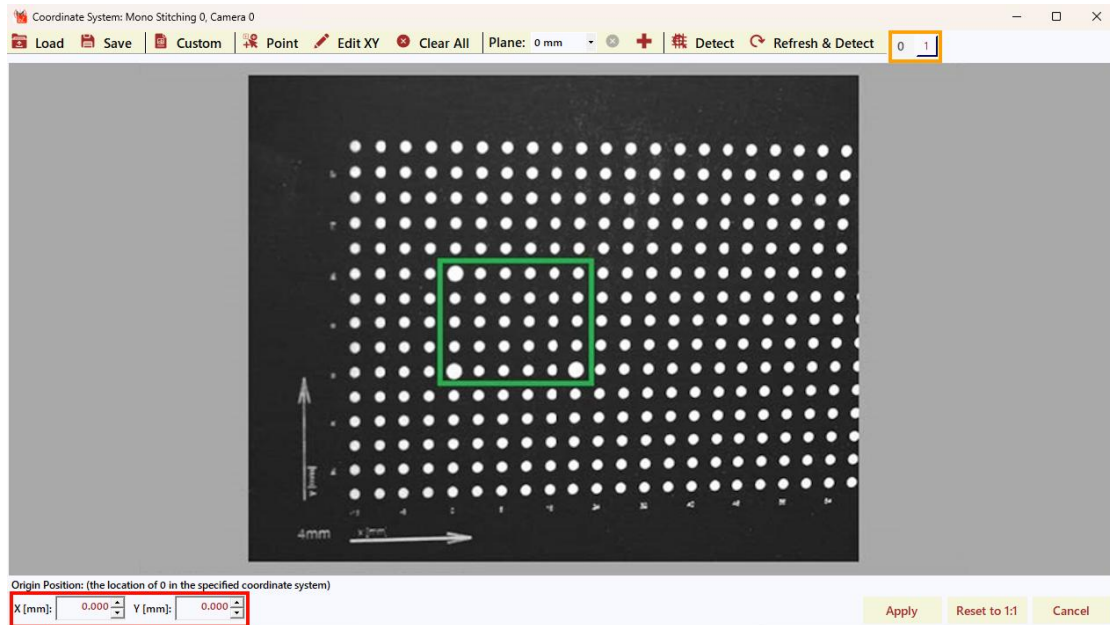


Figure 47: Coordinate system window in a stitched mono mode



Figure 48: Stitched mono mode – two cameras for FOV extension (an overlap between cameras is coloured yellow) scene

Stitched Stereo Coordinate System

Similarly to a stereo mode without stitching, the coordinate system which handles the conversion of computed values into physical units (mm) is already a part of the stitched stereo camera calibration. Such a coordinate system is based on the first camera in the setup and has its center located inside the camera, X-axis going to the right of the camera, Y-axis going to the top of the camera and Z-axis going away from the camera. No other coordinate system is available for these types of scenes.

3.2.6. Large Object Calibration

To calibrate cameras and define a coordinate system when measuring large objects such as entire buildings or bridges is possible, but requires certain precautions to be taken. In a mono mode, the camera calibration can be done; as usual, just the lens has to be temporarily focused on a shorter distance when capturing a calibration grid. Further steps are described in the following chapter.

Mono Scene

To define the coordinate system of large objects in a mono scene, click on the **Coordinate System** button on the right side of the **scene window** under **Scene Setup**. Enter any number into the unit distance box as it will not be necessary. There are four default points displayed in the window, which is the minimum number for the definition of the coordinate system. Additional points may be added by clicking the **Point** button in the upper panel of the window. Move the points to the positions whose coordinates are known. Save this configuration as a CSV file. Afterward, open this CSV file (for instance, in Excel) and edit the coordinate values to correspond with the real dimensions of the measured structure. Remember that all known points must be lying on the measured plane. Save the CSV file and load it in the Coordinate System window. After that, the measured plane and the coordinate system are set. The definition of the coordinate system already takes the perspective view into consideration.



Figure 49: Large object calibration in a stitched mono scene

Mono Stitched Scene

The definition of a coordinate system for large objects in a mono-stitched scene is mostly the same as in a mono scene. The only difference is that the relationship between the individual cameras needs to be taken into account when entering the coordinates of points. These can be set in two different ways. The first way is to set both coordinate systems separately (with a local origin of [0; 0] for each local coordinate system) and then offset them by known values filled in boxes at the bottom left of the window. The second way is to set both coordinate systems according to the absolute coordinates and avoid entering any offset.

Stereo Scene

To prepare the calibration of a stereo scene for measuring large objects, several steps must be taken in the appropriate order. Initially, the stereo scene needs to be opened as two separate mono scenes, and regular calibration of both cameras has to be performed. Both projects must be saved and closed afterward. After that, create a new project containing these two previously open cameras as a single stereo scene. Click on the **Large Object Calibration** button in the **Scene Setup** panel and follow the step-by-step instructions on how to proceed.

The required mono camera calibrations are already done, so select the calibration files by clicking on **Load Mono Camera Calibration** below the left and right camera view as depicted in Figure 50. Next, by selecting **Add Point** in the upper panel, position four or more points in one camera and modify their placement in the other camera if necessary. Click **Specify 3D positions of probes** at the bottom of the window and fill in the table with the proper coordinates of the placed points. After these necessary steps, the stereo calibration for large objects is done.

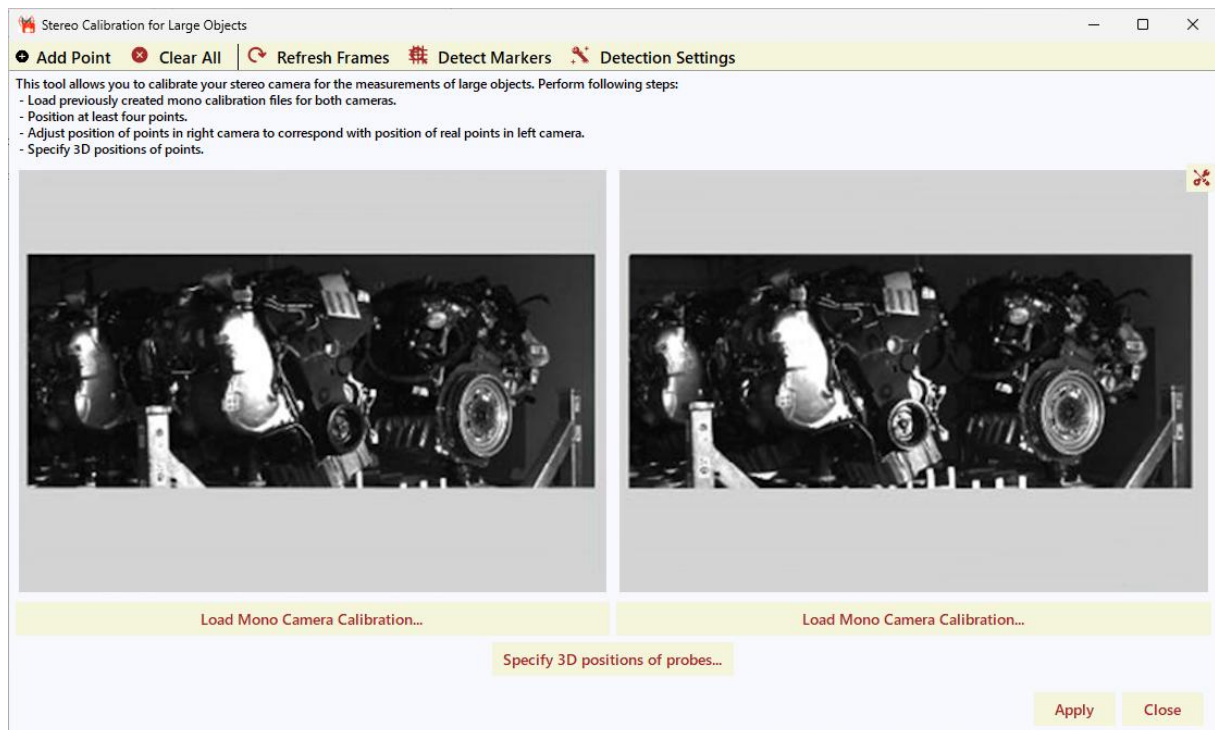


Figure 50: Large object calibration in the stereo scene

3.2.7. Probes

The **Probes** panel contains all available tracking probes and other tools. As portrayed in Figure 51, different buttons are located within this panel for each of the project types, as some probes do not have their equal counterpart in some other modes. The descriptions and usage of individual probes are provided below.

 Probes	 Probes	 Probes
 Point Probe	 Point Probe	 Point Probe
 Rigid Plane Probe	 Line Probe	 Line Probe
 Line Probe	 Chain Probe	 Chain Probe
 Chain Probe	 Polyline Probe	 Polyline Probe
 Polyline Probe	 Force Gauge	 Force Gauge
 Force Gauge	 Point Group	 Point Group
 Point Group	 Surface	 Strain Gauge
 Neck Gauge	Area:	Area:
 Strain Gauge	 Include	 Include
 Angle Probe	 Exclude	 Exclude
 Shear Probe	 Clear All	 Clear All
 Torsion Probe		
Area:		
 Include		
 Exclude		
 PIV Field		
 Crack Probe		
 Clear All		

A) Tracking probes for a mono

B) Tracking probes for a stereo (with and without stitching)

C) Tracking probes for a stitched mono mode

Figure 51: Tracking probes for a) a mono, b) a stereo (with and without stitching) and c) a stitched mono mode.

All probes regardless of their type can be manipulated only when the reference frame is displayed in the corresponding **camera view** (indicated by either the **LIVE** or **REFERENCE** label in the title of the **scene window**) and this reference frame is unlocked (indicated by a grayed-out icon of a lock in the **camera view controls panel**). The manipulation can be performed in one of the following ways:

❖ Add probes:

- Select a probe type in the **Probes** panel.
- OR Select the desired probe type by pressing the corresponding keyboard shortcut (see Appendix D).
- Click on the desired position in the corresponding **camera view**.
- OR **Drag and drop** to enter a Line Probe, Chain Probe, Polyline Probe, Force Gauge, Angle Probe or Shear Probe.
- OPTIONALLY When adding a polygon (Area / PIV Field), **left-click** its first node (highlighted) to finalize it and start a new polygon.
- Press **Esc** button, **right-click** anywhere or deselect the probe in the **Probes** panel when finished.

❖ Delete probes:

- **Right-click** the probe and select **Delete** from the context menu.
- OR Hold the **Shift** button and **left-click** the probe.
- OR Press the **Clear All** button in the **Group Operations** panel to delete all probes.

❖ Move probes:

- **Drag and drop** points or lines to move the probe to the desired location.
- OR **Drag and drop** the width measurement points to adjust their position.

- OR **Drag and drop** one of the nodes of a polyline or a polygon to adjust its shape.
- OR **Middle-click** and **Drag** a strain gauge to rotate it.
- OR Hold the **Middle mouse button** and **Drag and drop** a neck gauge or a polygon to move it entirely.

❖ **Change the properties of probes:**

- **Right-click** the desired probe.
- Select the name of the probe at the top of the context menu to change its name.
- Or Toggle the computation of desired values by selecting their corresponding items in the context menu. All probes support this feature even when a deformed frame is displayed in the **camera view**, or the reference frame is locked.
- Or Change a numeric parameter by entering the exact desired value into its box or selecting one of the standard values from the drop-down menu.
- Or Perform one of the advanced operations supported by the probe by selecting it in the context menu.

The grey area displayed around the reference probes or some of their components represents the area of the correlation template as set in the corresponding section of the **Computation Settings**. Usually, it uses the template size from Correlation in Time, but in a stereo mode, the template size from Correlation between Stereo Cameras is used instead. Additionally, the points for the measurement of width always use the template size from Width Correlation. The displayed area may also be coloured differently according to the estimated quality of the underlying template if this feature is enabled in **Computation Settings** under **Correlation** (see 7.3.1).

Point Probe

Point probes (shown in Figure 52Error! Reference source not found.) are represented by a single marker and are primarily used to measure the position and displacement of the selected point on the surface of the measured specimen. The features of point probes are:

❖ **In all modes:**

- The computation of positions, displacements and their standard deviations.
- The computation of velocities and accelerations.
- The vector visualization of displacements, velocities and accelerations – in the camera view for mono, in the 3D graph for stereo.

❖ **Only in mono and stitched mono:**

- The readout of absolute 2D coordinates of the point probe in the reference frame.
- The conversion to rigid plane probes.
- The computation of positions and displacements in polar coordinates.

- The computation of velocities and accelerations in polar coordinates.

❖ Only in mono:

- The computation of the width of the measured specimen. When selected, a width line is displayed across the point probe.
- The computation of the width of the measured specimen in polar coordinates.



Figure 52: A point probe (the measurement of the bending displacement of a tree)

Thermal Probe

Thermal probes (shown in Figure 53) are only available in a mono mode **with a thermal camera** and are represented by a single marker. Their fundamental difference from point probes is, however, that they are not correlated in time, but rather remain at specific locations in the image throughout the entire measurement instead. They are used for measuring temperatures (incl. temperature changes) at these places. When using a specialized **thermal calibration** (see 12), these probes can also be used to measure strain values at their positions in the image. The shown temperature, as well as the color of the underlying thermal image, are influenced by the **temperature range** parameter of the **Thermal Camera panel** (see 3.2.2).

Probes	
	Point Probe
	Rigid Plane Probe
	Thermal Probe
	Line Probe



Figure 53: A thermal probe used for temperature readout at specific locations in the image

Rigid Plane Probe

Rigid plane probes (shown in Figure 54) are only available in a mono mode, are represented by a single marker and are used to compute the movement of the coordinate system over time. When one or more rigid plane probes are present during a measurement, the coordinate system in each deformed frame is moved so that the change in position (in physical units) of rigid plane probes is minimized. If less than five rigid plane probes are used, this minimized change of position is always equal to zero. For visualization, the images displayed in the **camera view** are also transformed, so that the present rigid plane probes always stay at the same position in relation to the **scene window**.

In a stereo mode (without stitching), the functionality of rigid plane probes is replaced by an optional **Motion Removal** feature of the **Custom Coordinate System** as already described in the chapter Stereo Coordinate System.



Figure 54: Rigid plane probes (applied on the stator of a bearing)

Line Probe

Line probes (also known as **optical extensometers**, shown in Figure 55) are represented by a pair of markers connected by a line and are primarily used to measure the distance between two points (the length of the line probe) on the surface of the measured specimen. The features of line probes are:

❖ **In all modes:**

- The computation of distances and their change from the reference length.
- The computation of angles, angular velocity and angular acceleration.
- The computation of values for stress vs. strain graph (requires a cross-section area to be specified).
- The conversion to point probes, chain probes and polyline probes.

❖ **Only in mono and stitched mono:**

- The computation of lengths in polar coordinates.
- The readout and entry of the exact physical length in the reference frame.
- The fixation of endpoints – disables the correlation of a given endpoint.
- An option to lock the length and rotation to prevent any further changes of relative positions during adjustment of the probe.
- An option to align the line with the X or Y axis during the adjustment of the probe.

❖ **Only in mono:**

- The computation of the transversal extension and Poisson's ratio of the measured specimen. When selected, a width line is displayed across the line probe.
- The conversion to neck gauges.
- The computation of the width of the measured specimen in polar coordinates.

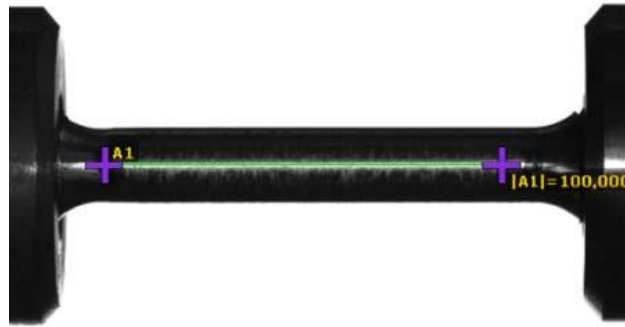


Figure 55: A Line Probe

Chain Probe

Chain probes (shown in Figure 57) are a modification of line probes (see Line Probe), where the line is uniformly divided into a specific number of segments, which are correlated and utilized to improve the precision of the resulting data and meet the specific requirements of the measurement. The number of the dividing segments of Gauge Length is modified through the context menu. The primary function of the chain probe is to compute data only by using the segment with the highest elongation (highlighted in red color).

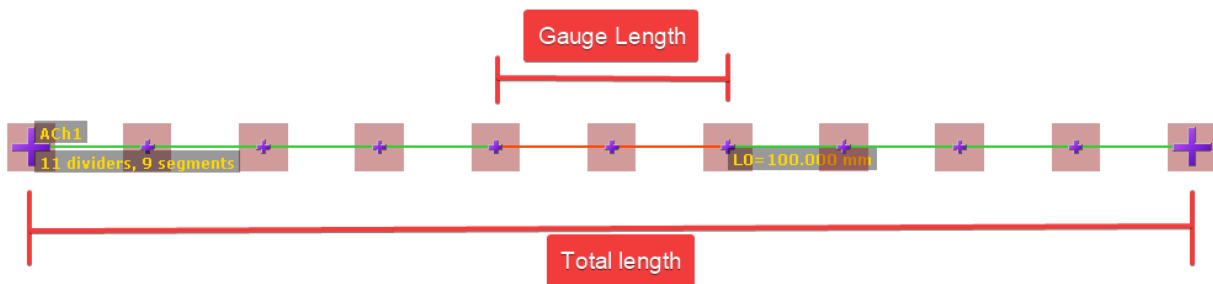


Figure 56: A chain probe

The points, which are not used during the computation at all, are colored grey. This mostly includes the two endpoints of a chain probe, but even some of the dividing points as well if the original gauge length is too high to be able to put them into use. In contrast to line probes, chain probes are stripped of the optional width measurement functionality.

The reference length of all the segments is set explicitly through the context menu. If there are many dividing points, the measured line may span over more than one segment. It is also allowed to measure double of the reference length as well. Mind that, unlike polyline probes, chain probes are only suitable to measure movement on a single axis.

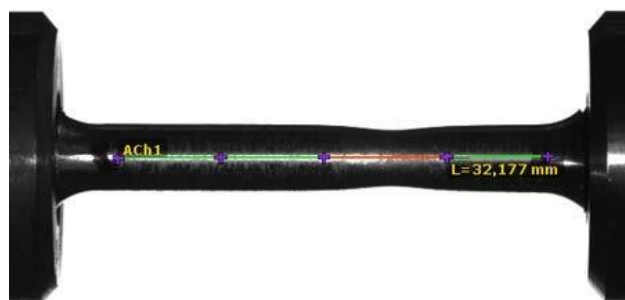


Figure 57: A chain probe during measurement

The features of chain probes are:

- ❖ In all modes:

- The computation of lengths and elongations.
 - The computation of values for stress vs. strain graph (requires a cross-section area to be specified).
 - An option to compute the selected data by averaging all lines of the chain probe until a certain threshold of elongation in % is reached (specified as Averaging Threshold).
 - The conversion to point probes, single line probes (discarding inner points) and polyline probes.
- ❖ **Only in mono and stitched mono:**
- An option to align the line with the X or Y axis.

Polyline Probe

Polyline probes (shown in Figure 58) are similar to chain probes in that they are formed by a line, which is divided by a specified number of separately correlated points, but their function is different. Whereas a chain probe only takes into consideration the displacement in a single axis, a polyline probe takes into account the deviation of an object from its axis, thus can measure the total length of a non-straight object after deformation or compute the maximum deflection of a bending cantilever. If desired, a polyline probe can be divided into independent parts, which function the same way as separate line probes.

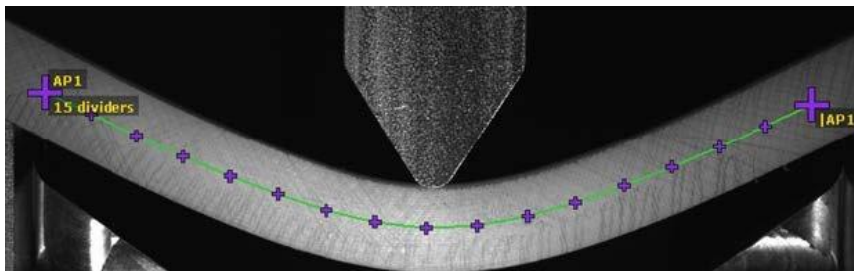


Figure 58: A polyline probe

- ❖ **In all modes:**
- The computation of lengths as a total of all segments.
 - The computation of elongations across the entire profile.
 - The computation of a true strain.
 - The computation of the maximum deflection (the largest displacement of a point on the line).
 - The computation of the degree of curvature.
 - Free edit, an option to move any divider to any position in the scene.
 - The conversion to point probes, single line probes (discarding inner points) or chain probes.
- ❖ **Only in mono and stitched mono:**

- The readout and entry of the exact physical length in the scene.
 - The fixation of endpoints – disables the correlation of a given endpoint.
 - An option to lock the length and rotation to prevent any further changes before measuring.
 - An option to align the line with the X or Y axis.
 - The computation of polar coordinates.
- ❖ **Only in stereo:**
- The computation of the curvature radius by the least-squares fitting.

Force Gauge

The **force gauge** (shown in Figure 59) is a modification of the line probe (see Line Probe) used for the computation of a simulated tear force. This simulation works as a transducer, complementing the values measured by a connected testing machine or replacing them if no such device is present. The resulting force is computed from the extension of the force gauge over time and a specified stiffness. The stiffness of the force gauge can be modified through its context menu. It is available in all scene types, and the computation of stress and true stress is available as well.



Figure 59: A force gauge

Point group

The **point group** (shown in Figure 60) is the extension of a point probe (see Point Probe), which consists of multiple arrow-shaped markers, whose exact number is determined when putting them into the scene one by another. In the middle of these points appears another cross-shaped marker. It effectively functions as a point probe of its own, able to compute most of the values a point probe could as well, with the major difference, that its position is not correlated in time, but always computed as a spatial average of the surrounding points. This approach is useful to observe the behavior even in the places of the image, which do not contain a suitable correlation template or to compute values related to the entire group of points, such as the changes in the rotation of the measured specimen. The surrounding points are correlated as usual, but the loss of one of them during computation results in the loss of the averaged point as well, so their total amount needs to be kept at a reasonable number. If desired, it is also possible to compute each evaluated value independently for each of the markers, not just the middle one, by toggling the **Points Independent** option in the context menu.

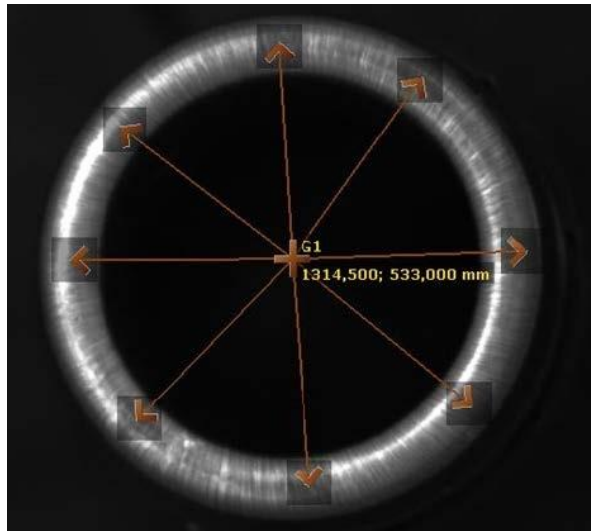


Figure 60: A point group used to measure a rotating specimen

Neck Gauge

Neck gauges (shown in Figure 61) are available only in a mono mode and are represented by a rectangle divided by a line across one of its directions and a specified number of cross-sections in the other direction. It is used to detect an emerging neck during the tensile test, as well as providing a useful tool for computing the Poisson's ratio and Plastic Strain ratio. The distance of the cross-section from either of the endpoints of the dividing line can also be computed and set to the output as desired. The number of cross-sections, and even their desired length (**Enforced Width**) can be set via the context menu. Additionally, either endpoint of the dividing line can be fixed in place, making its position in deformed images remain constant, ignoring any local deformations. There is also an option to compute data independently in each cross-section. The position of the neck-gauge is automatically locked when any of the width points are moved by the mouse.

Optionally, a neck gauge enables to use of anchor points, which means that every single cross-section is attached to a corresponding longitudinal location of a measured specimen (a point where the cross-section meets the dividing line). In this case, the templates for the tracking of movement are displayed in the middle of every cross-section, which assists them to remain at the correct position through the entire measurement. It is recommended to use this feature whenever there is a necking present as well as a suitable surface pattern of the sample to make the tracking of these points possible.

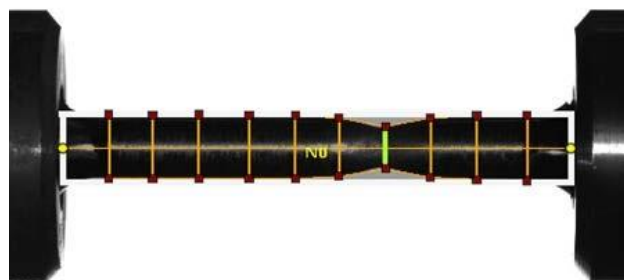


Figure 61: A neck gauge with highlighted neck detection

The width detection system supports two detection methods, selectable in Computation Settings → Width Detection:

- ❖ **Edge detection (default):** Width edges are detected using a two-stage approach: 1D threshold crossing for initial localization, followed by 2D Partial Area Effect (PAE) refinement for sub-pixel accuracy.
- ❖ **Correlation detection:** This method provides stable tracking when edges have sufficient texture for correlation, but may fail on high-contrast edges with uniform

intensity on both sides (singular Hessian) or produce unstable results along the edge direction.

During the measurement, the neck gauge is extended with the specimen using the digital image correlation technique. If DIC correlation of the line endpoints fails, width edge detection uses the reference line as a backup. Even if DIC correlation tracking is temporarily lost, width lines will continue to be displayed.

In situations where there is no spackle pattern, it's not possible to extend the neck gauge with the specimen using the digital image correlation technique. For this reason, the neck gauge includes the Detect Jaws feature, accessible from the context menu. When you activate this feature, a new rectangle is displayed that defines the area in which you can detect edges that extend with the measured specimen, such as the jaws of the testing machine. In this case, the length of a neck gauge is not calculated using the digital image correlation technique, but is extended together with the line that detects the edges.



Figure 62: Neck gauge – detect jaws feature

Strain Gauge

Represented by a rectangle, **strain gauges** (shown in Figure 63) are available only in mono or a stitched mono mode and are used for evaluating strain (or deformation) tensors as well as the Poisson's ratio. The information about the size of the strain gauge in physical units (mm) is displayed in the reference frame. The size of the rectangle can be set through the context menu. The vectors indicating the direction and magnitude of Strain E1 and E2 computed in the edges of the rectangle may be displayed as well, by enabling them in the context menu. In a stereo mode, strain gauges are replaced by surfaces (see Surface).

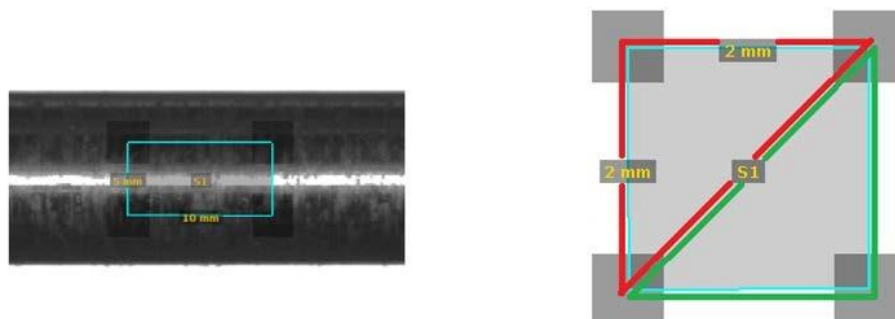


Figure 63: A strain gauge

The computation with strain gauges works in the following way. A correlation template is situated in each of the four corners and in the middle of the strain gauge. The middle point is connected to the pairs of corner points in a way that it forms four triangles as depicted in Figure 63 on the right. The deformation of the individual triangles is computed as an affine transformation. The resulting value is the deformation of the middle point averaged across all four triangles.

Surface

Surfaces (shown in Figure 64) are available only in a stereo mode and are primarily used to visualize the spatial relations between other tracking probes, hence providing additional visual information in the resulting 3D graph (see 3.3). They are specified as a polygon, which needs to have its nodes positioned on a single plane to achieve the intended results because a part of the image from the left camera is displayed in the 3D graph on the part of this plane enclosed by the polygon. Another typical use may be to enclose the template of a measuring probe by a surface to have it visible in the 3D graph afterward. Note, however, that only areas (see Area) may be used to fully reconstruct the shape of the measured specimen in 3D space and that both surfaces and areas cannot be viewed in the 3D graph at the same time.

Additional optional functionality of surfaces is to evaluate strain (or deformation) tensors, thus effectively replacing strain gauges (see Strain Gauge) in a stereo mode.

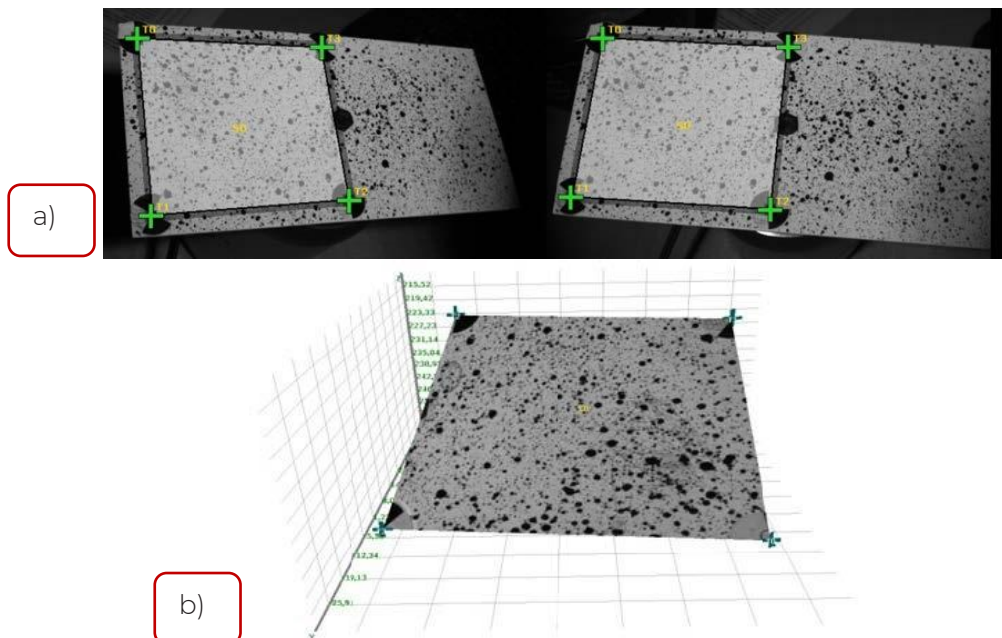


Figure 64: A surface used for the visualization of spatial relations between four-point probes a) during their input in the left and right camera of a stereo pair and b) in the 3D graph

Angle Probe

The **angle probe** (shown in Figure 65) is a tool represented by two lines, which share a common starting point. It is used to measure the angle between these two lines and other related values by performing correlation on all three of these points. The initial angle is displayed right in the camera view of the reference frame and can be set to a specific value from the context menu of the probe. This value can then be locked in the same context menu to prevent further adjustment of the angle when moving the probe around the image.

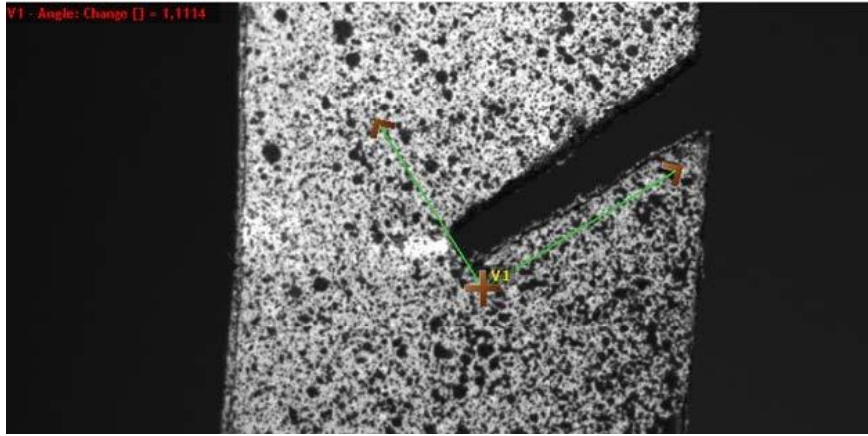


Figure 65: An Angle Probe

Shear Probe

The **shear probe** (shown in Figure 66) is a tool represented by two lines, which intersect in the middle. It is used for computing the angle between these lines, as well as the shear strain computed as the sum of the absolute values of their relative elongations. The computation is performed by correlating the endpoints of these lines (four points in total), which makes it suitable for lattice-like materials. As with the angle probe, the initial angle can be set to a specific value from the context menu of the probe. This value can then be locked in the same context menu to prevent further adjustment of the angle when moving the probe around the image.

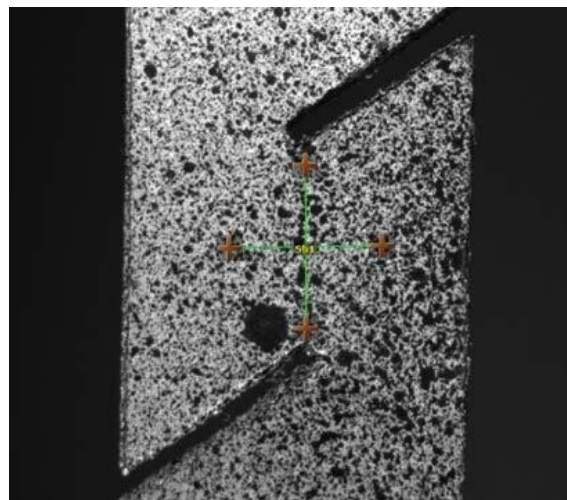


Figure 66: A Shear probe

Torsion Probe

The **torsion probe** (shown in Figure 67) is a tool represented by one line, with start point and end point. It is used to measure angular twist on cylindrical specimens by measuring the angle between start and end point by performing correlation on these points. The initial angle is displayed right in the camera view of the reference frame. In order to get results, it is necessary to specify a diameter of the cylindrical specimen from the context menu of the probe.

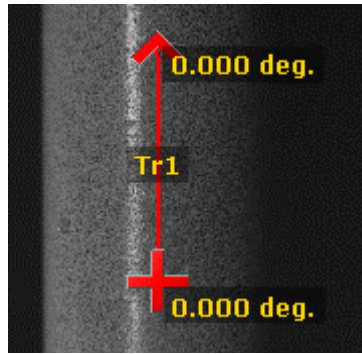


Figure 67: A Torsion probe

Area

Areas (shown in Figure 68) are used for a full-field analysis based on DIC (Digital Image Correlation). The features of the areas are:

❖ In all modes:

- The computation of displacements and their standard deviations.
- The computation of strain or deformation tensors. The type of the tensor is specified in **Computation Settings** under **Full-Field Measurement** (see 7.3.4).
- The computation of strain rates.
- The computation of velocities and accelerations.
- The computation of engineering stress, Von Misses and Tresca stress values. (requires manual input of E and Poisson Ratio in the context menu of the area)
- The selection of statistical functions applied to the computed data.
- An option to separate the area to multiple independent sectors, which causes the selected statistical functions to be applied to each of these separately instead of the entire defined area as a whole.
- The displaying of principal orientations of the computed strains (or deformations), as well as other vectors for displacement, velocity and acceleration.
- Mesh preview, which is helpful, especially when creating the area from point probes as described later in chapter 0.
- An option to automatically fill in holes in the mesh caused by loss of points during computation.

❖ Only in mono and stitched mono:

- The computation of positions and displacements in polar coordinates.
- The computation of velocities and accelerations in polar coordinates.

❖ Only in stereo:

- The computation of Tresca and Von Mises strains.
- The computation of the E3 plastic strain. (requires manual input of E and Poisson Ratio in the context menu of the area)

- The computation of thickness and thickness changes/reduction. (requires manual input of the initial thickness in the context menu of the area)
- The computation of curvature radius by least-squares fitting with the display of the corresponding fitted geometric shape in the 3D graph.
- The reconstruction of the shape of the measured specimen in 3D space. This can go up to 360° in stereo with stitching.
- The resulting thickness, curvature radius and an available test rig with stress in MPa available on Sensor 3 can also be used for the computation of the biaxial stress.

A full-field area is specified using one or more blue polygons, which determine the portion of the space to be included in the analysis (this is where the correlated points are generated) and an arbitrary number of red polygons, which further delimit areas within these blue polygons to be excluded from the analysis (where the points are not generated). In scenes with stitching, these polygons can be defined each in a different camera, thus extending their coverage over multiple camera views.

The generated points are displayed as yellow dots on the surface of the included area. They are correlated separately, so the computational load is heavily influenced by their count – the more points there are in a grid, the more time is required to compute a single deformed frame. The count of the generated points can be adjusted by changing the grid spacing in the context menu. If desired, there is also an option in the context menu which hides these points in the camera view.



Figure 68: An area comprised of three “included” and two “excluded” polygons

The measured values are computed for each point of an area and displayed as a colored map, where the values are mapped to their corresponding colors from the associated color scale as can be seen in Figure 69. Only a single type of computed value is displayed at a time. Right-clicking an area with computed data allows choosing the displayed value from a drop-down menu.

Initially, the quantities in graphs represent the average of values computed in the entire area (or whichever another statistical function is selected), but individual points may be selected for a display in graphs by left-clicking on them when the measurement is not running. Additionally, particular included areas can be divided into independent sectors, which allows computing the statistical data separately for each sector. As for the color scale itself, its placement can be adjusted by dragging it with the mouse, and it can be rotated by the right mouse button. Clicking the control points of a color scale switches between the local and global minimum and maximum, and dragging those control points sets a custom value. An exact value of the minimum and maximum can also be specified via the context menu. These settings are then remembered for further recomputations until the reference is unlocked. Note, however, that the initial values are set with respect to the minimal ranges specified in **Presentation Settings** under **Color Scale** (see 7.2.2).

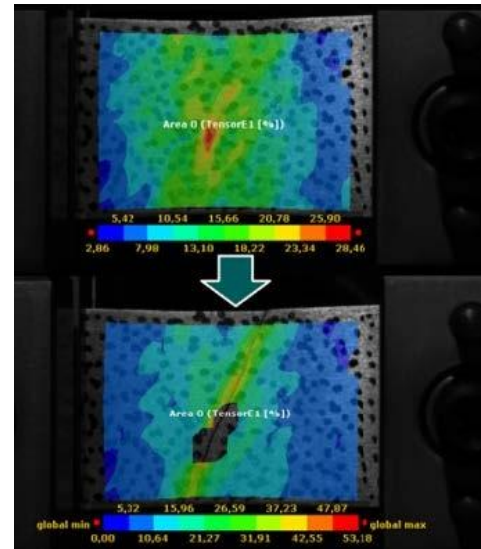
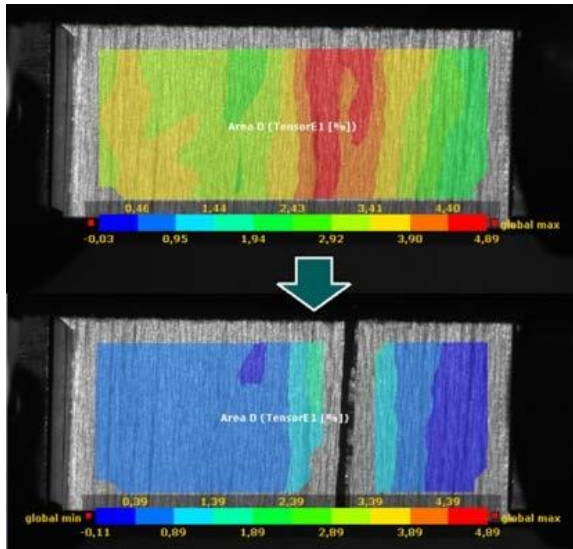


Figure 69: The strain distribution (strain E1) on specimens with a natural and speckle pattern

The display of principal orientations of the computed strains (or deformations) is available for Strain E1, E2 and E3. Other vectors are available for a generic displacement, velocity or acceleration (**not** those restricted to a single axis). In mono and a stitched mono mode, the vectors are displayed in the camera view, while in a stereo mode they are **only** displayed in the 3D graph as they are computed in 3D space and a 2D display is not sufficient for their visualization. The display of principal orientations is disabled by default and can be toggled by selecting the **Hide Vectors** function in the context menu. The reconstruction of an area in the 3D space can be seen in Figure 70. This is displayed in the 3D graph, and it is more precise, the more points have been used for the computation. The image data displayed on the resulting shape corresponds to the image data displayed in the camera view, where the area was specified.

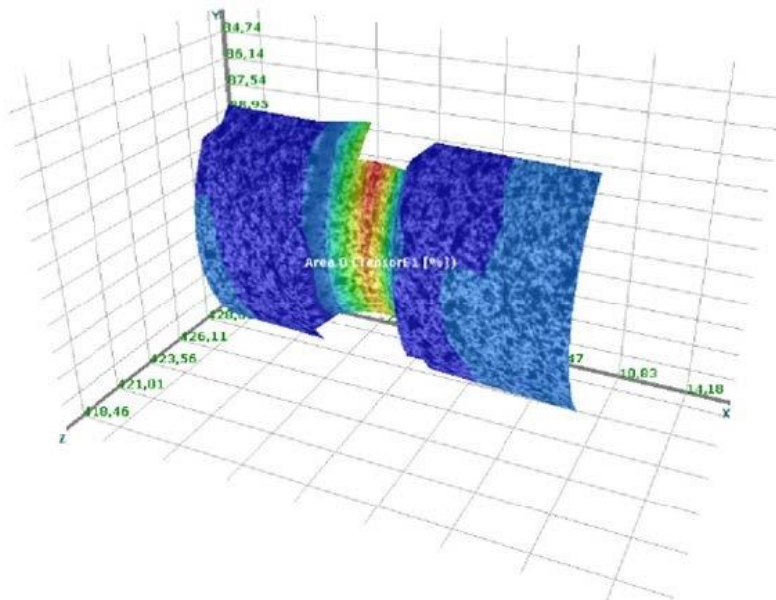


Figure 70: The 3D strain distribution (strain E1) in the 3D graph

When the curvature radius or the biaxial stress is selected for computation, a sphere is fitted to the points of the full-field area, and its radius is used for these computations. As shown in Figure 71, the fitted sphere can then be seen in the 3D graph display, which makes it available for visual verification.

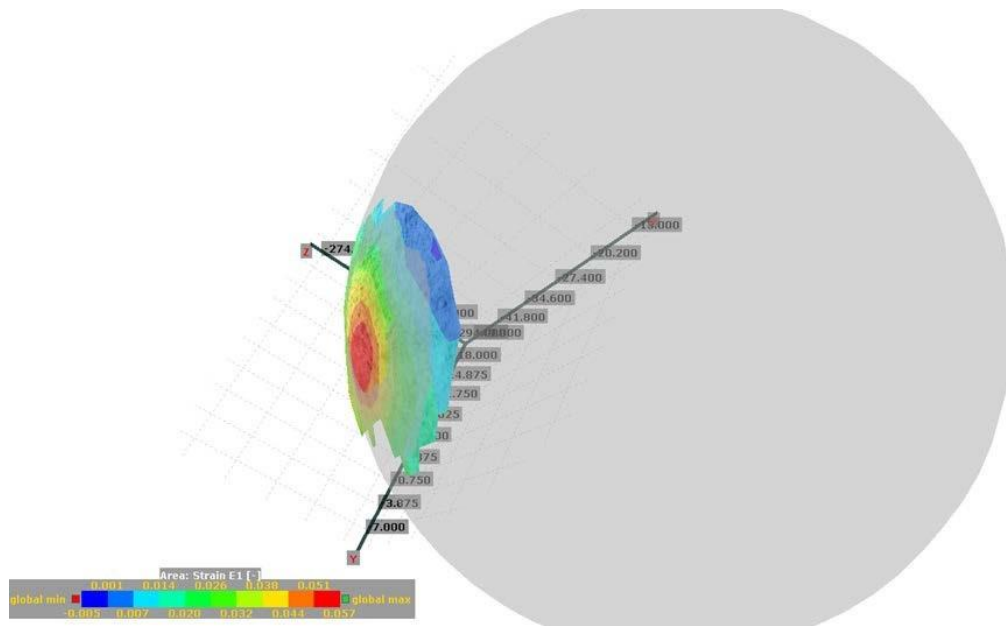


Figure 71: The fitted sphere displayed in the 3D graph

Additionally, there is a specialized **area cross-sections** graph used for the analysis of linear segments drawn on the surface of a computed area. After performing any full-field measurement, use the Area Section tool from Tools Panel and create a line with the path you are interested in to insert a **path measuring component** shown in Figure 72. All the desired courses of strain values are displayed in the **area cross-sections** graph. The parameters related to this process can be adjusted in the Presentation Settings under Post-Processing (see 7.2.5).

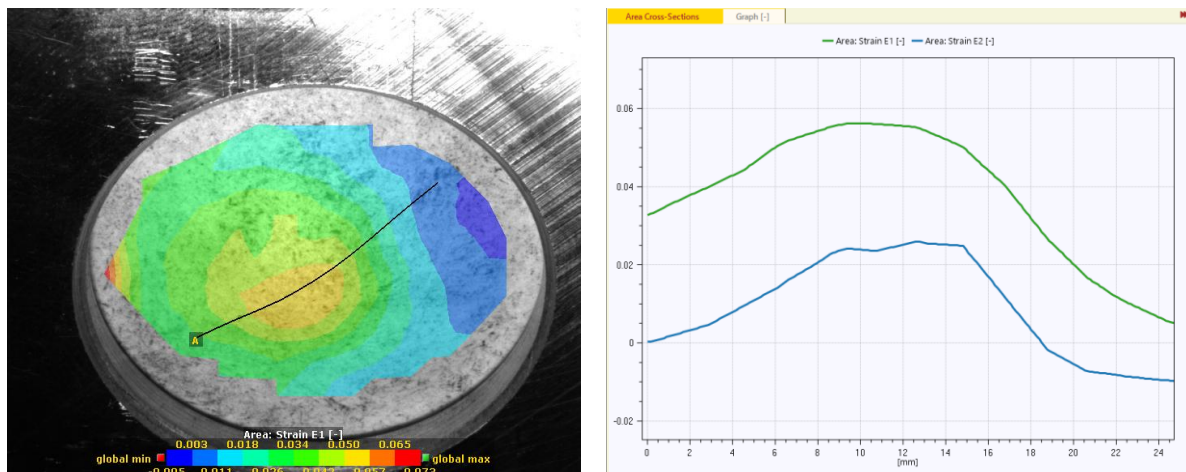


Figure 72: Path measuring along the component created by dragging the middle mouse button

PIV Field

PIV fields (shown in Figure 73) are available only in a mono mode and used for Particle Image Velocimetry. They are specified as polygons similarly to areas (see Area), with the exception that the points generated within do not represent points located on the surface of the measured specimen, but locations in the image itself, where changes are to be tracked. The computed displacements are, therefore, not cumulative over time but always related to the preceding frame. Also, the functions provided by PIV fields are identical to the ones provided by full-field areas, with the only exception that the computation of tensors is not possible in PIV fields and vectors are always shown for a generic displacement, velocity and acceleration to indicate their direction and magnitude.

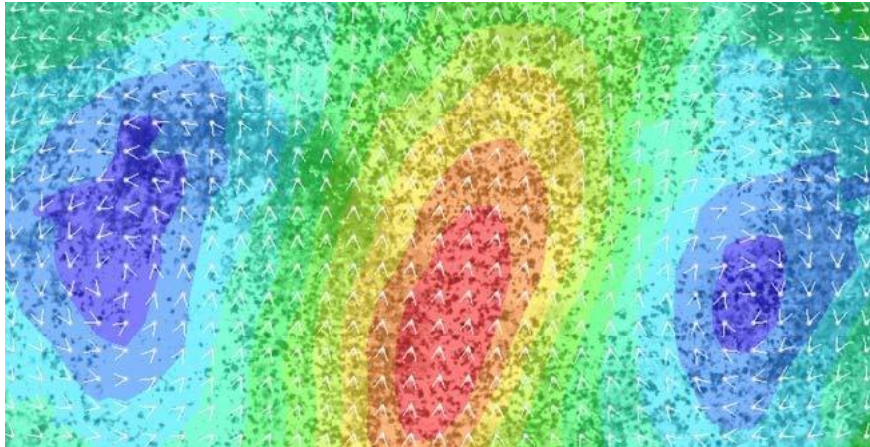


Figure 73: Path measuring along the component created by dragging the middle mouse button

Crack Probe (Beta)

Crack probe (shown in Figure 76Error! Reference source not found.) is a technological preview of a tool developed for the measurement of the crack propagation in materials like metals, polymers or composite materials. These probes work only in a mono mode without stitching. **The limitation of current version of the tool is that it can only measure from left to right side.**

The crack measurement can be performed by two methods.

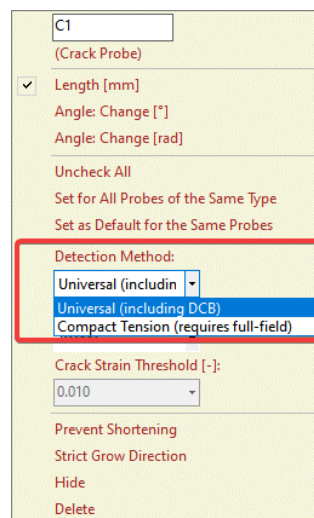


Figure 74: The context menu of a crack probe

- **Universal method** - This method uses Deep Neural Network (DNN) for crack segmentation. It does not require the use of full-field area. The DNN model is trained to also detect cracks of Double Cantilever Beam (DCB).

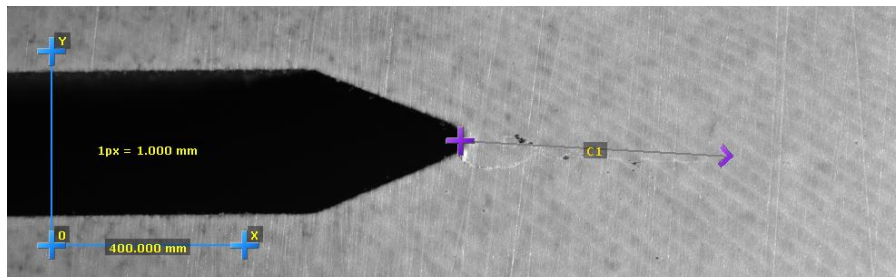


Figure 75: Crack probe – Universal method

The conditions for a proper measurement with the crack probe are as following:

- ❖ The first image should not contain crack. If it does, it will be not detected and crack is considered to start from its end (tip) in the first image.
- ❖ Images cannot contain any other movement besides crack growing. If there is a movement then anchor points (see Rigid Plane Probe) must be used to stabilize it. Anchor points mustn't be affected by crack growth and thus are usually placed on opposite (to reference point) side of sample.
- ❖ Crack should be clearly visible and other parts of measured sample should contain as little variance as possible.

- **Compact Tension (CT) method** - This method is requires full-field measurement and can be performed only in postprocessing. This method uses a strain measurement on the surface of the specimen for its evaluation, and therefore a **full-field area** (see Area Probe) is necessary as well. The conditions for a proper measurement with the crack probe are as following:
- ❖ The full-field area should be defined to compute strain on the surface where crack propagation is expected.
 - ❖ The crack probe must be placed over this area with its origin set to the point where the crack is expected to emerge.
 - ❖ It is helpful to use rigid plane probes (see Rigid Plane Probe) to remove the motion of the surface in the image. As seen in Figure 76, two or more Rigid Plane Probes are input to remove the rigid body motion in the camera view for better detection of the crack.

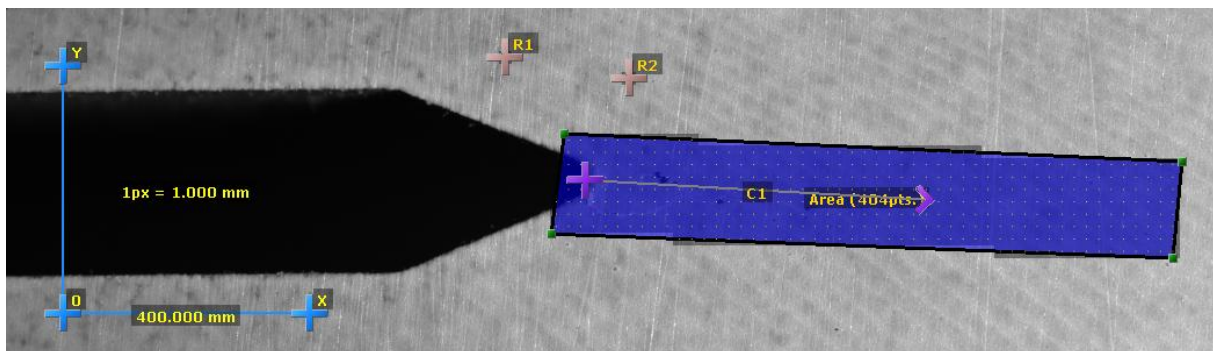


Figure 76: Crack probe over a full-field area

The propagation of the crack is detected only within this area as the position where the computed strain is larger than the selected threshold. The length of the crack is measured

from the fixed origin of the crack probe to the furthest point of the detected crack area. The angle of the crack growth is determined as an angle between the direction of the reference probe and the direction defined by the furthest segment of the crack of the length specified as Angle Measurement Distance.

Crack probes have the following unique parameters, which are adjustable via their context menu shown in Figure 74:

❖ **Detection Method**

- Universal method – crack is detected using Deep Neural Network (Deep Learning).
- Compact Tension – CT method of crack detection that defines the crack as an area where strain exceeds some specified threshold.

❖ **Angle Measurement Distance** – The length that is used for the definition of the angle of the crack growth. It is the length of the furthest segment of the crack that defines the direction of crack growth.

❖ **Crack Strain Threshold** – The sensitivity of the crack detection, i.e. the amount of strain that indicates the presence of the crack.

❖ **Prevent Shortening** – It can happen that the probe will lose the area that has been considered as a crack before, and the crack will become shorter. This prevents the tip of the detected crack from moving back and makes it stay in the last detected position until it starts to grow again.

❖ **Strict Grow Direction** – If the strict growth option is enabled, the growth direction must precisely align with the direction of the crack itself.

Thermal Area

Thermal Areas (shown in Figure 77) are used for a full-field analysis based on Temperature field. Measurements in the thermal area work the same way as measurements using the normal area, except that in the normal area the deformation is measured at the given points, in the thermal area the temperature is measured at the given points. The thermal area can measure a temperature variable or temperature difference and can display mean, minimum, maximum, median, or standard deviation. Measurements and outputs are displayed in graphs. Outputs can also be exported to CSV or HDF5 from the graph or area data.

Each camera has temperature ranges stored within it for measuring temperature. In MercuryRT it is possible to select the range to be used. E.g. From -20 To 100 °C, 100 To 250 °C. 150 to 900 °C.

It is not necessary to calibrate the thermal camera in mono mode using the calibration grid. The camera detects the infrared radiation and converts it to temperature. The image that is seen is the temperature field. Using the pseudo colors button, it is possible to switch from a black and white image to a color image.

Temperature measurements can only be performed in monoscene, but a combination with an optical camera is possible.

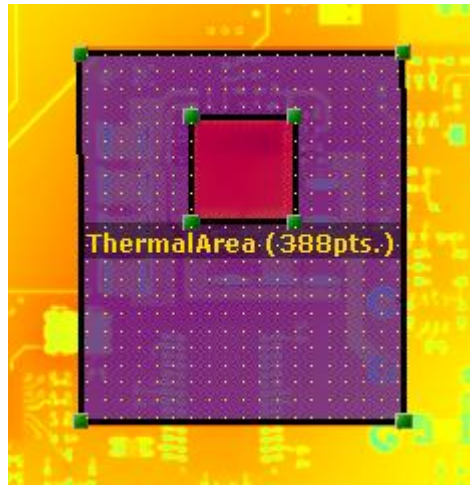


Figure 77: Thermal Area

3.2.8. Group Operations

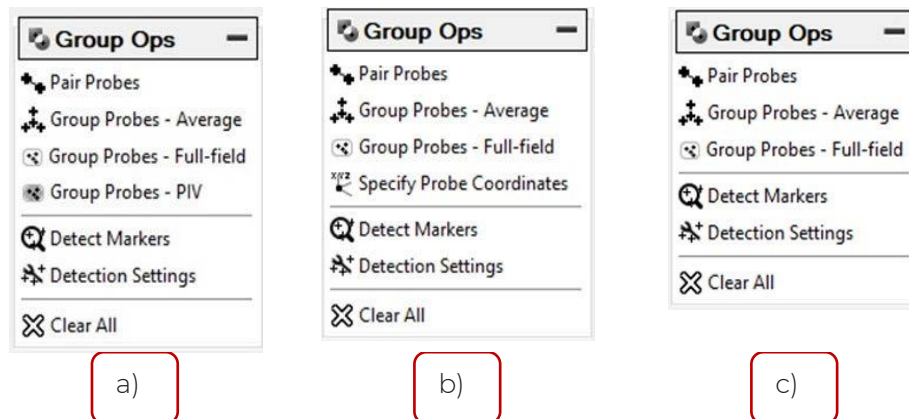


Figure 78: Group Operations panels for a) mono (with and without stitching), b) stereo, c) stitched stereo mode

The **Group Operations** panel shown in Figure 78 provides a set of operations which manipulate with multiple probes together as a group. They are as follows:

- ❖ **Pair Probes** – Creates an extension line by pairing two **point probes**, as shown in Figure 79. To perform this operation, press the **Pair Probes** button and select two-**point probes** with a **left click**. In a stitched mono mode, it is even possible to pair probes between different camera views this way. Notice that this will not create a line if the total count of extension lines in the corresponding **camera view** exceeds the licensing limits.



Figure 79: Pairing of probes

- ❖ **Group Probes** – Creates different types of probes listed below by grouping existing point probes together.
 - **Average** – Creates a point group (for evaluating the average position of the probes).
 - **Full-field** – Creates a full-field area.
 - **PIV (mono only)** – Creates a PIV field.

If there is already an **area** created this way, it appends the new positions to the ones already present. To revert this operation, select **Convert to Points** from the context menu of the area.

- ❖ **Specify Probe Coordinates (stereo only)** – Opens a dialogue window, which allows to manually specify the physical coordinates of the input probes to form a custom 3D coordinate system. At least four-point probes must be previously placed in the scene to use this feature.
- ❖ **Detect Markers** – Performs the detection of markers according to the currently set parameters of **Marker Detection in Computation Settings** (see 7.3.5).
- ❖ **Detection Settings** – Opens a dialogue shown in Figure 80 which provides access to the adjustment of the parameters of **Marker Detection**. These are identical to those found in **Computation Settings**, so see chapter 7.3.5 for descriptions of specific parameters.
- ❖ **Clear All** – Deletes all probes in the scene.

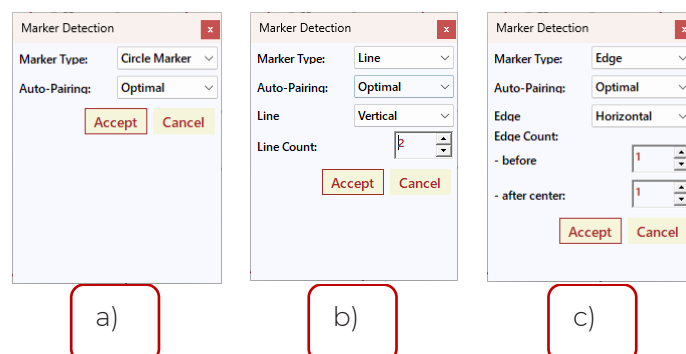


Figure 80: The dialogue of marker detection settings showing a) general detection parameters, b) general parameters including those specific for the detection of lines and c) general parameters including those specific for the detection of edges

3.2.9. Tools

- ❖ **Scale Caliper Tool**  – Measures distances on the image in the space defined by the active A tool called Scale Caliper is available for setting the scale factor for a mono scene. This tool allows you to specify a known distance within the scene. In this way, it is possible to define a relationship between a pixel and a physical unit in millimeters. In the toolbar, select the Scale Caliper tool. Use the Scale Caliper tool to draw a line between two points in a mono scene where the distance is known. Then manually measure the real distance between the two points and enter that distance in the distance field (you can also enter the distance in the context menu, which can be displayed by right-clicking on the ScaleCaliper). ScaleCaliper can only be used on a

project that is not locked  and where the coordinate system position is not locked. By specifying the Scale Caliper distance in mm, the Scale Factor is recalculated in unit [mm/px]. So Scale Factor specify how much mm equals one pixel.

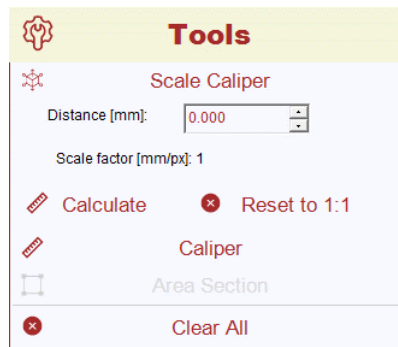


Figure 81: Tools Panel – Scale Caliper

- ❖ **Caliper Tool**  – Measures distances on the image in the space defined by the active camera calibration and coordinate system. This function is also available on any of the recorded images even when the reference frame is locked. Stereo mode, however, requires the cameras to be calibrated first and the endpoints need to be found in both cameras.

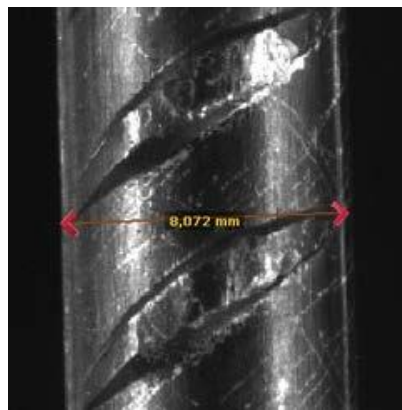


Figure 82: Caliper Tool functionality

- ❖ **Area Section** – This tool allows to creation of a linear segment on the surface of the computed full-field area after performing any full-field measurement. All the desired courses of strain values are displayed in the area cross-sections graph. The parameters related to this process can be adjusted in the Presentation Settings under Post-Processing (see 7.2.5).
- ❖ **Clear All** – Deletes all Calipers and or Area Sections from the scene.

3.2.10. Parameters

The panel of parameters depicted in Figure 83 allows the modification of the most used correlation parameters as well as some parameters related to post-processing of displayed data. All correlation parameters can be modified in **Computation Settings under Correlation** (see 7.3.1). The panel is divided into several sections and contains the following:

- ❖ **Polygon Input** – Specifies the **Mode** of the input of polygonal shapes such as areas and PIV fields. In the case of the Discrete Circle option, the **Number of Vertices** of such a circle can be specified here as well.
- ❖ **Incremental Step** – Specifies the frame interval of the incremental correlation. If the number -1 is set, an adaptive (automatic) incremental correlation is performed.
- ❖ **Vector Density** – Specifies the number of vectors to be displayed on full-field areas and PIV fields relative to all the computed vectors in the corresponding grid (only every n-th vector is shown in each direction).
- ❖ **Vector Multiplier** – Specifies the multiplier applied to all displayed vectors.
- ❖ **Template Size** – Specifies the **template size**. The **Automatic template size** button located next to it tries to find the optimum template size for the currently present probes. The two template sizes in a stereo mode are initially changed together because it is not necessary to have them differ in typical situations, but changing them in **Computation Settings** can override this. It is also possible to completely **detach the template size from settings** by using the checkbox below. This sets the size for the respective scene independently from all other scenes and settings, allowing to set of a different template size for each scene in the project.
- ❖ **Correlation Speed** – Specifies the correlation speed.
- ❖ **Transformation Type** – Specifies the type of correlated transformation.

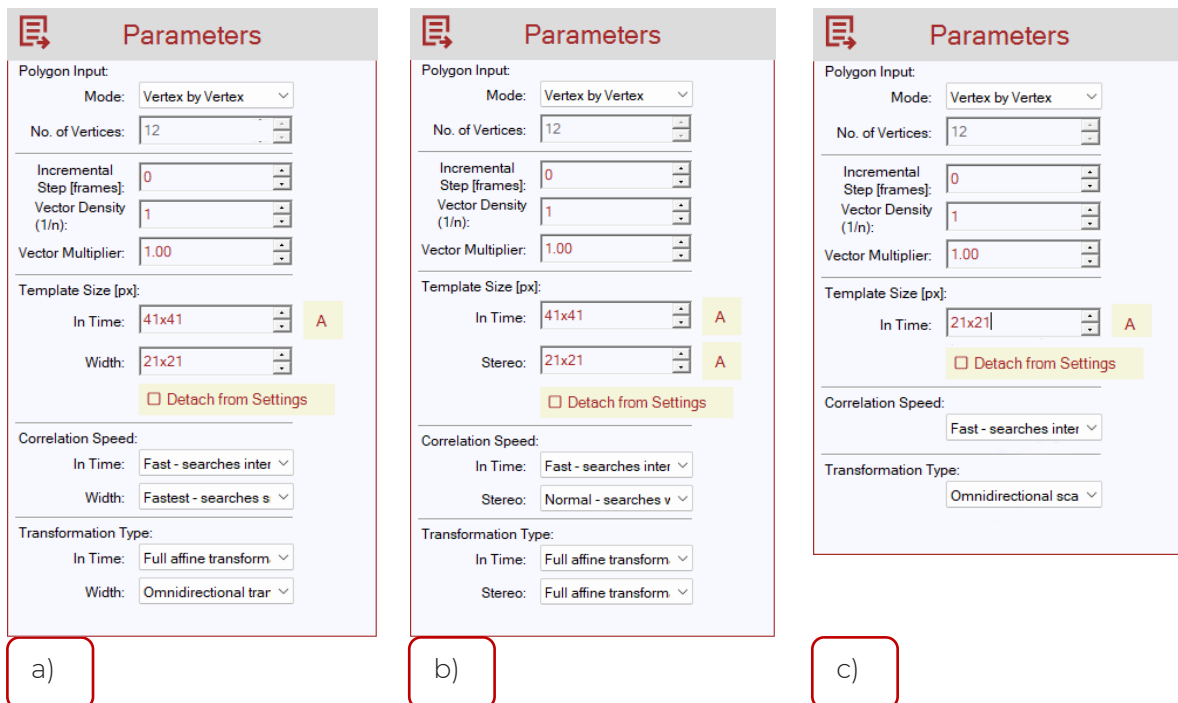


Figure 83: The Parameters panel for a) a mono, b) a stereo (with and without stitching) and c) a stitched mono mode

3.2.11. Seek Panel

The small seeker in the Seek panel shown in Figure 84 can be used as an alternative to the seeker in the main window. Additionally, it is possible to seek a next/previous frame by pressing the Page Up/Down button.

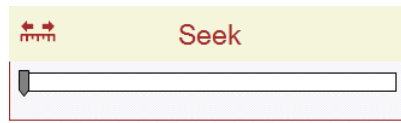


Figure 84: The Seek panel

3.3. 3D GRAPH

The 3D graph depicted in Figure 85 is used only in a stereo mode and shows the computed positions of the specified tracking probes in a 3D space. The 3D graph is available in the panel next to the left and right camera in the top left of the **scene window**. The graph supports basic ways of handling – rotate (left mouse button + mouse move), zoom (scroll mouse wheel or right mouse button + mouse move) and move (middle mouse button + mouse move). Right-click offers a context menu, which contains the following:

- **View rotation pivot** – Selects either the center of the graph or any of the displayed probes as the pivot for view modifications (rotation, zoom, and more).
- **Lock Rotation Pivot** – Locks the rotation pivot to its current location in 3D space, effectively preventing it from changing when moving to a different recorded frame.
- **Copy to Clipboard / Save Image as / Save Video Sequence** – Saves the displayed contents of the 3D graph to an image or a video file in the same way as described in 3.1.
- **Orthographic Projection** – Toggles between orthographic and perspective projection.
- **Invert Colors** – Toggles the inversion of displayed colors.
- **Hide Labels** – Hides all text labels from the display.
- **Hide Textures** – Hides all mapped textures from the display.
- **Hide Color Map** – Hides colour map from the displayed full-field area, thus making the underlying texture visible more clearly.
- **Hide Color Scale** – Hides the colour scale associated with a full-field area from the display.
- **Displayed Value** – Selects the value displayed by the colour map of a full-field area.
- **View Surfaces / Areas** – Toggles between the display of surfaces and full-field areas if both are present in the measured scene.

4. IMPORT

The importing capabilities of the program are provided by the **Import** section of the main menu bar shown in Figure 86. However, if it is desired to load previously recorded images or videos for offline measurement, such a process is performed via the **New Project** wizard instead, as already described in 2.2.

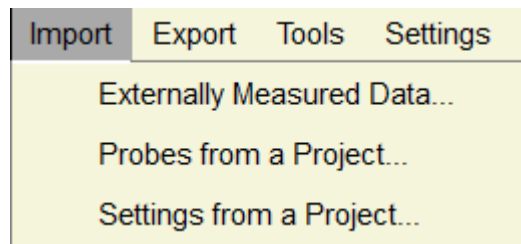


Figure 86: The Import section of the main menu bar

4.1. EXTERNALLY MEASURED DATA

The data measured outside the program can be imported through the **Import Data** wizard (see Figure 87) and associated with the currently open project. Its prerequisites, however, are that the input data are stored in a CSV file and aligned into one of its columns. The input CSV file, in which the externally measured data are stored, is set through the field labeled **Measured Data CSV File**. Next, the number of the column (with 0 being the first one) in which the measured values are contained, is specified in the corresponding numeric box and the type of these values is selected right next to it from some of those, which are used within the program and may also be used as a component in a **custom series** (see 15). Another note is that the delimiter used in the input CSV file is set to a semi-colon by default and may also be modified. After confirming the selection, the **Measured Data Import Tool** window (described in section 4.1.1) is open.

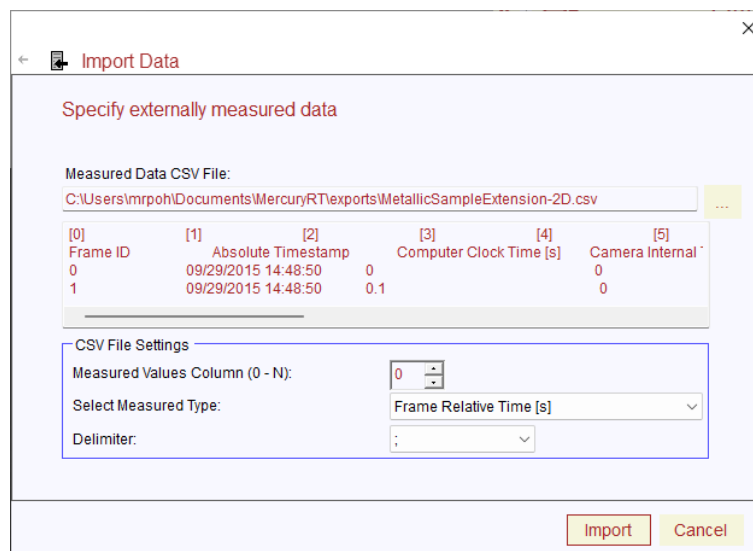


Figure 87: Import Data wizard

4.1.1. Measured Data Import Tool

The **Measured Data Import Tool** seen in Figure 88 allows any necessary changes in the alignment of the imported measured values with the values already present in the open project. The window consists of two graphs. The upper graph shows a series of **measured values** in the open project. The series can be changed using the **selected series** control containing a list of available values in the open project. The lower graph shows the imported data from a CSV file. The alignment is affected by the location of the red limiters.

The selection of the final range can be specified either by Start and End or Start/End and Sampling Frequency.

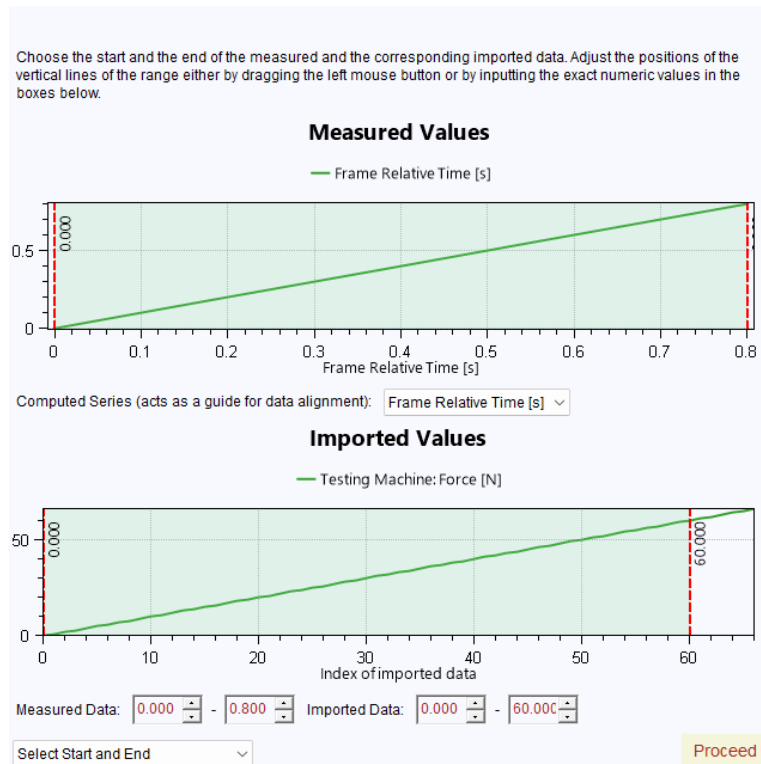


Figure 88: Measured Data Import Tool for setting the alignment of externally measured data

4.2. PROBES FROM A PROJECT

Allows importing probes from a different project. This assists with the evaluation of a group of measurements, where it is desired to use precisely the same kind and position of probes. However, it is only allowed if the types of scenes present in the currently open project match the scenes in the imported project. The probes that are already present are discarded.

4.3. SETTINGS FROM A PROJECT

Allows importing the **Presentation** and **Computation Settings** from a different project. Unlike importing probes from a different project, the scenes in these projects do not need to be compatible with each other. Also note, that all of the parameters are modified during this kind of import, so it is not possible to import only correlation parameters this way or so.

5. EXPORT

This chapter brings an explanation of exporting data from the current project as files for further processing. As seen in Figure 89, there are multiple options for export.

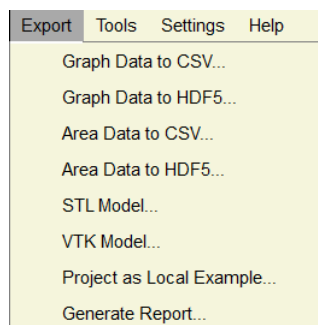


Figure 89: The Export section of the main menu bar

5.1. EXPORT GRAPH DATA TO CSV AND HDF5

The first item, called **Graph Data** requires any recorded data. As seen in Figure 91, it is necessary to select the target path, a field separator and a decimal separator. Moreover, only the selected range of the main seeker may be exported if desired. According to Figure 90, it is possible to select an arbitrary number of available values to save them in a CSV format. The format of exported data is fully compliant with common spreadsheet editors such as MS Excel.

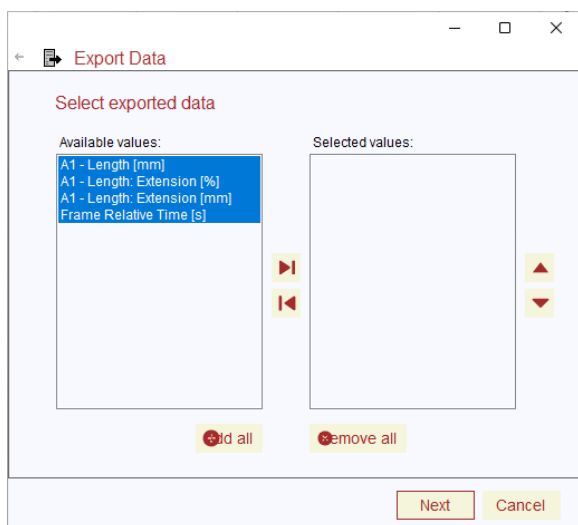


Figure 90: The selection of the exported data

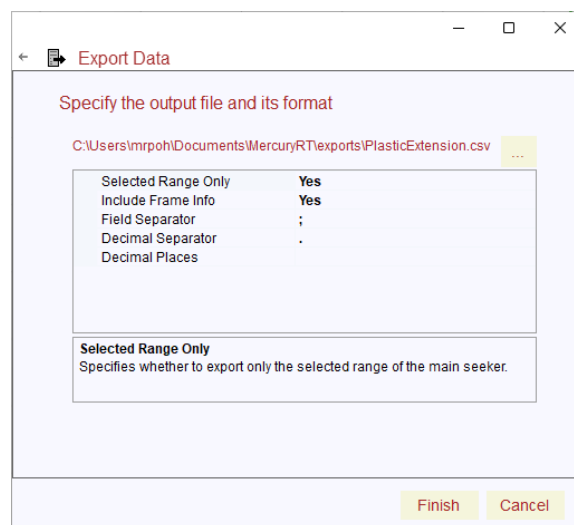


Figure 91: The settings of the export of graph data

5.2. EXPORT AREA DATA TO CSV AND HDF5

The second option, Export **Area Data to CSV** regards only full-field data. In the CSV file, all data from the points in the range selected as **Source Data** are included. It is, however, possible to split the export among several files (One File Per Slice option in Figure 92) to make the transitions between consecutive frames recognizable more clearly. The dialogue previously depicted in Figure 90 is not present in this option.

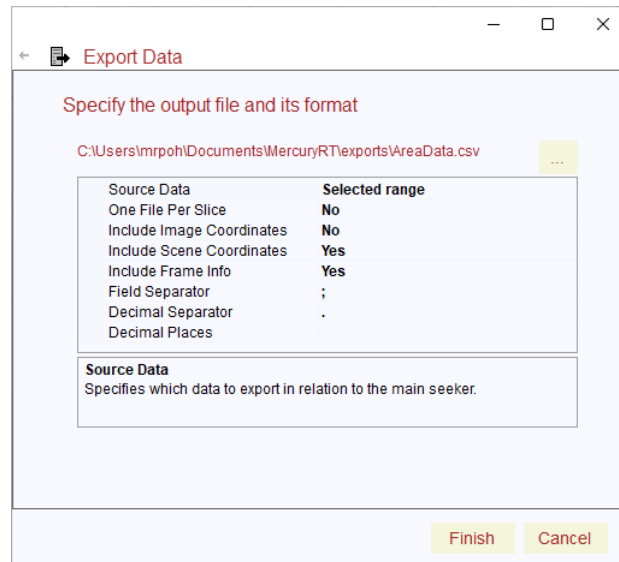


Figure 92: The settings of the exported of area data

5.3. EXPORT STL AND VTK MODEL

The export of data as an **STL Model** (mesh only) or a **VTK Model** (mesh with computed values) requires a stereo measurement with the computed full-field area and a marked time slice. It means that the **Set Mark** button has to be applied at the desired moment in time. In this option, a window depicted in Figure 93 opens. In the case of an STL model, only one parameter is available, to save the model as a binary file or not. A VTK model does not require specifying any additional parameters.

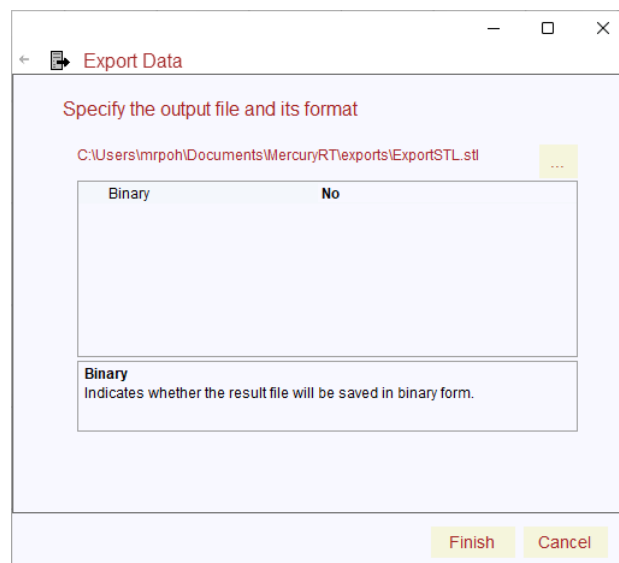


Figure 93: The settings of the STL model

5.4. EXPORT PROJECT AS LOCAL EXAMPLE

The option to export **Project as Local Example** is mostly used to create examples, but can also be utilized to create project backups. Because of the need of having data small enough, there are two choices - to convert data format either to JPEG or PNG format (see Figure 94). Conversion to PNG files makes it slower and the size of the package smaller. Conversion to JPEG files makes the size of the package even smaller but causes data loss. The directory of local examples is open as a first choice when selecting the target path.

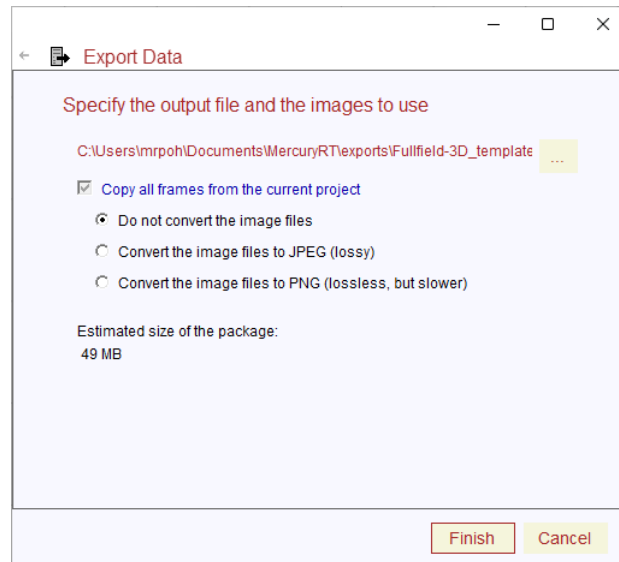


Figure 94: The settings of exporting a project as a local example

5.5. GENERATE REPORT

The last available option for export is to **Generate Report** in the form of a pdf file. As seen in Figure 91, it is necessary to select the target path and two optional parameters. **Header Logo Path** – The path of the image to be used as a logo in the header of the report. **Include Project Notes** – Specifies whether to include the project notes (see 2.3.10) in the generated report. It is only applied when the template of the notes is modified in any way.

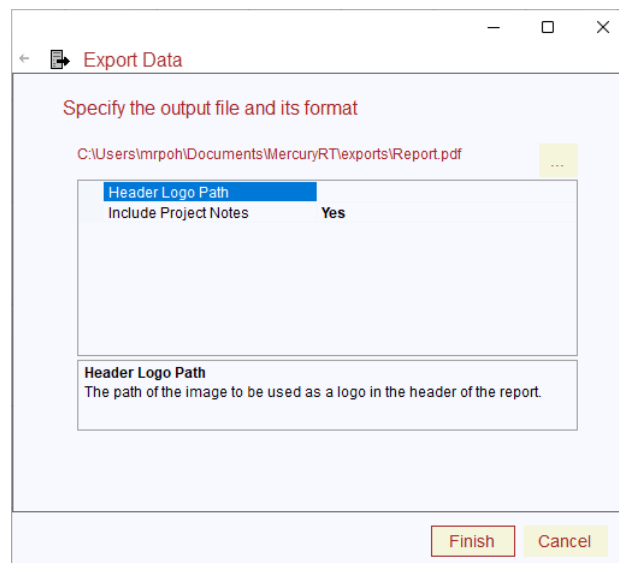


Figure 95: The settings of Report Generation

Aside from the optional notes, the body of the generated report contains the images of all the charts currently displayed in the project (see 2.5). These are followed by screenshots of the camera displays, which show the currently sought frames along with the computed probes (see 3). This includes the 3D graphs as well in case any are available (see 3.3). Note that no computed graph data outside the displayed graphs are present in the generated report, so its content does not overlap with exported graph data.

6. POST PROCESSING

This chapter contains the explanations behind various post-processing utilities found within the program, available under the **Tools** section of the **menu bar** in the **main window**.

6.1. VIBROGRAPHY

The **Vibrography** tool is used for the analysis of data in the frequency domain.

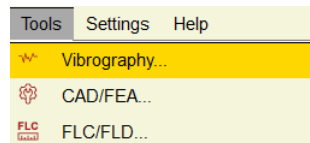


Figure 96: The Vibrography tool button

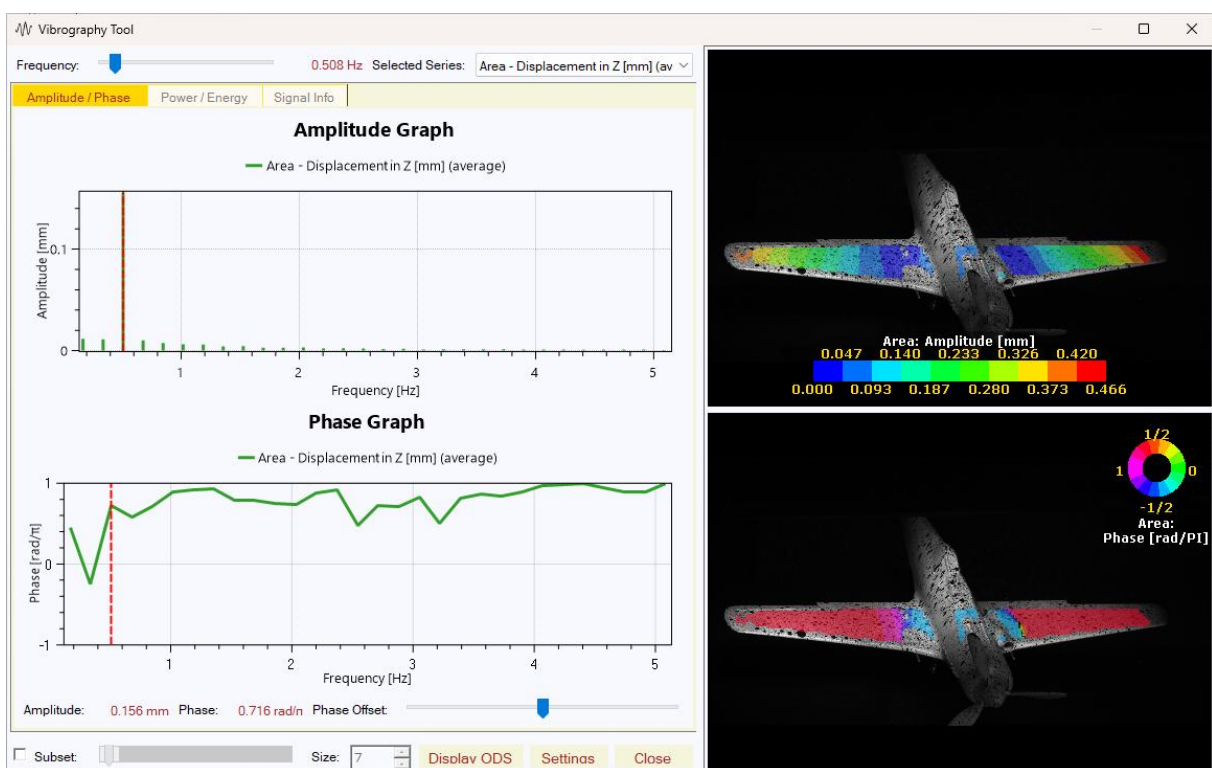


Figure 97: The Vibrography Tool window

The data for a vibrography analysis is selected using the **Selected Series** drop-down box in the top-right. By default, the entire data series are analyzed. After the spectrum analysis is done, a frequency can be selected by using the **Frequency** slider. The computed data is shown in the form of several graphs (**Amplitude**, **Phase**, **Power** and **Energy**), numerical information found primarily under the **Signal Info** tab and images for reference and mapping of data to full-field areas.

To analyze only a selected subset, check the **Subset** box in the bottom-left and adjust the position (the slider next to it) and the **Size** of the chosen subset. When hovering over the subset slider, the information about the selected subset (the start and end time, the excitation frequency, i.e.) is shown. Using subsets can be useful when analyzing data where frequencies change over time, as seen in Figure 98.

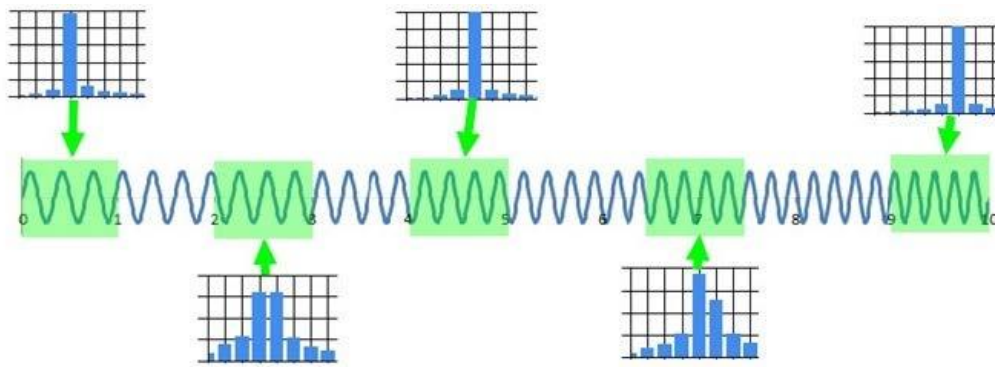


Figure 98: Result of the spectral analysis performed on different segments in data generated with an increasing frequency

6.1.1. Amplitude / Phase Tab

This tab contains the graphs of amplitude and phase:

- ❖ **Amplitude Graph** – Displays the computed amplitude for each frequency. The amplitude axis can be changed to a logarithmic or decibel scale in the context menu. The frequency axis can be changed to octaves in the context menu as well, allowing to perform an octave analysis.
- ❖ **Phase Graph** – Displays the computed phase for each frequency. The phase axis can be toggled between degrees and radians in the context menu. The **Phase Offset** control under the graph allows moving the position of a zero phase. At the bottom of the tab, the value of amplitude and phase for the selected frequency is displayed.

6.1.2. Power / Energy Tab

This tab contains the power and energy spectral density graphs:

- ❖ **Power Spectral Density Graph** – Displays the computed power density for each frequency. The frequency axis can be again changed to an octave in the context menu, allowing to perform an octave analysis.
- ❖ **Energy Spectral Density Graph** – Displays the computed energy density for each frequency. The frequency axis can be once again changed to an octave in the context menu, allowing to perform an octave analysis.

At the bottom of the tab, the value of power density and energy density for the selected frequency is displayed.

6.1.3. Campbell Diagram

A **Campbell diagram** is used for the assessment of eigenvalues and other dynamical quantities, mostly in rotor dynamics. The Campbell Diagram tab is only visible when the **Subset box** in the bottom-left corner is checked (see Figure 99).

- ❖ **Subset size** – Defines the size of data in the time domain for the construction of individual vertical lines of the Campbell diagram.
- ❖ **Subset overlap** – It is a measure of the overlap between individual adjacent subsets.
- ❖ **Quantization bin count** – Defines the count of quantization bins. It means that the data set in the vertical direction of the Campbell diagram is distributed in the specified number of bins.
- ❖ **Export subset sweep** – Performs computations for different positions of a subset with the size specified in the corresponding control at the bottom of the **Vibrography Tool window**. The subset is moved between the individual computations so that the overlap

with its previous position is the one specified in **Presentation Settings** under **Vibrography** (see 7.2.6). A file is created, which contains the range of timestamps delimiting these subsets and the associated values of frequency, amplitude and phase, where the amplitude is the maximum among computed values. If the values of excitation frequencies are present among the input data, they are exported to the output file as well, and the maximum value of the amplitude is picked from the frequencies in the range of these excitation frequencies.

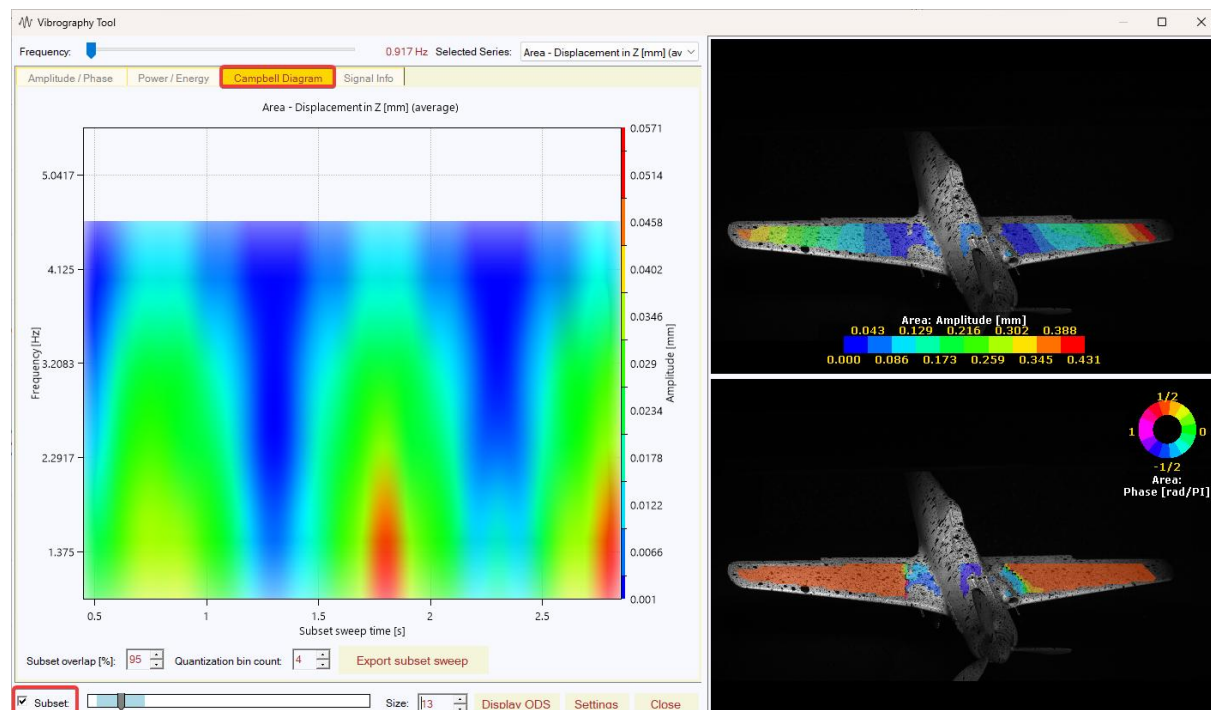


Figure 99: The Campbell Diagram tab in the Vibrography Tool window

6.1.4. Signal Info

This tab contains information about the analyzed data:

- ❖ **Minimum** – The minimum value among the data.
- ❖ **Maximum** – The maximum value among the data.
- ❖ **Peak** – The maximum displacement from zero among the data.
- ❖ **Peak to peak** – The difference between the maximum and the minimum.
- ❖ **Effective value** – The effective value of the data (also called root mean square).
- ❖ **Crest factor** – The crest factor of the data. The crest factor is a measure of a waveform showing the ratio of peak values to the average value. In other words, the crest factor indicates how extreme the peaks are in a waveform.

When performing a full-field analysis, the displayed values are averages of the computed values for each point. Additionally, if the **Subset** box is checked, improved **Signal Info** is available. While the **Signal Info** tab with an unchecked subset shows only one set of signal data for the whole interval, the improved **Signal Info** provides a specific number of signal data sets for the individual intervals displayed in graph.

6.1.5. Preview

The preview panel (the images on the right side of the window) contains the computed data at the selected frequency previewed on the reference image. Both the amplitude and the phase for the selected frequency are displayed. When previewing data computed for a

full-field area, the amplitudes and the phases are computed in the entire area and displayed using a color map. In the phase preview (bottom), the reference point can be selected by left-clicking the points of the color map. When the reference point is selected, phases are computed relative to the phase of this point (the phase of the reference point will be zero). Otherwise, phases are computed according to the start of the measurement.

6.1.6. Export

Some of the data computed as a part of the vibrography analysis are available to be exported into a CSV file and processed externally in a spreadsheet editor such as MS Excel. This option is performed through the context menu of the graphs of amplitude and phase. As of now, the data can be exported as follows:

- ❖ **Export Data** – Creates a file containing the values of the computed amplitude and phase for each frequency.
- ❖ **Export Subset Sweep** – Available via the Campbell diagram tab, see 6.1.3.

6.1.7. Other Controls

- ❖ **Display ODS** – Opens the Operational Deflection Shape dialogue (see Figure 100). This dialogue shows a 2D or a 3D graph of the desired quantity for the frequency selected in the Vibrography Tool window. For a better visualization in the ODS dialogue, change the following parameters:
 - **Multiplier** – Defines the multiplication rate. The higher this multiplier is, the more significant the displacements and deformations are in this window.
 - **Loop** – This box sets the length of the period of the displayed motion in the time domain. The shorter the loop is, the faster the played motion is.
- ❖ **Settings** – Opens a dialogue with the most common **Vibrography** settings. All of these settings can be found in Presentation Settings under Vibrography (see 7.2.6).

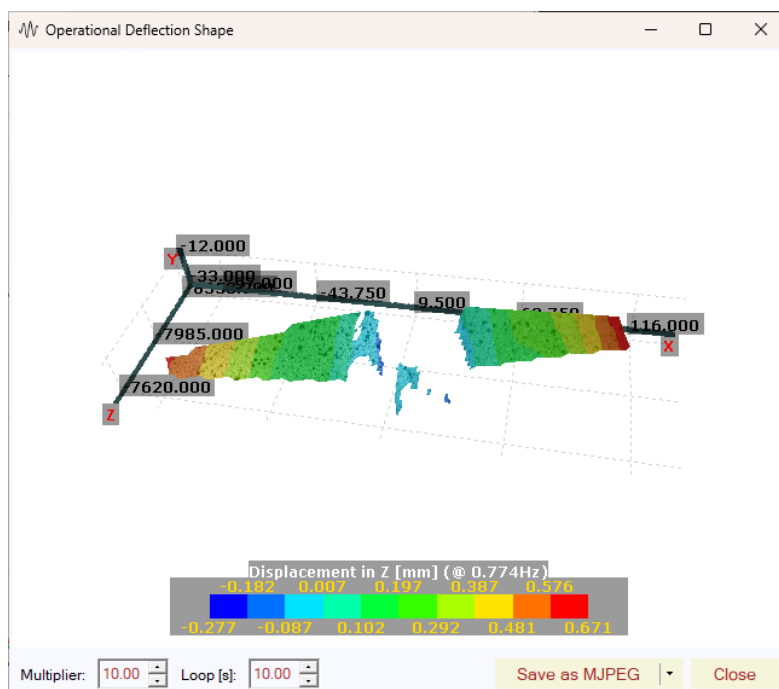


Figure 100: The Operational Deflection Shape dialogue

6.2. CAD / FEA VALIDATION

The primary purpose of the **CAD/FEA tool** is to perform the validation of externally computed models using full-field data computed by MERCURY RT. This is for the external models with values obtained through **Finite Element Analysis** or any other means. Also, external models of measured objects without any computed values can be used to compute differences between the positions of the nodes, which comprise the mesh of the model, and the points of the full-field area computed in MERCURY RT.

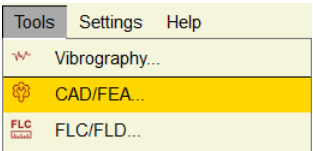


Figure 101: The CAD/FEA tool button

Please note, that access to this feature is only available in a project with any stereo camera, which contains full-field data computed using an **area** (see Area). Also, the precise moment in time with data, which is to be used for the validation, has to be marked in the **project seeker** of the **main window** using the **Set Mark** button (see 2.4).

6.2.1. CAD / FEA Tool Window

At first, the window shown in Figure 102 only contains its own 3D graph display with the full-field data selected in the previous step. The view is controlled in the same way as it is in the **3D Graph** of the **scene window** associated with a stereo camera (see 3.3).

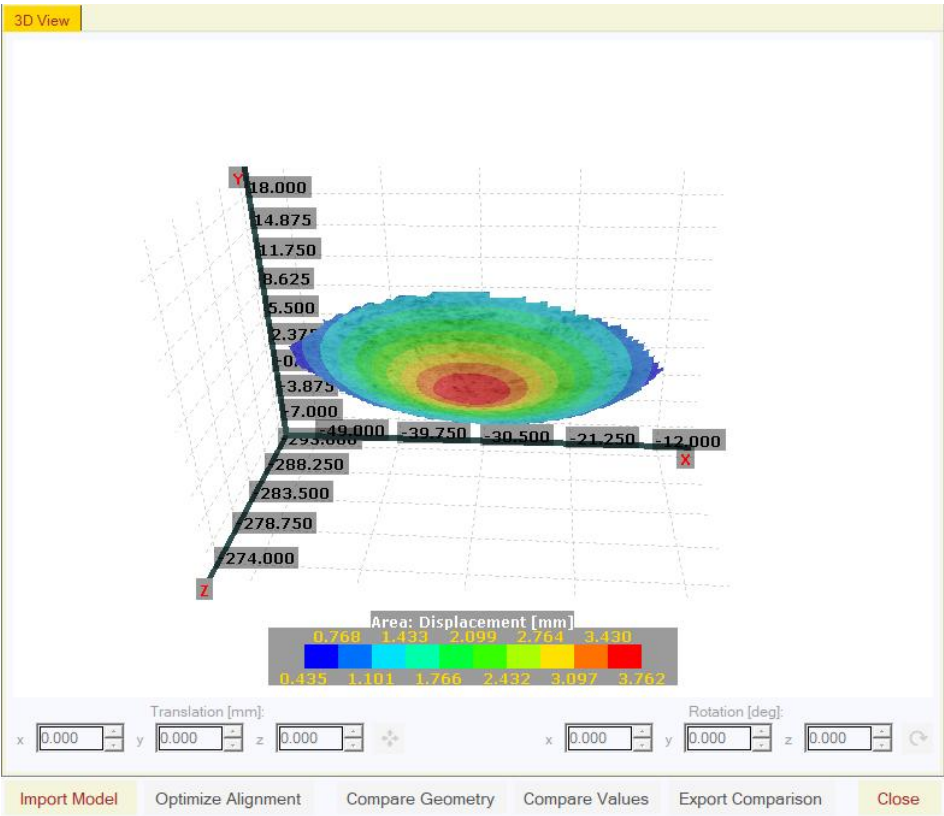


Figure 102: The CAD/FEA tool window

The import of the external model to be displayed alongside the computed 3D area is done by the **Import Model** button located at the bottom-left of this window. The detailed function of this button, as well as of the other buttons situated in the bottom part of this window, is described as follows:

- ❖ **Translation, Align centres, Rotation and Flip imported model** – You can manually move and rotate the model using numeric dials below the 3D graph after a model is imported. Also, you can align the center of an imported model with the center of the surface detected by MERCURY RT using the button next to translation controls and flip the imported model with respect to XY plane using the button next to rotation controls.
- ❖ **Import Model** – Imports an external model from STL, CSV (Comma Separated Values) or VTK file. In the case of a CSV file, a dialogue is shown, which prompts to select the columns containing the positions of the imported nodes and optionally also values associated with them, if such is present in the file. The imported model is then displayed in the 3D graph displayed above, alongside the model computed in MERCURY RT. Then according to whether the imported file contains information about the triangulation of the model as well, it is displayed either as an interconnected mesh or a point cloud. If the positions of the nodes were imported with the associated values, they are mapped to the color of either the points in the cloud or the surface of the model. Lastly, if only the triangulation is available and the values are not, the surface of the model is not shown by default but can be enabled by pressing the button, which appears in the top right corner of the 3D graph display. This is, however, not recommended in the case of large, complicated models due to performance reasons.
- ❖ **Optimize Alignment** – Optimizes translation and rotation of the imported model to match the nodes of the surface detected by MERCURY RT. Consider that global optimization can get stuck in a local minimum so if the fully automatic alignment result is not satisfactory, try manually adjusting starting position for the optimization. Also, the optimizer can get confused if the imported model contains additional elements than just those detected by MERCURY RT or model does not contain a sufficiently fine mesh of features to be aligned. Currently, no mesh refinement is done by MERCURY RT, and a model of sufficient quality should be provided.
- ❖ **Compare Geometry** – Matches each point of the computed full-field area with the closest node of the imported model and computes the displacement from the point to the node alongside the surface normal in the position of that point. The results of this operation are then mapped to the color of the surface of the computed full-field area and represent a geometry comparison between the computed and imported model. Pressing this button again restores the display to its original state before the comparison.
- ❖ **Compare Values** – Matches each point of the computed full-field area with the closest node of the imported model and computes the difference between the value associated with that point and the value associated with the node of the imported model. This functionality is, therefore, available only if the imported model contains any externally computed values. Just like following the geometry comparison, the results of this operation are mapped to the color of the surface of the computed full-field area. Pressing this button again restores the display to its original state before the comparison.
- ❖ **Export Comparison** – Exports the results of the selected comparison into a specified CSV file. The format of the exported data can be easily imported into common spreadsheet editors such as Microsoft Excel.

6.2.2. Alignment Of Models

Although it is required for the imported model to be defined in the same coordinate system as the model computed in MERCURY RT regarding the distances between the points on the surface of the model, the origin points of these two coordinate systems will be different, which brings the need to perform a manual alignment of these two models. For the aforementioned purpose, the **CAD/FEA tool** provides means of manipulating the placement of the imported model, specifically by modifying its translation and rotation parameters. These controls are below the graph as described in the previous section and are comprised of three numeric boxes for translation and three for rotation – one for each axis. In addition to these boxes, there is a button next to the controls of the translation parameters, which aligns the center of the imported model with the center of the computed full-field area. This may serve as a good starting point for further adjustments. Automatic alignment can be started at any time, but the recommendation described in the section above holds. Even after the automatic alignment, some manual adjustment can be required for a satisfactory result, especially for large flat areas or models of low detail or resolution.

6.3. FLC / FLD ANALYSIS

The **Forming Limit Curve (/Diagram)** analysis is a method used for assessing the ability of sheet metal forming. The curve represents the limit of material in deformation, and it is obtained from FLD (Forming Limit Diagram) in which the results from Nakajima or Marciniak test are plotted. To make FLC, a series of samples with different geometry have to be measured. Forming limit curves provide information on whether a drawn component is designed well or needs some optimization. The FLC/FLD analysis can only be performed in stereo mode. The FLC tool provides an effective way to obtain forming limit curves. Applicable standard: **ISO 12 004** – Determination of Forming Limit Curves.

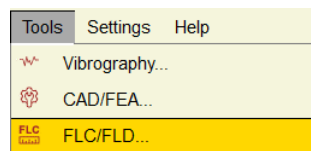


Figure 103: The FLC/FLD tool

6.3.1. Preparation of Input Data

To get a forming limit curve, the following process is necessary to perform in preparation for the FLC analysis itself. Also, the higher the number of measurements, the more reliable results are expected. In order to receive the correct results for the analysis, it is necessary to choose the right type of tensor. This is done before computation by clicking on Grid Area and selecting Tensor Type to be **True Strain** (Figure 104). The measurement itself can be performed as usual by the **Run/Recompute** buttons with the full-field area defined in a stereo project.

The forming limit diagram consists of principal strain values at the moment of failure, which is why it is necessary to mark the moment of failure with the **Set Mark** button (Figure 104). By selecting the moment in time of failure, the Set Mark button change to Unset Mark. This moment should be located one frame before the crack appears in the image and interrupts the continuity of the points computed by the full-field area. Save the project afterward.

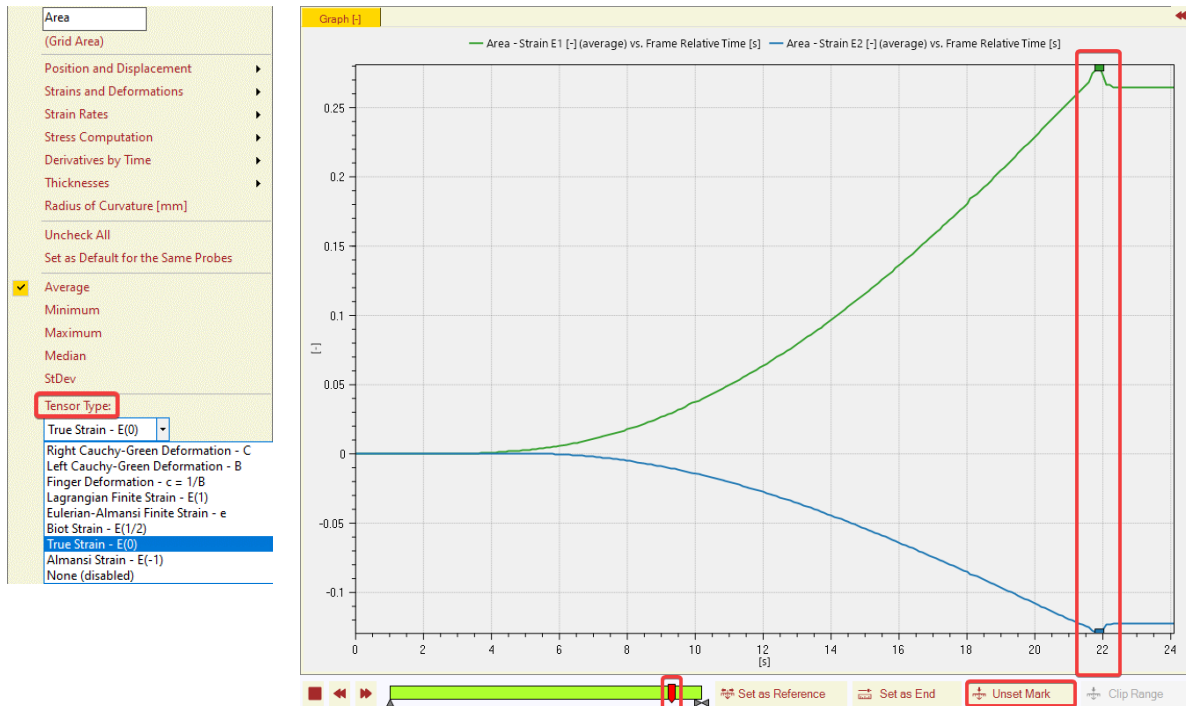


Figure 104: The important points when preparing the input data for an FLC analysis

The same process should be done for other measurements, which must be saved under different names as individual projects in the same directory. When all the projects like the previous one are saved in one directory, then the **FLC/ FLD** tool (see Figure 103) has to be opened. There is also a shortcut called “**MercuryRT FlcAnalysis**” installed with the software, which launches the **Forming Limit Diagram** window seen in Figure 105. When using the aforementioned shortcut, no data is selected for analysis at first, so a working directory needs to be selected by using the **Change working directory** button on top.

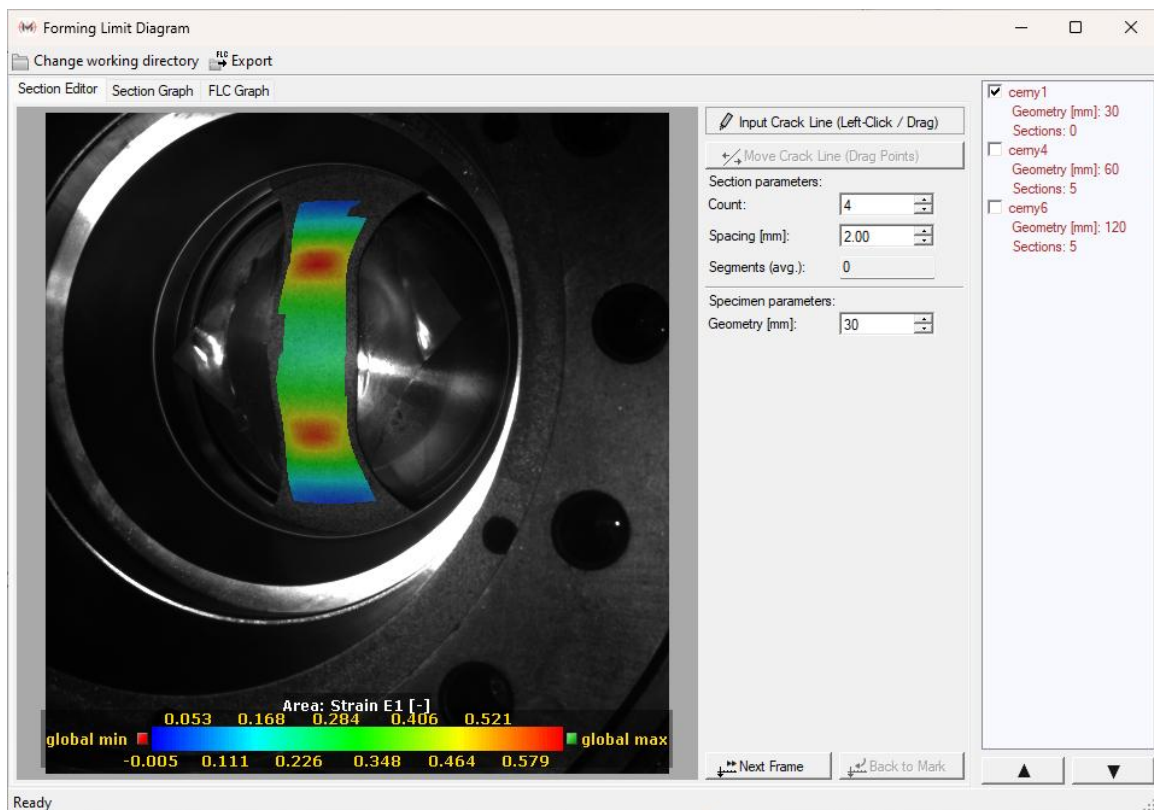


Figure 105: The Forming Limit Diagram window

6.3.2. Section Editor

Before the forming limit curve can be computed and displayed, the cross-sections and the geometry of the sample need to be specified for each measured specimen. The prepared projects with the individual measurements can be selected in the panel on the right or by the **up** and **down** buttons below it. The values displayed under each project indicate which ones still need to be configured properly before being included in the analysis. The necessary configuration is then performed under the **Section Editor** tab shown in Figure 105.

The sections need to be positioned perpendicular to the crack, so it is essential to locate the crack accurately. This is done by using the **Next Frame** button, which switches the display to show the frames following the marked one. The marked frame can be restored anytime by pressing the **Back to Mark** button next to it. When the frame with the crack is located, the **Input Crack Line** button can be used to place a line, which goes straight through the crack. It can either be dragged to the desired position by the mouse or positioned by left-clicking. The **Move Crack Line** button can be used to modify it later. Once the line is placed, the sections are generated perpendicular to the line according to the specified parameters.

These parameters are located on the right of this tab and are specified as follows:

❖ **Section parameters:**

- **Count** – The number of parallel sections generated orthogonally to the crack line. (3 by default)
- **Spacing [mm]** – The absolute distance between sections on the specified crack line. (2 by default)
- **Segments (avg.)** – The average number of segments comprising each generated section.

❖ **Specimen parameters:**

- **Geometry [mm]** - The diameter of the specimen, which is used for grouping projects for the FLC analysis.

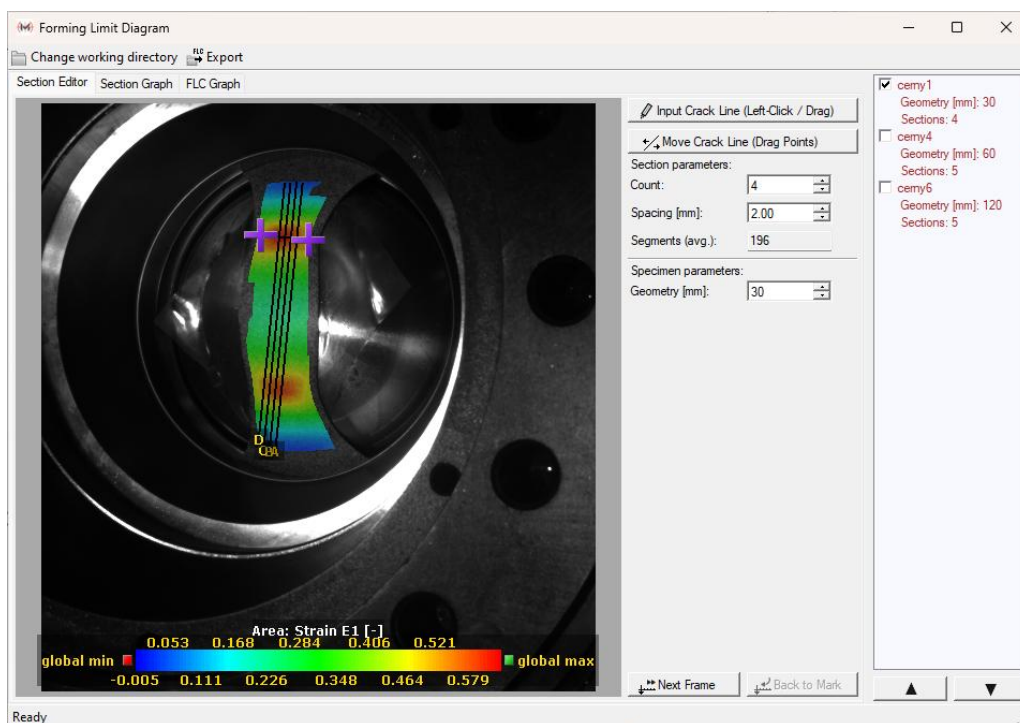


Figure 106: The Section Editor tab of the Forming Limit Diagram window

6.3.3. Section Graph

Once the sections are correctly positioned, the evaluation of data from these sections can be verified under the **Section Graph** tab shown in Figure 107. For each of the sections, there are four curves and additional highlighted points displayed in a plot. The first and the second curve are the computed strain values mapped along the section line. The latter two curves are inverse parabolas fitted onto the measured data. The blue highlighted points represent the measured values, which are selected for fitting a parabola. For more information about how the inverse parabola is fitted, please see the **ISO 12 004** standard. The red points represent the evaluated location of the crack on the section. The different sections can be verified by using the drop-down list on the top right.

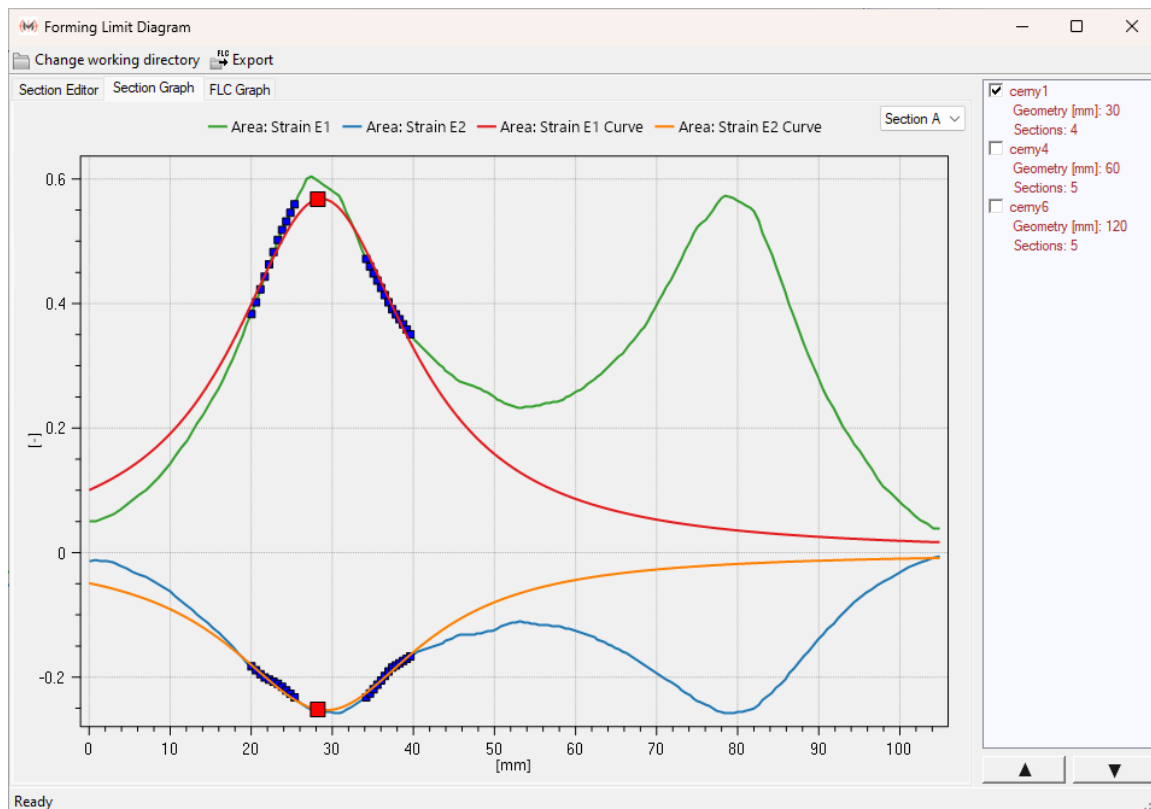


Figure 107: The Section Graph tab of the Forming Limit Diagram window

6.3.4. FLC Graph

When all measurements have their parameters and sections specified, it is possible to see the resulting values from sections in all these measurements under the **FLC Graph** tab. The graph represents FLD (Forming Limit Diagram), where Major Strain data are plotted versus Minor Strain. The red points are the resulting values from sections in the selected project, while the green point in their center is the average of these points. If there are several samples with the same geometry, the green point consists of all sections of samples with the same geometry. If the measurement of a particular material is complete, it consists of several samples, which differ in geometry. The FLC graph displayed in Figure 108 is made of 6 samples.

By clicking on the red points, it is possible to exclude them from the computation of the average (green point). Additionally, the resulting data can be exported into a CSV file by using the **Export** button on top. The data exported this way also include standard deviations of the section data from their average.

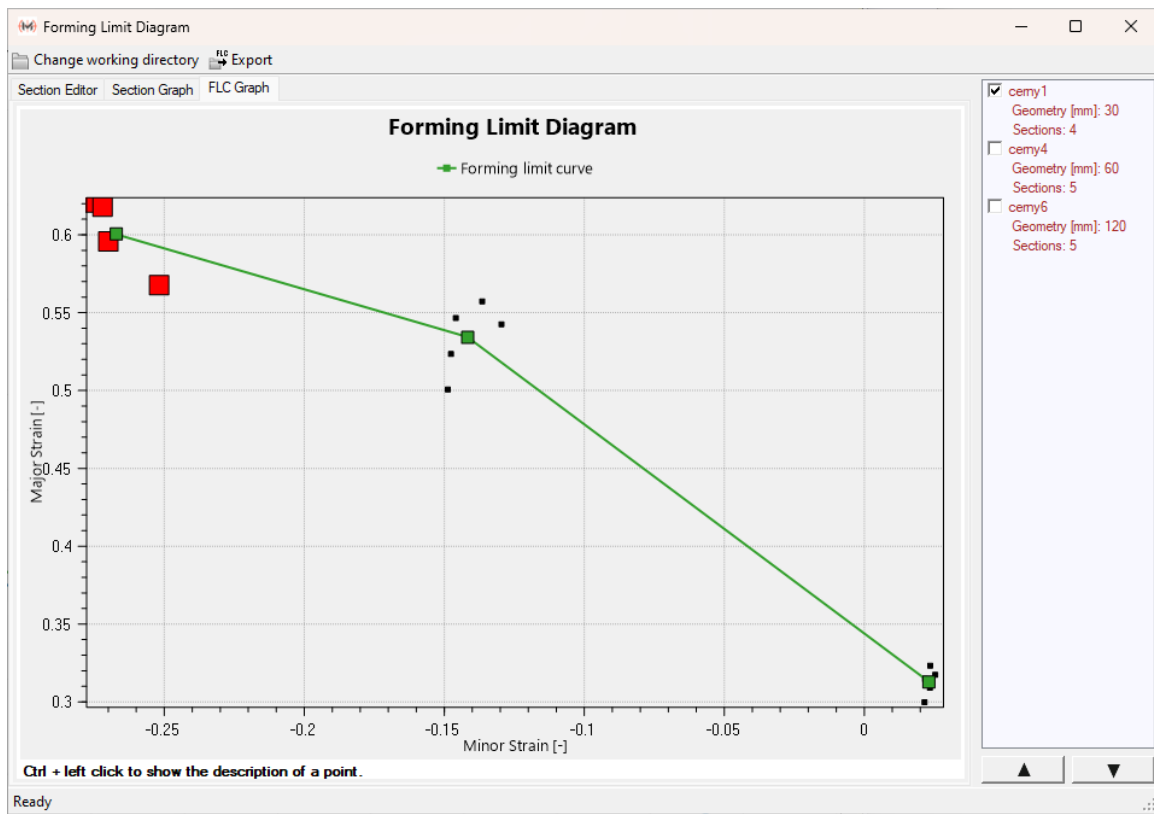


Figure 108: The FLC Graph tab of the Forming Limit Diagram window

7. SETTINGS

The following chapter is an overview of settings that can be configured through the **settings windows** accessible from the main menu (Figure 109). The individual options are separated into a group of settings applied through the entire application regardless of which project is open (referred to as **System Settings**) and a group of settings applied only within the open project (referred to as **Presentation** and **Computation Settings**). Next, the options within these groups form several sub-categories according to which part of the application they are logically associated with. The descriptions of these options are also available inside the settings window underneath the property grids.

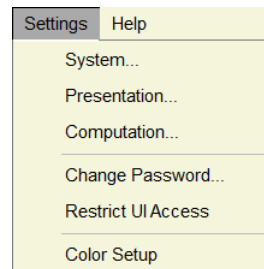


Figure 109: Settings section of the main menu bar

7.1. SYSTEM SETTINGS

The System Settings window contains the group of settings applied through the entire application regardless of which project is open. They are saved automatically when exiting the application and loaded when it starts.

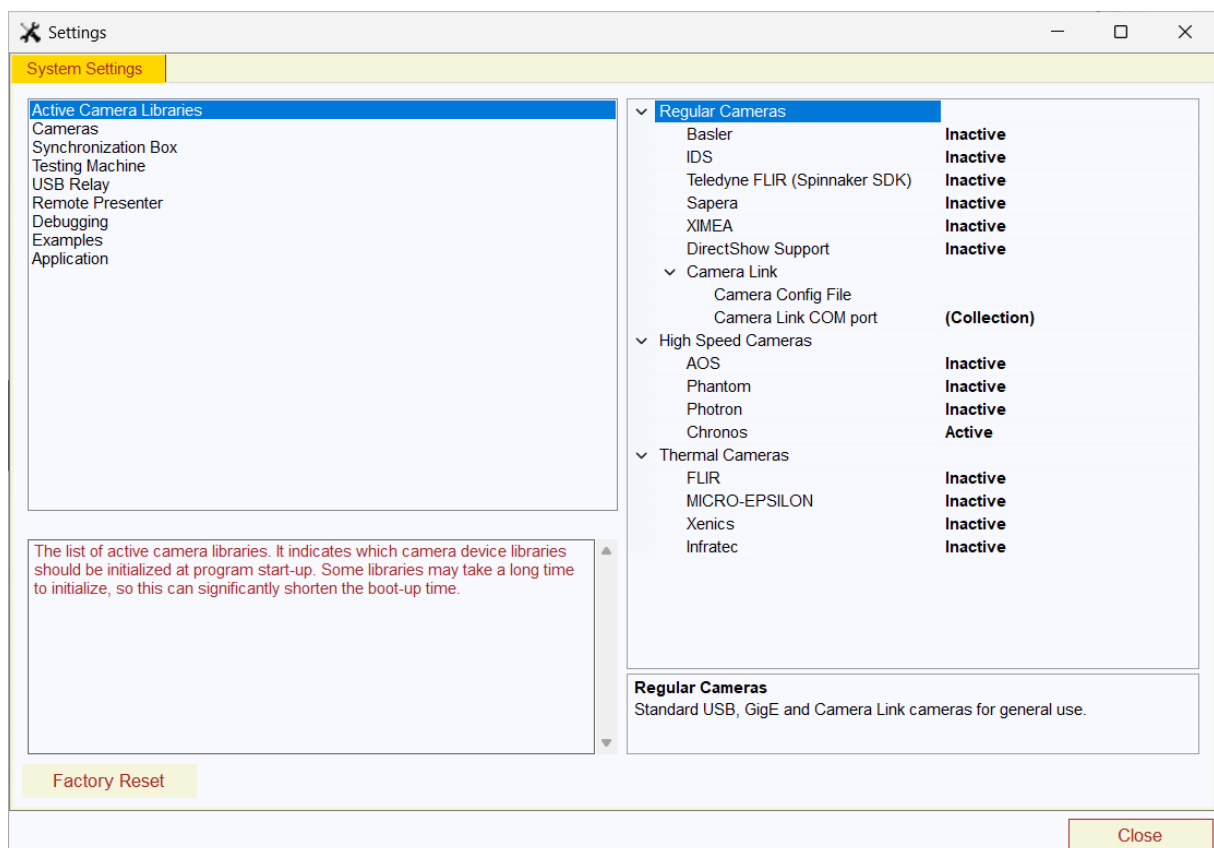


Figure 110: System Settings window

7.1.1. Active Camera Libraries

This section contains the list of active camera libraries. It indicates which camera device libraries should be initialized at program start-up. Some libraries may take a long time to initialize so this can significantly shorten the boot-up time. The most commonly used libraries are enabled by default. Changes in these settings will be applied by reinitializing the cameras, which is performed automatically if possible and notified upon if not.

When using Ethernet cameras in certain versions of MS Windows, it might not be enough to select the desired cameras from this list, but it is also necessary to allow the application in the Firewall settings of the operating system!

Camera Link

This sub-section contains the global parameters of Camera Link cameras. It is applicable when AVT Camera Link Cameras or Basler Cameras are active concurrently with Samera devices.

- ❖ **Camera Config File** – The full camera configuration file path of your camera. Please contact MERCURY RT development team, if no configuration file exists for your camera.
- ❖ **Camera Link COM Port** – The COM port parameters used for the communication between AVT cameras and a frame grabber. They all represent settings of the used COM ports and are as follows: **Port Name, Baud Rate, Parity, Data Bits, Stop Bits** and **Handshake**. Specify an empty string as port name to set the COM port as none.

7.1.2. Cameras

This section contains the parameters of live cameras.

Slave Camera Trigger

See Slave Camera Trigger for detailed information.

Master Camera Trigger

See Master Camera Trigger for detailed information.

Ethernet Cameras

This sub-section contains the parameters of Ethernet cameras.

- ❖ **Network Packet Size MTU** – The size of MTU packet in bytes. For most values to function correctly, it is necessary to have jumbo packets allowed in the settings of the associated network interface.

Basler Cameras

This sub-section contains the parameters of Basler Cameras.

- ❖ **Allow Light Control** – Specifies, whether to allow the control of lights connected to the camera by sending a User Output 2 signal through GPIO1 (Line 3). This pin is then reserved for the control of lights and no synchronization will be allowed by using it.

DirectShow Cameras

This sub-section contains the parameters of DirectShow cameras.

- ❖ **Use max resolution** – Determines whether to use the maximal camera resolution by default.
- ❖ **Default width/height** – The default width/height of the camera picture in pixels.

IDS Cameras

This subsection contains the parameters of IDS cameras.

- ❖ **Maximum FPS Limit [%]** – Specifies the percentage which adjusts the maximum settable FPS of the camera. This is because using an optimal pixel clock together with small AOIs and/or higher exposure times may result in camera-internal overload, which prevents frames from being transmitted correctly. (98% is the recommended value according to uEye documentation)
- ❖ **Synchronization FPS Limit [%]** - Determines the percentage of maximum FPS, to which the camera is set when externally synchronized (including slave mode). The resulting absolute FPS value needs to be higher than the operational FPS value because otherwise, it has been shown to restrict the incoming pulse. On the other hand, a high FPS value restricts the upper limit of the exposure time, so it is advisable to adjust this value below full 100% as necessary.
- ❖ **Use optimal pixel clock** – Specifies whether to automatically detect and set an optimal pixel clock when opening the camera for the first time (requires a restart) — recommended when it is desired to have a small AOI and the highest possible FPS.
- ❖ **Testing Period [ms]** – The time period during which it is unwanted to drop a single frame during the detection of the optimal pixel clock. Higher values yield more stable results, but the image capture is suspended when the detection takes place (displaying only white frames or none at all). Must be in the interval of 4s – 20s.
- ❖ **Fallback Pixel Clock [MHz]** – The value of the pixel clock in MHz which is set to the camera in case an optimal pixel clock is desired, but its automatic adjustment is not supported by the camera.

Photron Cameras

This subsection contains the parameters of Photron cameras.

- ❖ **IP address for automatic search** – The IP address you enter will be used to search for Photron cameras. If you enter the IP address 192.168.0.1, the range of address 192.168.0.1 – 192.168.0.254 will be searched. The last number of the IP address entered is therefore not taken into account.

Camera Display

This sub-section contains the parameters of camera displays.

Default Number of Camera Frames per Second – The system-wide parameter for the default value of camera FPS.

Other

This contains all parameters, which do not have their own sub-section

- ❖ **System Timestamp Correction Enabled** – Enables correction of frame timestamps assigned by the system. Useful for cases, when it significantly differs from the timestamp provided by the camera due to some delay on the frame acquisition interface. Do NOT use this with hardware synchronization and in other cases, where the frame rate may vary through a single run of the camera.

- ❖ **Input buffer size for receiving camera frames** – Larger values will even-out incoming camera frames, potentially computing more data. The cost is an additional delay. Minimal and the default value is 1.

7.1.3. Synchronization Box

See 13.3 for detailed information.

7.1.4. Testing Machine

This section contains the parameters of a testing machine. Changes in these settings will be applied after restarting the program.

- ❖ **Active Testing Machine** – The type of currently active testing machine for sensor readout and control.
- ❖ **Active Sensors** – Indicates whether the corresponding value will be used for all outputs (graphs, displays, analog/digital outputs, and more)
- ❖ **Sampling Rate [Hz]** – Sampling rate of data recording in Testing Machine Controller projects.

Doli EDC

This sub-section contains the parameters of a DOLI DoPE EDC device for sensor readout and control.

- ❖ **Version** – The version number of DOLI EDC, DoPENet.dll and DoPE.dll.
- ❖ **Device ID** – EDC device number (0-n).
- ❖ **Setup Number** – EDC setup number (0-8).

Manual Control

This sub-section contains the parameters of the speed during the manual control of the testing machine's cross-head under different circumstances.

- ❖ **Movement Speed – Slow [mm/min]** – The speed of the cross-head during manual control. In units of mm/min.
- ❖ **Movement Speed – Fast [mm/min]** – The speed of the cross-head during manual control when a Ctrl button is held. In units of mm/min.
- ❖ **Mouse X-head Movement – Slow Step [mm]** – The slow step speed of the cross-head when scrolling the mouse. In units of mm/min.
- ❖ **Mouse X-head Movement – Fast Step [mm]** – The fast step speed of the cross-head when scrolling the mouse (when a Ctrl button is held). In units of mm/min.

Analog Input

This sub-section contains the parameters of the analog input for sensor readout using MCC and Advantech devices.

- ❖ **Device Number** – Number of analog devices used for input of sensor data.
- ❖ **Use 200 Hz filter** – Activates or deactivates filtering of input data. Input data are buffered and averaged in a 5 ms window — applicable ONLY for Advantech devices.
- ❖ **Load Channel [N]** – Parameters of load channel (with values in units of N). These are the number of the channel for this analog input, **minimal input value** and **maximal input value**.

- ❖ **Extension Channel [mm]** – Parameters of extension channel (with values in units of mm). These are the number of the channel for this analogue input, minimal input value and maximal input value.
- ❖ **Position Channel [mm]** – Parameters of position channel (with values in units of mm). These are **the number of the channel** for this analog input, **minimal input value** and **maximal input value**.
- ❖ **Sensor N** – Parameters of the channel corresponding to the N-th sensor. These are **the number of the channel** for this analog input, **minimal input value** and **maximal input value**.

Digital / Analog Input COM Port

This sub-section contains parameters of the COM port for Digital Input or Tensoamp Analog and Tensoamp Bridge Input. They all represent the settings of the used COM port and are as follows: **Port Name**, **Baud Rate**, **Parity**, **Data Bits**, **Stop Bits** and **Handshake**. Specify an empty string as a port name to set the COM port as none.

Digital Input Format

This sub-section specifies the format of digital input.

- ❖ **Message Delimiter** – The delimiter, which separates individual messages received on the input.
- ❖ **Value Delimiter** – The delimiter, which separates individual values contained within received messages.

7.1.5. USB Relay

To connect a USB relay that serves as a device for switching lights (either automatically or manually through the **Live Camera panel**, see 3.2.1), the connection parameters must be set in this section.

- ❖ **Connection** – The COM port parameters of the connection with the device. They all represent settings of the used COM ports and are as follows: Port Name, Baud Rate, Parity, Data Bits, Stop Bits and Handshake. Specify an empty string as a port name to set the COM port as none.
- ❖ **Switch Output State Delay [ms]** – Time how long it takes to switch the output state.
- ❖ **Communication Timeout [ms]** – Defines how long the software will wait for a device response.

7.1.6. Remote Presenter

This section contains the configuration parameters of remote wireless presenters. Such a remote presenter is a device used for assistance with the camera calibration (by remote activation of the **Capture Image** button) and the definition of the coordinate system (by pressing the **Refresh and Detect** button). It can also be used for the activation of a **Snap Frame** button. Either of the configured activation keys may be used for any of the aforementioned functions.

7.1.7. Report Generation

The parameters of report generation.

- ❖ **Header Logo Path** – The path of the image to be used as a logo in the header of the report.

- ❖ **Include Project Notes** – Specifies whether to include the project notes in the generated report. It is only applied when the template of the notes is modified in any way.

7.1.8. Debugging

This section contains the parameters for debugging purposes. The technical support may request a change of some of these parameters, which should be avoided otherwise.

7.1.9. Examples

This section contains the parameters of the use-case examples.

- ❖ **URL** – URL of online examples for downloading.
- ❖ **Examples Local Path** – Local path of examples folder.

7.1.10. Application

This section contains the parameters of the application interface.

- ❖ **Language** – The language of the user interface.
- ❖ **Request Password** – Indicates whether to request a password prior to allowing access to the main application window. Other application entry points such as Lite View are unaffected.
- ❖ **Free Disk Space: Remaining Time for Warning / Fail** – When the remaining disk space where the target project directory is located is less than the Warning / Fail threshold, a warning/failure message is issued to notify the user that there is only a limited time for recording or that they cannot run a test.
- ❖ **UI Update Frequency [Hz] – Idle** – Images and values in the UI are updated with the specified frequency. This is applicable when a test is not running, or data is not recomputed. The allowed range is Hz. Does not affect data value output to connected systems. The default value is 10Hz.
- ❖ **UI Update Frequency [Hz] – Running** – Images and values in the UI are updated with the specified frequency. This is applicable when a test is running, or data is recomputed. The allowed range is H. In very high-speed tests, 0 can be specified to completely disable UI updates for higher performance. Does not affect data value output to connected systems. The default value is 2Hz.
- ❖ **CPU Core limit (default: All)** – Configures the maximum number of CPU cores the application is allowed to use (CPU Core Limit). This allows to balance computation power with other critical applications (e.g., testing machine software) and ensure that they are running smoothly during measurements.

7.2. PRESENTATION SETTINGS

The Presentation Settings window is only accessible in an open project. The saving and loading of these settings take place altogether with the rest of the project data.

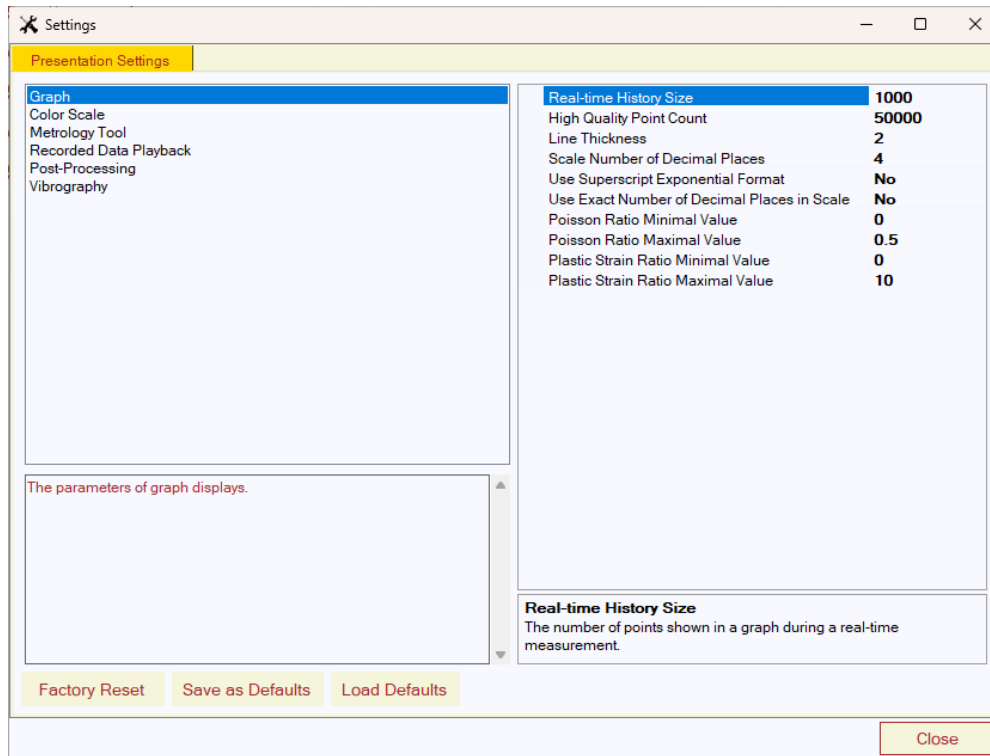


Figure 111: The Presentation Settings window

7.2.1. Graph

This section contains the parameters of graph displays.

- ❖ **Real-time History Size** – Number of points shown in the graph during real-time measurement.
- ❖ **High-Quality Point Count** – Number of points shown in high quality. A large number decreases performance in large data sets.
- ❖ **Line Thickness** – Line thickness of graph series.
- ❖ **Scale number of decimal places** – Number of decimal places in scale.
- ❖ **Use superscript exponential format** – This format will convert $1.5E+03$ to $1.5 \cdot 10^3$ and render the superscript correctly.
- ❖ **Use exact number of decimal places in scale** – Determines whether all scale labels have exactly defined the number of decimal places or the maximal number of decimal places.
- ❖ **Poisson's Ratio Minimal/Maximal Value** – The minimal/maximal value of Poisson's ratio measured for the current sample that may be displayed. (used to filter out noise during measurement)
- ❖ **Plastic Strain Ratio Minimal/Maximal Value** – The same, but for plastic strain ratio.

7.2.2. Color Scale

This section contains the parameters of the color scale associated with full-field areas and PIV fields.

- ❖ **Level Count** – The number of levels on the color scale.
- ❖ **Hue Range** – The range of hues covered by the colours of the scale. Must be in the interval of (0, 360).

- ❖ **Min Resolution [px]** – The minimal resolution of the color scale when computing values related to lengths, distances, speeds etc.
- ❖ **Min Resolution [mm] (in 3D only)** – The minimal resolution of the colour scale when computing values related to lengths, distances, speeds etc. in measurements with stereo cameras.
- ❖ **Min Resolution (other)** – The minimal resolution of the color scale when computing values related to relative change, engineering stresses and others.
- ❖ **Reverse Colors** – Specifies whether to use the color for maximum instead of the color for minimum and vice versa. This is applied to any color scale or line coloring, which uses these parameters.

7.2.3. Metrology Tool

The parameters of the 2D measurement tool.

- ❖ **Scale Step** – The distance between neighboring lines in physical units (mm).
- ❖ **1st/2nd Limiting Line on X/Y axis** – The X/Y coordinate in physical units (mm) of the first/second limiting line, which is perpendicular to the X/Y axis.
- ❖ **Subpixel Mode** – Enables the readout of distances using a measurement tool (and some of the probes as well) with subpixel precision. Not available in stereo cameras and not recommended for computation purposes!

7.2.4. Recorded Data Playback

This section contains the parameters of the playback of recorded data. They are applied when saving video sequences as well as during regular playback.

- ❖ **Frame Rate** – The speed of playback in frames per second.
- ❖ **Play Only Computed Frames** – Indicates whether to skip frames that do not contain any computed data during playback.
- ❖ **Play Only Saved Frames** – Indicates whether to skip missing frames during playback.

7.2.5. Post-Processing

This section contains the parameters of post-processing, mostly related to full-field measuring tools.

- ❖ **Vector Density** – Specifies the number of vectors to be displayed on full-field areas and PIV fields relative to all the computed vectors in the corresponding grid (only every n-th vector is shown in each direction).
- ❖ **Vector Multiplier** – The factor by which all vectors are multiplied during visualization. This also includes the vectors associated with point probes, strain gauges and surfaces.
- ❖ **Section Segment Count** – The number of segments generated for a newly entered area cross-section. The existing cross-sections are unaffected.

7.2.6. Vibrography

This section contains the parameters of vibrography.

- ❖ **Method** – Selects the method of the Discrete Fourier Transformation, by which the spectrum is calculated.
 - **Single Spectrum** – Spectral analysis is calculated in the whole length of the sequence.

- **Welch's Method** – Spectral analysis is calculated in parts. All parts are added together and averaged.
- ❖ **Window Type** – Selects the window function that will be used for windowing of data before performing the spectral analysis.

Supported window functions are:

 - Rectangular Window
 - Hann Window
 - Hamming Window
 - Tukey Window
 - Blackman Window
 - Flat Top Window
- ❖ **Data Step** – The number of points that is skipped between measurements of the spectrum. (Welch's method only)
- ❖ **Window Size** – The size of the window from the entire data that is used to analyze the spectrum at a given time. Must be even. (Welch's method only)
- ❖ **Octave Analysis** – The parameters of the octave analysis.
 - **First band nominal frequency [Hz]** – The center frequency of the first octave band.
 - **Last band nominal frequency [Hz]** – The maximum allowed frequency for the center of the last octave band.
 - **Octave fraction number** – The number of created bands between two consecutive main octave bands. The center frequency of each main octave band is equal to two times the center frequency of the previous main octave band. For example, the fraction number 3 corresponds to the 1/3-octave analysis.
- ❖ **Lowest Decibel Value** – The lowest dB value to be displayed in the graph of amplitude. Must be negative.

7.3. COMPUTATION SETTINGS

The Computation Settings window contains parameters applied only within the open project. Their saving and loading take place altogether with the rest of the project data.

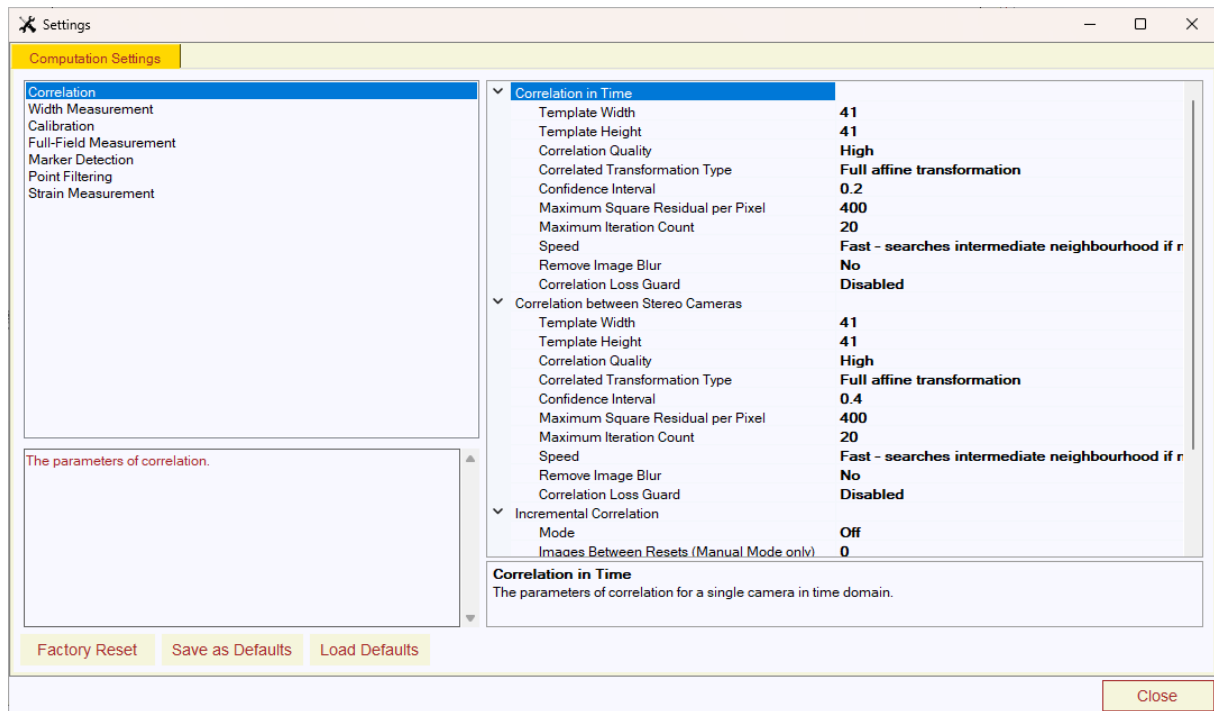


Figure 112: Computation settings window

7.3.1. Correlation

This section contains the parameters of correlation.

Correlation in Time

This sub-section contains parameters of correlation for a single camera in the time domain. The principle by which these parameters are used to compute data associated with deformed frames is depicted in Figure 113. Parameters of correlation of width points (see Width Correlation) and the correlation between left and right camera in stereo camera pairs (see Correlation between Stereo Cameras) are specified independently, but consist of the same set of parameters nonetheless.

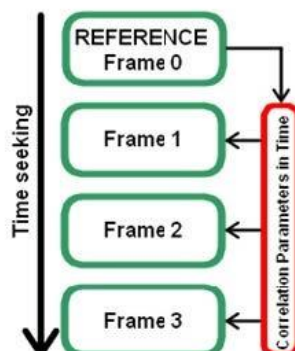


Figure 113: Principle of correlation in the time domain

- ❖ **Template height/width** – Height/width of the correlation template (subset) in pixels. These specify the number of pixels which are used for the correlation template. The size of the template should match the size of the smallest structures found in the image. Large values are more likely to be found, however, take more time and may not sufficiently represent local deformations. Small template sizes are faster and able to represent local deformations well. However, the lack of image information might result in points not being correlated.

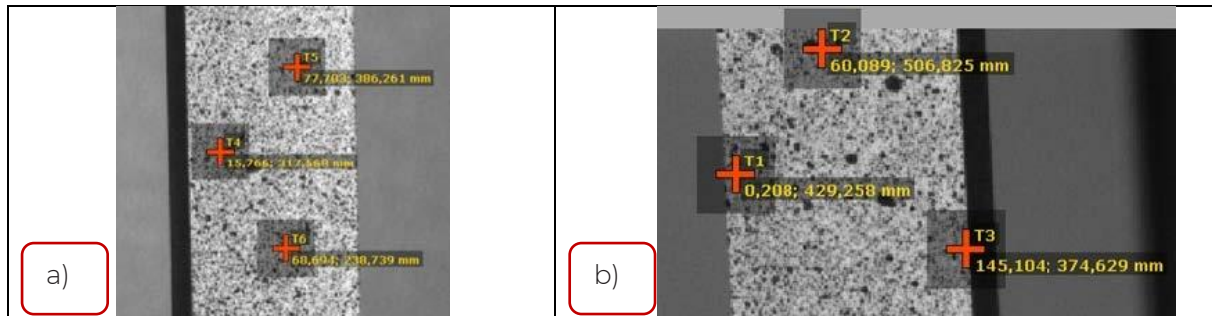


Figure 114: Template size and placement – a) the right way to do it, b) the wrong way to do it

- ❖ **Correlation Quality** – Specifies the interpolation method used in correlation. More complex methods are slower.
- ❖ **Correlated transformation type** – Specifies parameters that are correlated. The precise meaning of the terms used in these descriptions can also be found depicted in Figure 115. To avoid problems during computation, the transformation type should be estimated according to the expected movement of the measured specimen. Can be set to one of the following options:
 - **Omnidirectional translation** – Defines displacement in both axes (vertical, horizontal).
 - **Horizontal translation** – Defines horizontal displacement in relation to camera.
 - **Vertical translation** – Defines vertical displacement in relation to camera.
 - **Omnidirectional scale and translation** – Defines either stretch or contraction with a combination of displacement in both axes.
 - **Horizontal scale and translation** – Defines either stretch or contraction in a horizontal direction with a combination of horizontal displacement.
 - **Vertical scale and translation** – Defines either stretch or contraction in the vertical direction with a combination of vertical displacement.
 - **Horizontal scale and omnidirectional translation** – Defines either stretch or contraction in the horizontal direction with a combination of displacement in both axes.
 - **Vertical scale and omnidirectional translation** – Defines either stretch or contraction in the vertical direction with a combination of displacement in both axes.
 - **Full affine transformation** – The affine transformation type contains all three types together (translate, scale and shear). There are 6 calculated parameters. Rotation can be described as well by the composition of shear and scale.

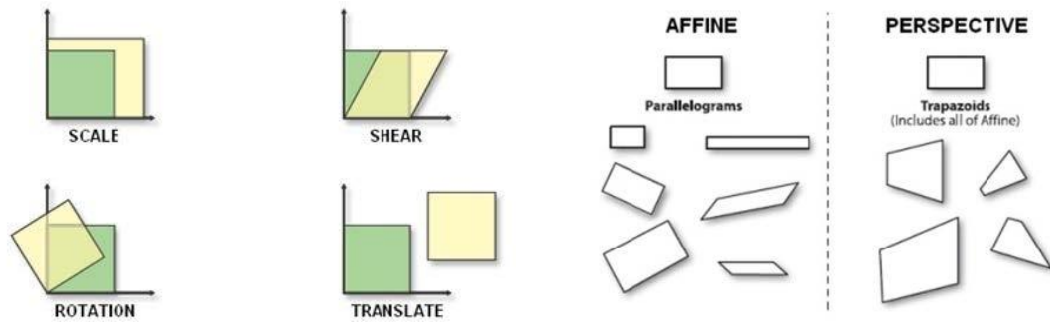


Figure 115: Transformation Types

- ❖ **Confidence interval** – Reliability threshold for a 95 % confidence interval in pixels. Represents the measurement of the correlation quality. For instance, the default value of 0.2 px means that the found point is located within ± 0.2 px within the computed location with a 95 % probability. Smaller values are more discriminating (i.e. fewer points may be computed with higher reliability).
- ❖ **Maximum square residual per pixel** – Maximally allowed average squared error between reference image part and deformed image part warped using correlated transformation. The value is calculated as an average of the squared difference between values in individual pixels.
- ❖ **Maximum iteration count** – Maximum number of iterations performed per point.
- ❖ **Speed** – Specified base correlation method. Slower methods have a higher chance to track larger movements. Can be set to one of the following options:
 - **Fastest** – Searches the small neighborhood.
 - **Fast** – Searches intermediate neighborhoods if necessary.
 - **Normal** – Searches whole image for a limited number of points if necessary.
 - **Slow** – Searches whole image for all points if necessary.
- ❖ **Remove Image Blur** – Tries to blur either a reference image or a reference image so that they match as close as possible. Helps when there is a difference in focus between images (for example when correlating between left and right camera).
- ❖ **Correlation Loss Guard** – Prevents the loss of points during correlation by correlating additional points around each correlated point.
- ❖ **Correlation method (default: Standard)** – Select the used correlation method.
 - **Standard** – SSD - sum of squared differences (Weighted L2 Norm) with multiplicative contrast compensation (but does not compensate for additive changes in brightness)
 - **Illumination-robust** – ZNSSD - zero-normalized SSD compensates brightness and contrast changes. It works well under constant lighting conditions, where brightness changes multiplicatively (changes in exposure, reflectance) rather than additively.
 - **Fully robust** – Additionally tolerates local specimen changes such as paint peeling.

Correlation between Stereo Cameras

This sub-section contains the parameters of correlation between cameras in a stereo scene (pair of cameras / stitching). The principle by which these parameters fit into computation done during measurements using stereo camera pairs is depicted in Figure 116. They are also applied during the input of reference probes through camera displays of these cameras. In stereo stitching, this concept is just further expanded by each set of two neighboring cameras forming a separate stereo camera pair. For an explanation of these parameters, see Correlation in Time.

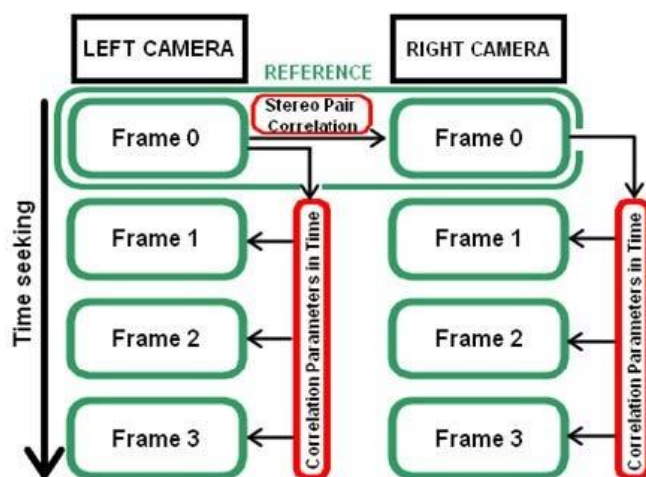


Figure 116: Principle of stereo pair correlation

Incremental Correlation

This sub-section contains the parameters of incremental correlation. Finding correspondences between the current and the first frame starts to be impossible when the scene changes significantly over time. To solve this problem, incremental correlation can be used. When incremental correlation is used, the reference frame is regularly updated. When the current frame is being set as the reference frame, correspondences between the first and current frame are stored. Calculation of correspondences between a new frame and the first frame is done by combining correspondences between the first and reference frame and between the reference and new frame. It is desired to change the reference frame when as many as possible correspondences are found because those not found will not be found in all next frames.

- ❖ **Mode** – Determines a mode for the incremental correlation.
 - **Off** – Turns the incremental correlation off.
 - **Manual** – The length of the incremental correlation sequence is set manually by the next parameter.
 - **Automatic** – The reference images are automatically reset when not enough points are computed.
- ❖ **Images between resets** – The number of images in correlation sequence after which a reference is reset to a current image.

Stereo Correlation

This sub-section contains the parameters of correlation for a stereo camera in the time domain.

- ❖ **Maximum Accepted Triangulation Error** – Maximum allowed triangulation error of correlated points. A value of 0 disables the calculation of this error.

Tensile Tracker

This sub-section contains the parameters of the tensile testing tracker, which is utilized by chain probes.

- ❖ **Relative Required Sections** – The relative number [0 – 1] of required valid sections on a tracked line in order to extrapolate missing point positions. Out of range values are treated as truncated.

Other

This contains all parameters, which do not have their own sub-section.

- ❖ **Evaluate Pattern Quality** – Indicates whether the quality of the correlation pattern should be evaluated individually for each marker and visualized as the color of the displayed template.

7.3.2. Width Measurement

This section contains the parameters of width measurement.

Neck Detection

This sub-section contains the parameters of neck detection.

- ❖ **Select Longest Section** – If enabled, selects the longest section instead of the shortest one.
- ❖ **Selection Mode** – Specifies the criterion by which to select the section for analysis. By default, the section is selected by the **absolute length**. The other options are to select it either by the **absolute** or relative **change** in its length.

Width Detection

This sub-section contains the parameters of the detection of width points.

- ❖ **Automatic movement of width points** – When turned on, width points are moved according to the movement of anchor points. This happens before the correlation of locations of width points.
- ❖ **PAE area [px] (default: 20)**: Size of the square 2D patch used for PAE edge refinement (Edge mode only). Larger values incorporate more image context for edge position estimation, which can improve stability on noisy images. Smaller values are faster and may work better when edges are close together.
- ❖ **Detection method (default: Edge)**: Selects between Edge detection (threshold crossing + PAE refinement) and Correlation (2D DIC template matching).

Width Correlation

This sub-section contains the parameters of the correlation of width points. The correlation of these points takes place in the time-domain. For an explanation of these parameters, see Correlation in Time.

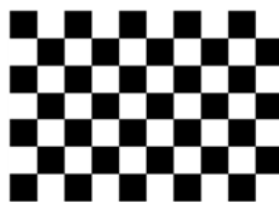
7.3.3. Calibration

This section contains the parameters of calibration, including the calibration grid for the definition of the coordinate system, the correction of distortions and the mapping of physical units. The calibration grids are displayed in Figure 117. Grids with attached QR codes have the capability of automatic detection of their parameters, so they do not have to be set manually. The calibration grid dialogue appears automatically when starting a

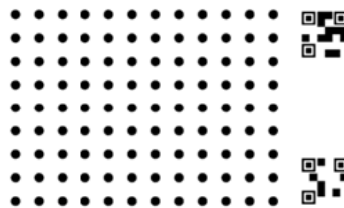
new camera calibration as well as when opening the **Coordinate System** window. **This dialogue is the only place in the program, where these parameters can be modified!**

- ❖ **Grid Type** – Specifies the type of the calibration grid. Can be one of the following:
 - **Chessboard** – Black and white squares. The whole grid must be visible.
 - **Circle Grid** – Black circles in a regular grid. The whole grid must be visible.
 - **Enhanced Circle Grid** – Black circles in a regular grid with three enhanced circles. The enhanced circles must be visible. Currently, this type of grid is supplied with the software.
 - **Automatic Grid Type** – The detection algorithm iterates through all available types until the correct one is found.
- ❖ **Grid Width/Height** – Number of inner square corners or circles on the calibration grid in horizontal/vertical direction. This value is ignored when an enhanced circle grid is used.
- ❖ **Unit Distance** – Size of a single square or distance between circle centers in physical units (mm).
- ❖ **Detection Method** – Method of grid detection. Is comprised of the following:
 - **Fast Simple** – The fastest detection with the lowest accuracy.
 - **Fast Complex** – Fast detection with decreased accuracy.
 - **Accurate Simple** – Slow detection with increased accuracy.
 - **Accurate Complex** – The slowest detection with the highest accuracy.
- ❖ **Radial Distortion Coefficients** – Number of calibrated radial distortion coefficients.
- ❖ **Lock Principal Point** – Specifies whether to fixate the principal point to the center of the image during calibration. This helps with the calibration of a lens with high magnification, where distortions are small and could lead to a large asymmetry of the calibration.

Chessboard (9x6)



Circle Grid with QR Code (12x9)



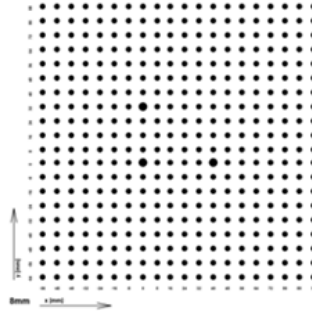


Figure 117: Grid types

7.3.4. Full-Field Measurement

This section contains the parameters of measurement with full-field measuring tools.

- ❖ **Compute All Values** – Indicates whether to compute all supported graph data values in addition to the already selected ones, so the selection can later be changed without having to recompute the data. Certain values are still, however, computed only if explicitly selected due to a high computation load (sphere radius and such). Disable this option in case the maximum computational performance is desired.
- ❖ **Clip Template to Boundaries** – Allows the correlated grid points to be generated at the boundaries of the input polygons by clipping their correlation templates to fit inside these polygons. This makes it possible to compute even points located by the edges of the specimen, where a correlation template would otherwise be unsuitable for measurement.
- ❖ **Mesh type** – Specifies the arrangement of grid points. Possible values are Orthogonal and Equilateral.
- ❖ **Polygon Input Method** – Indicates how the newly created polygon is inputted, It can be either an arbitrary polygon defined **vertex by vertex** or as a **discrete circle**.
- ❖ **Discrete Circle: Vertices** – In the case of the polygon input method set “Discrete Circle”, specifies the number of vertices of the input circle.
- ❖ **Minimum Angle of Boundary Triangles** – Sets minimum angle (in degrees) of boundary triangles. This turns on the filtering of sharp triangles that often leads to less accurate results.
- ❖ **Maximum Allowed Strain** – The maximum allowed value of computed strain values for them to be considered as valid (non-dimensional).
- ❖ **Filter Areas** – Enables filtration (smoothing) of computed area. Currently, only strains are filtered.
- ❖ **Filter Areas: Sigma** – The sigma [mm] of the Gaussian kernel used for the filtration of areas.
- ❖ **Maximal Ratio of Average Error to Radius for Spherical Fit** – Average fit error is defined as the root of the average square of error (sum of squared residuals divided by valid points count). A fit is considered valid only if this error is under some radius fraction that is determined by this setting.
- ❖ **3D Tensor Computation Method** – The method of computing tensors in 3D. Each method supports the evaluation of different tensor values. Can be one of the following:
 - **Full 3D** – Deformation “out of surface” is estimated so that volume is constant. Then full 3D tensors are computed for this deformation. All tensor values are supported.

- **XY-Plane** – The specimen is placed in the XY plane (usually using the custom coordinate system) and surface tensors are computed in this plane. Z movement is ignored. Supported tensor values are StrainE1, StrainE2, StrainEXX, StrainEXY, StrainEYY.
- **Local Surface Tensors** – A local plane is estimated for each measured point of the specimen. Surface tensors are computed in this plane. Supported tensor values are StrainE1, StrainE2.
- ❖ **Deformation Computation:** Used Points – Number of additional points used to compute a deformation in a single point. A deformation cannot be computed for values less than 2. Higher values increase accuracy but decrease locality.

7.3.5. Marker Detection

This section contains the parameters of marker detection.

- ❖ **Type** – The type of detected markers. Can be set to one of the following options, which are also previewed in Figure 118:
 - a) **Circle Marker** – Detects circle markers on the surface of the specimen.
 - b) **Cross** – Detects contrasting crosses in the image.
 - c) **Dot** – Detects contrasting dots in the image.
 - d) **Marked Line** – Detects lines with a specific tip.
 - e+f) **Line** – Detects the specified number of lines with either vertical or horizontal direction.
 - g+h) **Edge** – Detects the specified number of edges with either vertical or horizontal direction.

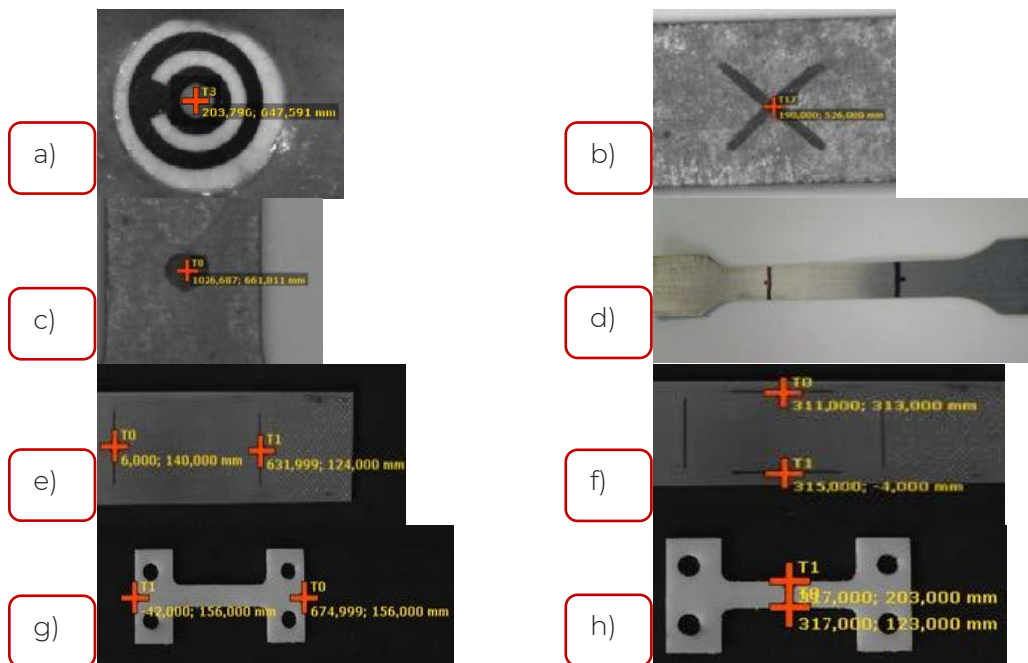


Figure 118: Marker detection types – a) circle marker, b) cross, c) dot, d) marked line, e) vertical lines, f) horizontal lines, g) vertical edges and h) horizontal edges

- ❖ **Automatic Pairing** – Type of automatic pairing of detected markers. It determines the desired length of resulting extension lines, as shown in Figure 119. Note that only specific cases of marker placement may effectively utilize this feature. Can be set to one of the following options:

- **Off** – Deactivates the automatic pairing.
- **Shortest** – Pairs the detected markers in such a way, that the resulting lines are as short as possible.
- **Optimal** – Pairs the detected markers in such a way, that the resulting lines are neither the shortest nor the longest.
- **Longest** – Pairs the detected markers in such a way, that the resulting lines are as long as possible.
- **Random** – Pairs the detected markers randomly.

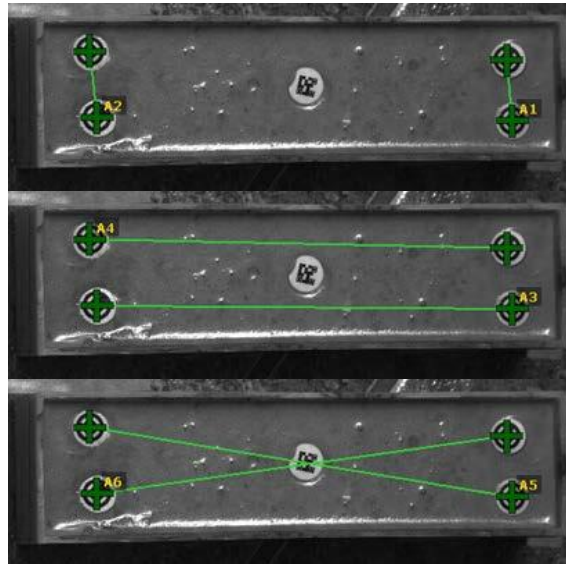


Figure 119: Automatic pairing types – a) shortest, b) optimal and c) longest

LINE

This sub-section contains the parameters of line detection.

- ❖ **Line direction** – Direction of detected lines (vertical or horizontal).
- ❖ **Number of lines** – Maximum number of detected lines. A value of 0 denotes the detection of any number of lines.
- ❖ **Center of detection** – Relative position of the center of detection ([0, 0] is top left and [1, 1] is bottom right) around which lines are detected.
- ❖ **Minimum length of line in mm** – Minimum length of a line in millimeters. (Not applicable in stereo)
- ❖ **Maximum length of line in mm** – Maximum length of a line in millimeters. (Not applicable in stereo).

EDGE

This sub-section contains the parameters of edge detection.

- ❖ **Number of edges after center** – Maximum number of detected edges after (to the right or bottom) center of detection.
- ❖ **Number of edges before center** – Maximum number of detected edges before (to the left or top) center of detection.
- ❖ **Center of detection** – Relative position of the center of detection ([0, 0] is top left and [1, 1] is bottom right) around which edges are detected.

- ❖ **Edge direction** – Direction of detected edges (vertical or horizontal).
- ❖ **Maximum distance from center** – Maximum distance between detected edge and center of detection in pixels.

7.3.6. Point Filtering

This section contains the parameters of point filtering.

- ❖ **Filter Type** – Type of the filter applied for point filtering during computation. This option is not applicable to calibration projects.
- ❖ **Filtered Time Window Size [s]** – Size in [s] of filtered history. Not applicable in combination with batches averaging.
- ❖ **Filter Only Valid Samples** – Specifies whether to return the resulting value as invalid if any point in the filtered sequence is invalid. This is enabled by default and recommended when measuring moving specimens.

7.3.7. Strain Measurement

This section contains the parameters of strain measurement.

- ❖ **Strain Data Units** – The strain data units that are used for strain computation and presentation. Possible strain data units are non-dimensional [-] or percentage [%].

7.4. OTHER CONTROLS

- ❖ **Factory Reset** – Resets the values in the respective settings (system, presentation or computation) to their factory defaults.
- ❖ **Save as Defaults** – Saves the values in the respective settings (presentation or computation) as defaults.
- ❖ **Load Defaults** – Resets the values in the respective settings (presentation or computation) to their defaults.

8. EXAMPLES

MERCURY RT allows browsing illustrative examples, which demonstrate the software capabilities and typical use-cases. The examples are published via the internet. This way provides access to our library of online examples, guaranteeing up-to-date examples. It is possible to download an example to the hard drive and explore the results and settings.

User can try different settings, compare the results and revert the local changes to the original example state.

The available examples can be found in the **Examples Browser window** shown in Figure 120. Both remote and local sources of examples can be specified:

- ❖ **Remote Source** – Specifies the URL address of the available examples. Our online library of examples is located at <https://www.mercury-dic.com/downloads/examples/>.
- ❖ **Local Source** – Specifies a local folder where the examples are downloaded. The default location of the downloaded examples is in My Documents\MercuryRT\examples\ . It is possible to choose a custom folder directly from the **Examples Browser window** by pressing the [...] button.

When changing the remote and local source, it is required to press the **Refresh** button for the changes to take effect. After that, the modifications are saved and will be used next time the **Examples Browser window** is open. The changes in the remote and local source settings can be reverted by using the corresponding button in the bottom-left of the window. There is also an option named Reset to default in the context menu of remote and local textboxes. The remote and local source can be defined in the **System Settings** under **Examples** (see 7.1.9) as well.

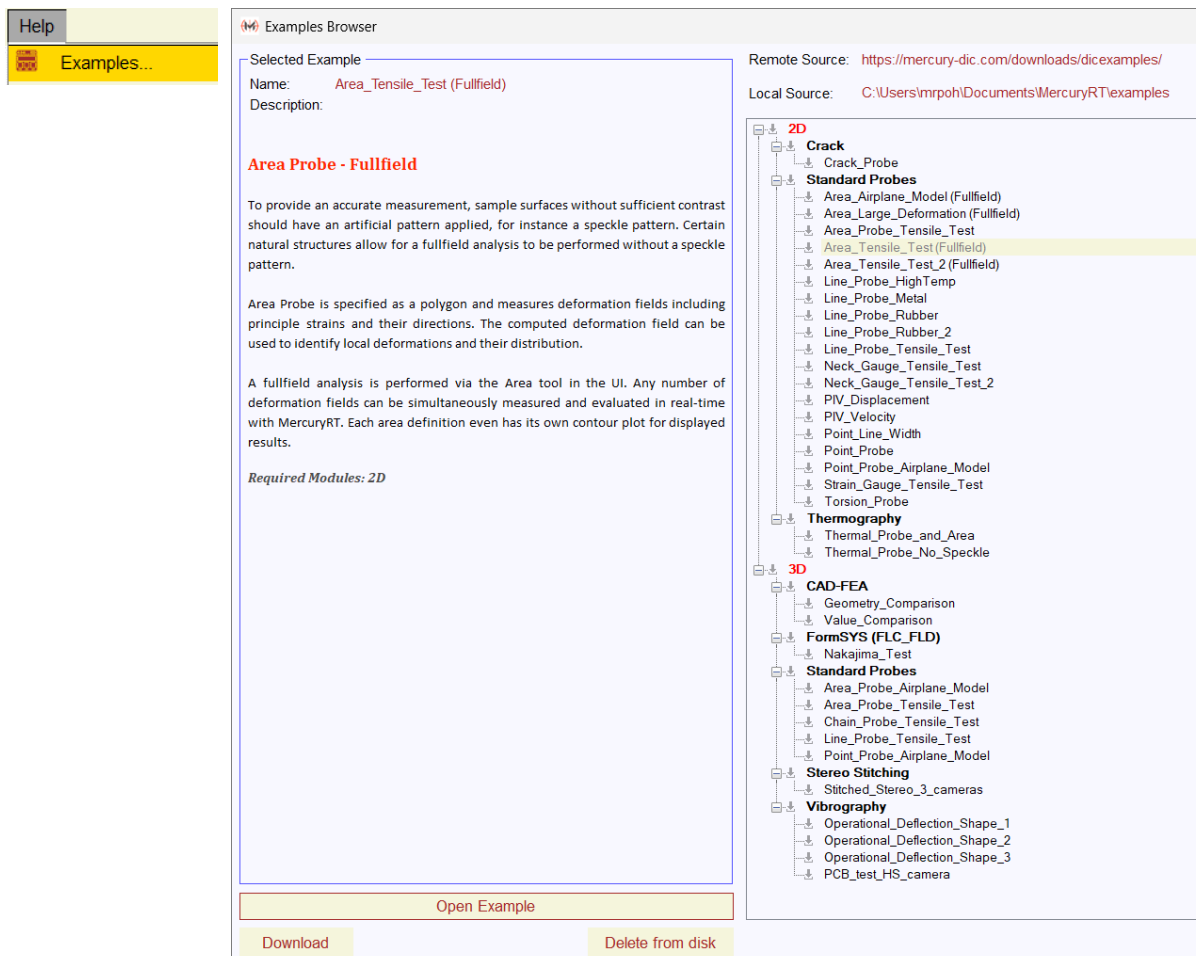


Figure 120: The Examples Browser window showing a tree structure of categories and highlighted downloaded examples (bold font)

The examples are divided into several categories. This division is represented by a tree structure, which forms the main part of the Examples Browser window. A particular example is the leaf of the tree structure and can be recognized by the icons



The examples may be in several different states. The explanations of the possible states are as follows:

 Extension-2D_v2	This example is not downloaded yet
 Fullfield-2D_v2	This example is already downloaded.
 Extension-2D_v2 (Modified)	This example is downloaded and has already been open and modified.
 NeckGauge-2D_v2 (Modified)	This example is downloaded and has been already open and modified, but there is a newer version of the example in the library of online examples.

When an example is selected, the Selected Example section of the window is updated with the information about the selected example. Besides the example name, there is a description of the example. There are several options on what to do with an example:

- ❖ **Open Example** – Opens the selected example. If the example has not been downloaded yet, it is downloaded and then opened.
- ❖ **Download** – Downloads the selected example to a local source.
- ❖ **Revert Project File** – Reverts changes of the selected modified example.
- ❖ **Delete from disk** – Deletes the selected downloaded example from a local source.

9. TESTING MACHINE CONFIGURATION

This chapter provides a detailed description of the configuration of testing machines which can be utilized for the testing of material properties.

9.1. ACTIVE TESTING MACHINE

The type of the active measuring device and several other parameters adjusting its configuration can be specified in System Settings (shown in Figure 121). It is possible to connect a Doli EDC device, one of the four types of supported analogue inputs or a digital input using a serial COM port. For further explanation of the associated parameters, see 7.1.4.

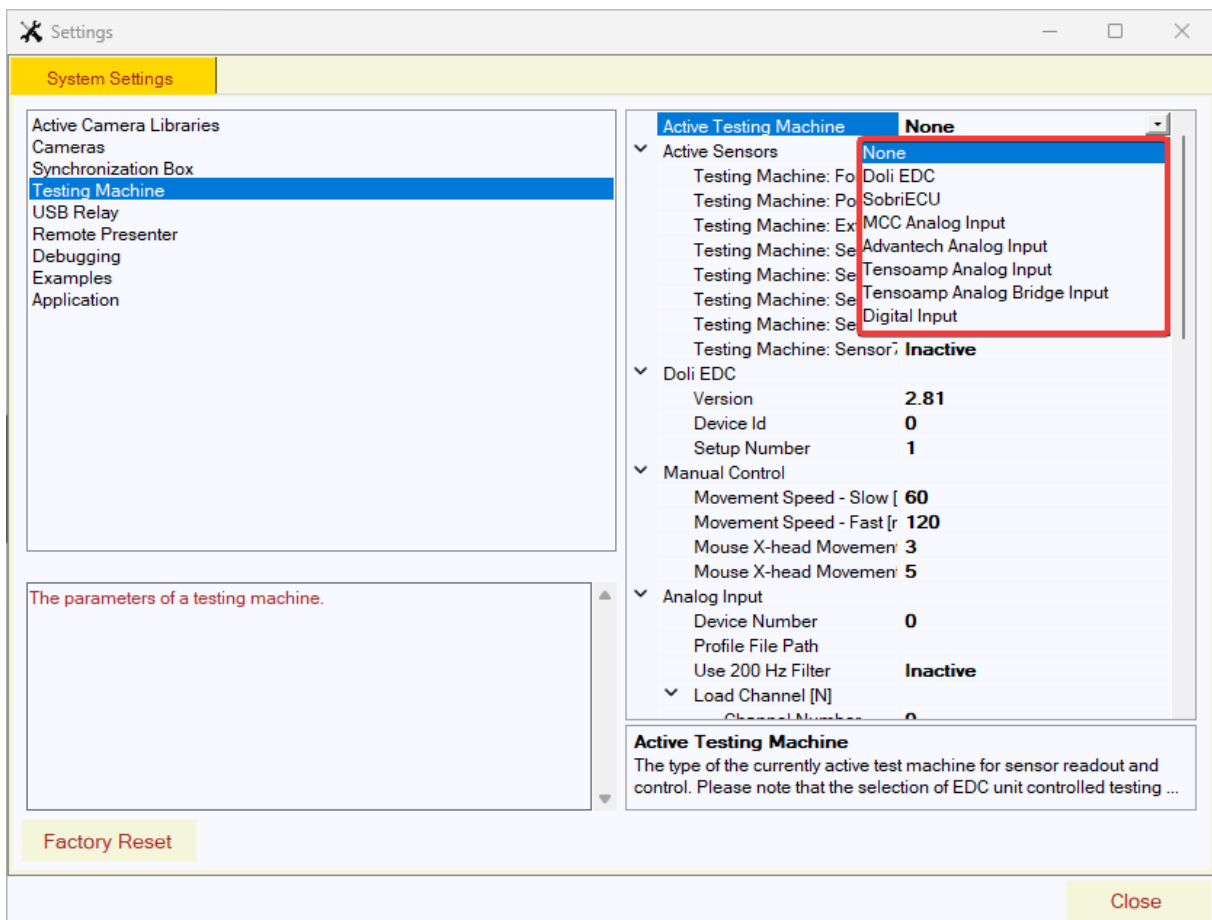


Figure 121: System Settings - Testing Machine parameters

9.2. DOLI EDC

The following chapter is a description of all controls, which are made accessible when using a DOLI DoPE driven testing machine, as well as all attributes which have to be set before running a new test with it. To select the testing machine, specify the Doli EDC option as the **active testing machine**.

9.2.1. Testing Machine Panel

Represents a tab in the main window, which provides the means to control DOLI DoPE driven testing machines. The recording of all displayed data takes place automatically when a test is running, regardless of the movement of the testing machine's cross-head.

The explanation of the controls within the **Testing Machine** panel illustrated in Figure 122:

- ❖ **Force [N]** – Displays the actual force being applied to the test specimen in real-time.
- ❖ **Position [mm]** – Displays the actual position of the testing machine's cross-head in real-time.
- ❖ **Extension [mm]** – Displays the actual extension of the tested specimen in real-time.
- ❖ **Tare (Force/Position/Extension/All)** – Resets the specified testing machine sensors.
- ❖ **Preload** – Applies the preload value as set in the procedure configuration window. (See Test Start Settings)
- ❖ **Cross-Head Up/Down** – Adjusts the position of the testing machine's cross-head. An alternative to these buttons is provided by means of scrolling the mouse wheel button, which can be activated by its corresponding button on the right and may also be done with increased speed by keeping a **Ctrl button** held down.
- ❖ **Halt Cross-Head** – Stops the movement of the testing machine's cross-head.
- ❖ **Testing Machine Settings** – Displays a detailed configuration window of the testing machine. (See 9.2.2)
- ❖ **Active Procedure** – Contains a list of created **procedures** with the currently selected one applied during the measurement.
- ❖ **Auto Run** – Toggles the option to activate the movement of the testing machine's cross-head automatically by the Run button in the project controls, right before starting an actual test in which the recording of measured values takes place.
- ❖ **Free Run** – Activates the movement of the testing machine's cross-head with active procedure settings. Please note that the data measured this way are not recorded unless a new test is started by the **Run** button among project controls.

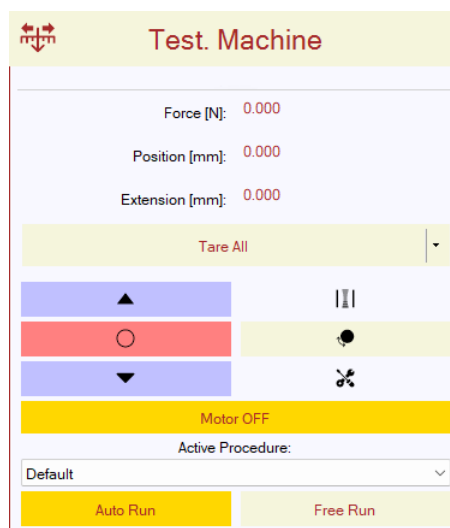


Figure 122: The Testing Machine panel – Active Testing Machine: Doli EDC

9.2.2. Procedure Configuration

The testing machines have their specific settings stored in the form of special configuration files called procedures, which are selected independently of the currently open project. The detailed properties of the testing machine can be adjusted through the **Testing Procedures** dialogue.

The controls located in this dialogue are specified as follows:

- ❖ **Create** – Creates a new testing procedure. When pressed, a dialogue appears, prompting to specify whether to copy the settings of the currently selected procedure or to use defaults.
- ❖ **Import** – Imports a previously created configuration file.
- ❖ **Delete** – Deletes the selected procedure.

SAMPLE SETTINGS

The Sample settings tab includes the calculator of the specimen's cross-section as well as an option to use this parameter for the computation of stress and strain.

- ❖ **Specimen shape** – There are three basic predefined specimen shapes, namely circular, rectangular and tube. The dimensions of a particular shape are entered in the box below. The cross-section is then calculated automatically. In the case of some other specimen shape, the cross-section is entered as a pre-computed value.
- ❖ **Stress/Strain** – To ensure the computation of stress and strain values by using the values measured by a testing machine, the appropriate checkboxes must be checked, and the reference length L_0 filled in.

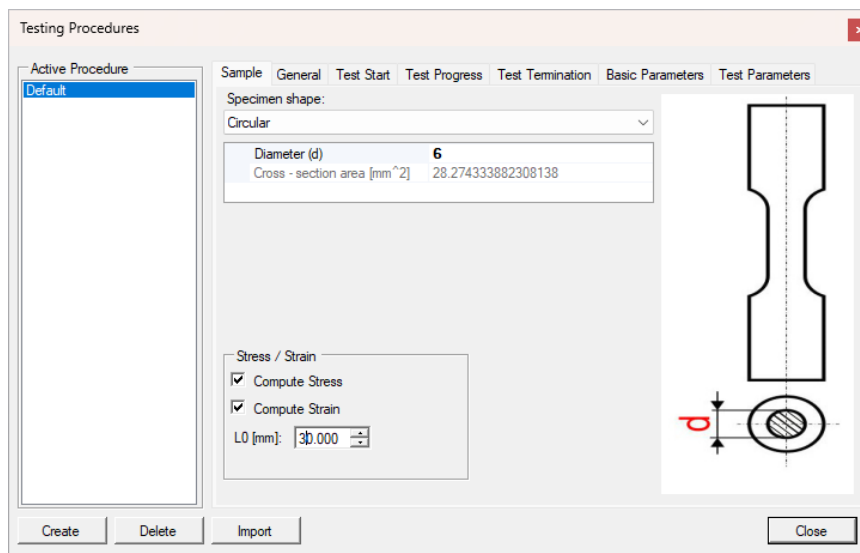


Figure 123: The Sample settings tab

GENERAL SETTINGS

The General settings tab shown in Figure 124 contains mostly parameters related to the speed and direction of the testing machine's cross-head. It is divided into several sub-sections described underneath.

- ❖ **Procedure Name** – Contains a modifiable name of the configuration file. Must be unique.
- ❖ **Test X-head Movement** – Adjusts the direction of the movement of the cross-head, effectively specifying the type of the test (tension or pressure). Can be either upwards or downwards.
- ❖ **Speed** – Adjusts the speed of the cross-head utilized during the test.
- ❖ **Original Positions** – Specifies whether to return the cross-head to its original position after the test or not.

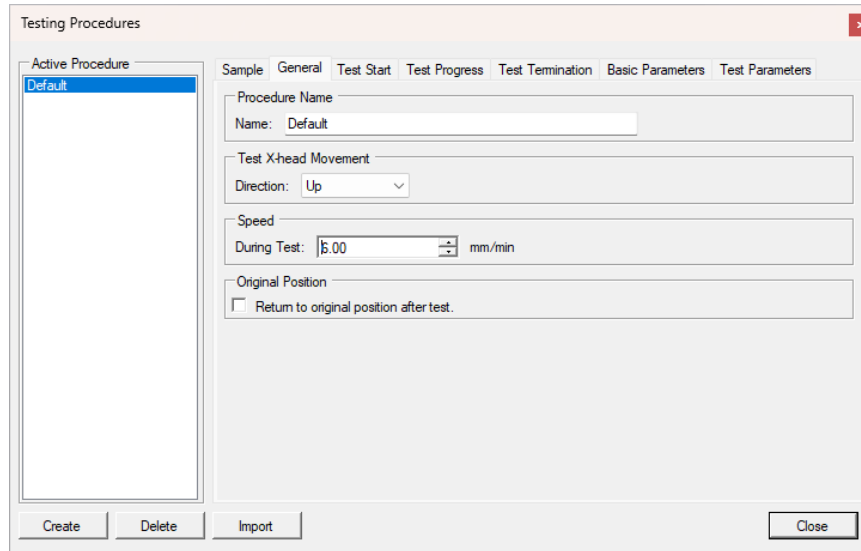


Figure 124: The General settings tab

TEST START SETTINGS

The **Test Start settings** tab shown in Figure 125 contains the parameters of the preload applied to the specimen. When enabled, these are applied by pressing the **Preload** button of the **testing machine** tab (see Figure 122), but also automatically when a new test is started, before the actual test.

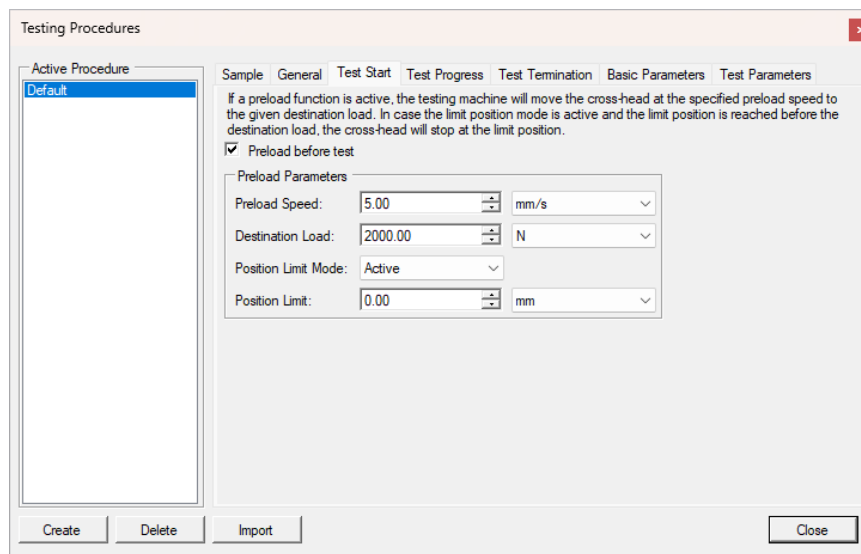


Figure 125: The Test Start settings tab.

- ❖ **Preload before test** – Toggles whether the preload parameters are active and applied. By default, this option is NOT active.
- ❖ **Preload Parameters** – This sub-section contains the following:
 - **Preload Speed** – Adjusts the speed of the cross-head during a preload. Can be configured either to units of mm/s or mm/min.
 - **Destination Load** – Adjusts the value of the target load applied to the specimen. Can be configured either to units of N, kN, MPa or GPa.

- **Position Limit Mode** – Specifies whether an absolute or a relative extension limit is applied to the specimen. If the position limit mode is active, such a condition is considered as well, in addition to the specified destination load. The fulfilment of either one of the specified conditions signifies the completion of the preload process.
- **Position Limit** – Adjusts the value of the position limit applied to the specimen. The control is available only if the position limit mode is active. Can be configured either to units of mm or m.

TEST PROGRESS

The **Test Progress settings** tab shown in Figure 126 contains the parameters of an optional periodical repetition of the testing machine's cross-head. These are applied during the test.

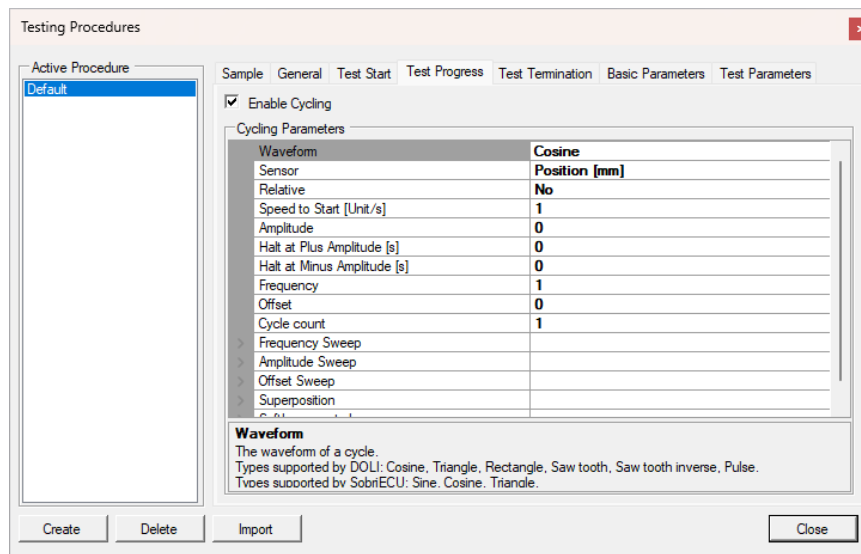


Figure 126: The Test Progress settings tab.

- ❖ **Enable cycling** – Toggles whether the cycling parameters are active and applied. By default, this option is NOT active.
- ❖ **Cycling parameters** – This sub-section contains the following:
 - **Wave Form** – The wave form of the cycle. The supported types are Cosine, Triangle, Rectangle, Saw tooth, Saw tooth inverse and Pulse.
 - **Sensor** – The type of sensor which controls the test.
 - **Relative** – Indicates whether the values are relative or absolute.
 - **Speed to Start [Unit/s]** – Specifies how fast the testing machine will reach the starting position of a cycle.
 - **Amplitude** – The amplitude of the cycle. An amplitude lower than 0 starts the test from a negative value.
 - **Halt at Plus Amplitude [s]** – Specifies how long to stay at a positive amplitude.
 - **Halt at Minus Amplitude [s]** – Specifies how long to stay at a negative amplitude.
 - **Frequency** – The frequency of the cycle.
 - **Offset** – The offset of the cycle.

- **Cycle count** – The number of cycles. A value of zero means infinity.
- **Frequency Sweep** – The sweep of the frequency. Specified by Mode, End value, Time and Count.
- **Amplitude Sweep** – The sweep of amplitude. Specified by Mode, End value, Time and Count.
- **Offset Sweep** – The sweep of the offset of the selected sensor type. Specified by Mode, End value, Time and Count.
- **Superposition** – An option to superimpose all waveforms with a cosine wave. Specified by Mode, Frequency and Amplitude.
- **SoftLoop control** – SoftLoop allows to run the test in, e.g. position control, but keep a certain, e.g. load. The load is controlled by changing the offset of, e.g. position. Specified by Mode, a control Sensor, one or two Values depending on the mode and Scale.

TEST TERMINATION

The **Test Termination settings** tab shown in Figure 127 contains the parameters of an optional automatic stop of the cross-head after a defined termination condition is met. Each of the termination conditions takes into consideration a specified limit of value on one of the input sensors.

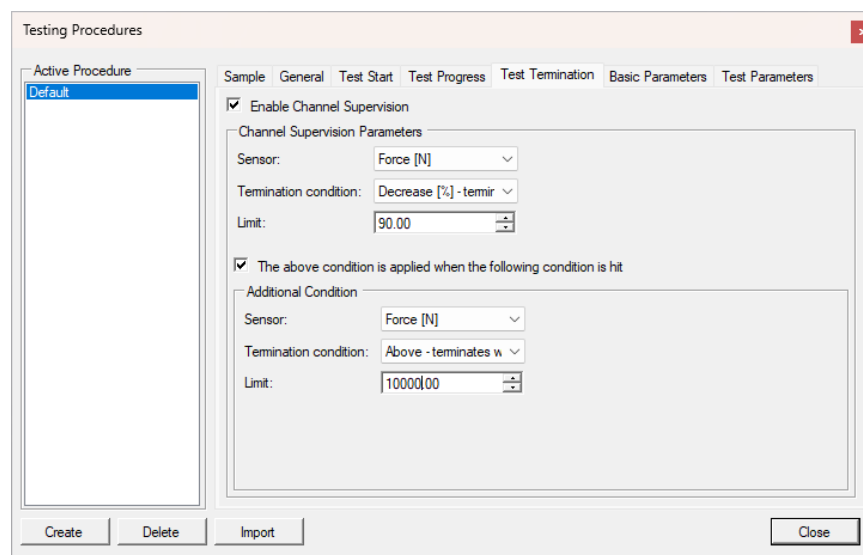


Figure 127: The Test Termination settings tab

- ❖ **Enable Channel Supervision** – Toggles whether the channel supervision parameters are active and applied. By default, this option is NOT active.
- ❖ **Channel Supervision Parameters** – This sub-section contains the following:
 - **Sensor** – Specifies the type of sensor to be supervised.
 - **Termination condition** – Specifies the condition of the termination to be fulfilled. Can be set to one of the options described in Figure 128.
 - **Limit** – Specified the limit value referred to in the termination condition.
- ❖ **The above condition is applied** – Toggles whether the additional condition is active and applied. By default, this option is NOT active.

- ❖ **Additional Condition** – This sub-section contains the same parameters as the previous one. If checked, the above condition is applied when the following condition is hit. In this case, the test terminates when both conditions are hit in the given order.

Below - terminates when value is lower than limit.
 Above - terminates when value is higher than limit.
 Decrease [%] - terminates when value will decrease by defined limit in [%].
 Rise [%] - terminates when value will rise by defined limit in [%].

Figure 128: The terminating conditions of selected sensors

9.3. ANALOG / DIGITAL INPUT

The analogue or digital inputs are other options on how to retrieve values from a testing machine. MERCURY RT supports MCC and Advantech A/D converters for analogue input, as well as a Tensamp device. Further information about the Tensamp device can be found in chapter 10.3.2. A digital input is realized using serial communication (COM port). **Active Testing Machine** (see 9.1) has to be set to the appropriate option:

- ❖ Mcc Analog Input or Advantech Analog Input for getting data from an A/D converter.
- ❖ Tensamp Analog Input or Tensamp Analog Bridge Input for getting data from a Tensamp device.
- ❖ Digital Input for getting data using serial communication.

9.3.1. Testing Machine Panel

The Testing Machine panel only serves to display data from the analogue or digital input in case of the absence of a testing machine supporting DOLI DoPE. **The control of the cross-head of a testing machine is not possible.** Therefore the control buttons are disabled. Only the **Tare** button is enabled for resetting the values (see Figure 129).

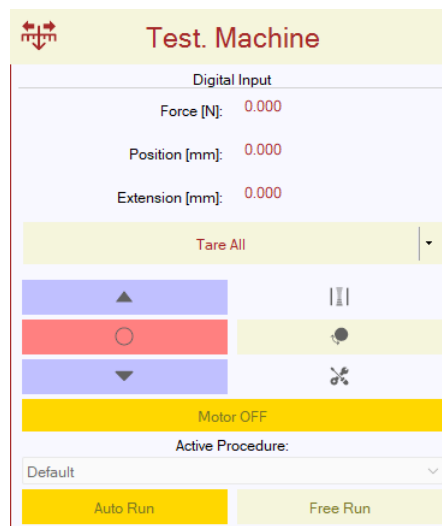


Figure 129: Testing Machine panel – Active Testing Machine: Digital Input

9.3.2. Digital Input Format Description

The default format of digital input from a testing machine to MERCURY RT via a COM port is described below. In order to support more varied inputs, the delimiters can be modified via **System Settings** under **Testing Machine** (see Digital Input Format).

Message delimiter \x04 (EOT)
 Value delimiter ;

Value order	load [N], position [mm], extension [mm], sensor3 [-], sensor4 [-], sensor5 [-], sensor6 [-], sensor7 [-]
Valid examples	1559.12\␣ 1559.12;15.3\␣ 1559.12;15.3;2.3;3;4;5;6;7\␣

10. I/O SERVICES

This chapter describes the setup of I/O Services. MERCURY RT allows sending user-defined values of measured quantities to a selected output. Described are the configuration options of the analogue, digital, DOLI Binary Serial and Testing Machine outputs, as well as HP Video and Remote Control API protocols.

The configuration of services is handled by the **I/O Services** panel illustrated in Figure 130, which is situated in the main window. Any new added I/O service is shown in the **Active**

Services list. To add new service click on plus button . If a service is properly configured, a green circle will appear next to its name. A connection error of an I/O service is indicated by a red circle. The description of the error is shown in the tooltip of the service. If a service is manually stopped by Stop button, the circle turns grey. Additionally, each created service can be edited  or deleted  via the buttons at the bottom of the panel.

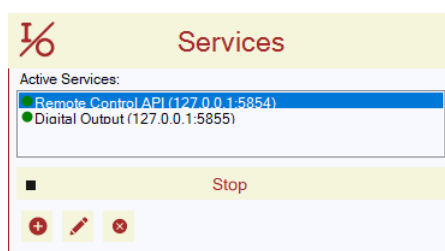


Figure 130: The I/O Services panel

10.1. ADDING A NEW SERVICE

It is possible to choose from several kinds of services which differ in the way of communication. For the proper function of each available service, it is necessary to specify the connection parameters. Moreover, some of the services allow the adjustment of the

output format. To add a new service click on the plus button , show in the Figure 130. The service parameters are adjusted using the **Add I/O Service** wizard, which is displayed in Figure 131. There is no restriction to the number of added services of the same type with the exception of a Remote Control API, Mobile Control API and API Adapter, which can only be added once.

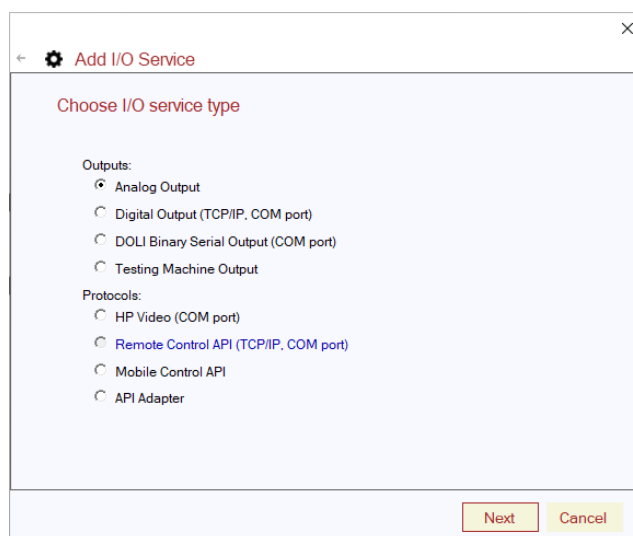


Figure 131: The Add I/O Service wizard

10.1.1. Analog Output Service

The **Analog Output** service allows sending a single value via a D/A converter. The value is sent every time new data are computed, namely during real-time tests and recomputations. MERCURY RT supports D/A converters from Advantech and MCC manufacturers, as well as DigiGauge devices. **Before using an MCC converter, the Instacal program included in the MERCURY RT installation file must be used to create a configuration file!** The Analog Output service has several parameters, which are configured in the **Add I/O Service wizard** shown in Figure 132. The parameters are described below.

Analog Output service parameters.	
Analog Output Device	Advantech
Device Number	0
DigiGauge Connection	
Port Name	
Baud Rate	115200
Data Bits	8
Parity	Odd
Stop Bits	1
Handshake	None
DigiGauge Buffer Delay [ms]	100

Analog Output Device
The type of the device for the transmission of extensometer output through an analog data acquisition device.

Finish Cancel

Figure 132: Add I/O Service wizard - Analog Output service parameters

- ❖ **Analog Output Device** – Specifies the type of the used device and must be set to one of the supported D/A converters. The converter can be selected either from MCC or Advantech, or alternatively, a DigiGauge converter can be used instead.
- ❖ **Device Number** – The number of the analogue device used for analogue output. Applicable only for an MCC or Advantech device.
- ❖ **DigiGauge connection** – The parameters of the COM port connection to a DigiGauge device. They all represent settings of the used COM ports and are as follows: Port Name, Baud Rate, Parity, Data Bits, Stop Bits and Handshake. Specify an empty string as port name to set the COM port as none.
- ❖ **DigiGauge Buffer Delay [ms]** – The buffer delay and camera FPS determines the number of samples to be buffered before the data is sent to the output. If no data is computed before the delay timeouts, the data is sent to the output without buffering.

10.1.2. Digital Output Service

The **Digital Output** service allows sending either up to eight selected measured values or all measured values. The service offers two types of connection – TCP/IP or a COM port (Figure 133). In addition, the user can adjust the output format of sent messages according to his specific requirements for both types of connection.

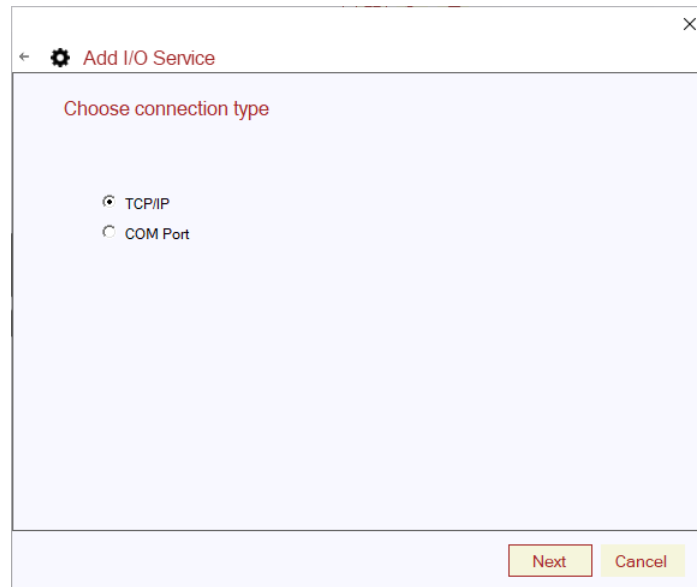


Figure 133: The available connection types of the Digital Output service

TCP/IP

The TCP/IP variant of the **Digital Output** service listens for an incoming connection on the specified address and port and sends a message in a user-defined format every time some new data is computed, namely during real-time tests and recomputations. The service has several parameters, which are configured in the **Add I/O Service** wizard and shown in Figure 134. They represent the settings of a TCP/IP connection, namely the **Server Address** and a **Port Number**, and the output format:

- ❖ **Message Delimiter** – Delimits the entire message, i.e. one package of data for a one-time moment.
- ❖ **Value Delimiter** – Delimits each computed value.
- ❖ **Not Computed Value** – Specifies the value which is used for null, i.e. not computed values.
- ❖ **Decimal Places** – Specifies how many decimal places to include in the formatted output.
- ❖ **Decimal Point** – Specifies which symbol to use as a decimal point.

Example of a sent message:

5.701||126.8609\r\n The example uses the default output format. The message starts with the first value (5.701). Two value delimiter '|' signs follow, which means the second value is not computed. After that, the last value (126.8609) follows. The end of message is specified by the message delimiter \r\n.

← ⚙ Add I/O Service

Digital Output (TCP/IP, COM port) service parameters.

▼ Connection	
Server Address	127.0.0.1
Port Number	5854
▼ Output Format	
Message Delimiter	\r\n
Value Delimiter	
Not Computed Value	4
Decimal Places	4
Decimal Point	Dot ('.')

Connection

Finish Cancel

Figure 134: The parameters of a TCP/IP connection with an output format

COM PORT

The COM port variant of the **Digital Output** service runs on a specified COM port and sends a message in a user-defined format every time new data is computed, namely during real-time tests and recomputations. The service has several parameters, which are configured in the **Add I/O Service** wizard shown in Figure 135. They represent the settings of a COM port and the output message format. The settings of a COM port include **Port Name, Baud Rate, Parity, Data bits, Stop bits and Handshake**. They must correspond with the COM port settings in the operating system for its proper function. The output message format consists of the same items as in TCP/IP.

← ⚙ Add I/O Service

Digital Output (TCP/IP, COM port) service parameters.

▼ Connection	
Port Name	
Baud Rate	115200
Data Bits	8
Parity	Odd
Stop Bits	1
Handshake	None
▼ Output Format	
Message Delimiter	\r\n
Value Delimiter	
Not Computed Value	4
Decimal Places	4
Decimal Point	Dot ('.')

Connection

Finish Cancel

Figure 135: The parameters of a COM port connection with an output

10.1.3. DOLI Binary Serial Output Service

The **DOLI Binary Serial Output** service implements the DOLI protocol for sending up to four measured values to a DOLI EDC device. The configuration of parameters can be done in the **Add I/O Service** wizard illustrated in Figure 136. These are the parameters for the formatting of measured values and for the COM port used for the communication with a DOLI EDC device. The settings of a COM port include **Port Name, Baud Rate, Parity, Data bits, Stop bits and Handshake**. They must correspond with the COM port settings in the operating system for its proper function. The measured values are formatted by the

multiplication **Float Factor**. It determines how many decimal places of the measured values are preserved. Use the same value as configured in the corresponding DOLI EDC device.

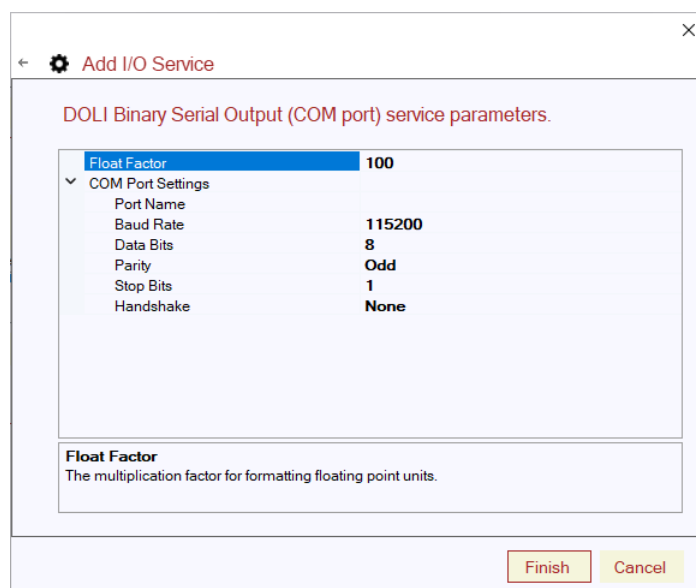


Figure 136: The DOLI Binary Serial Output service configuration.

Supported commands for DOLI Binary protocol

The **DOLI Binary Serial Output** service also supports the following commands. With these commands, it is possible to control MERCURY RT from external software by using DOLI electronic without the need for manual input in the software.

- ❖ **S** = Starts a new measurement.
- ❖ **Q** = Stops the currently running measurement.
- ❖ **L** = Followed by a decimal number, sets the length of all applicable length-measuring probes (also known as the initial gauge length).
- ❖ **T** = Followed by a decimal number, sets the width of all applicable width-measuring probes in the first camera configuration of the currently open project (e.g. the initial width).
- ❖ **W** = Followed by a decimal number, sets the width of all applicable width-measuring probes in the second camera configuration of the currently open project (e.g. the initial thickness).

10.1.4. Testing Machine Output

The **Testing Machine Output** service can be used to output specified values to the control unit of the connected testing machine. This is then used by some of the units to control the movement of the cross-head. The only parameter in this option is the **Sending Interval [Hz]**, which indicates how often the measured values are sent to the testing machine. A large rate can lead to an overload of the communication channel. Consider using the value filtering feature to reduce communication with the testing machine.

10.1.5. HP Video Service

The **HP Video** service implements the HP Video protocol for bi-directional communication between MERCURY RT and another application implementing the HP Video protocol. The service allows the transmission of up to four values via a COM port. The COM port configuration can be done in the **Add I/O Service** wizard illustrated in Figure 137. The settings of a COM port include **Port Name**, **Baud Rate**, **Parity**, **Data bits**, **Stop bits** and

Handshake. They must correspond with the COM port settings in the operating system for its proper function.

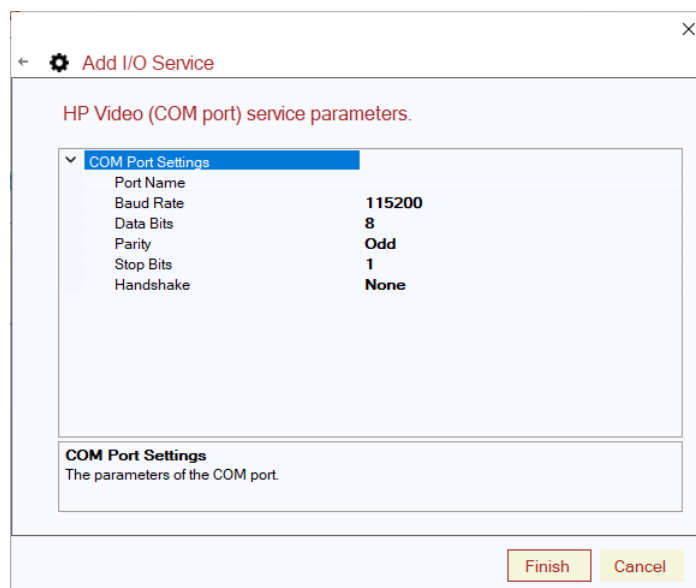


Figure 137: HP Video Service configuration

10.1.6. Remote Control API Service

The **Remote Control API** service allows controlling MERCURY RT either via TCP/IP or a COM port communication. Only one instance of the service can be running at a time. The documentation with a detailed description of the API communication protocol is available on demand.

TCP/IP

The TCP/IP variant of the API service listens for an incoming connection on the specified address and port and sends messages in a user-defined format. The parameters of the service can be configured in the **Add I/O Service** wizard shown in Figure 138. These are the settings of a TCP/IP connection, namely **Server Address** and **Port Number**, and the message output format consisting of the same items as in TCP/IP.

COM

The COM port option of the API service runs the service on the specified COM port and sends messages in a user defined format. The parameters of the service can be configured in the **Add I/O Service** wizard shown in Figure 138. These are the settings of a COM port and the output message format. The settings of a COM port include **Port Name**, **Baud Rate**, **Parity**, **Data bits**, **Stop bits** and **Handshake**. They must correspond with the COM port settings in the operating system for its proper function. The output message format consists of the same items as in TCP/IP.

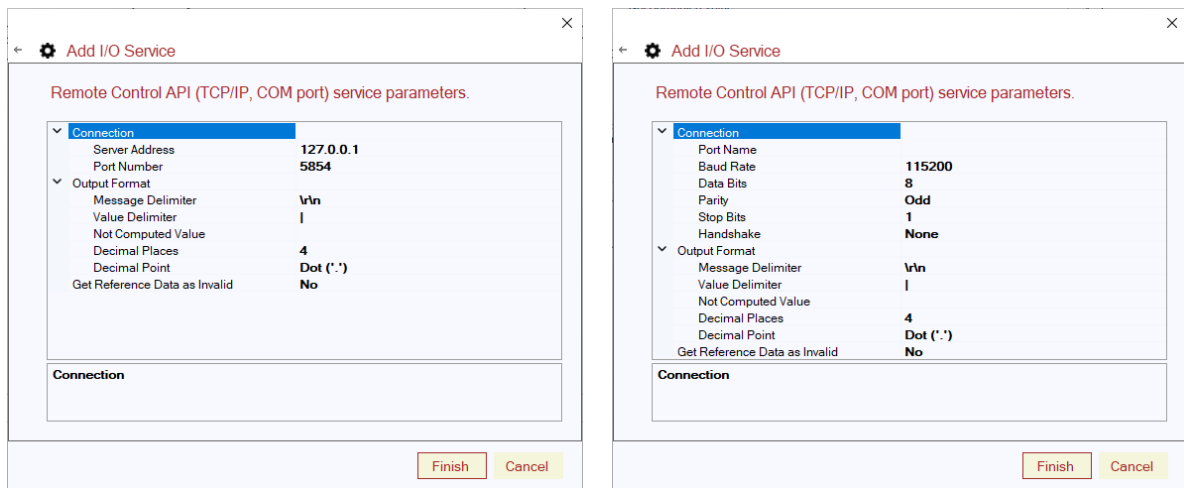


Figure 138: The Remote Control API service - TCP/IP configuration, COM port configuration

10.1.7. API Adapter Service

The API Adapter service allows you to receive commands from third-party applications through a defined application programming interface (API). Only one instance of the service can run at a time. Documentation describing the API Adapter service is available as a separate document.

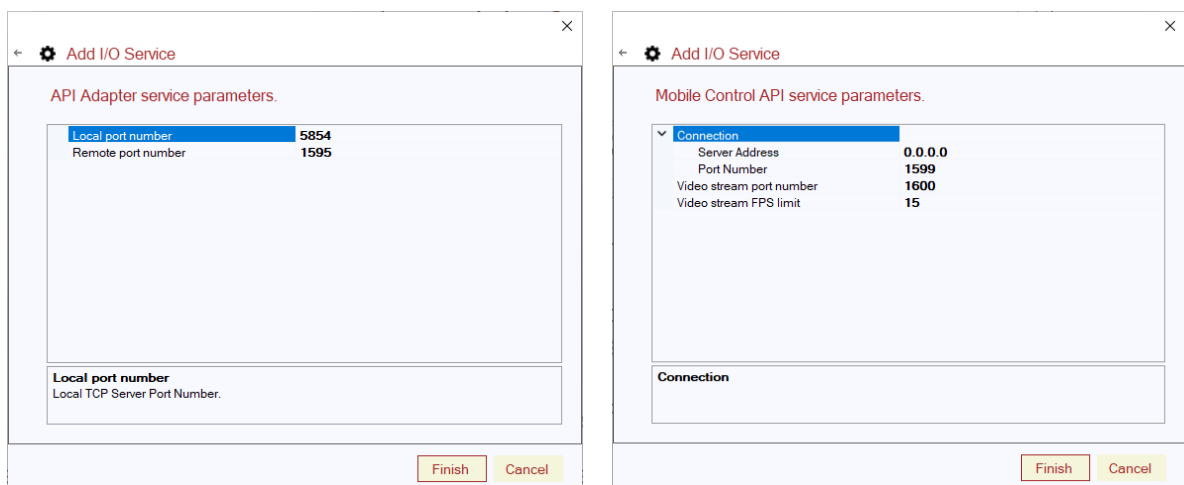


Figure 139: API Adapter Service configuration, Mobile Control API Service configuration

The API Adapter service listens for an incoming connection on the localhost address and local port and sends messages to localhost address and remote port in a third application format. The parameters of the service can be configured in the Add I/O Service wizard shown in Figure 139.

10.1.8. Mobile Control API

The Mobile Control API service allows you to set up communication with MERCURY RT Mobile application running on Android or Apple device. Only one instance of the service can run at a time. Documentation describing the MERCURY RT Mobile is available as a separate document.

The Mobile Control API service listens for an incoming connection on the localhost address and local port and sends video stream on specific port number to MERCURY RT Mobile. The parameters of the service can be configured in the Add I/O Service wizard shown in Figure 139.

10.2. CONFIGURATION OF THE OUTPUT VALUES

The settings of the output of particular measured values can be specified in the Graph Data panel on the left of the main window. Each measured value in the panel illustrated in Figure 140 has a Settings button on the right side. The colour of this button shows whether the value is sent to output and its tooltip also shows which specific output that is, possibly even if there is a visual alarm set for the value (see 2.6.1). Press any Settings button  for access to the activation of individual measured values.

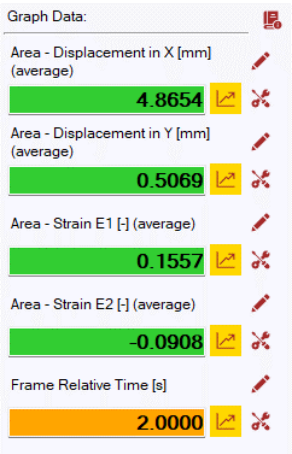


Figure 140: The Graph Data panel with measured values and an output signaling

After pressing the Settings button, a Graph Data Settings dialogue appears. The list of active services is shown on the left side of the dialogue. The Digital Output service and the Remote Control API service can send either all computed values simultaneously or up to eight measured values labelled A – H (illustrated in Figure 141).

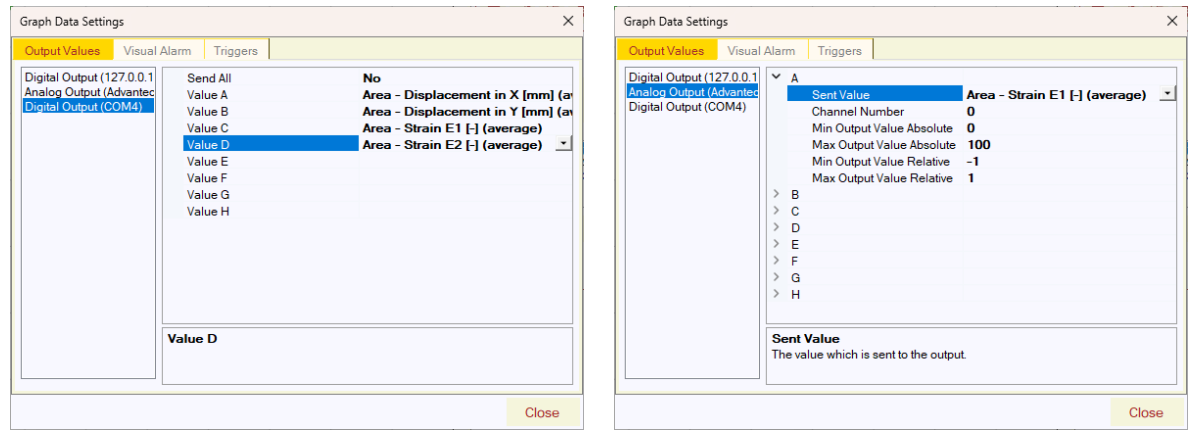


Figure 141: The output values of the Digital Output service, Analog Output (Advantech)

The Analog Output service can send up to eight measured values labelled A-H, initially corresponding with the channels on the D/A converter numbered 0-7 as illustrated in Figure 141. Furthermore, the following parameters, especially about the recalculation between the measured values and the measuring range of the D/A converter, must be specified as well:

- ❖ **Channel Number** – The number of the channel for analogue output. Indexed from zero.
- ❖ **Min Output Value Absolute** – The minimum for values in absolute units sent via analogue output. Lower values are clipped to this value. If an absolute value is sent to the output, sets the value assigned to the minimum of the analogue range. For example, if set to 10 and the analogue range is ± 10 V, a value of 10 will be assigned -10 V.

- ❖ **Max Output Value Absolute** – The maximum for values in absolute units sent via analogue output. Higher values are clipped to this value. If an absolute value is sent to the output, sets the value assigned to the maximum of the analogue range. For example, if set to 85, and the analogue range is ± 10 V, a value of 85 will be assigned 10 V.
- ❖ **Min Output Value Relative** – The minimum for values in relative units [%] sent via analogue output. Lower values are clipped to this value. If a relative value is sent to the output, sets the value assigned to the minimum of the analogue range. For example, if set to -5, and the analogue range is ± 10 V, a value of -5 % will be assigned -10 V.
- ❖ **Max Output Value Relative** – The maximum for values in relative units [%] sent via analogue output. Higher values are clipped to this value. If a relative value is sent to the output, sets the value assigned to the maximum of the analogue range. For example, if set to 85, and the analogue range is ± 10 V, a value of 85 % will be assigned 10 V.

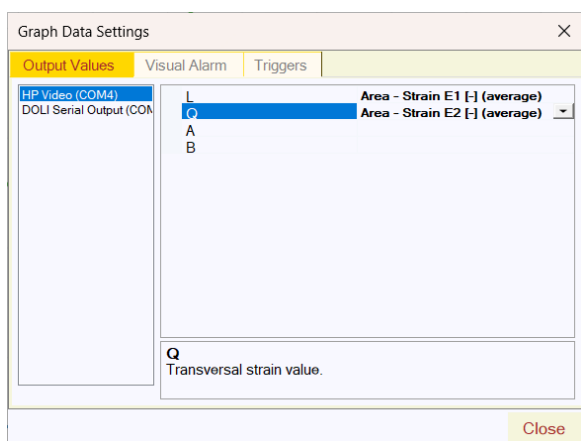


Figure 142: The output values of the HP Video Output service

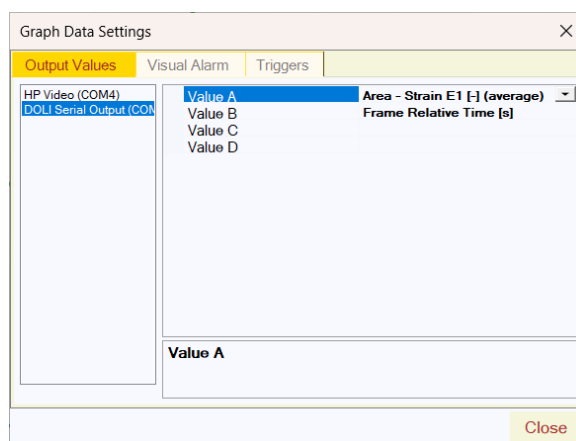


Figure 143: The output of DOLI Binary Serial Output service

The **HP Video service** can be adjusted to send up to four measured values as specified by the HP Video protocol (illustrated in Figure 142Error! Reference source not found.):

- ❖ **L** – Extension value.
- ❖ **Q** – Transversal strain value.
- ❖ **A** – Second extension value.
- ❖ **B** – Second transversal strain value.

The **DOLI Binary Serial Output service** allows the transmission of up to four values A-D (illustrated in Figure 143).

After closing the settings window, the selected output values turn green. A green colour indicates the values sent to any output. The associated output services are shown when moving the mouse over the I/O button. It is possible to readjust all output settings whenever the values are currently not being computed.

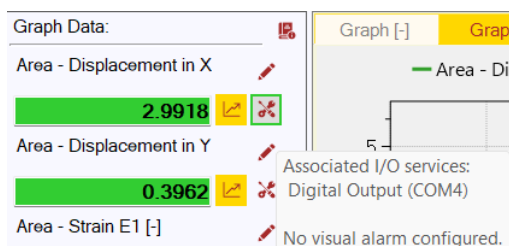


Figure 144: Green highlighted output values associated with an output service in the Graph Data panel

10.3. MERCURY RT I/O ACCESSORIES

10.3.1. Digi Gauge

DigiGauge is a device with a full software set-up serving as a 16-bit D/A converter providing time-synchronized analogue outputs and a signal conditioning (processing). It can be used to simulate a strain gauge as well. It features an open-source communication protocol. The devices are made in 1, 2 or 4 channel configurations.

Two types of outputs are possible:

- ❖ A standard ± 10 V analogue low-impedance output.
- ❖ A strain gauge emulated low-voltage differential output. It can be connected to any strain conditioners up to 1000 ohm. The bridge output is powered by external 5V excitation, is galvanically isolated and features a 1000 ohm fullbridge emulation. The output differential range: ± 200 mV/V, ± 20 mV/V or specified by a customer.

DigiGauge may be used for the types of test machines which have neither digital nor analogue input but have support for foil strain gauges. Moreover, it can be used for the calibration of the strain gauge amplifier. Any bridge type sensor amplifiers, converters and conditioners may be connected.

10.3.2. Tenso Amp

TensoAmp is another device designated for use with MERCURY RT. It is a 16-bit A/D converter featuring 1-4 channels, with variable oversampling and full software set-up. Provides signal conditioning for up to 4 strain gauges or various other bridge sensors. It can work as a $\frac{1}{4}$, $\frac{1}{2}$ or full bridge.

There are two types of analogue inputs:

- ❖ A standard ± 10 V high-impedance input.
- ❖ A bridge connection of various strain gauges, load cells, pressure sensors and any other bridge type sensors. Each bridge input is digitally configured and may be connected with bridge completion resistors (120 ohm, 350 ohm and 1000 ohm) included in the device. Programmable sensitivity settings 0.03-290 mV/V correspond to a strain range with approximately 60-580 000 $\mu\text{m}/\text{m}$. Offers programmable excitation with fixed 3 V, 5 V or variable DAC 1.8 V to 5 V setting.

Two types of outputs are possible:

- ❖ A standard ± 10 V low impedance analogue output (a fully analogue signal path, a programmable gain).
- ❖ A digital sampling (a 16-bit A/D converter with variable oversampling).

11. EXTENSOMETER CALIBRATION

Apart from the calibration of camera distortions and the coordinate system, MERCURY RT also offers an advanced feature named **Extensometer Calibration**. It represents a way to perform a correction of the positions computed in physical units using externally measured positional data, which is entered manually into the program alongside the respective computed data. Such a definition needs to be performed only once in a specialized extensometer calibration measurement, and its output is an extensometer calibration file. This file can then be loaded in other projects, which use the same hardware setup as the project, in which the extensometer calibration was performed. The detailed description of all these steps is provided below.

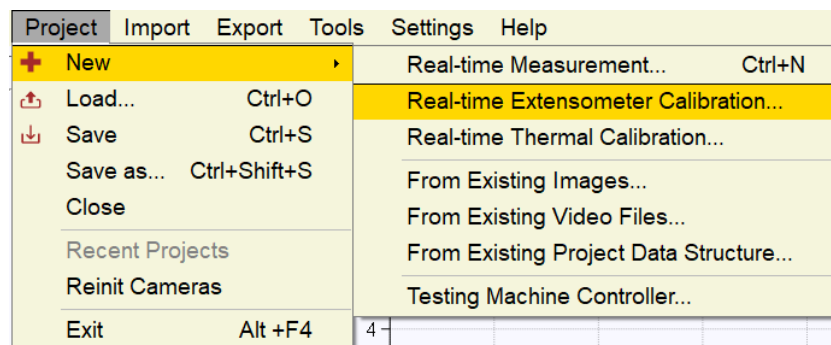


Figure 145: The Real-time Extensometer Calibration option in the main menu

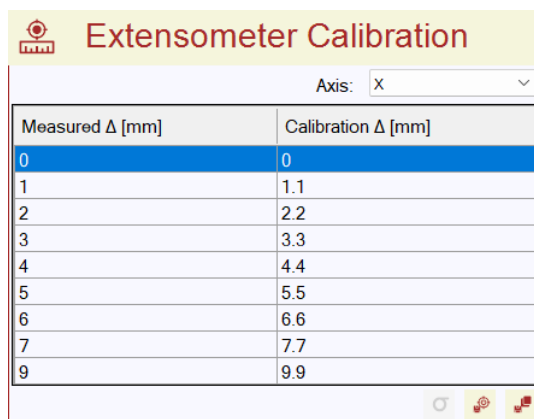
11.1. CREATING AN EXTENSOMETER CALIBRATION MEASUREMENT

The **extensometer calibration measurement** is a special type of project, which provides only the tools required for the definition of extensometer calibration. Most importantly, this includes the optional calibration of camera distortions and the coordinate system but excludes the input of tracking probes. Only a specialized calibration probe is available in each of the camera displays in the calibration measurement, which is being tracked in the same way as a usual point probe. If there is already a measurement available, which uses the same hardware setup and will be expected to use the extensometer calibration afterwards, it will have to be manually ensured, that the newly created extensometer calibration project uses the same calibration of camera distortions and the coordinate system as those measurements.

11.2. THE DEFINITION OF THE EXTENSOMETER CALIBRATION

Once the extensometer calibration measurement is open and both the definition of the coordinate system and the calibration of camera distortions are set as desired (although neither one of them is mandatory), it is required to move the specialized calibration probe to a position, where it can be tracked by MERCURY RT and have its displacement measured outside the program as well. The actual recording and computation are then performed as usual, by pressing the **Run** button in the **project controls** panel located in the **main window** (see 2.4). The only difference here is that only the **Run in Snap Mode** option is available in order to allow the frames to be captured when the calibration probe is in a position where its precise value of displacement is known from outside the program.

To assist with the manual input of externally measured values of displacement, the **Extensometer Calibration** panel is available on the right side of the **main window**, as displayed in Figure 146. It is, however, also shown automatically when running a test in an extensometer calibration measurement, so it is available right when it is needed. The first drop-down controls in this panel determine, which scene and axis are being calibrated at the time and only the latter is visible in a project containing just a single scene (a mono camera, a stereo camera or a mono stitching). While all the scenes in a project have their extensometer calibrations defined separately, only the selected axis is considered for a given scene. In conclusion, this means that only the deformations taking place in the selected axis will be corrected by the defined extensometer calibration.



Measured Δ [mm]	Calibration Δ [mm]
0	0
1	1.1
2	2.2
3	3.3
4	4.4
5	5.5
6	6.6
7	7.7
8	8.8
9	9.9

Figure 146: The Extensometer Calibration panel

Spanning through the middle of the panel is a table filled with the displacements of the calibration probe computed in MERCURY RT in the left column, while the right column is mostly left blank for the manual input of externally measured displacements of the probe in those specific positions. If the batch size was set to a higher number than one before the recording of the frames, the values displayed in the left column would represent the average of the computed displacement in that batch. The manual input of values to the right column can be done anytime, either directly during the recording of the frames in snap mode or afterwards. Clicking on a row with values also moves the **project seeker** to the corresponding moment in time.

The buttons located at the bottom of this panel are described as follows:

- ❖ **Show standard deviation** – Replaces the values in the right column of the table above with a display of the standard deviation of the computed displacements of the calibration probes in the associated batch. This option is only available if the batch size is higher than one. Click on the button again to restore the values in the right column of the table back to the input of externally measured displacements.
- ❖ **Save as** – Saves the configured definition of the extensometer calibration to a specified XML file. If this file is saved directly to the data directory of a project, where the extensometer calibration is to be used, it will be loaded automatically when opening that project. The same file is also available in the data directory of the project, where the extensometer calibration was defined.
- ❖ **Save to all measurements** – Saves the definition of the extensometer calibration to the data directory of all measurements contained within the same directory as the current project. These files are automatically loaded when opening those projects.

11.3. USING THE EXTENSOMETER CALIBRATION

When an extensometer calibration is loaded in a project, it will automatically perform a correction of physical units computed for the positional data in the axis for which it was configured. The indication of whether an extensometer calibration is active in a project and in which axis it takes place is located at the bottom of the **scene window**, as shown in Figure 147.

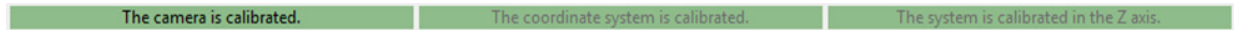


Figure 147: Status indication of the extensometer calibration

Currently, it is up to the user to ensure that the measured deformations will take place predominantly in the given axis. Also, as mentioned above, the extensometer calibration is only valid in combination with the calibration of camera distortions and the coordinate system it was associated with during its configuration. As a consequence, it is not possible to change any of these if an extensometer calibration is loaded in a project. To undo this effect, as well as to see in which axis the system is calibrated in, press the **Unload Extensometer Calibration** button located in the **Scene Setup** panel of a **scene window**. If no extension calibration is used at the moment, this button is replaced by a **Load Extensometer Calibration** button, which loads the extensometer calibration from a specified XML file.

12. THERMAL CALIBRATION

When using thermal cameras with MERCURY RT, the main usability comes from **thermal probes** (see Thermal Probe), which are used for temperature readout at static positions in the thermal imagery and thermal areas (see Thermal Area). This process already assumes the calibration of the thermal camera sensor, which is performed externally and **not** covered by the functionality of our software. The only feature available in this regard is the adjustment of thermal parameters and loading of an external calibration file, both of which are available in the Thermal Camera panel of the Scene Window (see 3.2.2) and only supported by certain thermal camera brands.

There is, however, an optional **thermal calibration** feature available in the program, which enhances the functionality of the **thermal probes** by the ability to measure deformations as well as temperatures. It is performed by mapping the changes in temperature to a corresponding deformation. This is defined in a separate **thermal calibration** project and usable from then on in any project, which uses the same thermal camera and measures the same kind of samples.

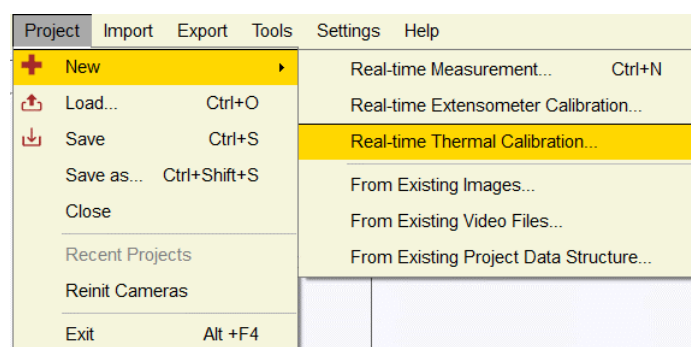


Figure 148: The Thermal Calibration option in the main menu

12.1. CREATING A THERMAL CALIBRATION MEASUREMENT

The **thermal calibration measurement** is a special kind of project, which provides the means of defining a **thermal calibration** - here understood as a mapping of a change in temperature in a thermal image to deformation measured by an extensometer in non-thermal images. This project **must** always consist of one mono camera scene with a thermal camera and another scene of any type (mono / stereo / stitching), which does not contain any thermal cameras. This is demonstrated in Figure 149, and the logic of the New Project wizard ensures that the scenes are configured exactly this way. A warning message is shown otherwise.

If the project is successfully created, it is open with the scenes already containing the tools required for performing the calibration. The scene with the thermal camera contains a static calibration probe for temperature readout, while the non-thermal scene contains an extensometer line, which computes its relative elongation.

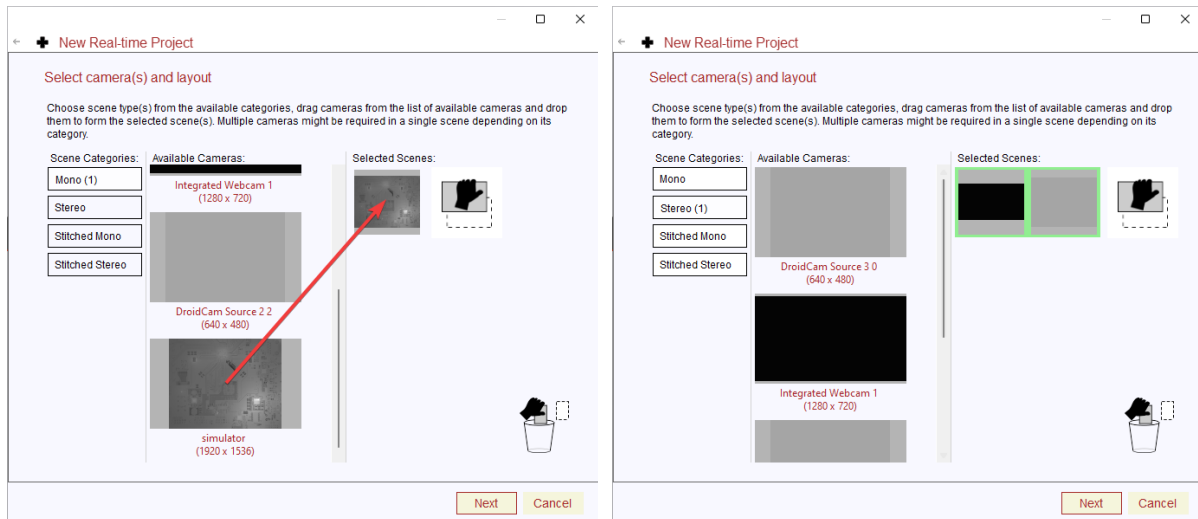


Figure 149: The creation of a thermal calibration project with a) a mono scene with a thermal camera and b) another scene (of any type without a thermal camera)

12.2. THE DEFINITION OF THE THERMAL CALIBRATION

When a thermal calibration project is open for the definition of the calibration, it is first required to perform the necessary camera and coordinate system calibration in the scene with the extensometer line, so that it can be measured properly. This process is no different from the way it is done before any usual measurement – refer to 3.2.4 and 3.2.5 for details. Note, however, that this is NOT required for the scene with the thermal camera, just the non-thermal one. If necessary, the synchronization of cameras in the non-thermal scene should be performed as well. With these steps out of the way, it is required to position the calibration probe according to the displayed specimen in the scene of the thermal camera, which positioning the endpoints of the calibration line in the non-thermal scene respectively. The markers, which are adjusted during this process, are shown in Figure 150.

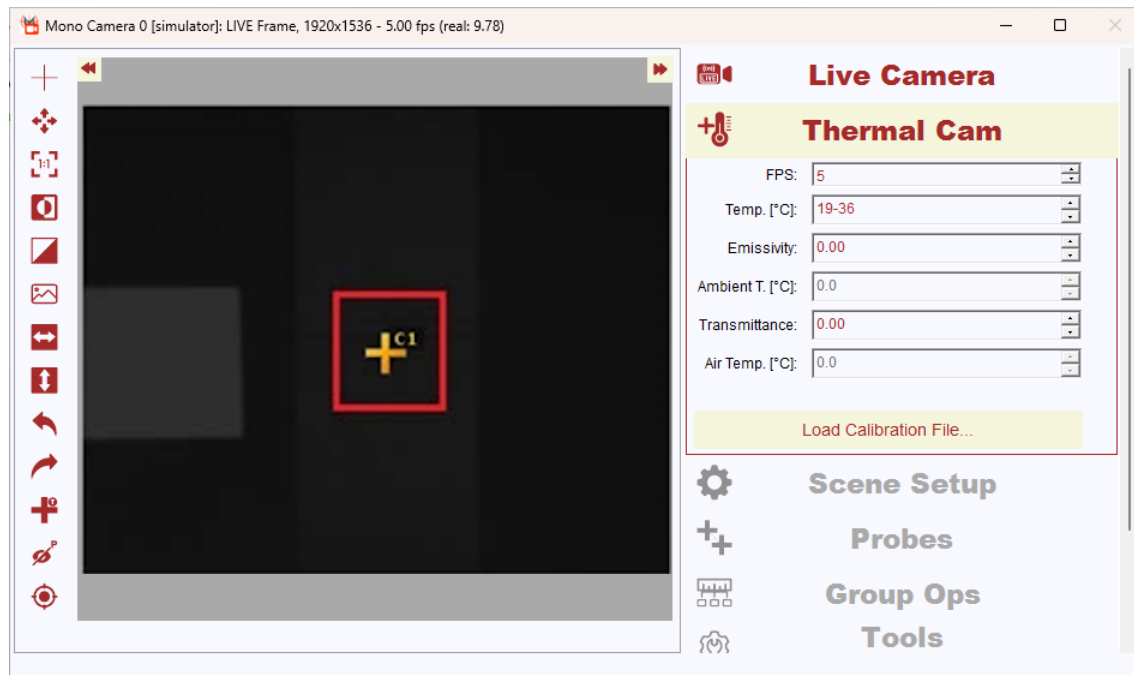


Figure 150: The adjustment of the tools used for a thermal calibration

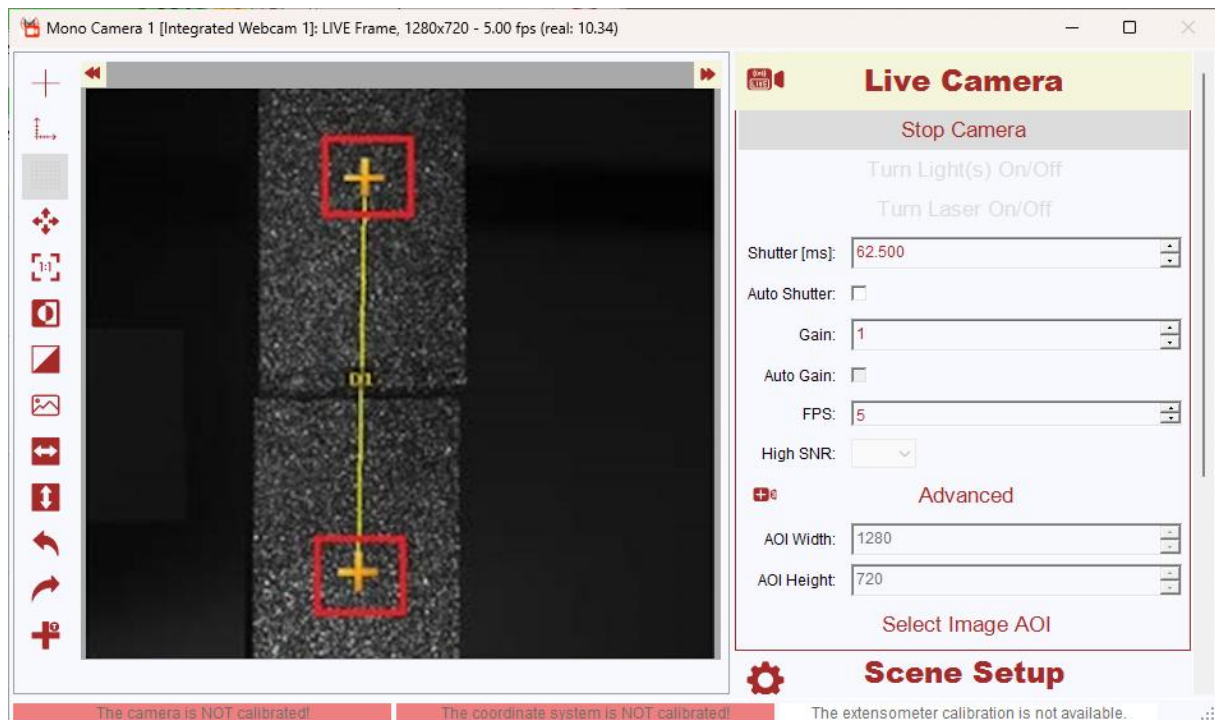


Figure 151: The adjustment of the tools used for a thermal calibration: a calibration (extensometer) line in a supplemental non-thermal scene

When the measurement is prepared this way, a live measurement can be started by using the **Run** button in the Main Window. After capturing the requested range of frames, it is advisable only to select a sub-range of the measurement, which covers only the relevant portion of the frames. This can be done as usual by using the **Set as Reference** and **Set as End** buttons in the Main Window together with the range slider next to them. Use the **Recompute** button afterwards in order to compute all the necessary data in the selected range.

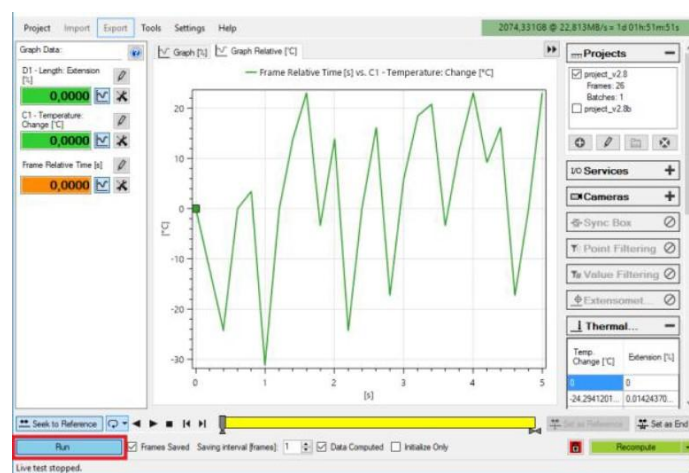


Figure 152: Measuring with the calibration tools – a live measurement

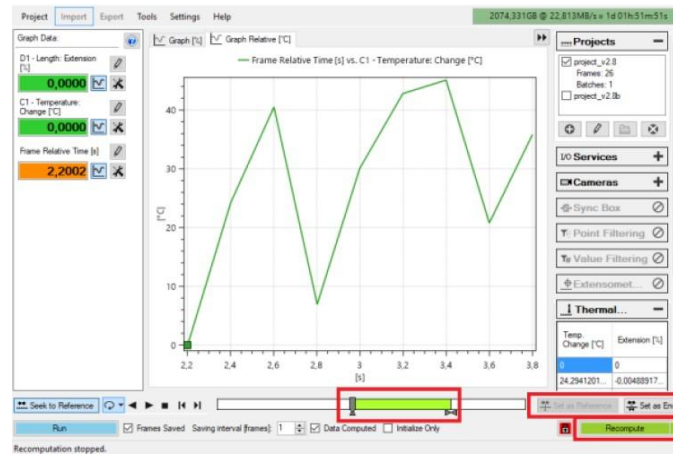


Figure 153: Measuring with the calibration tools – adjusting the range and recomputation

The Thermal Calibration panel should be visible at the right of the window. Use the displayed information to see which temperature (measured by a calibration probe in a thermal camera) corresponds to which extension (measured by a calibration line in the other camera) in the selected range. If the values are satisfactory, use the **Save** button (highlighted in Figure 154) at the bottom of the panel to save the thermal calibration to a file.

Thermal...	
Temp. Change [°C]	Extension [%]
0	0
24.2941201...	-0.00488917...
40.4902002...	-0.01261146...
6.94117718...	-0.02172213...
30.0784344...	-0.02762059...
42.8039259...	-0.03551276...
45.1176517...	-0.03752515...
20.8235315...	-0.04151070...
35.8627488...	-0.03712546...

Figure 154: The Thermal Calibration panel

12.3. USING THE THERMAL CALIBRATION

When the thermal calibration is defined by the previously described process, it is available for use in any project, which uses the thermal camera involved in the calibration, and more importantly even without the presence of any nonthermal camera in the same project. It can be loaded by using the Load Thermal Calibration button in the Scene Setup panel of the Scene Window, which allows selecting the previously saved thermal calibration. The presence of a thermal calibration in a project with a thermal camera can be recognized by a green indicator on the bottom of the window, which becomes visible if the window is wide enough.

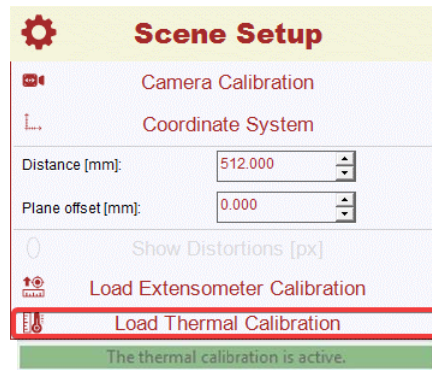


Figure 155: Scene Setup panel with the Load Thermal Calibration button and the related indication of the active thermal calibration

When this calibration is active, the thermal probes are added to the camera display as usual. However, due to the loaded thermal calibration, an option to measure strain by using these points becomes available in their context menu, as shown in Figure 156. Enable it as much as required by the measurement. When the measurement is then performed, as usual, the measured strain becomes visible in the respective graph display. It is computed by linear interpolation of the measured temperatures according to the calibration points defined by the thermal calibration.

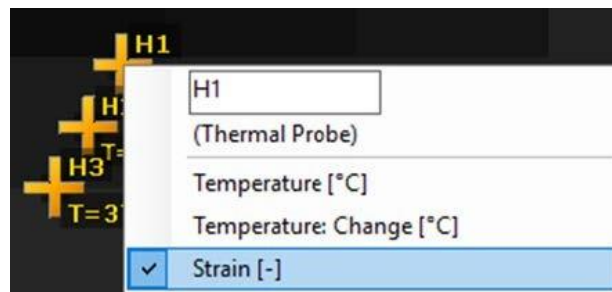


Figure 156: The option to measure strain available in the context menu of a thermal probe when a thermal calibration is active

13. HW SYNCHRONIZATION

13.1. INTRODUCTION

Most of the time, the internal camera synchronization is all that is needed. This means that when a certain FPS value is set for a camera, an image is taken in each corresponding interval after starting to capture. This is sufficient for lowspeed single-camera tests. However, other scenarios may require some sort of synchronization, for instance:

- ❖ A cycling test where an image is taken in a certain phase after a given number of cycles.
- ❖ High-speed tests where the start must be precisely given.
- ❖ Multi-camera set-ups, especially stereo cameras, where images from the left and from the right camera must be taken at the exact same time.
- ❖ The capture of vibration tests using regular speed cameras where a phase must be sampled in precisely given intervals.

The HW synchronization is about sending an electrical signal to the camera input pin to signalize when an image is to be taken. Please note that not all cameras support every option of synchronization.

13.2. CAMERA SYNCHRONIZATION PANEL

The external synchronization of a camera can be toggled by checking the **Enabled** box in the **Cameras panel** on the right of the **main window**, as seen in Figure 157. This enables the last used synchronization. If the synchronization options need to be adjusted, this can be done in **System Settings** under **Cameras** (see 7.1). The individual parameters of synchronization are described in the following chapters.



Figure 157: Camera Synchronization panel

13.2.1. Camera Synchronization Modes

MERCURY RT supports the following modes: all of them illustrated in Figure 158:

- ❖ **FireWire Bus Synchronization** – Valid only for FireWire cameras. Requires that all cameras are daisy-chained on a single FW adapter. The advantage is that no additional devices or cables are needed.
- ❖ **External Trigger** – All connected cameras are switched into an external synchronization mode where they are awaiting an electric pulse on an input. An external device is needed to trigger the cameras at the desired moment. Works for any kind of camera interface.
- ❖ **Master/Slave** – A synchronization mode where one of the cameras acts as a master identified by the **Master Camera Id** (i.e. broadcasts a pulse at the very moment the camera started to capture its image) and all other cameras are set to a slave mode (corresponds to the External Trigger mode above). The camera, which is set as the master, is indicated by a MASTER label in the header of its camera view. This mode does not require an external device – a simple cable can do the job and hence increases the ease of use. Works for any kind of camera interface.

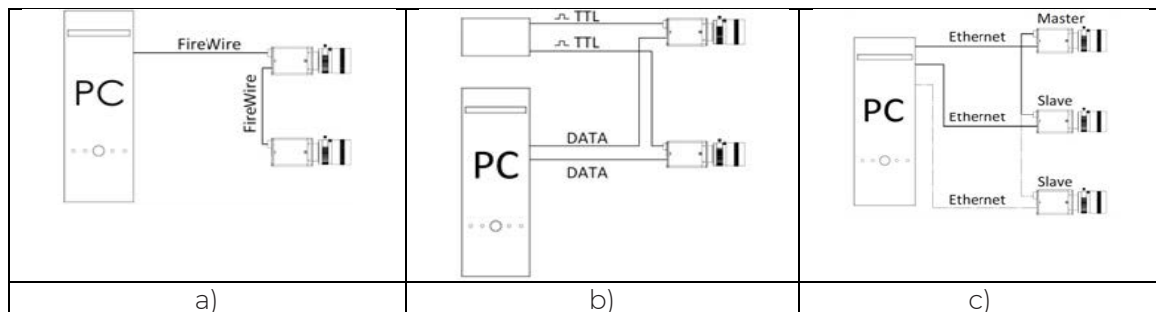


Figure 158: Schematic representation of HW synchronization set-ups. a) FireWire Bus Synchronization, b) External Trigger, and c) Master/Slave

13.2.2. Additional Synchronization Settings

Further synchronization options can be found in System Settings under Cameras (see 7.1.2).

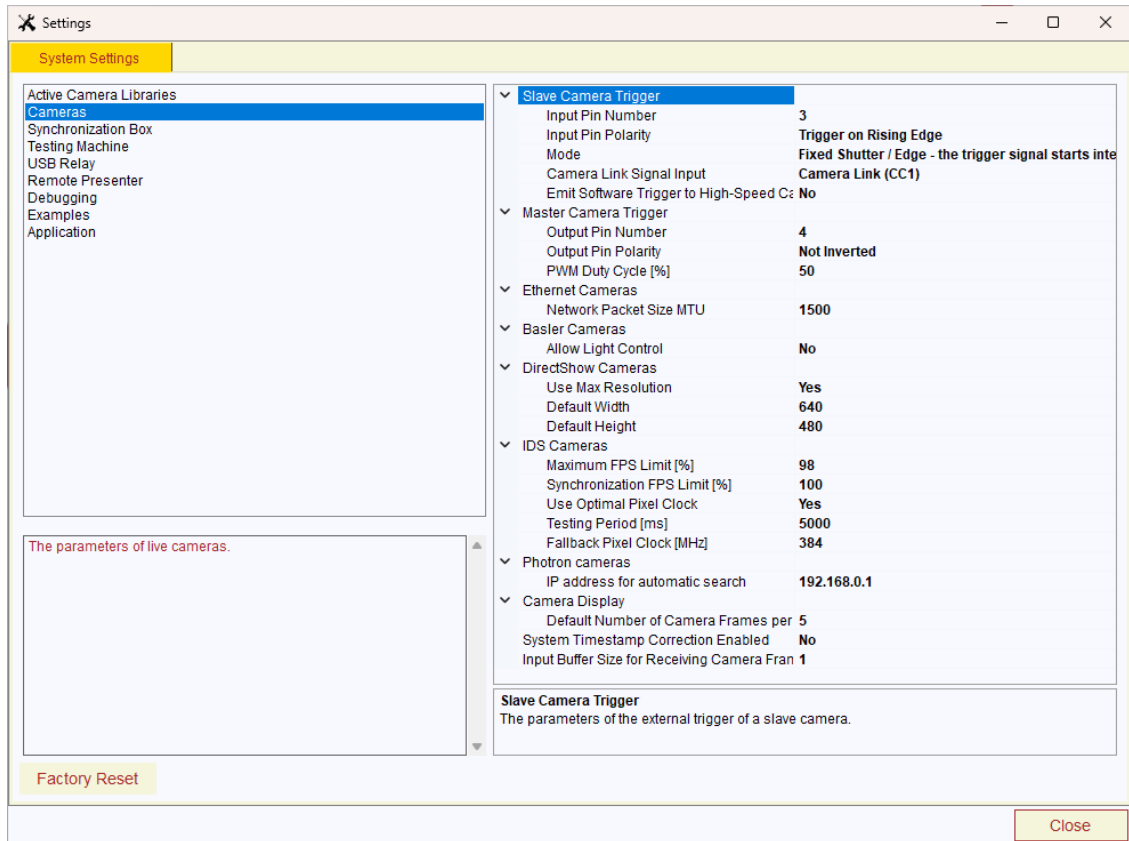


Figure 159: The Camera parameters section of the System Settings window

SLAVE CAMERA TRIGGER

Contains additional settings used for the Master/Slave (slave cameras) and External Trigger (all cameras) synchronization modes.

- ❖ **Input Pin Number** – The number of the camera pin to receive the TTL pulse. If left at 0 when using most USB3 cameras, the default opto-isolated input line is put into use. This line has higher delays than the direct-coupled line, so set this number to one of the GPIO pins if it is desired to have the lowest possible delay. (recommended) Further remarks on use with specific camera brands are noted in the extended description of this parameter.
- ❖ **Input Pin Polarity** – The polarity of the TTL pulse. Can either be set to Trigger on a Rising Edge or Trigger on a Falling Edge.
- ❖ **Mode** – The external triggering mode of the camera. Applied only when using AVT cameras. Can be set to one of the following options:
 - Fixed Shutter / Edge – The trigger signal starts the integration.
 - Integration Enable / Level – The trigger signal determines the integration time. (The value of shutter time is ignored)
 - Bulk Capture – The trigger signal starts a series of integrations.
- ❖ **Camera Link Signal Input** – The trigger signal input connector of Camera Link cameras. Currently applicable only to cameras by Sentechn. Can either be set to Camera Link (CC1) or Power/IO connector (No. 2 pin, SP4).

- ❖ **Emit Software Trigger to High-Speed Cameras** – Specifies whether to emit a software trigger of high-speed cameras regardless of their synchronization settings.

MASTER CAMERA TRIGGER

Additional settings used only during the Master/Slave mode (the master camera).

- ❖ **Output Pin Number** – The number of the camera pin to send the TTL pulse. If left at 0 when using most USB3 cameras, the default opto-isolated output line put into use. This line has higher delays than the direct-coupled line, so set this number to one of the GPIO pins if it is desired to have the lowest possible delay. (recommended) Further remarks on use with specific camera brands are noted in the extended description of this parameter.
- ❖ **Output Pin Polarity** – The polarity of the TTL pulse. Can either be Inverted or Not Inverted. Inversion is not applicable to PointGrey cameras.
- ❖ **PWM Duty Cycle [%]** - Certain models of cameras (currently only IDS) use Pulse Width Modulation to generate the trigger signal for slave cameras. This determines the value of the duty cycle, which is a parameter of the PWM function. It is specified in units of %, where 1% means the narrowest pulse and 99% the widest. The PWM function also has a frequency parameter, but it is computed automatically by using the FPS value set for the camera.

13.3. SYNCHRONIZATION BOX - VIBROGRAPHY APPLICATIONS

The Synchronization Box is a device, which is distributed separately. The box facilitates the analysis of high-speed periodic phenomena using regular (non-high-speed) cameras, which significantly reduces the cost of the equipment. The main application is a vibrography analysis of an excited specimen driven by a known periodic signal.

Figure 160 shows a typical connection of the synchronization box in a vibrography application. The source of the periodic signal is a generator, which simultaneously sends the signal into a shaker and the box. The camera synchronization is realized via the box according to the set of input parameters. The box determines the period of the input signal and sends it to the PC. Both cameras are connected to the output channels of the box. The communication between the PC and the box is realized via a serial COM port.

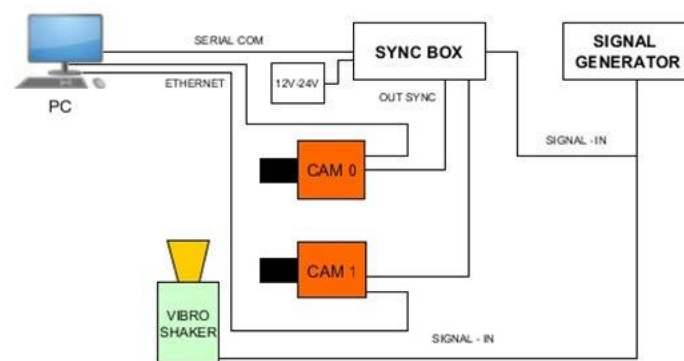


Figure 160: The wiring diagram of the Synchronization Box

The default operation mode of the box is the Phase Sweep Mode. The purpose of the box is to measure the input signal frequency, report this to the PC for a proper timestamp computation and trigger the camera(s) in the exactly correct moments to perform a so-called phase sweep. In the end, the specified number of “virtual” periods is recorded with correct timestamps, so that a vibrography analysis can be computed. The resulting data

should be almost as if it was recorded by a high-speed camera (provided the test is periodical, and the excitation signal is available); the only limitation is that the computed amplitudes are only valid for the excitation frequency and its harmonics.

13.3.1. Connection of the Synchronization Box

The connection settings of the box are located in **System Settings** under **Synchronization Box**, as shown in Figure 161.

The only necessary step to connect the synchronization box is to insert a proper COM port name. Control of the synchronization box is performed through an external application. Further information about this application is provided as a separate document.

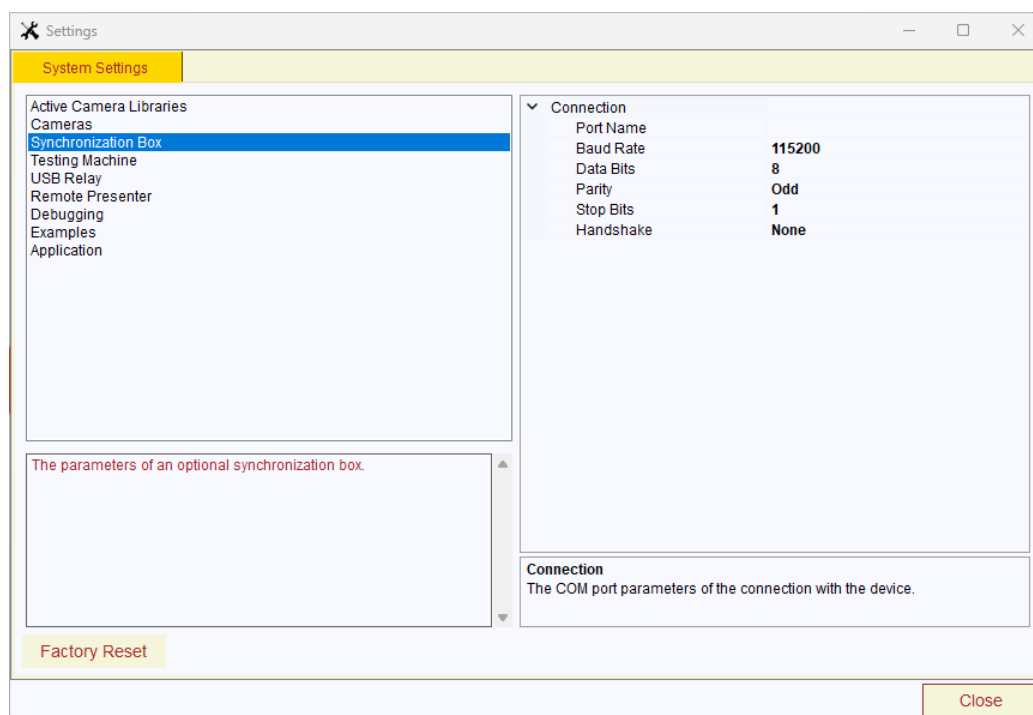


Figure 161: The Synchronization Box settings

The individual items of these settings are as follows:

- ❖ **Connection** – The COM port parameters of the connection with the device. They all represent the settings of the COM port used for bi-directional communication with the connected Synchronization Box and are as follows: **Port Name**, **Baud Rate**, **Parity**, **Data Bits**, **Stop Bits** and **Handshake**. Specify an empty string as a port name to deactivate the Synchronization Box.

14. HIGH-SPEED CAMERA MEASUREMENT

The current distributions of MERCURY RT offer the opportunity of measuring with high-speed cameras. Utilizing high-speed cameras together with the software gives new possibilities, especially when analyzing phenomena like vibration, crash tests etc.

14.1. CONNECTION OF THE HIGH-SPEED CAMERA

In this step, it is necessary to power the cameras using the included power cable and connect it to your computer using the included GigE cables. In order to make sure the software can recognize the cameras, it is also necessary to make sure the cameras and the ethernet ports are running in the same subnet.

First it is necessary to obtain the IP address of the camera.

After that change the IP address of the computer to have the address from the same subnet as the camera. This is done by configuring the **Internet Protocol Version 4** (TCP/IPv4) properties.

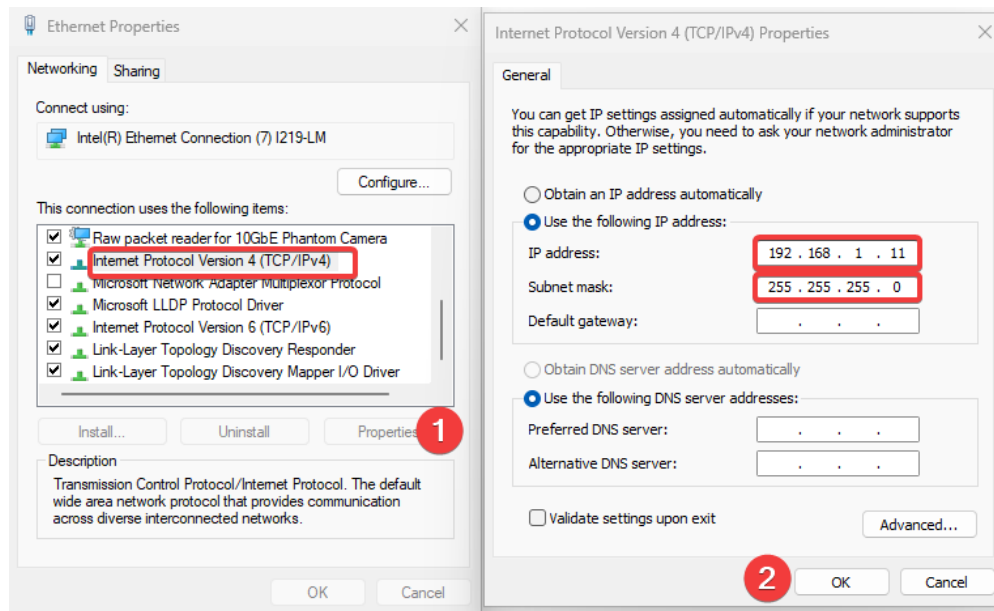


Figure 162: Setting the IP address of the computer

Thereafter make sure that the network adapter is capable of 1000Mbit/s data flow and allows to set large Jumbo Packets of 9k MTU. This is done in the configuration window of the network adapter properties (Control Panel\Network and Internet\Network Connections, choose the Ethernet connection used for the camera connection, and in the properties window click on Configure...). In the Advanced tab find Jumbo Packet property and select 9014 Bytes (see Figure 163).

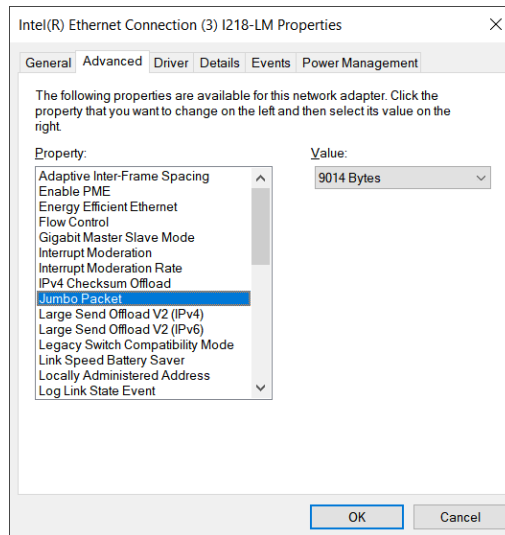


Figure 163: Jumbo packet modification of the network adapter

After these essential steps, a high-speed camera needs to be activated in System Settings under Active Camera Libraries (see Figure 164.) and camera will be ready to use.

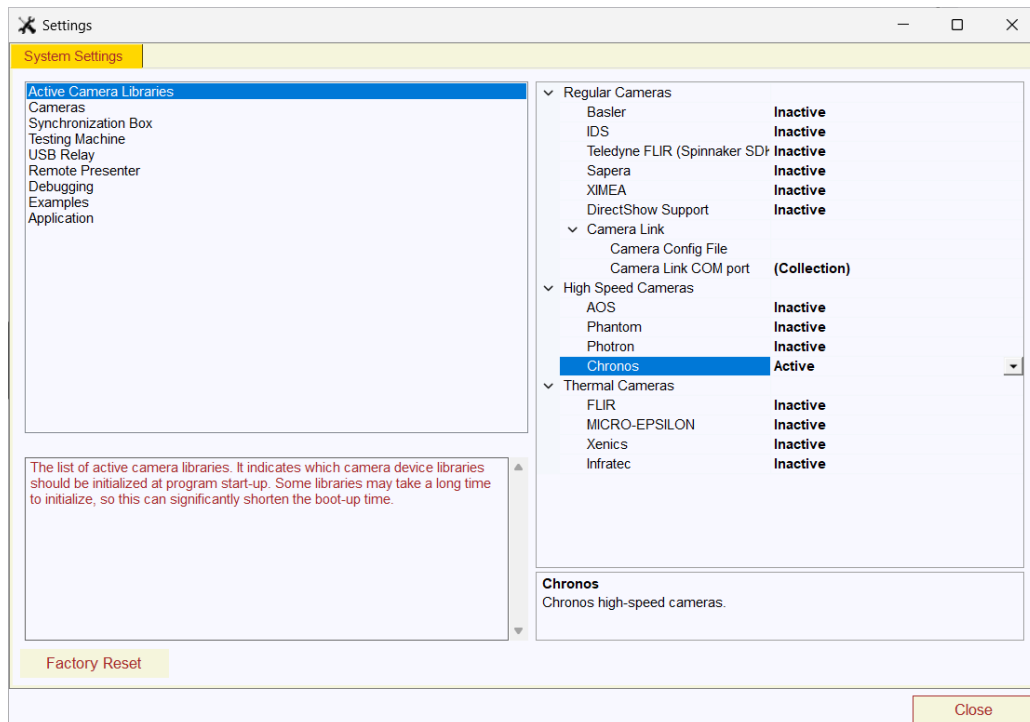


Figure 164: System Setting – Active Camera Libraries

When a high-speed cameras is Photron camera or Chronos camera, make sure if all the settings in the Cameras tab associated with Photron or Chronos camera are properly specified. For Photron cameras the IP address for automatic search needs to be specified and for the Chronos Cameras the static IP addressees of the cameras need to be specified (see Figure 165).



Figure 165: System Setting – High-speed Cameras configuration

14.2. OPERATING THE HIGH-SPEED CAMERA

Operating a high-speed camera in MERCURY RT differs from operating other cameras in the following way. When measuring a scene, the video must be recorded first and only after that may the computation take place. Performing a live measurement using a high-speed camera will only record a low-speed preview of the scene! To capture a sequence of frames, click the **High-speed Capture Tool** button in the **Cameras** panel on the right of the **main window** to open the **High-Speed Capture Tool** window depicted in Figure 166.

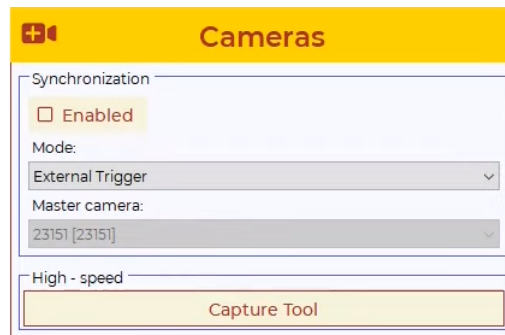


Figure 166: Opening the High-Speed Capture Tool

In the upper toolbar of this window (displayed in Figure 167), there are a few controls, which are essential for recording. The two most important parameters are **FPS** (frames per second) and **Sequence Length**, which can be set as a time interval or as a number of captured frames. **Pre-Trigger Length** stands for the percentage of the frames recorded after clicking **Ready** to be kept in the final sequence even after clicking the **Record** button. The **Ready** button prepares the camera for recording by starting to store frames in the internal memory of the camera. **The recording itself is started when clicking the Ready button and stopped after clicking the Record button and when the sequence is finished afterwards.** If the pre-trigger is set as 0 %, only the frames captured after clicking the **Record** button are stored.

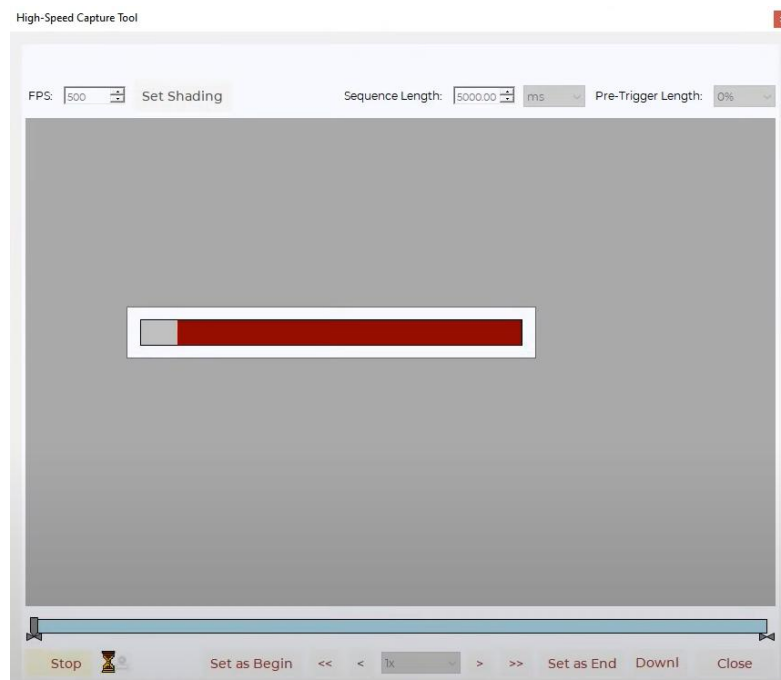


Figure 167: The High-Speed Capture Tool window

The lower toolbar includes several buttons in addition to the **Ready** and **Record** button. The selection of frames to be used within the project is performed by dragging the controls on the slider or using the **Set as Begin** and **Set as End buttons**. Because the relevant range of frames can be rather small compared to the entire recording, advanced options of seeking are available here as well, allowing to browse through the recorded frames in larger increments. By clicking the **Download** button, the final size of the sequence is computed and downloaded to the data directory of the project, making the recording ready for adding probes and performing an analysis.

15. CUSTOM SERIES

15.1. OVERVIEW

MERCURY RT provides a wide variety of computed values. Each probe has many different quantities, which can be turned on with a simple mouse click. However, for demanding users, this may still not be enough. Therefore, user-configurable data series can be specified via the built-in **Custom Series** window, also known as **Expression Editor**. These custom series are saved into a user folder and can be used in any project. The series can then be turned on and off independently for the specified project. Data is displayed in the graphs and exported in CSV. The specification of custom data series can be sent via email, downloaded from the Internet and easily imported.

15.2. CONFIGURATION

15.2.1.Expression Editor Access

The **Expression Editor** is accessed by selecting the **Configure Custom Series** option in the **graph panel's** context menu from the **main window**, as shown in Figure 168.

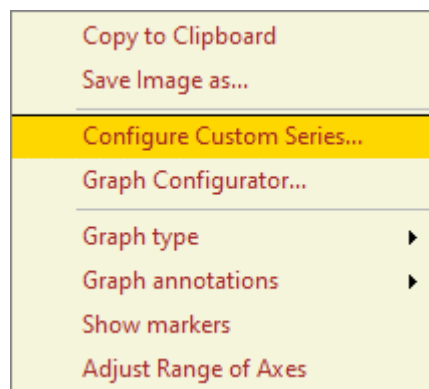


Figure 168: Access to the Expression Editor from the main window

15.2.2. Adding a New Expression

The **Custom Series** window is open, as seen in Figure 169. A new expression is added by clicking the **Create** button.

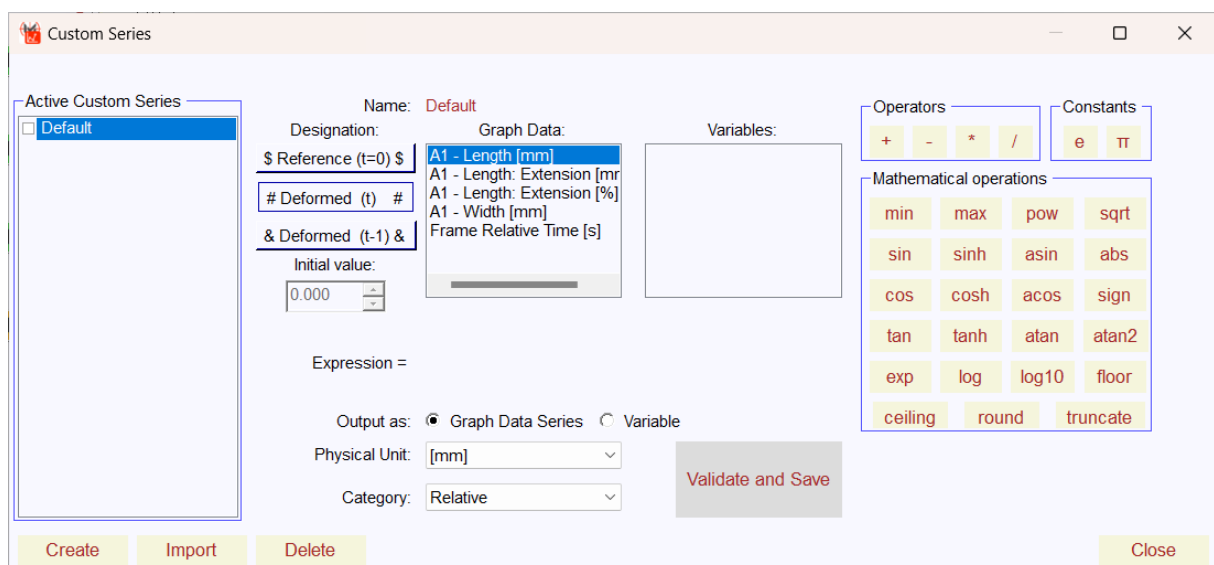


Figure 169: The Custom Series window

The window contains these sections, which are mandatory:

- ❖ **Name** – Specify the desired name of the expression. The default is “Default”. This name must comply with the file naming conventions as it is also the name for the file where the expression is stored.
- ❖ **Expression** – Denotes the desired expression, which can be written easily using the calculator on the right side and the lists of the available inputs above. Nevertheless, the syntax rules for the format of the expression are detailed in 15.3. Any mathematically valid expression is allowed.
- ❖ **Output as** – Determines what the output of the expression is used for – either as an additional Graph Data Series (the usual use-case) or as a Variable to use in other expressions.
- ❖ **Physical Unit** – Does not contribute to the expression itself. Merely determines the resultant type of the expression and therefore sets the destination graph.
- ❖ **Category** – Some output units have different variants, such as being absolute or relative. This also only determines the destination graph.

The sections below are included for better convenience of the user and may be fully replaced by a written text in the **Expression field**:

- ❖ **Designation** – Changes between the reference and the deformed designation of the input graph data. Most of the time, the deformed value (the actually computed value for the position) is what is needed (hence it is the default). However, for the computation of relative values (such as the elongation in units of a per cent), a reference value is also required. Additionally, it is possible to input the deformed value from the previous evaluated step in time, in which case the initial value is provided to determine the “previous” value in the first step (reference).
- ❖ **Graph Data** – Lists all available graph data in the project, including but not limited to the Force [N] from a testing machine or the Excitation Frequency [Hz]. By double-clicking, the name of the measured value is included in the Expression field along with all necessary parameters, all encapsulated by the tokens which determine the selected designation. The values are always of the double type, see below.
- ❖ **Variables** – Lists all available variables created as separate custom series with their output set as Variable. By double-clicking, their name is included in the Expression field, along with the tokens, which effectively substitute this item with the result of the respective expression during evaluation. The selected designation is ignored in this case.

When saving an expression, it is checked for syntax errors. This is either prompted automatically or performed manually by clicking the **Validate and Save** button. If the check fails, a message box with detailed information is shown. The expression is still added to the project and saved to a file, and it is up to the user to correct it.

As previously shown in Figure 169, there is a sidebar with buttons in order to operate easily and intuitively. These contain the supported operators and functions, whose detailed description is described in chapter 15.3 as a part of the supported syntax.

15.2.3. Activating an Existing Expression

The **Active Custom Series** box lists all available expressions, where each can easily be turned on and off by simply clicking the checkbox to the left. The information about the activated expressions is saved into the project file. If there are computed data already

present when activating a series, the computed results of the evaluated expression will be shown in the graph displays, so the project does not have to be recomputed. An expression is saved into a file name.mxp under Documents\MercuryRT\expressions\.

15.2.4. Importing an Expression

In the Custom Series window, click the Import button. A file selection dialogue will appear, requesting the user to enter a *.mxp file (see 15.5 for details). After importing the file, it is added into the user folder and to the displayed list in the UI.

15.2.5. Removing an Existing Expression

In the Custom Series window, click the Delete button. A confirmation dialogue will appear. After deleting the expression, the expression file from the disk is deleted as well, and it will no longer be available to any projects.

15.3. SYNTAX

15.3.1. Naming Convention and Precedence

Note: When the following table refers to a unique identifier of graph data, it refers either to a pair of a probe name and its measured quantity (separated by a comma, such as #T1,DisplacementEuclidean#) or a separate measured value, which is unrelated to any probes (for example #FrameRelativeTimeSeconds#). In case of the previous examples, it is necessary to input these identifiers by double-clicking the respective items in the list of Graph Data above the Expression field, but there is also an option to use a custom alias in place of the entire identifier, thus simplifying the text of the expression (making it read something like #Length1*# - #Length2*#).

SYNTAX	DESCRIPTION
\$id\$	Denotes a graph data value recognized by its specified unique identifier. Non-changing reference values will be used in the expression.
#id#	Denotes a graph data value recognized by its specified unique identifier. Varying deformed values will be used in the expression.
&initValue,id&	Denotes a graph data value recognized by its specified unique identifier. Varying deformed values from the previous step in time and an initial value of initValue will be used in the expression.
@name@	Denotes a variable of the specified name.
()	Determines the precedence of expression parts as per standard mathematics, can be used anywhere.

Table 1: Naming convention and precedence

15.3.2. Mathematical Operations

OPERATION	DESCRIPTION
val1 + val2	Returns the result of adding two values.
val1 - val2	Returns the result of subtracting two values.
val1 * val2	Returns the result of multiplying two values.
val1 / val2	Returns the result of dividing two values.

abs(value)	Returns the absolute value of a number.
acos(d)	Returns the angle in radians whose cosine is the specified number.
asin(d)	Returns the angle in radians whose sine is the specified number.
atan(d)	Returns the angle in radians whose tangent is the specified number.
atan2(y, x)	Returns the angle in radians whose tangent is the quotient of two specified numbers.
ceiling(a)	Returns the smallest integral value that is greater than or equal to the specified floating-point number.
cos(a)	Returns the cosine of the specified angle in radians.
cosh(value)	Returns the hyperbolic cosine of the specified angle in radians.
exp(d)	Returns e raised to the specified power.
floor(d)	Returns the largest integer less than or equal to the specified floating-point number.
log(d)	Returns the natural (base e) logarithm of a specified number.
log(a, newBase)	Returns the logarithm of a specified number in a specified base.
log10(d)	Returns the base 10 logarithm of a specified number.
max(val1, val2)	Returns the larger of two numbers.
min(val1, val2)	Returns the smaller of two numbers.
pow(x, y)	Returns a specified number raised to the specified power.
round(a)	Rounds a floating-point value to the nearest integral value.
sign(value)	Returns a value indicating the sign of a number
sin(a)	Returns the sine of the specified angle in radians
sinh(value)	Returns the hyperbolic sine of the specified angle in radians.
sqrt(d)	Returns the square root of a specified number.
tan(a)	Returns the tangent of the specified angle in radians.
tanh(value)	Returns the hyperbolic tangent of the specified angle in radians.
truncate(d)	Calculates the integral part of a specified floating-point number.

Table 2: Lists all operations available for the computed

15.3.3. Constants

CONSTANT	DESCRIPTION
e, E	Represent the natural logarithmic base, specified by the constant, e.
pi, Pi, PI	Represent the ratio of the circumference of a circle to its diameter, specified by the constant, π .

Table 3: Lists all available constants

15.3.4. Recursion

In its current state, the Custom Series editor supports the input of recursive expressions, i.e. the ones which take the value of the entire expression computed in the previous time step to compute a new value for the current time step. To do this, it is required to put the special

function written as previous(initValue) into the body of the expression, where initValue is the initial value of this function in reference.

15.4. EXAMPLES

EXPRESSION	MEANING
(#T1,DisplacementInZ# + #T2,DisplacementInZ# + #T3,DisplacementInZ#) / 3	Computes an average of displacement in Z-axis from 3 points.
abs(#A2,LengthExtensionPercentage#/#A1,LengthExtensionPercentage#)	Computes Poisson's ratio from two lines. $\nu = \frac{\Delta Transverse}{\Delta Longitudinal}$
#A1,AngleToXAxisRadians#*3/#A1,LengthInX#	Computes shear strain from one line during torsion test. $\epsilon = \frac{\theta r}{L}$
(2*#TestingMachineLoadN#/(pi*exp(3)))	Computes shear stress from testing machine sensor. $\tau = \frac{2T}{\pi r^3}$

Table 4: Lists examples of valid expressions

15.5. EXPRESSION FILE FORMAT

The expression file format *.mxxp (MERCURY RT Expression) is as follows:

```
<?xml>
<VE>
  <VES>ExpressionString</VES>
  <VEU>OutputUnit</VEU>
  <VEC>UnitCategory</VEC>
  <VEV>IsVariable</VEV>
</VE>
```

where:

- ❖ ExpressionString is the actual text representation of the expression as seen in the Expression field in the UI.
- ❖ OutputUnit is the name of the output unit type.
- ❖ UnitCategory is the category of the output unit.
- ❖ IsVariable specifies whether the expression specifies a variable or not.

Please note that an expression may also be edited in a text editor directly if needed.

15.6. TROUBLESHOOTING

PROBLEM	SOLUTION
When I enter a new expression / modify an existing one, an error is reported.	Make sure the syntax of the expression is mathematically correct, especially the number of opening and closing brackets. Make sure the name of the operations is supported as specified in 15.3. The

	shown error message usually describes the exact place where the problem is
I switched to another project / measurement, and now my expression does not show in the graphs	Most likely, the probe names mentioned in the expression are not present in the current project. The expression needs to be adjusted accordingly.
My configured expression does not show in the graphs.	See “When I enter a new expression / modify an existing one, an error is reported”. Some problems cannot be resolved when statically entering an expression (i.e. just the syntax) and will only manifest when used in the computation.
The distance between two points in two different cameras is not correct.	The two cameras are not properly adjusted into one reference frame. The coordinate systems must correspond with each other.

Table 5: Lists occurrences of problems with custom expressions and the appropriate approaches to resolving them.

16. GRAPH CONFIGURATOR

Besides the possibility of editing existing series and creating new series, MERCURY RT also allows configuring graphs according to custom requirements. This chapter describes the workflow behind the creation and configuration of such graphs.

16.1. GRAPH CONFIGURATOR ACCESS

The **Graph Configurator** window is accessed by selecting the **Graph Configurator** option in the **graph panel**'s context menu from the **main window**, as shown in Figure 170.

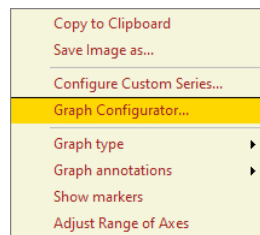


Figure 170: Access to the Graph Configurator from the main window.

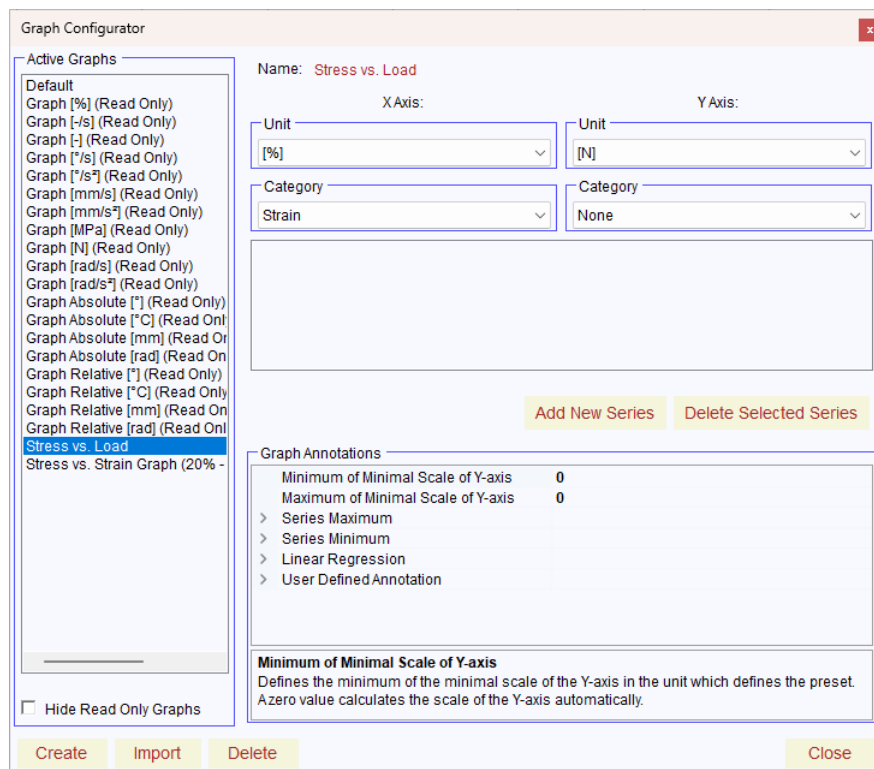


Figure 171: The Graph Configurator window

16.2. ADDING A NEW GRAPH

The procedure for creating a new graph is as follows. The new graph is added by clicking the **Create** button seen in the bottom left of Figure 171. The name of the graph is entered into the **Name** box at the top. The first step is to choose the appropriate units on the X a Y axes. Then the categories of these units are selected if available. Mind that only the computed (output) or the input value units are accessible. Individual variables can be chosen after clicking the **Add New Series** button, which opens the **Select Series** dialogue. As evident in Figure 172, the **Select Series** dialogue offers variables related to their units and

categories for each axis. Note that the default graphs are labelled “Read Only” and cannot be edited except for their **Graph Annotations** described in the following chapter.

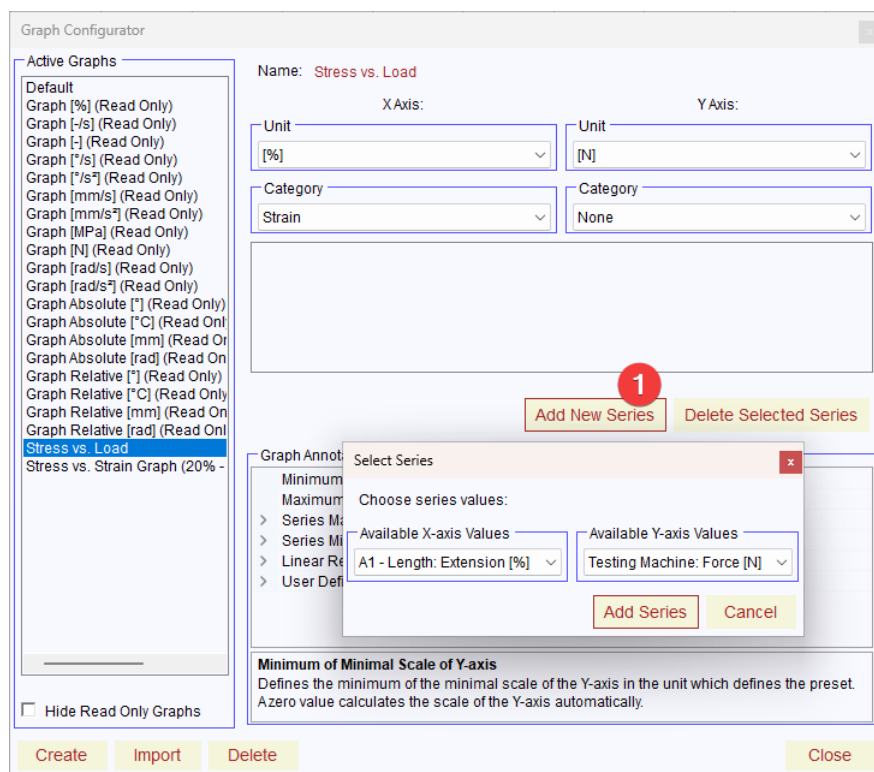


Figure 172: Selecting Series in the Graph Configurator window

16.3. GRAPH ANNOTATIONS

The Graph Annotations grid is located in the bottom part of the **Graph Configurator** window as previously seen in Figure 171. It provides several sets of optional parameters for custom adjustment. The graph annotations settings are as follows:

- ❖ **Minimum and maximum of minimal scale of Y-axis** – Defines the minimum of the minimal scale of the Y-axis in a unit, which defines the preset. A value of zero calculates the scale of the Y-axis automatically.
- ❖ **Series maximum and minimum** – Includes the options Enabled and Label.
- ❖ **Linear regression** – These are available primarily to analyze the yield strength and Young's modulus of elasticity.
 - **Yield strength analysis enabled** – Enables or disables the computation of Young's modulus.
 - **Selected Axis** – The axis, which is used for data filtering between “Minimal value” and “Maximal value”.
 - **Relative** – Indicates whether Minimal and Maximal values are absolute or relative.
 - **Minimal and maximal value [%]** – Defines the range of values in the selected axis used for the computation of linear regression (Young's modulus). Young's modulus is computed as a tangent of a straight curve fitting linear part of a stress-strain graph based on the least square method. Range of its computation is defined by the axis interval of which the minimal and maximal values might be altered. The default axis limit values are 20 % and 80 %. This adjustment is very useful because different materials are distinguished by

various stress-strain graphs, and therefore, fitting limits are needed to be changed appropriately to obtain an acceptable Young's modulus value.

- **Factor** – Multiplying factor which is applied for the displayed value of the slope of the linear regression line.
- **Enabled** – Indicates whether the annotation is shown in the graph.
- **Label** – Defines a label shown next to the computed values.
- ❖ **User defined annotations** – Allows making annotations on a chosen axis. Defines position and text label, which should be shown in the graph.
 - **Selected Axis** – Can either be the X-Axis or the Y-Axis.
 - **Position** – The position of the annotation.
 - **Enabled** – Indicates whether the annotation is shown in the graph.
 - **Label** – The text label of the annotation.

16.4. STRESS VS STRAIN GRAPH

As shown in Figure 173, stress vs. strain graph can be used to evaluate common material properties. The X-axis shows the deformation of the sample computed using probes capable of tracking extension, while the Y-axis displays the value of stress computed from the measured force and the cross-section area of the measured sample. The input of the cross-section area is accessed by right-clicking on the probes used for such measurement. The values of true stress and true strain can also be evaluated by using this graph if they are selected for measurement using the context menu of the relevant probes, but these values are only valid until the beginning of necking. For example, the evaluation of Young's modulus may be adjusted under the **Linear Regression** settings in this window. Alternatively, a custom copy of the stress vs. strain graph can be created here as well. This graph is automatically available when MERCURY RT is connected to a DOLI testing machine, receives force data, and stress/strain computation is enabled.

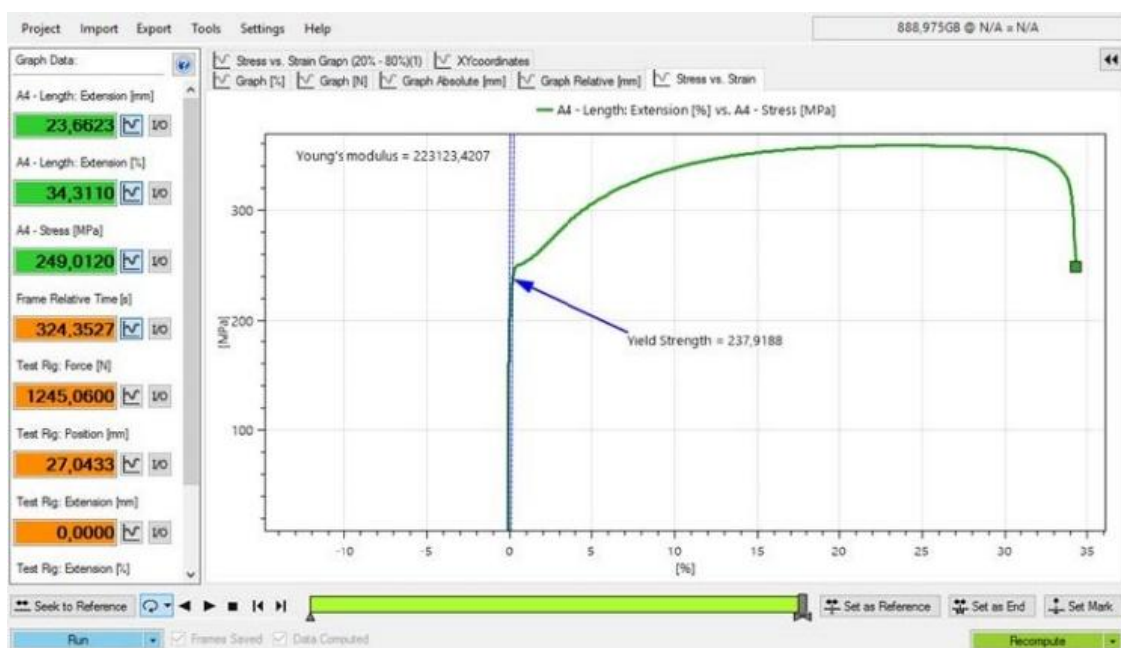


Figure 173: Stress vs. strain graph of low-carbon steel

APPENDIX A. MERCURY RT LITE VIEW

The lite version of the user interface is primarily designed for the usage in industry. A shortcut called “**MercuryRT LiteView**” launches this version. It supports all scene types and I/O services for remote control and the output of values. Only the left camera of a pair is displayed in stereo mode. LiteView only offers to work in a live mode, which means that there is only a button corresponding to the **Run** button and no such thing as a **Recompute** button. The project files are referred to in LiteView as **Presets** and are open as **read-only** in that they cannot be modified in any way.

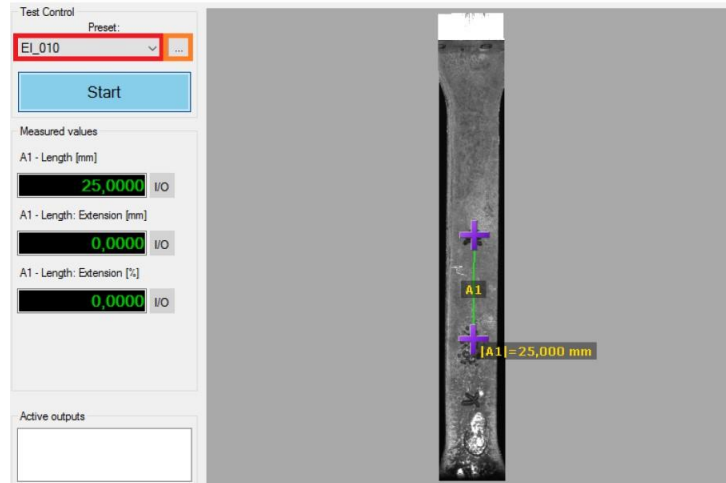


Figure 174: The MERCURY RT LiteView program

The first preset is loaded automatically from the selected preset folder, the path of which is specified as a startup parameter of UI.Launcher.exe. Alternatively, the folder can be selected by the button highlighted in orange in Figure 174. The individual presets located in this folder can be selected from the drop-down menu highlighted in red. The function of the prominently coloured **Start** button is the same as of the **Run** button in the standard UI.

It is permitted to move the probes in the scene to be able to specify a proper position before a measurement. In a 2D scene, the camera is always rotated so that the X-axis is headed to the right side and the Y-axis is headed to the top, and additionally, the rotation of the view from the original project is applied as well. As for information about the associated I/O services, there are light indicators on the right of the individual measured values. The active outputs are displayed in the box in the lower left corner.

APPENDIX B. TROUBLESHOOTING

Always adjust the parameters of the correlation that is causing the problem:

- ❖ Adjust Correlation in Time (see Correlation in Time) if experiencing problems with the computation between the reference frame and deformed frames.
- ❖ Adjust Stereo Pair Correlation (see Correlation between Stereo Cameras) if experiencing problems with the computation between the left and the right frame (note that the stereo pair correlation is being done only in the reference frame pair and then two correlations in time are performed for both sides).
- ❖ Adjust Width Correlation (see Width Correlation) if experiencing problems with the computation of width points.

PROBLEM	DESCRIPTION
Some probes have not been computed	❖ Increase the template size so that the template contains more information. Keep in mind that local deformations inside templates cannot be detected accurately. ❖ Adjust the correlated parameters. For example, omnidirectional translate is enough when the specimen only moves. The fewer parameters are being correlated, the less information is required to correlate them. ❖ Increase the confidence interval or the maximum square residual per pixel. This is usually required when light conditions are changing during the measurement or when the measured surface changes drastically. ❖ If a full-field analysis is being done on an unconnected surface, try turning off automatic filtration (see 7.3.4). ❖ If probes have been not computed in the right camera while being added, try dragging them in the right camera close to their correct locations.
Some probes have been computed in incorrect locations	❖ Increase the template size. This increases the chance that the algorithm will be able to differentiate between the reference and the incorrect location. ❖ Adjust the correlated parameters. For example, when tracking an edge, try correlation of a translation in the direction perpendicular to the direction of the edge because, for the algorithm, all positions on the edge are correct. ❖ Decrease the confidence interval or the maximum square residual per pixel. This increases the chance of incorrect locations being rejected. ❖ If a full-field analysis is being done on a connected surface, try turning on automatic filtration (see 7.3.4). This will filter out points with transformations that do not match transformations of the surrounding points. ❖ If more than one location seems to be the correct solution, change the correlation speed to fastest or fast to limit the searched area. Also, try removing the repeating pattern from the measured specimen. ❖ If incorrect locations have been computed in the right camera while adding probes, try dragging probes in the right camera close to their correct locations.

Table 6: Solutions of the most common problems

APPENDIX C. TIPS AND TRICKS

MEASUREMENT OF POISSON'S RATIO

Many users struggle to measure the Poisson's ratio. This paragraph provides advice on how to measure the Poisson's ratio in MERCURY RT as accurately as possible. The reasons behind incorrect results are as follows:

1. The edges of the specimen are skewed by lighting.
2. The transversal contraction is very low compared to its longitudinal extension.
3. The specimen moves out of the measuring plane. The suggested solutions are mentioned in the paragraphs below.

i. SPECIMEN EDGES SKEWED BY LIGHTING

The reflections of the lighting on the edges of the specimen can make measuring width less accurate. To avoid this problem, move the width templates from the edges to the body of the specimen. This is applicable only if using width measuring probes.

ii. LOW TRANSVERSAL CONSTACTION VALUE

Many specimens are too narrow to measure the transversal contraction with a common lens at a normal working distance. To increase the resolution of the measurement, it is necessary to use a camera with a higher resolution, lens with a higher focal length or decrease the working distance. This requires to lower the focus distance, which can be done using a macro lens or normal lens with an extension tube.

iii. SPECIMEN OUT OF THE MEASURING PLANE

Some testing machines do not keep the motion of the specimen sufficiently in the reference plane. The displacement of the specimen to another plane, which is not parallel to the reference plane, may devalue especially the transversal contraction and thus the value of the Poisson's ratio. The best solution is to switch to a stereo scene instead of a mono scene. Then, the Poisson's ratio can be computed using two line probes and setting an appropriate expression in the Custom Series (Expression Editor) window shown in Figure 169.

APPENDIX D. KEYBOARD SHORTCUTS

Shortcuts available in the application main window.

CTRL + N	New Project
CTRL + O	Open Project
CTRL + S	Save Project
CTRL + SHIFT + S	Save Project As

Shortcuts available in the camera window.

F1	Point probe
F2	Rigid plane probe
F3	Line probe
F4	Chain probe
F5	Polyline probe
F6	Force gauge
F7	Point group
F8	Neck gauge
F9	Strain gauge (mono) / Surface (stereo)
F10	Area: Include
F11	Area: Exclude
F12	PIV field
C	Clippings and histogram
I	Invert colors
P	Pseudo colors
CTRL + H	Flip image horizontally
CTRL + V	Flip image vertically
CTRL + L	Rotate image left

CTRL + R	Rotate image right
CTRL + I	Hide labels
CTRL + P	Hide probes
CTRL + C	Copy camera view to clipboard (also available in graph displays and 3D graph)
PAGE UP	Previous picture
PAGE DOWN	Next picture

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