

**image**  
SYSTEMS  
**TEMA**  
AUTOMOTIVE

## Product information

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**image**  
SYSTEMS

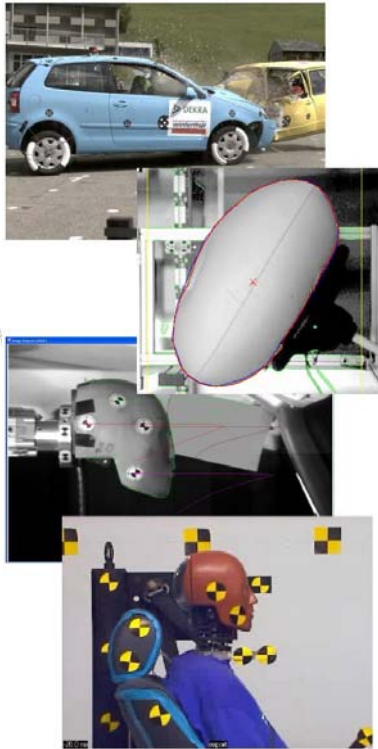
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# Introduction

TEMA Automotive is the world leading system for advanced motion analysis in the automotive industry. Starting with digital image sequences the operator uses TEMA Automotive to track objects in images, make analysis of the movement and present results in tables and graphs.

Typical applications:



- Crash tests and sled tests in automotive industry using 2D, 3D or 6DOF analysis.
- Airbag analysis. The inflation process is verified towards simulated modules and the shape, size and position of the airbag is checked towards boundaries. The analysis is based on contour and volume measurements.
- Steering column penetration, Roll-over test and Sled testing using cameras on-board or off-board is just some examples of applications with TEMA Automotive.

The flexible windows based user interface makes it fast and easy to find the best setup for your application. Every part of 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.

This implies a fast test performance; all test setups can be done prior to tracking, enabling result data presentation output in real time while tracking. Test templates create an effective workflow when doing repetitive tests. Tools for automatic generation of reports makes it possible to produce a designed report including tables, graphs and comments with a single command.

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.

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

# System description

## User interface

The windows based user interface of TEMA Automotive 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.

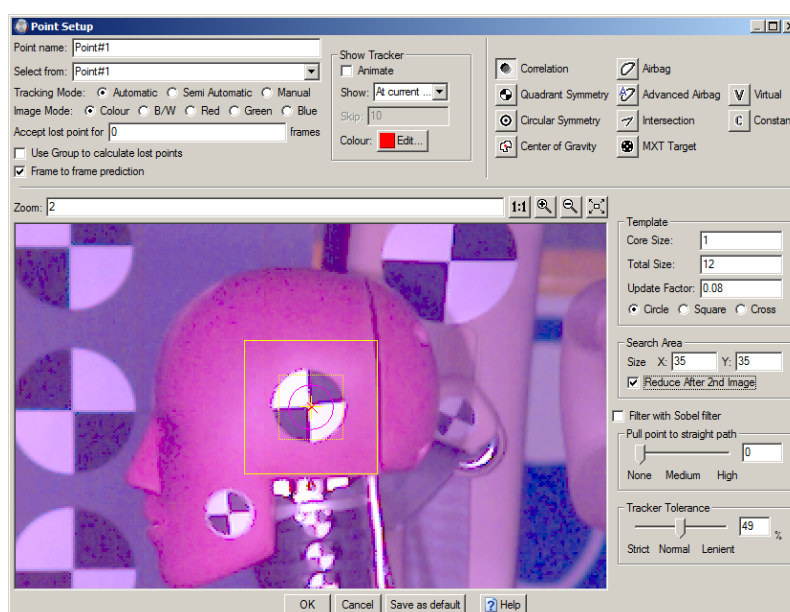
# Tracking

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 can be 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.

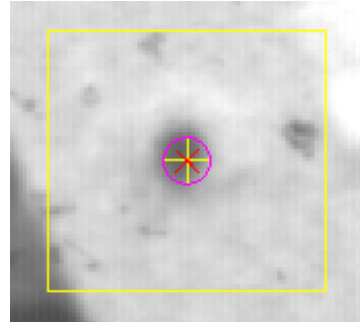
**Automatic tracking** - the operator sets a tracker tolerance, which specifies how much variation in the target features that should be tolerated. TEMA Automotive then tracks all targets frame by frame until the end of the sequence. If the tolerance can't be met the tracking stops and the operator is prompted 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.

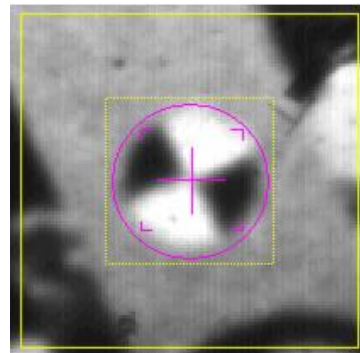
## Tracking Algorithms

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

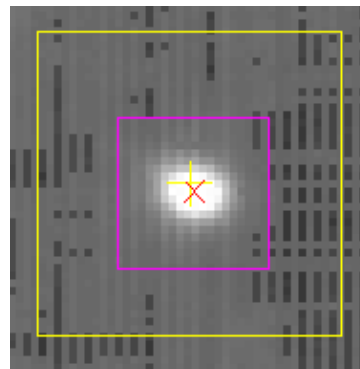
- **Correlation:** looks in each successive image for the area that correlates best with the pattern defined in the first image. This method is applicable in most cases, as it doesn't require a marker.



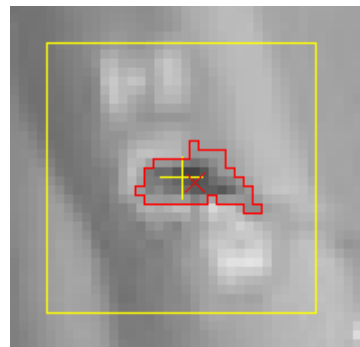
- **Quadrant:** finds the symmetry centre of quadrant targets and is invariant to rotation, scale and shading. Quadrant targets are often used in the automotive industry and are recommended for applications with high demands on accuracy and automation.



- **Circular Symmetry:** finds the symmetry centre of the target within the search area and is applicable to concentric circles, spokes on a bicycle wheel or combinations thereof.

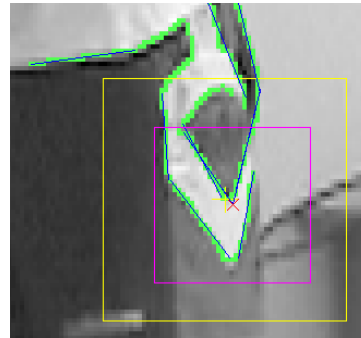


- **Center of gravity:** tracks the center of gravity of the contour of a marker or an object. The shape of the target may vary in the sequence and is captured with a user-defined intensity threshold.



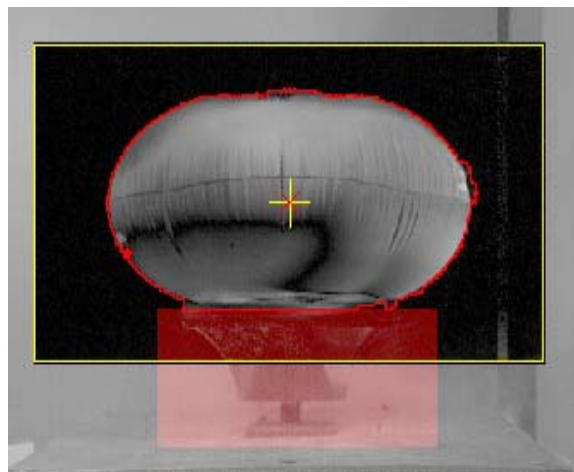
- **Virtual points:** specifies that the point is virtual, i.e. its position in successive images is calculated from the positions of the other points in its target group, rather than by measurement. It is commonly used to compute the location of a part of a rigid body that is not visible, e.g. the nose of a crash test dummy during airbag impact.

- **Intersection tracker:** tracks intersection points (corners) on any object shape. The intersections are between extrapolated straight lines applied on the object shape.

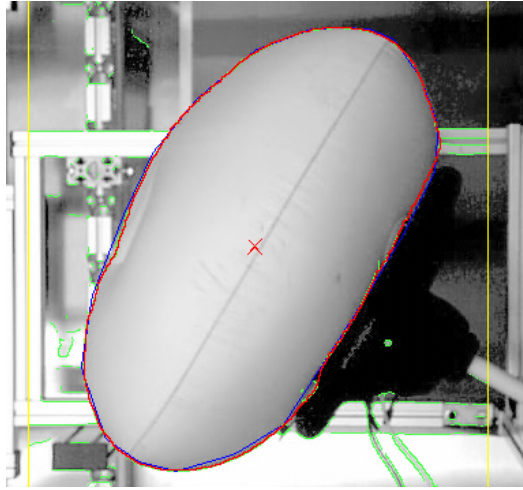


- **Airbag tracker (optional):** captures an object boundary to provide an outline around a body. The typical applications are component airbag analysis and crash tests. There are two different outline tracker options; one basic and one advanced.

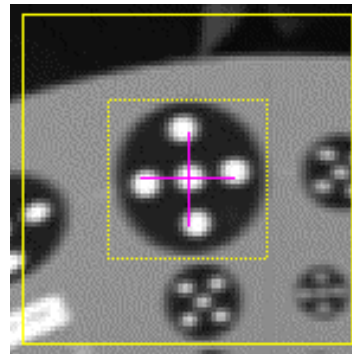
*The basic airbag tracker* analyses threshold values to find the colour or grey scale difference between the airbag and the background. To capture object shapes in test setups with a complex background, an image subtraction can be done. This will convert all parts of the image that are non-moving into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



*The advanced airbag tracker* looks for edges between different surfaces. It is often used when the colour or grey scale difference between the object and the background varies, or when the background is complex and dynamic. The tracker is perfect for analysing the propagation speed of an airbag in a crash test.



- **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.



# 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 Automotive 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 apply 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 distances, angles, angle velocities and angle accelerations 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 computed for each individual image. Cameras with non-square pixels are supported.

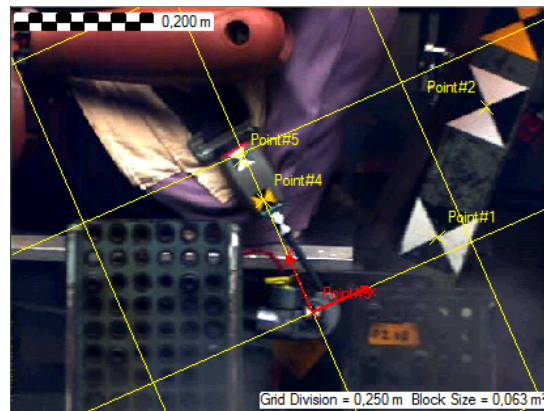
The scale of an object depends on the depth from the camera, i.e. the perpendicular distance between the sensor and the motion plane. Depth-scaling functionality is included to support applications where different target points are on different depths from the camera.

## 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.

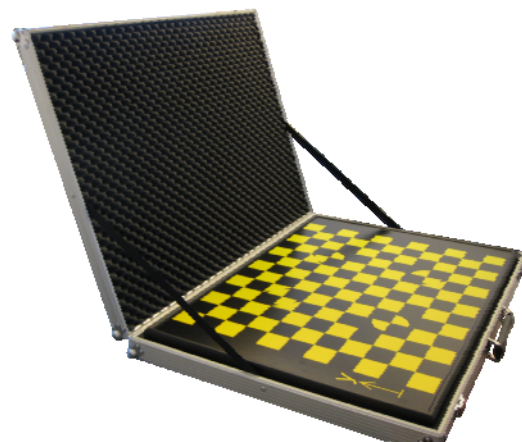


## Lens calibration

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.



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 (optional):** TEMA Automotive 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.



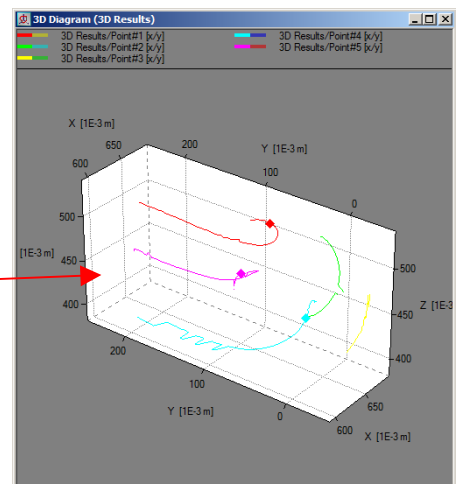
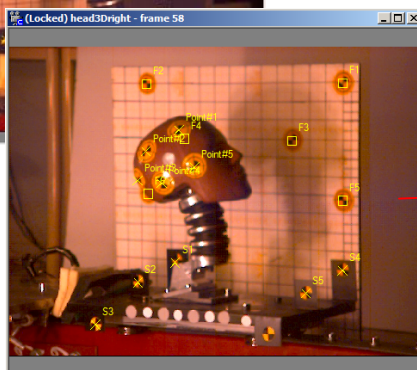
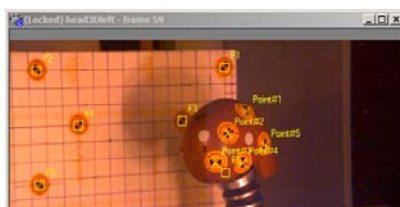
Calibrating camera



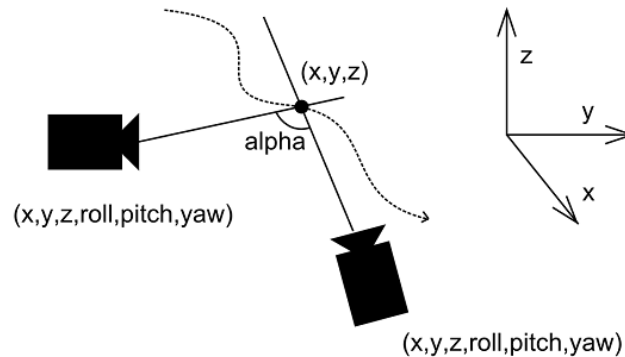
Aicon calibration board

### 3D (Optional)

TEMA Automotive 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.

## 6DOF (optional)

With the use of only one camera, TEMA Automotive 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.

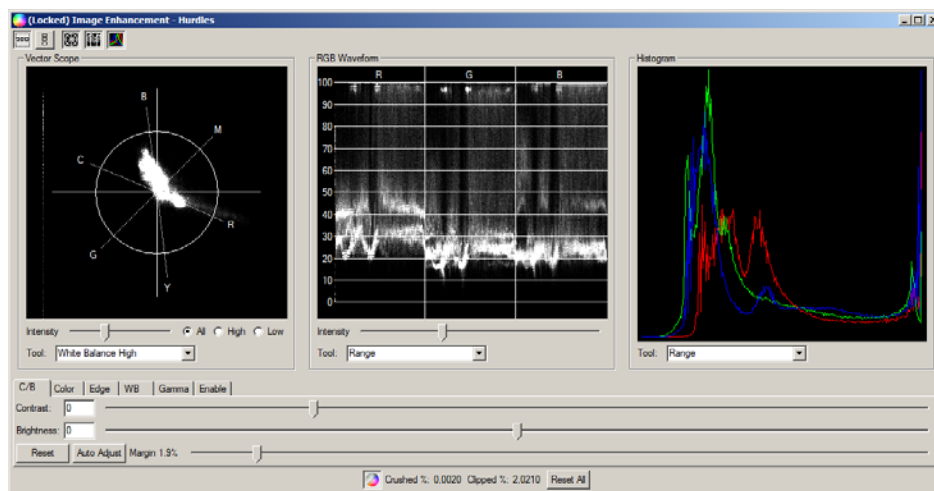


Analysing the 6DOF motion of a dummy head

# Tools and Accessories

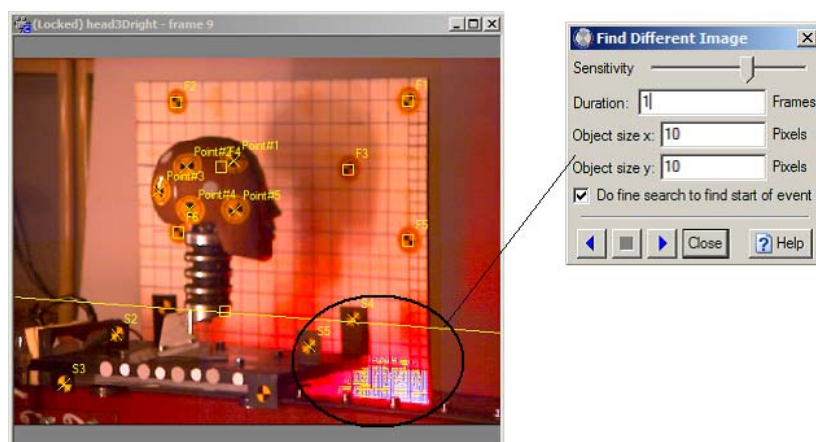
## Image enhancement

In order to enhance tracking and/or reviewing an image sequence, TEMA Automotive contains a complete Image Enhance functionality. RGB waveform diagram and vector scope helps to improve properties like colour 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.



# Import and Export of images and data

## Image Sequence import

TEMA Automotive 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

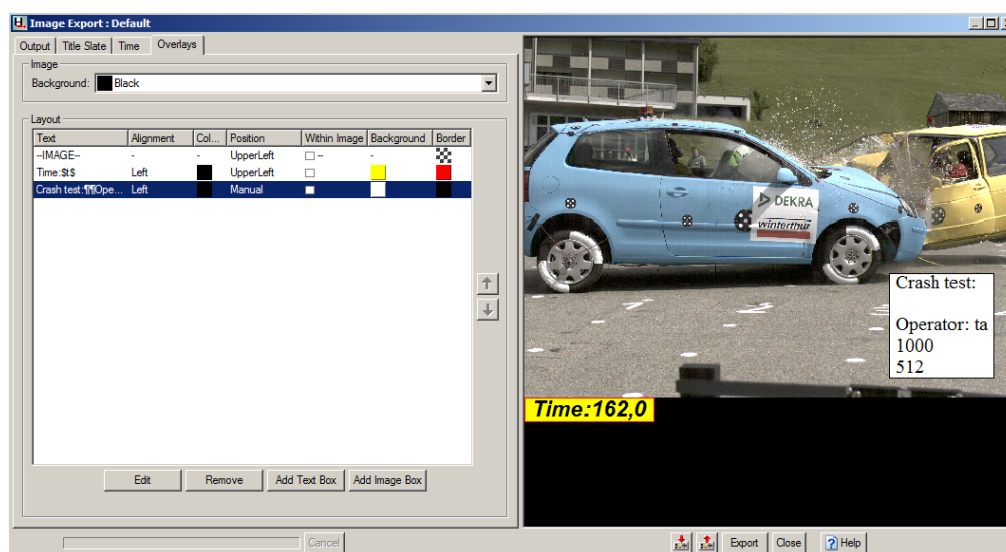
TEMA imports several different standard data formats like DIADEM, ISO13499, ISO-2, SDAS, DELL as well as custom specific ASCII data formats.

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 overlaid 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.



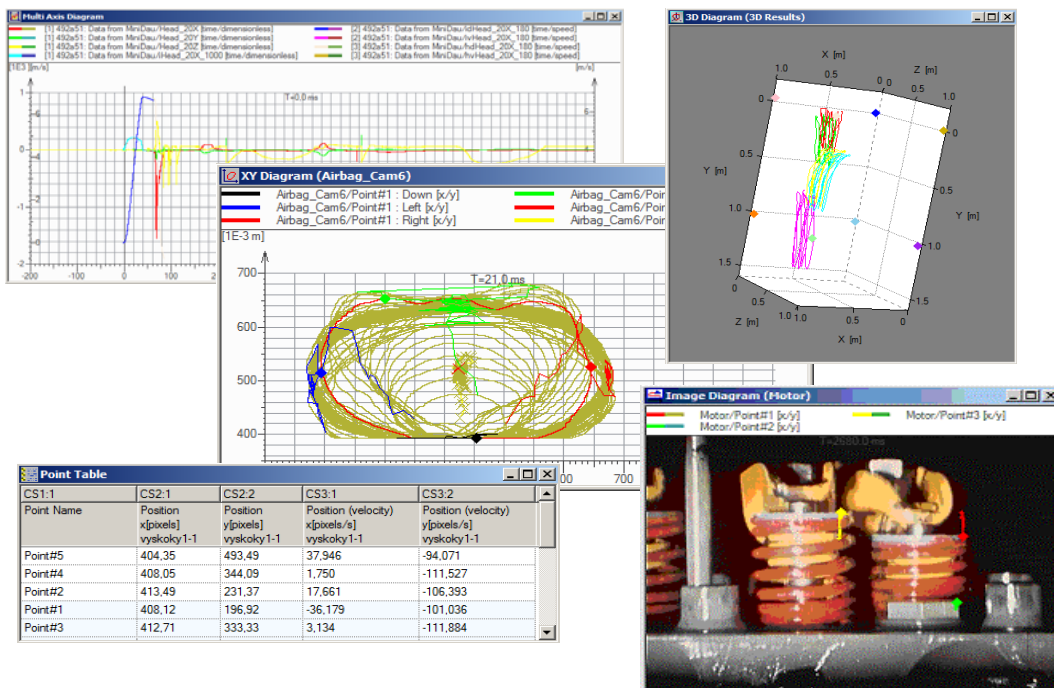
## **Data Export**

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 Automotive 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:** 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:** 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 Automotive 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 Automotive 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 Automotive system runs on standard stationary PC or a Laptop. The minimum requirements are:

	<b>Minimum</b>	<b>Recommended</b>
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 Automotive analysis software. Higher performance is normally needed if the system is TEMA camera control for high-speed digital cameras.

## Available configurations

Except TEMA Automotive, there are 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 Automotive 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 Automotive:** *“The world leading system for advanced motion analysis in the automotive industry”*. The premium TEMA configuration with full 2D functionality for advanced applications like sled tests, component tests and crash tests. Lens calibration is included.
- TEMA Player:** Image viewer and format conversion. It can view all formats that TEMA can view.

## Configuration vs features

Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Automotive
<b>Tracking algorithms</b>				
2D Tracking	●	●	●	●
Correlation	●	●	●	●
Quadrant			●	●
Circular				●
Center of gravity				●
Intersection tracker				●
Corner contour tracker				●

Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Automotive
<b>Tracking features</b>				
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 Airbag analysis option	
Suggest reference point position				●
Autofind similar point				●
Autofind new points (point generator)				●
Automatic point group finder				●
<b>Import / Export</b>				
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				●
<b>Scaling</b>				
Manual scaling	●	●	●	●
Dynamic scaling		●	●	●
Static scaling		●	●	●
Correction for depth scaling				●
<b>2D coordinate system</b>				
User defined 2D coordinate systems				●
Translation of origin				●
Rotation (axes definition)				●
Rotation (offset angle)				●
Visualizing coordinate systems				●
<b>Diagrams and tables</b>				
Time Table	●	●	●	●
X / T diagram	●	●	●	●
X / Y diagram			●	●
Multiple axes (4 axes) X / T diagram				●
Advanced X/Y diagram				●
Image diagram				●
Point Table				●
3D diagram			Included in 3D and 6DOF options	

Features	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Automotive
<b>Diagram Features</b>				
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				●
Stick figure plotting				●
Corridors				●
<i>* only through copy and paste to Word document</i>				
<b>Report</b>				
Report Generator				●
<b>Analysis and Calculations</b>				
Filtering of Data CFC / FIR	●	●	●	●
Velocity and acceleration		●	●	●
Angles between points			●	●
Distances between points			●	●
Contour analysis				●
<b>Lens calibration</b>				
Lens calibration				●
<b>Image handling</b>				
White balance	●	●	●	●
Printing of images	*)	*)	*)	●
Image enhancement				●
Image stabilization / rectification				●
Digital signature				●
<i>* only through copy and paste to Word document</i>				
<b>Other</b>				
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				●

## Options

	TEMA Starter I	TEMA Starter II	TEMA LITE	TEMA Automotive
<b>Options</b>				
Dongle license	●	●	●	●
Floating license			●	●
3D				●
6DOF				●
MXT tracker			●	●
Viewer			●	●
Advanced Viewer			●	●
Airbag analysis. Includes Basic and Advanced Airbag tracker.			●	●
Airbag volume analysis 3D				●
Lens Calibration Aicon				●