TEMA
MOTION

Product information

Introduction

TEMA Motion is the world leading software for advanced motion analysis. Starting with digital image sequences the operator uses TEMA Motion to track objects in images, make analysis of the movement and present results in tables and graphs.
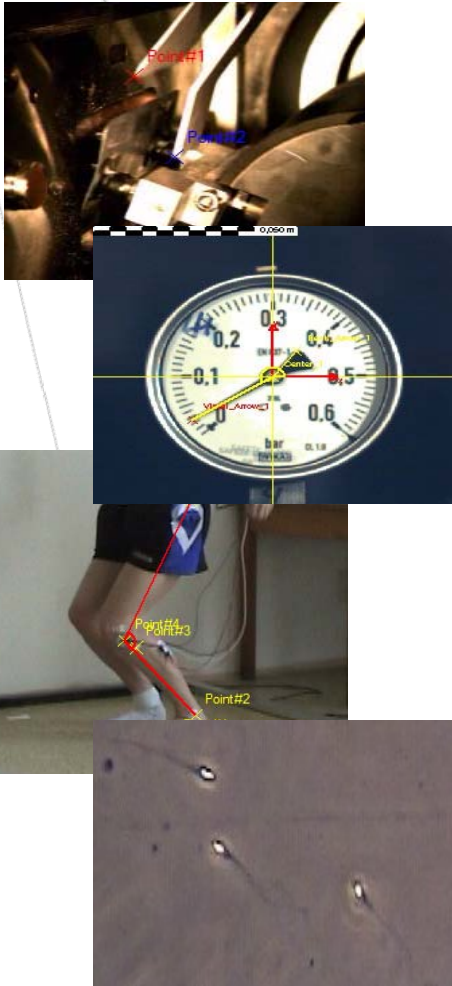
Malfunctions in production lines. The design of modern high-speed production and packaging lines requires high-speed imaging and motion analysis for a cost effective design process.

Drop tests. An important part of product development is the evaluation of mechanical robustness while dropping the product on various foundations.

Biomechanical analysis. Modeling of human body movement for studies of behavior and stress analysis under varying boundary and loading conditions.

Medical research. Studies of sperm activity in microscopy images. The fertility of the sperms are evaluated out of the movement patterns and speed of the sperms.

The flexible windows based user interface makes it fast and easy to find the best setup for your application. The User Interface is fully synchronized: any change of parameters or setup will directly affect all parts of the tracking session, updating results, graphs and tables.

The operator can choose between a large number of subpixel tracking algorithms and track an unlimited number of points through the image sequence. The system handles all major image formats on the market. A lens calibration system is included to compensate for lens inaccuracies, which is necessary for high accuracy and traceable results. The result can be presented in any of a large number of predefined graphs and tables. Free scaling for print outs makes it very easy to design reports or images.

TEMA Motion has a number of options available, e.g. 3D, 6DOF, Shape analysis, Viewer and Camera control.

System description

User interface

The windows based user interface of TEMA Motion provides a very flexible way of setting up a test. The operator can easily load one or multiple camera views and define which points to track in each image sequence.

The user interface is fully synchronized; there is only one current time in a test. Changing a parameter, clicking on an interesting value in a table or moving the time slider to an interesting position on a curve will automatically update all windows and show the corresponding image in the image sequence, curve or table.
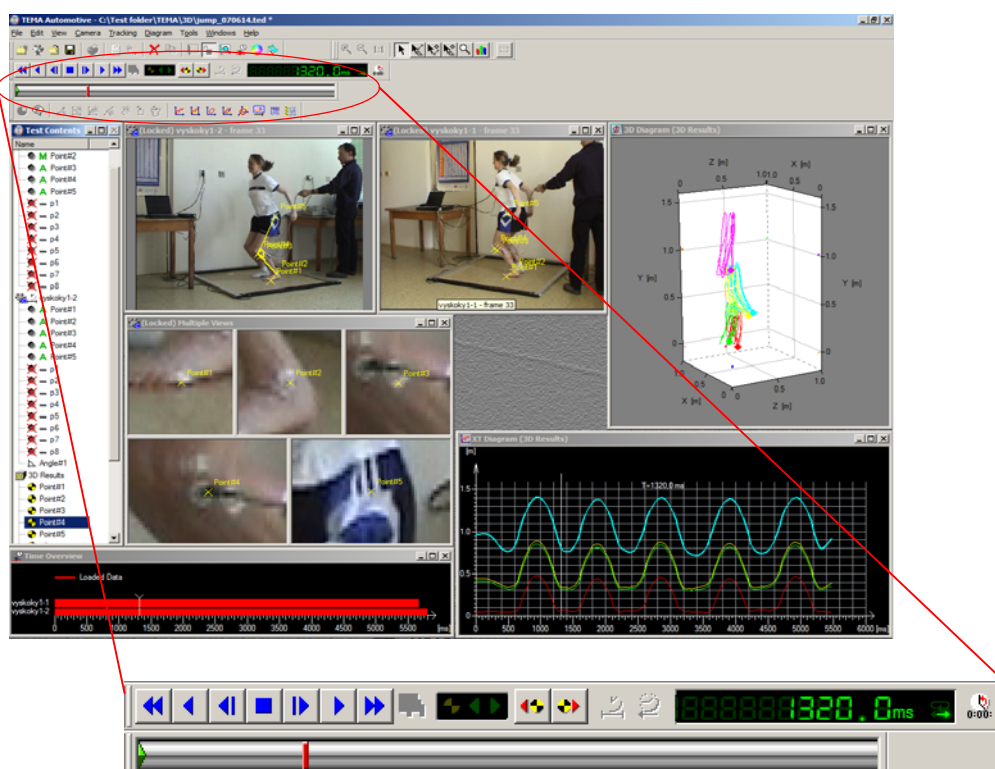
The time panel gives a perfect control and overview of playing and tracking the image sequence. Step by step, normal speed or fast-forward: All are supported in both directions.

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Tracking

The tracking function operates in two dimensions and produces 2D pixel coordinates in subpixel resolution for each tracked target point in each image.

Multiple image sequences can be tracked simultaneously and the output plotted in the same graph or spreadsheet.

Different applications have very different requirements on how to track a defined target. The image quality and appearance of the target could vary which means that different tracking algorithms and a robust tracking framework is needed to work efficiently.

The setup of the tracking is done per point or per tracking algorithm, allowing multiple points selection.
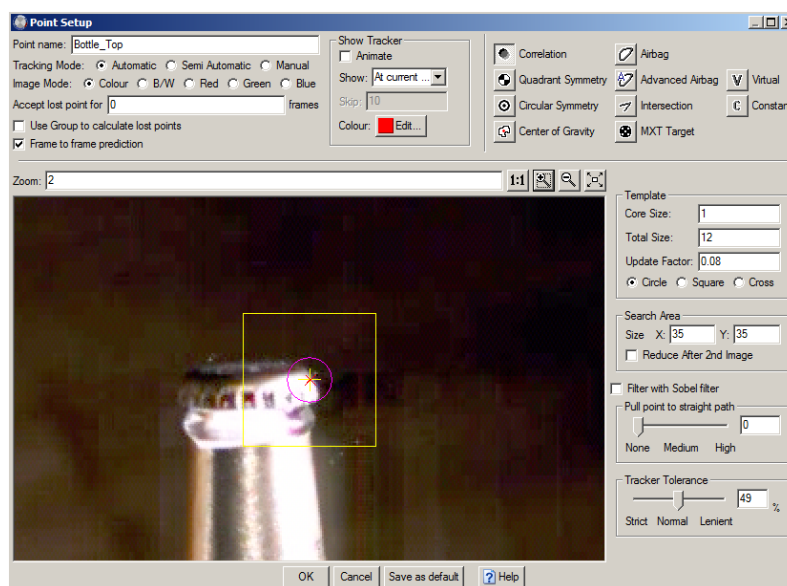
Tracking can be performed in B/W, colour, individual colour bands (red, green and blue) and enhanced images. Bit depths up to 16 bits are supported. This is important also when tracking in 8 bit images, as no information is lost if the images are enhanced.

The operator has full control of the tracking in TEMA with many possibilities to adjust for different applications. The tracking can be made Manual, Semi Automatic or Automatic.

Automatic tracking - the operator set a tracker tolerance, which specifies how much variation in the target features that should be tolerated. TEMA Motion then tracks all targets frame by frame until the end of the sequence. If the tolerance can't be met the tracking stops and the operator is promted to give the correct position.

Semi Automatic tracking - TEMA suggests a position for each target frame by frame and the operator either confirms or adjusts it.

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Tracking Algorithms

TEMA Motion has a number of different tracking algorithms available for different applications. All take advantage of the tracking framework and track in subpixel resolution:

- **Correlation**: looks in each successive image for the area that correlates best with the pattern defined in the first image. This method is applicable to most cases, as it doesn't require a marker.
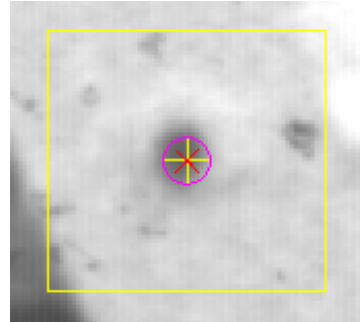
- **Quadrant**: finds the symmetry centre of quadrant targets and is invariant to rotation, scale and shading. Quadrant targets are recommended for applications with high demands on accuracy and automation.
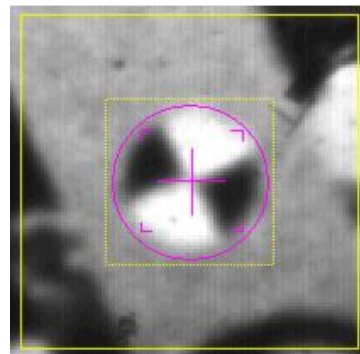
- **Circular Symmetry**: finds the symmetry centre of the image within the search area and is applicable to concentric circles, spokes on a bicycle wheel or combinations thereof.
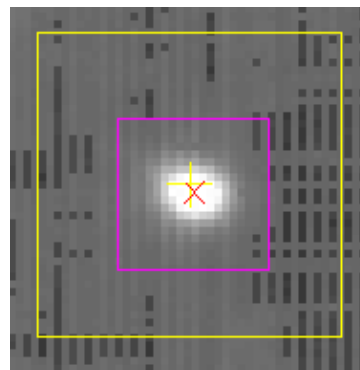
- **Center of gravity**: tracks the center of gravity of the contour of a marker or an object. The shape of the target may vary in the sequence and is captured with a user-defined intensity threshold.

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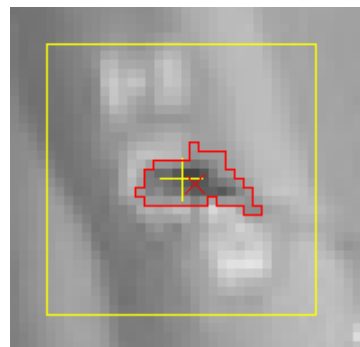
- **Virtual points**: specifies that the point is virtual, i.e. its position in successive images is calculated from the positions of the other points in its target group, rather than by measurement. For instance it can be used to define a part of a rigid body that is not visible in the image sequence.

- **Intersection tracker**: tracks intersection points (corners) on any object shape. The intersections are between extrapolated straight lines applied on the object shape.
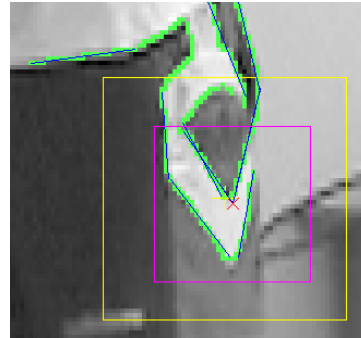
- **Outline tracker (optional):** captures an object boundary to provide an outline around a body. There are two different outline tracker options; one basic and one advanced.

The basic outline tracker analyses threshold values to find the color or grey scale difference between the body and the background. To capture object shapes in test setups with a complex background, an image subtraction can be done. This will convert all non-moving parts of the image into pitch black.
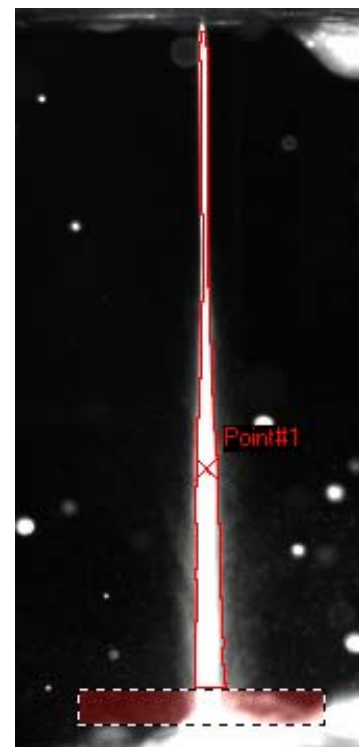
Tracking a water jet

The advanced outline tracker looks for edges between different surfaces. This is often used when the color or grey scale difference between the object and the background varies, or when the background is complex and dynamic
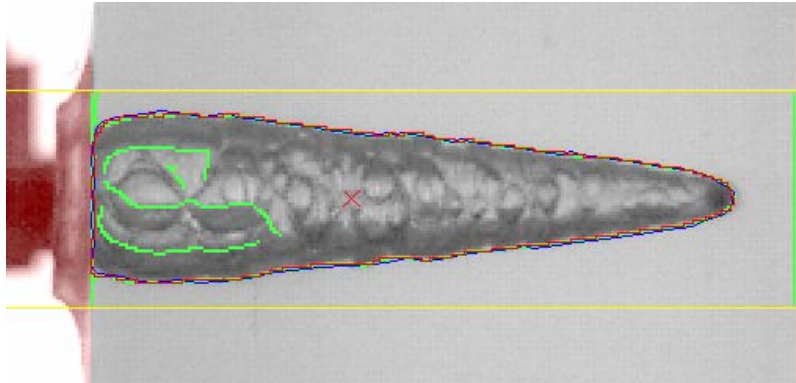
Tracking a cavity

MXT Tracker (optional) finds the symmetry centre of the target. The user can set the target to 1+4 and 1+5 MXT target tracking.

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Tracking Features

Suggest target point position

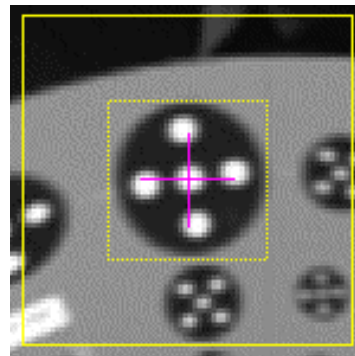To be used in an application where the same 2D target model is used at all times. The operator gives the position for one of the target points and TEMA Motion positions the rest of the target points in the image in relation to the first placed point.

Auto find similar

To be used in applications where a lot of similar types of patterns are to be tracked in an image sequence. The operator defines the suitable tracking setup for one of the patterns. TEMA will then find other patterns that applies to the same tracking setup and apply a tracking point to each of those patterns.

Auto find new points

This function is auto find similar but over time in a sequence. To be used in applications where new, static tracking targets appears subsequently in a sequence. The operator defines one such target when visible. At the following tracking, TEMA will apply a new tracking point to each new target that appears that applies to the setup.

Analysis

Analysis properties like position, velocity and acceleration are automatically calculated for all points in the session.

The operator can also define properties like angles and distances between tracked points. The system will then automatically calculate distance, angles, angle velocity and angle acceleration between related points.

Scaling

The user can at any time rescale pixel data into units of measurement. Thanks to the fully synchronized interface, all data and plots in the entire test will update to the new unit instantly.

The scale can be setup as static or dynamic, meaning a scale is be computed for each individual image. Cameras with non-square pixels are supported.

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User defined Coordinate Systems

Based on tracked points, the user can define multiple new coordinate systems to express tracking data and analysis results.

A user-defined coordinate system can be dynamic, i.e. follow the movements of objects, which opens up new possibilities to effectively analyse otherwise complex movements.

It is also possible to **rectify and stabilize** an image sequence by displaying it in an image diagram using a dynamic coordinate system.
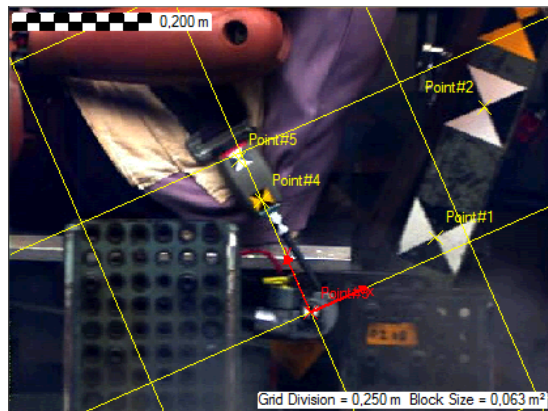
Lens calibration

The inaccuracy of a lens is called **lens distortion**, and all lenses have it built-in to a certain degree. The distortion is most prominent for wide-angle lenses, where images of straight lines become visibly curved. Great accuracy improvements and traceable results are obtained by correcting the image data with a calibrated mathematical model of the distortion.

The calibration is normally performed prior to the test and the result is saved to a file. It is possible to save calibration results for many different camera/lens combinations. During the actual test the operator then chooses which lens calibration to apply.

Using a series of images of a flat calibration pattern in different angles, the calibration is performed in an automated wizard. The output is the focal length and distortion of the lens, as well as the principal point of the sensor.

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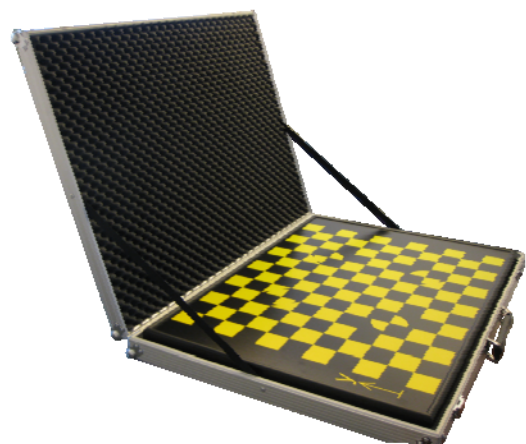
The calibration pattern can be printed from an included file. There is no requirement on surveying the printout: using a high-quality printer and attaching the printout to a flat surface is sufficient for most applications. Though for the highest accuracy possible, we also have a calibration board (sold separately) available.

- **Lens calibration Aicon**: TEMA Motion optionally comes integrated with a calibration system from Aicon 3D Systems Gmbh. The Aicon Lens calibration applies to the German National Bureau of standard requirements. The user just captures an image sequence of the board in random positions in front of the camera; the program handles the rest automatically.

Calibrating the camera

Aicon calibration board

3D (Optional)

TEMA Motion 3D takes the analysis from 2D on the screen to 3D in the real lab.
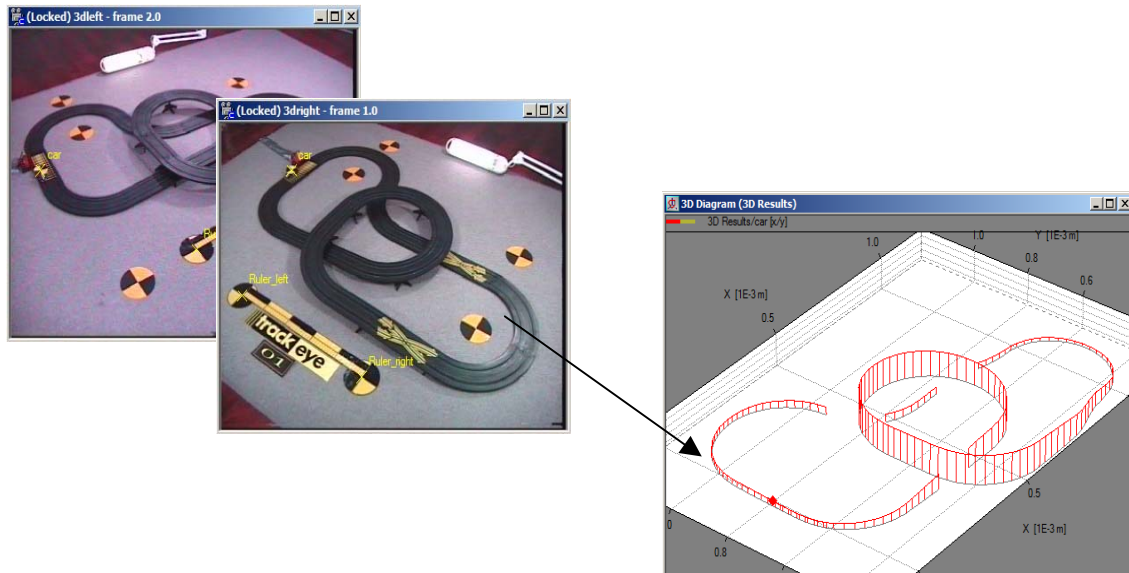
By tracking the object from two or more cameras, the analysis is carried out in 3 dimensions using the concept of intersection. The target observations (tracked 2D pixel coordinates) and poses of the cameras are used to compute the 3D position of the target as the best fit to the observations.
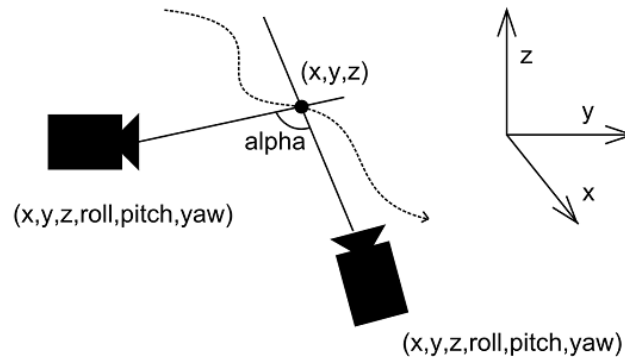
Two different methods are available to calibrate the camera poses: absolute and relative camera orientation. With absolute orientation a few points with surveyed coordinates are used for reference. With relative orientation it is sufficient to identify a few common points of the camera views for reference and add a scale, i.e. there is no need for any coordinate measurement equipment or cumbersome and restricting calibration fixtures.

As a consequence, measurement volumes of any size are supported.

3D from moving cameras is supported by tracking the reference points in the image sequence.

6D (optional)

With the use of only one camera, TEMA Motion 6D can calculate the real orientation and position of any rigid object.

The position of a rigid body can be described with six parameters: three positions coordinates (x, y and z), which gives the position of a specific point on the body, and three attitude angles (roll, pitch and yaw), which gives the orientation in space. The term 6DOF, or *6D position* of the body, refers to these six parameters.

Tracking in 6 degrees of freedom (6DOF), also known as 6-dimensional (6D) tracking, is an optional feature that computes the position and orientation of a rigid body from a single camera view.
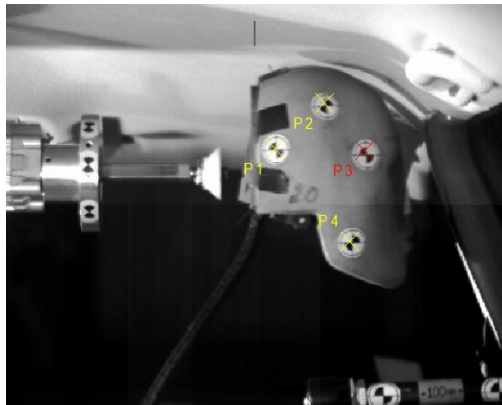
Analysing the 6DOF motion of a dummy head

Tools and Accessories

Image enhancement

In order to enhance tracking and/or reviewing an image sequence, TEMA Motion contains a complete Image Enhance functionality. RGB waveform diagram and vectorscope helps to improve properties like color balance, contrast, brightness and gamma correction in the image. The enhanced image sequence can be saved or imported to other image formats after adjustments.
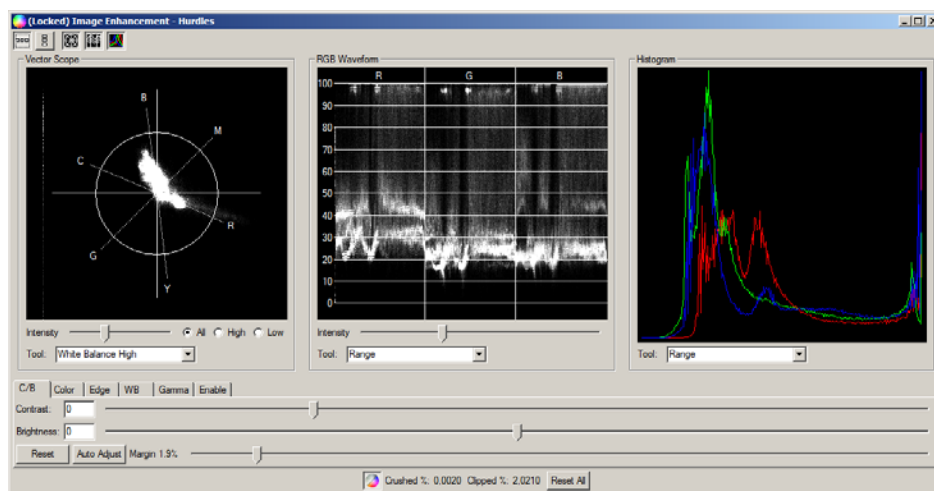
Event Finder

The Event finder identifies and finds one image or an interval of images of interest out of a whole sequence.

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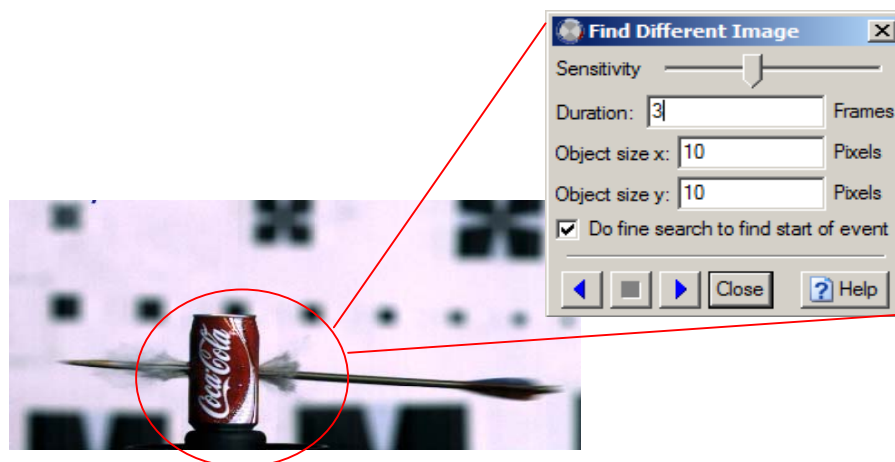
Import and Export of images and data

Image Sequence import

TEMA Motion software uses digital image sequences as input for the analysis. Most raw formats from high speed cameras and a large number of compressed digital formats can be read: AVI, TIFF, BMP, JPEG, MPEG2 and many others.

TEMA is continuously updated to support new image formats when they became available.

Data import

TEMA imports several different standard data formats like DIADEM, ISO13499, ISO-2, SDAS, DELL as well as custom specific ASCII data formats.

The imported data is available for all parts of the program and can be used in calculations, graphs and tables.

Image Sequence export

All image sequences can be exported from TEMA , with or without overlayed tracking data. The Image Export can be extensively customized:

- Settable image size, format, sequence time range and skip count.

- A title slate can be added, acting as the first frame of the exported sequence. This can be specified with any describing text.

- Text box overlays on the exported sequence, including text and interactive information like the time for each frame, operator name etc.

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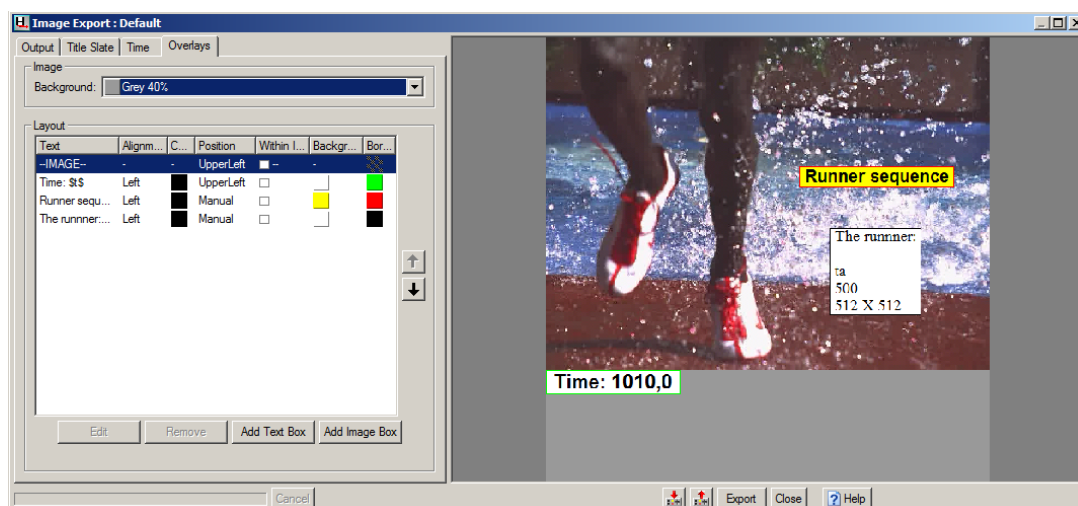
Data Export

After tracking and analysis, the result can easily be exported to several different formats like Excel, CASDAS, DIADEM, ISO, Matlab or ASCII files.

Presentation

TEMA motion can present the analysis data and results in a variety of customized graphs and tables. It is easy to add comments and add custom graphics to customize the appearance of a certain view or plot. The main tools for presentations are:

- **3D diagrams**: (included in 3D and 6DOF options) Plot 3D, 6DOF and camera data on 3 axes in a rotatable 3D box. The plot can also be equipped with curtains to enhance the understanding of the 3D data.

- **2D diagrams**: plots data against time or other data (X/Y-diagrams). All data, whether tracking data, or data input separately, can be plotted in single or multi axis X/T or Y/X plots with many options to customize.

- **Time tables**: All type of data can be presented in tabulated form using rows and columns. The rows will be time indexed. The diagram can easily be customized with different headers or combination of data. The row of the current time will always be highlighted.

- **Image diagrams**: Plots data as overlays on top of image sequence from the tracking view. It is also used to rectify and stabilize images.

- **Point tables**: (Only as an option) All type of data can be presented in tabulated form using rows and columns. The rows will be indexed per point added to the table. The data in each cell will then update according to the current time. The diagram can easily be customized with different headers or combination of data.

- **Report generator**: (Only as an option) Framework to populate a whole set of graphs and tables from a test that can be output using one single command.
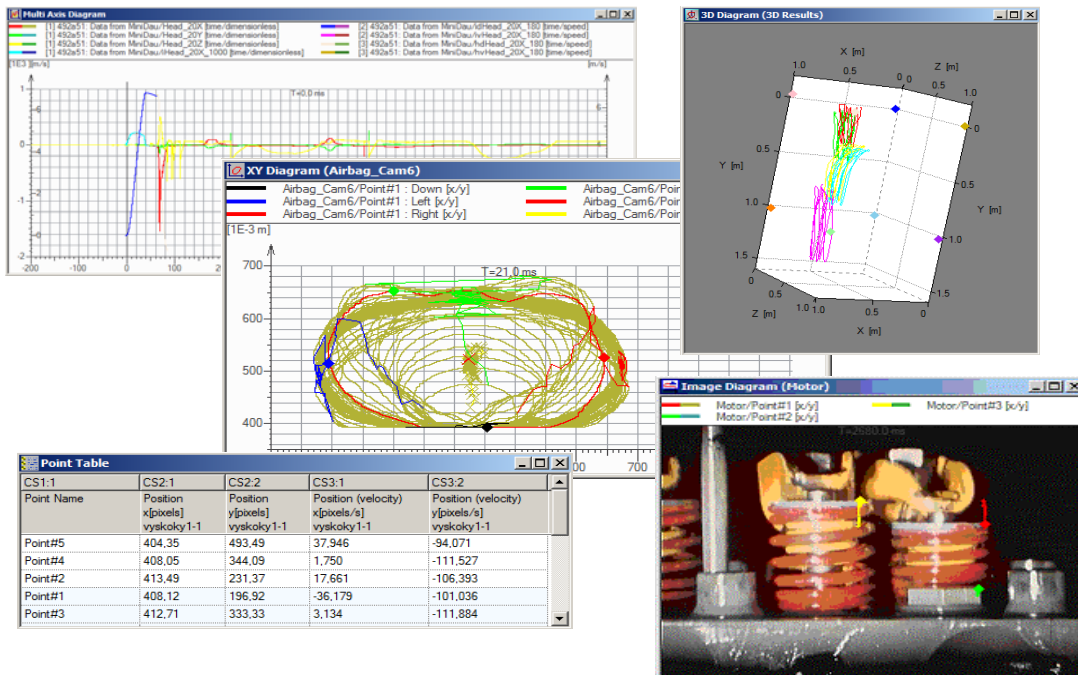
TEMA Viewer

A TEMA Motion test can be exported to a self-running CD that allows the recipient to rerun the tracking with the images, graphs and spreadsheet data synchronized. Just like in TEMA Motion itself. Data from the viewer can in its turn be copied into another document. The TEMA Viewer does not require any extensive program installation to run. Also, the same Viewer can be loaded onto a network for shared use. There are two versions of the Viewer, basic and advanced.

Basic Viewer – The user can only review the data using the current graphs and tables. He can also export the result.

The Advanced Viewer has all the functionality as the basic, but the user can also add new graphs and tables to the setup. Still, no new data can be added.

Hardware requirements

The TEMA Motion system runs on standard stationary PC or a Laptop. The minimum requirements are:

	Minimum	Recommended
Operating System	Windows Vista/XP/2000 Professional	Windows XP Professional
CPU	2.0 GHz	3.0 GHz
RAM	1GB	1GB
System disk	100 GB	100 GB
Image disk	Not required	200 GB
Graphics	>19″ @ 1280 x 1024	>19″ @ 1280 x 1024
CD / DVD	CD	CD / DVD

Please note that the required performance specified above only apply for running the TEMA motion analysis software. Higher performance is normally needed if the system is TEMA camera control for high-speed digital cameras.

Available configurations

Except TEMA Motion, there is also a number of different entry levels, where your specific application determines the level of the program you require. An entry level can over time be updated to the complete TEMA Motion product. A summary of the functionality is described below.

TEMA Starter 1:   Allows tracking of single point with correlation tracker. Possible to plot one point and make table of positions.

TEMA Starter 2:   *"Basic analysis without markers"*. For basic applications where markerless tracking is sufficient. Allows tracking of 5 points with correlation tracker. Possible to plot points and make tables of positions, velocity and acceleration. Some additional scaling functionality.

TEMA Lite: *"High accuracy analysis using markers"*. For applications where accuracy, repeatability and automation are important. Consists of Starter 2 plus quad tracking, X/Y diagrams and export of data.

TEMA Motion: *"The world leading system for advanced motion analysis"*. For advanced applications where the highest level of accuracy and functionality is required. Lens calibration is included.

TEMA Player: Image viewer and format conversion. It can view all formats that TEMA can view.

Configurations vs features

Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Motion
Tracking algorithms				
2D Tracking	●	●	●	●
Correlation	●	●	●	●
Quadrant			●	●
Circular				●
Center of gravity				●
Intersection tracker				●
Corner contour tracker				●

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Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Motion
Tracking features				
Number of points to be tracked in one session	1	5	5	Unlimited
Tracking in 16 bit/BW/color/R/G/B and automatic/manual	●	●	●	●
Interpolation of hidden points	●	●	●	●
Constant tracker				●
Virtual points				●
Exclude areas				●
Image subtraction (tracking feature)			Included in Outline tracker (Shape analysis option)	
Suggest reference point position				●
Autofind similar point				●
Autofind new points (point generator)				●
Automatic point group finder				Option on request
Import / Export				
Export of diagrams and images to Word document	●	●	●	●
Import of images: AVI,TIFF,MPEG,JPEG,etc	●	●	●	●
Export of data files: Diadem,ISO,ASCII,etc			●	●
Export of images: AVI,TIFF,MPEG,JPEG,etc				●
Import of data files: Diadem,ISO,ASCII,etc				Option on request
Scaling				
Manual scaling	●	●	●	●
Dynamic scaling		●	●	●
Static scaling		●	●	●
Correction for depth scaling				Option on request
2D coordinate system				
User defined 2D coordinate systems				●
Translation of origin				●
Rotation (axes definition)				●
Rotation (offset angle)				●
Visualizing coordinate systems				●
Diagrams and tables				
Time Table	●	●	●	●
X / T diagram	●	●	●	●
X / Y diagram			●	●
Multiple axes (4 axes) X / T diagram				●
Advanced X/Y diagram				●
Image diagram				●
Point Table				Option on request
3D diagram			Included in 3D and 6DOF options	

Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Motion
Diagram Features				
Individual setting of horizontal and vertical axis range	●	●	●	●
Legends	●	●	●	●
Printing of diagrams*	*)	*)	*)	●
Text boxes				●
Setting of measurable scales in diagram printouts				●
Printing of logotypes, test comments				●
Contour plotting				Option on request
Stick figure plotting				Option on request
Corridors				Option on request
* only through copy and paste to Word document*				
Report				
Report Generator				Option on request
Analysis and Calculations				
Filtering of Data CFC / FIR	●	●	●	●
Velocity and acceleration		●	●	●
Angles between points			●	●
Distances between points			●	●
Contour analysis				Option on request
Lens calibration				
Lens calibration				●
Image handling				
White balance	●	●	●	●
Printing of images	*)	*)	*)	●
Image enhancement				●
Image stabilization / rectification				●
Digital signature				Option on request
* only through copy and paste to Word document*				
Other				
Event Finder	●	●	●	●
Fully synchronized user interface	●	●	●	●
Point zoom	●	●	●	●
Test templates	●	●	●	●
Setting of default units	●	●	●	●
Number precision	●	●	●	●
Free setting of Reference Time t0	●	●	●	●
Multiple camera views				●
Macros				Option on request

Options

	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Motion
Options				
Dongle license	●	●	●	●
Floating license			●	●
3D				●
6DOF				●
MXT tracker			●	●
Viewer			●	●
Advanced viewer			●	●
Shape analysis. Includes Basic and Advanced Outline tracker.			●	●
Volume analysis 3D				●
Lens Calibration Aicon				●
Other options available on request	●	●	●	●

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