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Introduction

This chapter describes some of the basic principles involved in image processing and motion analysis. Image processing can be carried out for various purposes (surface analysis, pattern recognition, size determination etc.). The aim of image processing in this case is motion analysis. The issues raised in motion analysis are of interest in industrial research (e.g. safety regulations for motor vehicles), in ergonomics (the functional optimization of utility objects), for recording motor development, for the analysis of techniques in movement and finally for obtaining motion-specific parameters for movements in various sports. The resulting data (spatial coordinates) can be used for further processing in design and animation programs.

Image Processing

The measuring principles and other basic concepts of image processing are described by BAUMANN (in BALLREICH et al, ‘Trainingswissenschaft 1’, Bad Homburg 1992, pages 81-92). This chapter describes the requirements which must be met in order to use image analysis effectively to achieve meaningful results. Compared with most other methods of measurement, image analysis has the advantage that it has no direct repercussions. That is to say: the determination of quantitative dimensions by means of this measuring system has no influence on the behavior of the measured object (expressed in physical terms: no energy is extracted from the object by the measurement). This is because the actual measurement is not carried out on the object itself but on an image of the object. For the simplest measuring technique this fact presents one disadvantage: a three-dimensional object is represented in two dimensions. This disadvantage is acceptable if only two dimensions are of interest, e.g. for determining heights jumped, run-up speeds for the long-jump or the take-off angle. When recording these movements it is important that the movements can be completely described on a single plane. In order to avoid mistakes resulting from certain parts of the body moving out of the motion plane, the camera should be positioned far away from the motion plane. The physical dimensions recorded by this measurement are in the first instance cinematographic dimensions (distance, time, speed, acceleration, angles).
Motion Analysis

Motion is understood physically as the change in coordinates in a certain time span. This system of coordinates can first be arbitrarily chosen and is then fixed. This has two requirements:

- a system of coordinates
- timing data

System of Coordinates

This serves to establish a correlation with the actual (realistic) orders of magnitude when a picture is evaluated later. As well as the concept of the system of coordinates, the concept of a “calibration system” is also a familiar topic in the literature about image processing. These two concepts are related as follows:

The calibration system measures the space (in three-dimensional analysis) or the plane (in two-dimensional analysis) in which the motion takes place. The system of coordinates is the mathematical device by means of which it is possible to calculate the actual spatial dimensions.

For the person taking the measurements, the relationship between the calibration system and the system of coordinates is not important. This relationship is established by the software which processes the raw data. Two measuring rods of known length set up at right angles to each other and which are visible in the picture can be used as a calibration system. They should, of course, be set up at the site (or at least in the immediate vicinity of the site) where the action is to take place.

It is sufficient if this calibration system is visible in only one picture if it is ensured that once the camera setting (focal length, position, focus, focal plane) has been chosen, it is not then changed.

Note: optional program modules are available which allow the recording of movements with a camera using pan and zoom features.

The scale of the image varies according to the chosen focal length. It is possible for an actual length of 100 m to be represented by a length of 1 mm in the picture.

The selection of the image is purely of academic interest to the person taking the measurements. Only two features have to be taken into account:
• the motion plane must fill as much of the picture as possible (the rods selected for the calibration system must also fill as much of the picture as possible)
• there should be a considerable distance between the motion plane and the focal plane (use a zoom)

Timing Data

This gives details about when the picture was taken. This information can be presented either as an absolute value (e.g. on 3rd January 1998 at 4.27, 12 seconds and 312 milliseconds) or as a relative value (0.01 seconds after the previous picture). In order to obtain this data, either an accurate timer must be displayed in the picture or the length of time between the frames must be known.

For the majority of questions regarding motion analysis, a relative time value is of more interest. This is determined by the frame frequency of the recording system used. For video recordings this is 25 complete frames per second or 50 fields per second (PAL) or 30/60 (NTSC).

Note: Simi Motion also allows the use of high-speed cameras for motion recording.

Two- and Three-Dimensional Recordings

If motion is recorded with one camera only, then satisfactory results can only be expected for two-dimensions. The effort involved in achieving three-dimensional results is very great and certain assumptions have to be made which can lead to more significant errors.

The following equipment is required to solve a two-dimensional problem:
• one camera
• a calibration system consisting of two measuring rods of a known length set up at right-angles to each other

The following equipment is required to solve a three-dimensional problem:
• at least two cameras whose optical axes should be at an angle of between 60° and 120°
• these two cameras should be able to take pictures simultaneously
• a calibration system consisting of a spatial 3–D object (cuboid, pyramid, cube etc.). The position of the corners of this 3–D object must be known
Difficulties Involved in the Analysis of Pictures

Once the movements have been recorded, the evaluation (analysis) of the pictures can be carried out. To do this, points on the body and points which are of particular importance for the execution of the movement are determined, e.g. tennis ball, football, points on a tennis racket or on a golf club etc. The points of the body used are usually the break-through points of the joint axes or the center of the joint axes. In identifying these, there are three main sources of error:

- the joint axes cannot be clearly identified
- the break-through points of the axes cannot be clearly distinguished in the picture
- the break-through points are hidden by other parts of the body and are not visible in the picture

Solutions

- Only a precise knowledge of anatomy can minimize this error
- the break-through points can be marked by a clearly contrasting color
- the center of the joints must be estimated

Errors and Margins of Error

- errors in determining the length of time between the frames in a sequence of pictures
- errors in identifying the position of the measuring points
- cumulative errors which arise when calculations are made with values which are themselves incorrect, e.g. speed = distance/time, when the measured distance and time are both inaccurate
The extent of these errors can be calculated as a mathematical function of the resolution of the film used, the accuracy of the image capture method, the accurate identification of the focal points for measuring, errors made in registering the time and other errors. The very variety of these factors shows how complex the calculation can be.

In practice it is sufficient if the margins of error are ascertained with reference to known external values. If, for instance, the value of the distance between the upper ankle-joint and the knee-joint is known, then the same value must be arrived at after image capture and calculations have been carried out.

**Camera Resolution**

When a camera is used, an image of reality is copied as a series of electronic or photographic pictures (film). This is subject to the following restrictions:

- Actual 3-D objects are represented on one plane (focal plane)
- The size of this representation in the picture plane is not the original size
- The recording is not continuous, but is made at certain intervals, for instance 25 times in a second

When the recording is examined later, the resultant problems can be seen and solutions considered:

- Depth of information is lost. This loss can be compensated for by using several cameras and combining the information from them (see the chapter on calibration). Making several recordings, however, involves a correspondingly greater amount of work
- The size of the focal plane is limited. There are only a certain number of pixels available in both horizontal and vertical directions. This is the local resolution of the camera or film used. Common resolutions are 768x576 and also 640x480 pixels. The higher the local resolution, the more accurately a movement can be recorded
- For each picture, a camera focuses all the light coming through the lens during a certain time span (exposure time). The exposure time must be kept as short as possible for recording motion, since otherwise the object under consideration moves too far during the exposure time which results in a blurred picture. An exposure time of 1/500 seconds is usual when using a normal video camera (50 fields per second)
- The time interval between one frame and the next is then relatively long (in the example: 50 frames per second means that one picture is taken every 0.020 s, i.e. outwith the exposure time of 0.002 seconds
one is literally left in the dark for 0.018 seconds. Any information about the movement during the interval between the two pictures is lost and can only be estimated. This is the temporal resolution of the camera used. The higher the temporal resolution, the more information is available.

**Local Resolution**

The camera’s local resolution and the size of the actual area under consideration determine to a great extent the exactness of the recording of the coordinates:

if we assume that the camera can record an area of 7 meters in width, then, using the normal camera resolution of 768x576, one pixel corresponds to one centimeter. It is possible to take measurements in a sub-pixel range using appropriate image-analysis processes, but depending on the system used a discrepancy of several millimeters would probably have to be accepted. More accurate results can be gained if the area under consideration is restricted.

**Temporal Resolution**

For an exact measurement the camera speed must be adjusted to the speed of the movements:

if, for instance, a standard 50 frames per second camera is used to make a recording of a sprinter running at a speed of 8 meters per second, then the hip, for example, has moved approx. 16 centimeters between frames and the hands and feet may have moved as much as 30 centimeters! An exact recording of the movement is certainly not possible using this method.

Special care is also necessary with rackets (golf, tennis, badminton) and balls (tennis, volleyball).

**Complete Frames and Fields**

The European video camera standard is PAL (768x576 pixels, 25 frames per second), in North America the standard is NTSC (640x480 pixels, 30 frames per second).

Both formats record in "interlaced" mode, i.e. in the first exposure (first field) the even-numbered lines (0,2,4,6,,8...) are recorded and in the second exposure (second field) the intervening odd-numbered lines (1,3,5,7,9...).
Fig.: The two fields create the typical "picket fence effect"

If, for instance, one considers the fast-moving pointer of a dial, it is quite clear that in the first field (even numbered) the pointer is in a different place from that in the second field (odd numbered). This is often called the “picket fence effect”.

Fig.: Separate fields (left) and interpolation of the missing lines (right)
The Simi Motion image analysis software can separate the two fields, complete the missing lines through interpolation and display them in sequence for analysis. Thus we can effectively achieve 50 (PAL) or 60 (NTSC) frames per second.
N.B. Of course, each field only has the vertical resolution and thus the picture may appear somewhat grainy.
Other cameras (e.g. high-speed cameras) usually do not tend to use this field technique. Instead they take complete frames at the frequency indicated (e.g. 100 hertz).

**Synchronizing the Cameras**

In order to calculate the 3-D coordinates of a point, it is not enough to know its position in one single video picture. At least one further picture is required which shows the position of the point at exactly the same time but from a different perspective.
If two standard cameras are used for the recording, it is very unlikely that they will expose at exactly the same time. This is especially true if they have a very short exposure time.
Example:
Camera 1 exposes at the following time intervals - 0,000 s / 0,020 s / 0,040 s / 0,060 s ... with an exposure duration of 1/1000 seconds.
Camera 2 runs independently of camera 1 and exposes at the following intervals - 0,010 s / 0,030 s / 0,050 s ... with the same exposure duration. The hip of a person walking across the area at a speed of 2 meters per second covers a distance or approximately 2 centimeters in the time between exposure of cameras 1 and 2. Because of this discrepancy, the 3-D coordinates cannot be accurately calculated from these two pictures. Even if all other mistakes are ignored and it is assumed that the position given by both cameras can be averaged out, then an error in the position of approx. 1 cm. arises simply because of the different exposure times.

For a sprinter (8m/s) this would correspond to an error of approx. 4 cm. If, instead, cameras which take 200 frames per second are used, the error is reduced to 0.25 cm (walker) and 1 cm (sprinter).

As can be seen, the magnitude of the error depends on the camera speed and the speed of the movement being recorded. The maximum discrepancy in time between two cameras ("worst case") is exactly half the time which elapses between the exposure of two consecutive frames.

There are three possible solutions to this problem:

**Triggering the Cameras**

There are various possibilities here (e.g. genlock), which all consist of connecting the cameras through special cables and triggering them by one signal. Some methods, however, only guarantee that the pictures are read out of the cameras simultaneously. This does not necessarily affect the actual exposure time, which is determined by the shutter. Exact synchronization of pixels or at least lines is only possible with high-quality, usually digital cameras. In any case considerable costs are incurred.

**Using Digital Cameras**

It is not possible to start standard cameras in a sufficiently short time (e.g. because the mechanics must "get into gear"). This is, however, often not the case with digital cameras. These are activated by a signal ("trigger") and begin simultaneously with the recording. If all the cameras are started in this way at the same time, on the one hand it is guaranteed that the moment of exposure will be simultaneous and on the other hand it is not necessary to identify the reference frame because all the camera sequences begin with the same picture.
Measuring the Time Discrepancy

Using the appropriate electronic equipment it is possible to measure the discrepancy in time between cameras which are not synchronized (with an accuracy of 0.0001s). This time lag must then be taken into account in the mathematical computation of 3-D data. The error can thus be greatly reduced. However, as in the previous solution, there is the danger of only measuring the moment at which the picture is taken and not the exposure time (shutter speed). Apart from that, this is a relatively cost-effective solution.

Optimizing the Speed of the Camera relative to the Speed of the Movement

If the movement is slow enough or the camera speed is fast enough, the error will be so small as to be negligible in comparison with the other recording errors (e.g. optical resolution, calibration errors etc.). The maximum discrepancy in time between the two cameras (worst case) is exactly half the time elapsed between the exposure of two consecutive frames. Moreover, it can be assumed that the error can be moderated by using more than two cameras.

In any case it is important to identify those frames in the film sequence of each camera which have the smallest possible time lag.

Finding Synchronous Frames

If there is no exact information available and the equipment used does not guarantee synchronous recording, then the frames with the smallest possible time lag must be looked for in each camera.

Here there are also several possible solutions:

Optical Signal

A signal is generated which is visible from every camera angle in order to indicate that the measurement is beginning. The recording of the movement by the individual cameras begins with this optically marked frame or is displaced by a constant time factor.

This signal can also often be used to control other measuring instruments or can be generated by these when measurement begins. The problem in this case is that the maximum discrepancy in time between two cameras is not simply half the frame frequency, but in the worst case is almost equal to a whole
frame (i.e. when the signal is generated very shortly before the beginning of exposure of the first camera and very shortly after that of the second camera). **Acoustic Signal**

A synchronized audio signal is recorded for every camera. This signal can either be caused by the movement itself (e.g. when a ball is hit in golf), by an assistant (e.g. by clapping) or electronically produced (e.g. bleeping). The advantage of electronic signals lies in the fact that they can be generated by other measuring instruments (see Optical Signal) and inaudibly but directly recorded onto the audio track.

Note: A connection box which is optionally available from Simi can send an audio signal to all video recording devices at exactly the same time. **Estimating on the Basis of the Recorded Movement**

As distinctive a place as possible (for example the point of contact of a foot or point of impact of a ball) should be identified in the recorded sequence of movements. This moment in time must then be determined for all of the cameras and the beginning of the analysis displaced by a constant time factor (e.g. 40 frames previously). The disadvantage of this method is that there may be no obviously distinctive point in the movement or that it is very difficult to find one. Moreover, it will rarely happen that this distinctive point in time occurs exactly during the exposure time of one of the cameras. The user must therefore always decide whether the frame "shortly before" or the frame "shortly after" corresponds more closely to the moment in question. This, however, has the intrinsic advantage that in the worst case the maximum discrepancy in time is only one half frame. In special cases it is even possible to estimate accurately the interval between the two frames in question and thus obviate the need to use expensive electronics for measuring the frame intervals (see above, this chapter).

**Concluding Remarks**

As a non-obtrusive technique, image processing is an ideal method for collecting cinematographic parameters. Mathematical techniques enable the calculation of data using the spatial coordinates from at least two planes. Only a few conditions must be met to achieve satisfactory results. The fulfillment of these conditions can be verified in the following check-list:

- Is a calibration system visible in the picture?
- Does the test object fill the picture as much as possible?
- Is the length of time between the frames known?
• Are the cameras positioned so that the site or positioning of the cameras as well as the camera settings cannot be changed during the recording?
• Is there sufficient lighting?
• Are the points which are to be captured later clearly visible?

If all these conditions are met, then nothing stands in the way of successful analysis using Simi Motion.
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Using Simi Motion

Start

After the software has been started, the following screen is displayed:

The following options are available in this window:

- Read help on Simi Motion
- Open an existing project
- Great a new project
- Select from database

Read help on Simi Motion

On-line Help includes explanations of all the important software functions. Press F1 to get help on the dialog box displayed on the screen.

Open an Existing Project

The Open dialog box allows you to open Simi Motion 5.x projects (*.SMP files) which already exist. If you want to load projects saved by a previous version of Simi Motion a compatibility problem can occur. In this case open the files with pressed shift key.
Create a New Project

In the “Project label” box, type the name of the project, e.g. “Motion Example”.
In the “Author” box, enter the name of the author, e.g. “Simi...”. This information will be automatically displayed later in the dialog box for selecting project properties.
Choose the “…” button to load a specification file which has already been created. It is possible to use old Motion 4.x specifications as well as new Motion 5.x specifications. This means that once a specification has been created, it can be used several times.
Up to six cameras can be entered in the “Number of Cameras” box.
Choose the “Create and Save” button to create and save a new project.
It is very helpful if the file name is chosen carefully to describe each project precisely so that earlier projects can be easily identified later.
Moreover, all the files which belong to a project (video files *.avi, Simi Motion project files *.smp) should be saved in the one folder.
After all the settings have been chosen, the Simi Motion desktop is displayed.
Select item from Database

Open the database on the path $\text{file} \rightarrow \text{database}$. In this dialog box you can choose and load Simi Motion projects already created.

Search
- By title
- By keywords

By the two fields in this dialog box it is defined with which systematic the database entries shall be shown in the display window. In the description field beneath the display field the path of the Simi Motion project (*.SMP) is shown.

Title
In this window the title of the chosen project is displayed.

Subject
In this window the subject of the project is stated.

Keywords
In this window the keywords of the project are displayed.

Comment
In this window the comment on project is shown.
Desktop

The above illustration shows the Simi Motion desktop: the Project, Specification and Camera folders are standard. The method of working with the folders is the same as with the Explorer in Windows 95/98 and Windows NT. The Camera folder includes one to six cameras, depending on the settings made in the Welcome window.

Project

This folder contains the following two folders:
- Properties
- Comments
Properties

In the “Properties” dialog box it is possible to change the current project name, define the subject and enter keywords and comments. The “Statistics” tab is for inputting reference information.

Comment

In the Comments dialog box it is possible to enter details of each project.
Options

Choose in the menu bar *edit→options*. Now a dialog box appears in which settings for the using of Simi Motion can be made. On the index card *general* you can among other things select the time after which the data shall be saved automatically.

Capture videos

If you click on *project→capture video*, the Simi Motion capturing window opens.

A symbol bar which offers the following options is available:

- ![Search for cameras](image)
  
  If you click on this button the computer searches for all connected cameras.

- ![Save capturing](image)
  
  With this button the capturing last carried out is saved.

- ![Capture start/stop](image)
  
  With this button a capturing can be started and stopped again. A capturing can also be stopped with the button *Esc*.

- ![Camera configuration](image)
  
  This button opens the dialog box *camera configuration*. In the entry fields you can name the different cameras (e.g. left camera).
  
  In addition you can select the video mode for the cameras here. To set an identical video mode for all cameras you have to activate the corresponding box. Otherwise the video mode can be adjusted separately.

  Furthermore you can import saved camera configurations and export newly adjusted camera configurations in this dialog box. The made adjustments can either be saved as standard or be adopted for the single use with the button *close*.
This button opens the dialog box *capturing options*. In *view-mode* you can select the quality of the pictures in the *live-view* or in *during the capturing* (If you select a lower quality you reduce the cpu-burden).

In Capture-files you can adjust the size of the file. This value is only a reserved value and shows the maximum of the file-size, of course a capturing can be shorter.

In the entry window below, the path where the video-data is saved on the harddisk is shown. You can define a new path with the button *search*. With the button *close* the made adjustments are rejected, with *Ok* they are applied and adopted.
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Working with 2D Data

Work with two-dimensional data consists of the following steps:

- creating a specification
- setting up a camera
- calibrating the camera
- capturing the image coordinates
- calculating the scaled 2-D coordinates
- presenting the data

In addition, the optional program feature “2-D Freeze-Frame Measurement” can be used after calibrating the camera.

Creating a Specification

A specification consists of

- a list of the points which are to be captured later in the video frame
- the visible connections between these points.

A specification can either be imported from files which already exist or newly created or edited as required.

Importing a Specification

To import a specification which has already been created, either click with the right mouse button on the “Specification” folder and choose the “Import” command or choose this command from the “Project” menu.

It is possible to use old Motion 4.x files (*.spz) as well as new Motion 5.x specifications (*.smp).

Editing a Specification

Editing consists of two steps: first of all a list must be made of the relevant points, then the connecting lines between these points can be defined.
Edit Points

To edit the list of points, open the context-sensitive menu for “Points” in the “Specification” folder. Alternatively it is possible to choose the appropriate command in the “Project - Specification” menu.

On the left is a list of points which are frequently used. If one of these points is required, then it can be moved to the list box on the right (“Used Points”) by dragging and dropping it.

To add other points or edit points which have already been selected, click on the “Used Points” list box with the right mouse button to open a context-sensitive menu with three available options.

Properties

To change the name and color of a point, select the point in the right-hand list box and choose the „Properties“ option.
The color of the point which is chosen here is used, for instance, in tracing points in the Analysis Module.

**Add**

To define new points and add them to the list, choose the “Add” option.

**Delete**

To delete a point, select it in the right-hand list box and choose the “Delete” option.

The sequence of the points within the list can be re-arranged by dragging and dropping them.

The sequence of the points should be defined in the order in which the points are to be captured later.

For example, a possible sequence would be:

- Head
- Neck
- Right shoulder
- Right elbow
- Right wrist
- Left shoulder
- Left elbow
- Left wrist

In this way, continual jumping from left to right or up and down can be avoided.

When all the settings have been made, click on the “Close” button to return to the Simi desktop. The settings which have been made are saved automatically.
Edit Connections

To edit connections, open the context-sensitive menu for “Connections” in the “Specification” folder. Alternatively it is possible to choose the appropriate command in the “Project - Specification” menu. Connections describe the visible lines or circles between specification points. They are shown in the line drawing.

If points from the list of suggested points have been used, then meaningful connections are already displayed. These, of course, can be changed or deleted as required.

There are two types of connections:
- a line connecting two points and
- a line around a point.

![Specification: Edit connections](image)

Defining a New Connecting Line

Choose the “New Connecting Line” button.
The name and color of the connecting line can now be defined. Then the starting point of the connecting line is selected from the “Starting Point” list box, which contains all the specification points which were previously defined. If the option “Line To” is selected, the end point of the connecting line must also be defined.

If a circle is to be drawn around a point, define the required size under the second option “Circle with Radius”.

Click “Apply” to save the settings.

**Changing a Connecting Line**

The boxes below the list of connecting lines show the properties of the selected connecting line. These can easily be changed.

Click “Apply” to save the new settings.

**Deleting a Connecting Line**

To delete incorrect connecting lines or lines which are no longer required, select the connecting line and click the “Delete connection” button.

**Setting Up a Camera**

A camera folder includes the properties of the available video clips, their calibrations and settings.
Adding a Camera

When a new project is started, either one or more cameras, depending on how many are required by the user, are automatically set up.

More cameras can be added by choosing the appropriate command from the “Project” menu. Alternatively choose the command from the context-sensitive menu (right mouse button) of an existing camera (or the “Camera” folder).

Data in a Camera Folder

Open the Camera folder to display the “Raw Data” and “Filtered Data” folders.

These two folders contain all the specification points which have previously been defined. At first, they also contain empty data records.

“Raw Data” contains the coordinates of the points which have been either entered manually or automatically tracked.

“Filtered data” also contains the coordinates of these points, but after these have been processed by filter algorithms.
Camera Properties

The “Properties...” dialog box can be opened using the context-sensitive menu (right mouse button). First of all the name of the camera must be entered.

In general the following steps must then be carried out:

Select the video file with the recording of the 2-D calibration system
Either open an existing file or make a new recording.

Select the video file with the recording of the movement which is to be captured
Either open an existing file or make a new recording. If necessary, decide whether complete frames or fields are to be captured.

Calibrate the camera
Capture the 2-D calibration system so that the computer can scale the measurements in meters.

Capture the movement
Capture the movement either manually or using automatic tracking.
Calibrating the Camera

Definition: Calibration is the assignment of actual spatial coordinates to the video picture.

Calibration must be carried out before motion can be captured. The camera perspective (distance, zoom, etc.) is determined by this process.

The user only has to mark a number of predetermined points in the picture (by clicking with the mouse).

This is done by studying a reference object (calibration system) whose measurements are already known.

The calibration system should fill as much of the picture as possible. The motion which is to be captured should always take place within the calibrated area (3-D) or on the calibrated plane (2-D).

The form of the calibration system depends on the type of calibration. In the simplest case it can consist of a rod of a known length.

The position and alignment of the system are crucial in ensuring that the calibration is exact: the further away from the calibrated plane or from the calibrated area the motion is carried out, the less precise the result is.

Errors in the recording of the calibration system affect all the calculated coordinates!

In practice it will usually not be possible to record the calibration system at the same time as the motion, but that it will be recorded either before or after the motion. A very short recording, in fact a single picture, is sufficient for calibration.

The camera should not be moved, panned or zoomed between the recording of the calibration system and the recording of the motion.

Using 2-D Calibration

Two-dimensional recordings are suitable for movements which take place on the plane, i.e. which do not have any spatial depth.

Examples: jumping and stretching, walking on a treadmill etc.

A single camera is sufficient for a 2-D recording.
Only coordinates which lie on the calibrated plane can be correctly recorded. The further the points are from this plane the less precise the results are.

2-D calibration using a vertical and a horizontal distance of a known length

In this case a motion plane which lies straight ahead of the camera is calibrated, i.e. it is not possible to record an oblique view using this method.

In order to make the necessary calculations, the system must be supplied with the actual lengths of both distances (in meters) and the coordinates of the end points of the distances in the recorded picture.

Two end points may be identical (e.g. bottom left). A right-angled, L-shaped object is therefore most suitable.

When defining the calibration points, it is important always to mark the upper point of the vertical distance first and the left-hand point of the horizontal distance first.
2-D calibration using one distance of a known length

Here, too, a plane is calibrated where the motion takes place perpendicular to the camera. In this case, however, it is also assumed that the horizontal and vertical lengths are equal (e.g. precise square pixels in the camera and on the monitor). Depending on the equipment used, it is possible that under certain circumstances this assumption will give a false result. This method should only be used if no other calibration is possible.

In order to make the necessary calculations, the system must be supplied with the actual length of the distance (in meters).

2-D calibration using four points

The motion plane is defined by the position of the four points and can be at an oblique angle to the camera. To apply this method more easily, it is recommended that the four corners of a rectangular object ("picture frame") are used. In order to make the necessary calculations, the system must be supplied with the actual coordinates of the four points (in meters) in the recorded picture.

In contrast to the previous methods, this method requires the input of the actual coordinates of the four points. The system of coordinates is arbitrary here, but must lie on the same plane. To simplify the process for a rectangular object, the point "bottom left" could be given the coordinates (0;0). Then the other points (in a clockwise direction) would have the coordinates: (H;0), (H;V) and (0;V), whereby H and V are the lengths of the horizontal and vertical edges of the rectangle respectively.
In general, the position of the points can be freely chosen (i.e. they do not necessarily have to be at right-angles), but they must all lie on the same plane and be measured in relation to the same system of coordinates.

It is possible to change the calibration method or the calibration data by clicking on the “Camera Properties” button and selecting the “Edit Calibration System” command. A dialog box appears in which it is possible to set all the options required.

**Example: Calibration using a vertical and horizontal distance**
Description
In this text box, type the name of the 2-D calibration system.

Horizontal
Type the length in meters of the horizontal distance used.

Vertical
Type the length in meters of the vertical distance used.

Calibration Points
In the text boxes, type the names of the calibration points.

Import
New Motion 5.x 2-D calibration data (*.ca2) as well as old Motion 4.x calibration data (*.cal, *.koo) can be imported here.

Export
Calibration data can be exported and saved here. This makes it possible to make use of this calibration data for other projects.
For example, if the same calibration system is used for different projects, then the same calibration file can always be used.

2D Calibration Properties

This context-sensitive menu contains the following items:

Save calibration as default
Saves the current calibration system as the default calibration system for all future projects.
**Edit calibration system**
Opens the “Edit 2-D Calibration System” dialog box.

**Camera properties**
Opens the “Camera Properties” dialog box.

**Quit**
Closes the “2-D Calibration” dialog box without applying the settings.

---

**Capturing the Coordinates**

The coordinates of the points (raw data) are recorded when motion capture is performed. This can be carried out either by clicking on the points with the mouse (point for point, frame for frame) or by automatic tracking (image processing algorithms).

If automatic tracking is used, light or dark markers (e.g. stickers) must be placed on the points which are to be captured (e.g. human joints) before the recording is made. The user then has to assign each point once and thereafter tracking of the video sequence is carried out by the computer. Intervention by the user is only required in the case of difficulties (e.g. when markers are concealed).

---

**Selecting the Starting Frame**

Click on “Tracking” in the “Camera Properties” dialog box to open the “Select Starting Frame” dialog box.

The starting frame defines the first frame in the capture sequence. It is used to synchronize video recordings which have been made by different cameras.

The required frame can either be selected using the scroll bar at the top of the dialog box or it can be defined by an optical or acoustic signal.

In both cases click on the “Apply” button to save your selection.

**Optical Signal**

If the “Optical Signal” option has been selected, it is possible to have an automatic search made for changes in a certain part of the frame (e.g. light signal).
To do so, click on the “Set Area” button and then on the required point in the picture. Use the scroll bar to define the size of the area in which the software should search for changes.

Audio Tracking

If this option has been selected, then the starting frame can be defined using the audio track of the video clip. To do so, a signal must be recorded synchronously in all the cameras used. A connection box is optionally available which can simultaneously send an appropriate signal to all video recording devices.

To find the starting frame, look for the rising or falling curve of the audio signal.

2D Capture Properties

Click on the “Properties” button (top right) to open the menu.
**Move mouse pointer automatically**
The mouse pointer is always placed automatically at the position defined for each point in the previous frame. This is particularly useful when the positions of the points do not change very much, since the mouse pointer remains within the area to be captured, thus allowing a quick and easy method of capturing the points in the frame.

**Check after each frame**
Once the list of points has been processed, it is possible to check if the points which have been captured are correct before the next frame is displayed. This is particularly recommended if the points are captured using automatic tracking.

**Synchronize with other windows**
If this option has been selected, then the current frame of the video recording is synchronized with all other open windows (line drawing, graphs), i.e. all windows correspond to the current video frame.

**Adjust start frame**
This allows a new starting frame to be defined.

**Camera properties**
Opens the “Camera Properties” dialog box.

**2D still mode**
Opens the “Freeze-Frame Measurement” dialog box.

**Quit**
Closes motion capture. Points which have been captured are saved automatically.

**Motion Capture**

The list of points on the right-hand side of the dialog box indicates which points are to be captured.

The symbols in front of the descriptions of the points show how the points are to be captured (e.g. manually or automatically). The color of the symbols
shows whether the point in the current picture has already been captured (green) or not (red).

The highlighted line shows the current point. Click with the mouse on the point in the video frame to save the coordinates. The highlight then moves to the next point.

For positioning the points more precisely in the picture there is a magnifying glass down right in the dialog window. To put a point exactly you have to push down the left mouse button till you have found the optimal position of the point with help of the magnifying glass.

**Mouse Controls**

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse button</th>
<th>Action</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Click</td>
<td>Define point</td>
</tr>
<tr>
<td>Shift</td>
<td>Left</td>
<td>Drag</td>
<td>Alter XY area</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Right</td>
<td>Click</td>
<td>Zoom in</td>
</tr>
<tr>
<td>Ctrl+Shift</td>
<td>Right</td>
<td>Click</td>
<td>Zoom out</td>
</tr>
</tbody>
</table>

Click on the symbol with the right-hand mouse button to open a context-sensitive menu.
Show Point
The mouse pointer automatically jumps to the point's previously defined position.

Click manually
An arrow is displayed in the button. This point must be clicked on manually in every video frame.

Track automatically
An exclamation mark is displayed in the button. This point will be captured automatically by the tracking system.

Do not track
A cross is displayed in the button. This point will not be captured and will be skipped during the capture procedure.
This setting is useful, for example, when objects are to be captured which are not visible in this section of the frame until later.

Fixed Point
An equals sign is displayed in the button. This point will always be captured automatically at the same position.
This setting is useful, for example, when static objects are to be captured which do not change throughout the video sequence, such as gymnastic apparatus.

To define one particular capture method for the whole column, click on the button with the dot above the list of points.

Discard Point
The highlighted point is deleted and the button reverts to red.

Discard Point from Here
The current point and any data relating to the capture of this point in the following frames are deleted.
**Edit raw data**

Opens the “Edit Raw Data” dialog box (see below).

When all the video frames and points in the required sequence have been captured, these are then available as a set of motion data.

**Automatic tracking**

The prerequisite for an automatic tracking is that the markers can be recorded well, therefore the colours of the markers must be selected in the contrast to the surroundings. Before the tracking goes off automatically, at first all points must be tracked manually in the first picture. When this is completed, click on the button above the period listing and click on "track automatically" in the context menu. The automatic tracking starts by clicking on the button and adjusting "search automatically" there. Otherwise the pictures have to be switched further one by one manually.

There is the possibility to adjust the qualities of the points that have to be recorded manually, before the automatic Tracking, to achieve better results in the automatic tracking.

For that choose "Properties" in the respective item of the context menu whereupon the following dialogue window opens.
(The automatic tracking is activated if the control-box in front of "Use advanced tracking" in the control window "Options" [Edit → Options → General] is marked.)

Colors can be represented in various ways in the computer. Only a small choice of portrayal possibilities is listed in this dialogue window. The single components must be so adjusted, that the search pattern (the part of the picture of the Markers) is covered well. The more precisely this happens, the better are the following search results. With markers that are bad to recognize you have to re-regulate. This happens by the fact that the trafficking regulators get so oriented that the area that is shown blue corresponds to the Marker. All values that are between the regulators belong to the Marker, while the values which are above the maximum or below the minimum don't belong to the marker anymore. If all adjustments regarding color shares and color spaces were carried out, you can have displayed the individually defined marker-result on the right side below in the dialogue window. If you click on the button “Cancel” the predefined settings are restored. Click "OK" to apply to the new adjustments. You can proceed the same way for all other items. If you now choose "Search automatically" the program tries to recognize the markers.
that were manually clicked on before, automatically in every single video picture. If the button in front of a point becomes yellow, this means that the program can identify the respective marker only with a certainty which lies at the lower area of the confidence-area indicated in the dialogue window Properties. If the certainty of the recognition lies below the confidence area, the button in front of the pint turns red and the automatic Tracking is aborted. Then this point must either be tracked further manually or its properties have to be defined more exactly. If an automatic Tracking shall be interrupted, press the "Esc" button

Calculating the Scaled 2-D Coordinates

Provided that a valid 2-D calibration has been performed, scaled 2-D coordinates are automatically calculated from those points which were captured either manually or using automatic tracking. The corresponding folder is saved in the respective camera folder in the project hierarchy.

Standard Data

This calculation is based on “standard” data, which can be either “raw data” or “filtered raw data”. This selection is made in the context-sensitive menu of the corresponding folder. “Standard” data is displayed in red. It is thereby possible to test the effect of various filters on the resulting 2-D coordinates.

Edit raw data

For editing the raw data you have click on the folder raw data → Edit raw data with the right mouse button (or in the 2D tracking directly on the button of an item)and the following dialog box appears.
Captured data can be edited and any errors made during motion capture can be corrected in this dialog box.
Please note: the commands in this dialog box affect raw data. Any changes made here influence all other calculated values (coordinates, speed, angles etc.).

**Toolbar**

- **Undo**
  Reverses the last action taken.

- **Properties**
  Properties for the display of the graph can be modified here.

- **Beginning of Interval**
  The current position in the graph is selected as the beginning of the interval.

- **End of Interval**
  The current position in the graph is selected as the end of the interval.
Delete Interval
Deletes the highlighting of the interval.

List of selected points
The values of the selected set of data are displayed in the graph.

X-coordinate, Y-coordinate
The type of set of data is specified using these two check boxes. It is possible to display and edit each coordinate on its own or both coordinates together.

Graph
The colored curve shows the current state of the data, which may possibly have been altered. The gray curve displayed in the background shows the curve before the current modifications (which have not yet been saved). This allows the user to keep a continual check on what changes are being made.

Apply Changes
All changes which have been made are applied.

Discard Changes
All changes which have not yet been saved are discarded.
It is possible to edit either single values (marked by a vertical line in the graph) or a selected interval (highlighted in color in the graph).

Current Position
The operations and details in this box refer to the single value marked by the vertical line in the graph.
The current frame number is displayed on the left, the current position in seconds on the right.

Delete
Deletes the current value.

Adjust
If necessary, the current value is deleted and replaced to produce a simple connecting line between its neighboring points (linear interpolation).
**Interpolate**
If necessary, the current value is deleted and replaced to produce as smooth a curve as possible between its neighboring points (spline).

**Smooth**
The current value is smoothed by a simple filter process (moving average).

**Range**
The operations and details in this box refer to all the values in the interval of the graph which is highlighted in color.

**From, to**
The frame numbers are displayed on the left, the times in seconds for the beginning and end of the interval are shown on the right.

**Delete**
Deletes the values in the highlighted interval.

**Smooth**
The values in the selected interval are smoothed by a simple filter process (moving average). This operation is particularly suitable for smoothing intervals of data. Repeated use of this operation produces correspondingly smoother curves, but it diminishes the real characteristics of the data.

**Fill Gaps**
This operation fills any gaps which are present in the sets of data in the selected interval. Missing values are inserted to produce as smooth a curve as possible (spline).

**Filtered data**
To create filtered data you have to mark the raw data and then choose *create filtered data* in the context menu of the raw data.

You can edit the filtered raw data with choosing *properties* in the context menu. In the appearing dialog box there are different possibilities how to filter the data.
No filter

*The raw data is not filtered.*

### Moving average filter

The data will be smoothed with "moving average". The filter radius indicates the number of neighboring points that affect the calculation.

Parameter: Smoothing radius (whole number)

Example: little smoothing of raw data, to eliminate roaring

### Low-pass filter

Filters the data with the given "Low-pass-filters". Frequency shares above the swelling value (given as "Limit frequency") is filtered out (Butterworth-filter)

Parameter: Limit frequency (floating point number)

Example: Filtration of the 3D data at human movements (limit frequency e.g. 10 hertz)

### Spline filter

### Interpolation

If this box is activated, the interval about which shall be interpolated can be adjusted. This is used, if not all pictures were included. The interval must be chosen according to the number of the select pictures to close the gaps in the recording by the interpolation. Changes are applied by the button "OK".

### Generate New 2-D Coordinates

It is also possible to generate 2-D coordinates explicitly by choosing the command New 2-D Calculation from the context menu of the required camera. This new calculation can then be based either on "raw data", "filtered raw data" or "standard" data.
Displaying the Data

Line Drawing

The sets of data can now be examined as a line drawing or they can also be exported to other programs.

![Stick diagram](image)

The recorded movement is displayed in an abstract form in this window. It is possible to rotate the line drawing by holding down the left-hand mouse button and dragging horizontally.

2D still measurement

The “Freeze-Frame Measurement” is an optional part of the product and is therefore not available in every system.

It is hereby possible to measure angles and distances in single frames. To do so, 2-D calibration must have been successfully carried out, then choose in the camera properties menu the **2D still mode**.
To measure an angle or a distance, select the required type from the list and then, depending on which type of angle or distance has been selected, click two to four times on the video frame.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle defined by 3 points</td>
<td>3</td>
</tr>
<tr>
<td>Angle between 2 straight lines</td>
<td>4</td>
</tr>
<tr>
<td>Angle to the horizontal</td>
<td>2</td>
</tr>
<tr>
<td>Angle to the vertical</td>
<td>2</td>
</tr>
<tr>
<td>Distance</td>
<td>2</td>
</tr>
<tr>
<td>Horizontal Distance</td>
<td>2</td>
</tr>
<tr>
<td>Vertical Distance</td>
<td>2</td>
</tr>
</tbody>
</table>

The result is displayed immediately.
Variations for Measuring an Angle

When measuring angles, it is possible to specify variations in the type of measurement by selecting the options “clockwise” and “orthopedic angle”. If neither of these options is selected, the angle is always measured in an anticlockwise direction.

The orthopedic angle is the normal medical measuring method whereby, for instance, the fully extended leg gives an angle of 0° (instead of the mathematical 180°). Over-extension would then give a negative angle, and bending a positive.

Insert object

Click on this button to retain the display of this angle in the video frame. It is thereby possible to display any number of angles. Otherwise only the angle which has last been measured is displayed in the video frame.

Add to Protocol

Click on this button to add the measurement to the protocol. In this way individual frames can be used to carry out a complete brief analysis with several angles and distances.

Delete All Angles / Delete All Distances

These two options delete all the angles or distances from the video picture.

Note: only the protocol is retained after a freeze-frame analysis. All the angles and distances are deleted.
Reality Motion Systems GmbH

Working with 3D Data
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Working with 3D Data

Work with three-dimensional data consists of the following steps:

1. Creating a specification
2. Setting up a camera
3. Calibrating the camera
4. Capturing the image coordinates
5. Calculating the scaled 3-D coordinates
6. Presenting the data

Points 1 and 2 correspond to the same steps on a two-dimensional plane and are therefore not repeated here. See the section Working with 2-D Data for a detailed description of these procedures.

Calibrating the Camera

Basic Principles

Many movements cannot be observed on one plane alone because spatial depth is an important factor.

There are two prerequisites for spatial calibration: firstly there should be at least two cameras operating from different perspectives and secondly there should be 3-D reference objects (calibration systems). Cube-shaped calibration systems are often used.

The same applies here: the further the recorded points are from the calibrated area, the more inaccurate the results become.

The calibration system (and therefore the calibrated area) should also fill as much of the picture as possible.
Camera positions are not important for the recording and can be chosen arbitrarily. In particular, the cameras do not have to be positioned at the same height. If only two cameras are used, these should be set up at an angle of approx. 60°-120° to each other.

Additional cameras (in as far as they are supported by the current system) increase the accuracy, since errors can be better offset.

**Example:**

Shot-putting, one camera on the left at an angle, one on the right at an angle and one from above (optional).

The system requires a minimum of eight calibration points. These points must not lie on the same plane and should entirely surround the area to be calibrated. If a cube-shaped calibration system is used, the eight corners of the cube are the obvious choice.

The use of more calibration points (typically between 10 and 30) is recommended for increased accuracy. If a cube is used, for instance, then the middle of each edge and points inside the cube (e.g. the center) can be used.

In order to make the necessary calculations, the actual coordinates of all the points (in meters) and their coordinates in the recorded picture must be input to the system.

This procedure must be carried out for every camera. It is possible to use different calibration points for each camera.

The coordinates of all the calibration points for all the cameras must be defined in the same system of coordinates and in the same sequence.

In cases where motion is in a particular direction (e.g. running), it has proved helpful in practice to ensure that one axis of the system of coordinates selected points in the direction of the movement.
Note: The system assumes that the z-axis points upwards. This assumption has no effect on the calculation of the coordinates but it plays a role in the representation of the motion e.g. in a line drawing.

**Example:**

If a cube-shaped calibration system is used, select one corner as the origin of the system of coordinates and the edges of the cube as its axes. Then for a cube measuring 2m x 2m x 2m, the coordinates \((X; Y; Z)\) of the eight corners are as follows:

- \((0; 0; 0)\) origin
- \((2; 0; 0)\) Right-hand near corner (bottom)
- \((2; 2; 0)\) Right-hand far corner (bottom)
- \((0; 2; 0)\) Left-hand far corner (top)
- \((0; 0; 2)\) ...
- \((2; 0; 2)\) ...
- \((2; 2; 2)\) ...
- \((0; 2; 2)\) ...

This cube should then be positioned so that
- the spatial area to be calibrated lies as much as possible within the cube
- one axis (e.g. the X-axis) points in the direction of the movement
- the cube is recorded by all the cameras completely and fills as much of each picture as possible.

Note:

The motion which is to be captured must take place within the calibrated area. This means that if a full-size recording is to be made of a person, a correspondingly large calibration system is required.

A calibration system measuring 2m by 2m by 2m is therefore essential.

Example: If a crate of beer is used for the calibration, the calculated data cannot be used, since the movement takes place outside the measured space!

Tip: Mark the origin so that it can be clearly seen in all the camera recordings. This makes subsequent work with the system easier.
Selecting the Video File

To set up the camera for three-dimensional use, a video must first be selected. To do so, click on the “Select Video” button in the 3-D Calibration section. An existing video file (*.AVI) can be opened in this dialog box. After a video file has been opened, the data from this file is displayed on the screen. Click “Apply” to define this video sequence for calibration.

Creating and Editing the 3-D Calibration System

The standard calibration can be changed whenever required. To do so, click on the “Properties” button, and select the command “Edit Calibration System”.

![3D calibration system interface](image)
First of all type the name of the calibration system in the “Description” box. Then add all the points, depending on which calibration system is to be used. The coordinates of each point must be entered in meters. When the editing of a point has been completed, click on “Apply” to add it to the list.

At least 8 calibration points are required for 3-D calibration. The more points which are used, the more precise the calibration becomes.

The 3D reconstruction is dependent on an accurate calibration. Please use the “Camera constants” (in the 3D calibration menu) to check your calibration. Pay attention in particular to the calculated camera position and the principal point with “Optimization” turned off.

The options “Pan, Tilt and Zoom” are only available if the corresponding optional module has been installed. Please read the special manual to get more information.

**Additional information: “Camera position”**

The camera position (coordinates according to the calibration system) is calculated automatically during the calibration process, but if the exact position has been measured it should be entered. This information is optional and you can also enter only one component (e.g. the height of the camera) and leave all other textboxes empty.

**Additional information: “Principal point”**

The camera’s principal point is calculated automatically during the calibration process, but if the exact values are known they should be entered. The principal point is usually close to the center of the image. According to circumstances the default values “0.5 / 0.5” are sometimes good enough to achieve an improved accuracy.

There is also the possibility to measure the exact position of the principal point. It is not dependent on the camera’s position, rotation or setup but on the optics and the cameras itself.

Please contact the Simi support for a software tool to measure the principal point of your camera.
Edit Connecting Lines

If the user wishes connecting lines to be drawn in between the calibration points, this can be done using the “Connecting Lines” button analogous to editing the connecting lines in the specification.

Importing Calibration Data

Using the „Import“ button it is also possible to load calibration systems which have already been defined. It is possible either to load an existing 3-D calibration file (*.CA3) or to implement systems created using Simi Motion 4.x. To do so it is necessary to load the (*.KOO) file and optionally also the corresponding (*.SPZ) file.

Exporting Calibration Data

Using the „Export“ button the calibration file created can be saved as a (*.CA3) file and can thus be used in other projects without any problems.
Capturing the 3-D Calibration System

The video frame which was previously selected is displayed in the left-hand window.

The calibration points in the list must now all be assigned to the corresponding points in the video frame.

To do so, click on the points in the correct order in the video frame.

Calibration is complete when all the points in the frame have been registered.

If the arrows in the list box are still red, this means that the points have not yet been defined. Click on the corresponding position in the video frame to define each point which is then highlighted in green. The calibration points are retained the whole time in the video frame so that the calibration system can be completed later.

Clicking with the right-hand mouse button on a tool button in front of a point in the list allows two options:

- Show Point
- Discard Point

In the first instance the mouse pointer is displayed in the position previously clicked on and in the second instance the correspondence is removed, the point disappears from the video frame and reverts to red.

The same procedure must be followed for each camera.

Once every camera has been calibrated for 3-D, motion capture can begin. To do so, click with the right-hand mouse button on the “Cameras” folder and select “3-D Motion Capture” from the context-sensitive menu.
Both video sequences are now displayed in the left-hand window. Two lists of points, one for each picture, are displayed in the right-hand window.

## Capturing the Image Coordinates

### Preliminary Settings

Click on this button to open the following menu.

- Move mouse pointer automatically
- Check after each frame
- Search automatically
- Synchronize with other windows
- Adjust start frame
- Edit calibration system
- Camera properties
- 2D still mode
- Quit

If the “Move mouse Pointer automatically” option is selected, the mouse pointer is always displayed automatically at the previously defined position for the point.

Select the check option if you wish to verify if the points which have been captured are correct before the next frame is displayed.

If it is assumed that the cameras are to be processed one after the other, activate the “Columns first” option.

If various windows (line drawing, video frame) are to be synchronized, the corresponding option must be selected.

### Processing

### Preliminary Settings:

For tracking click with the right-hand mouse button on the button in front of a point to open the following menu.
“Show Point” places the mouse pointer automatically at the position in the video picture at which the point was previously clicked.

The following options are available for capturing points:

- Click manually
- Track automatically
- Do not track
- Fixed point

The “Discard Point” option deletes the highlighted point from the video picture and thereby removes its correspondence.

Click on the button with the camera number to select the same settings for all the points of that particular camera.
Example of Motion Capture

The two pictures represent the two avi files. On the right-hand side is the list of points to be captured. These points are assigned to points in the video picture by clicking on the corresponding position in the frame. If the button in front of a point is green, then this point has already been defined.

Setup

Click on this button to open the following properties menu.

- Move mouse pointer automatically
- Check after each frame
- Columns first
- Synchronize with other windows
- Adjust start frame
- Quit
Select here the options “Move mouse pointer automatically” and “Check after each frame”.

Capturing the Image Coordinates

After all the required settings have been selected, the video frames are processed one after the other.
Every point which has been defined is then shown in green.
A list of points is displayed for each camera, i.e. if two or more cameras are used, then two or more columns are displayed on the right-hand side of the dialog box.
The list for the camera picture which is currently being processed is highlighted in color. Only those points in the list which is highlighted in color are processed.
If a point has been incorrectly defined, it can be discarded and redefined. To do so, click with the right-hand mouse button on the button in front of the point and select the “Discard Point” option.
When all the video frames and points in the required sequence have been processed, then motion capture is complete and the data is now available for 3-D calculation.

Calculating the Scaled 3-D Coordinates

It is not necessary to use every camera to calculate the 3-D coordinates. The system only requires two cameras to carry out a 3-D calculation. If, however, more than two cameras are used, the resulting calculation is usually more accurate and fewer problems occur with points which have not been captured.
The required cameras can be selected here using the check-box options. Enter the type of raw data to be used in the corresponding list box.

It is possible to choose between two different types of raw data here: either normal raw data created during capture or filtered raw data which has already been slightly smoothed. One of these sets of data can be defined as standard. This standard raw data is then used to calculate the 3-D coordinates which represent the third possible choice.

Click on “OK” to create the “3-D Coordinates” folder.

These sets of data can now be viewed as a line drawing or exported to other programs.
Simi 3D Calibration System

(Subject to alterations) © Simi 2002

Please notice:

1. Do not fix screws too hard so the thread is not being damaged (stability is guaranteed by friction).
2. Handle profiles with care to hold up precision of register.

Content:
- Mounting kit with 24 x screws and washer
- 12 x measuring point carriers (4 x floor carrier with adjustable foot)
- 3 parts standing column (1 x with adjustable stand)
- Special screw wrench
- Allen wrench

Fig. 1

Fig. 2

Adjustable stand – standing column

centrepiece – standing column
Construction:

1. Connect four measuring point carriers with stands and floor column with stand to the button structure, with special screw wrench (Fig. 3 + Fig. 4 and 5)

![Fig. 3](image)

Adjustable stands

![Fig. 4](image)

![Fig. 5](image)

2. Next is to extend the standing column around the middle part. The middle part of the structure is marked with black stains in the middle of the profile for the measuring point carriers. Now the centrepiece and the button structure are connected. Please note that the standing column is connected by two profile connectors, only (use Allen wrench, Fig. 6)

![Fig. 6](image)
3. Fix four measuring point carriers to the centrepiece with the upper edge lying next to the black stain of the standing column. (Fig. 7)

4. The remaining four measuring point carriers are connected to upper part of the standing column (Fig. 8).

5. Now connect the upper part of the standing column (Fig. 9)
MANUAL

Capture DV
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Simi Capture DV

This manual describes the installation, technical operation and basic features of the Simi capture system. You should use the manual shipped with your Simi-product to get more information about the handling of the software.

The Simi Capture DV is available in various versions.

Examples:
Simi Capture DV-1 (for one camera)
Simi Capture DV-4 (for four cameras)

The system allows simultaneous video capturing of several DV- (digital video) cameras. Basically you can also use analog cameras (VHS / S-VHS), though capturing is limited to one camera, then.
Synchronous video capturing is not possible with analog cameras.
Requirements

Operating system

For capturing a single camera Microsoft Windows 98 (Second Edition) or Windows Me is sufficient. For two or more cameras you need Microsoft Windows 2000 or Microsoft Windows XP (SP1). At the moment no other operating systems are officially supported. Simi recommends Windows2000 or Windows XP for stable operation without problems. Attention: Windows XP (Home and Professional Edition) needs Service Pack 1 installed in order to cooperate with more than one camera.

Hardware

Computer

A detailed description cannot be made since computer configurations and their performance change almost daily. There are some general rules:
Usual modern computer configurations are sufficient for up to three cameras. Four or more cameras require special components, e.g. fast hard disks.
Example for a DV-2 configuration:
Pentium III, 1 GHz, 30 GB hard disk, 256 MB RAM, Windows 2000
Please consult the Simi-team to arrange a system which matches your application.

Periphery

The cameras are connected to the PC via the “Firewire“ interface (“IEEE-1394”, “iLink”). Most cameras on the market today have to be connected to separate Firewire buses, although, according to the specification, it is allowed to connect several cameras at the same time. The cameras do not correspond 100% to the specification in this point. So you need one Firewire card per camera, although at least the PCI cards provide several ports. Use one port per card only, it does not matter which one.
Installation

Software installation

The software should be installed BEFORE connecting the hardware, since otherwise the plug’n’play feature of the operating system makes wrong assignments.

(a) Microsoft DirectX-8.1 (on the Simi installation CD)
(b) Microsoft DirectX DV-Update (on the Simi installation CD)

Restart the computer every time the installation program asks for it.

You can use the DXDiag tool to find out which version of DirectX is installed on your computer.
Start - Run: “dxdiag”
In case of doubt you can also install again. This applies especially to the DirectX DV-Update.

Hardware installation

You can check the operating system’s detection of connected hardware in the “device manager”:
Windows2000: Right-click the symbol “My computer”, select “Properties”, “Hardware” and then click on the button “device-manager”.

a) Mount the Firewire-cards (PCI-card or PCMCIA for notebooks, if not already available on-board)
b) Connect a camera (cable connection between camera and Firewire-card) and switch on the camera.
c) Normally a dialog box for installing device drivers now pops up automatically. Confirm the default settings, but have all drivers being displayed (no automatic search). Then select “Microsoft DV camera and VCR” and not “1394 DV Camcorder”.
d) The camera appears in the device manager’s section „Imaging devices”. In case it is listed in “Audio-, Video-, Game-controller”, the wrong driver has
been assigned (see (c)). This should be changed in the device manager as described in (c).
e) Repeat the steps (c) and (d) for each camera.

This procedure is only necessary when you connect the cameras for the first time.

**Cabling**

The maximum length of Firewire cables is limited to 4.5m. Because of this there are no longer cables available in stores. But you can use several cables in a row, if you put “repeaters” between them. Depending on camera and computer types (especially notebook computers) and the resulting length of the cable, you might have to provide additional power supplies. Therefore repeaters are available with or without power supply.

According to the specification up to 16 cables (approx. 72m) can be used in a row.

Recently longer cables (10m and more) are on the market. Please contact the Simi-Team for further information.
Operation

Computer settings

The color depth of the graphic card must be set to “High Color” (16 Bit = 65536 colors) (control panel: Display/Settings).

The Direct Memory Access (DMA) for the hard disks must be activated (in the device manager).

Please make sure that no screen saver is activated during data acquisition (turn it off or enter a long idle time).

Switch on the cameras

When switching on please wait about three seconds between the cameras, so that the system can detect the devices correctly.

The order of the cameras in the application software depends on the used Firewire bus, not on the camera itself or on the order of switching on. Therefore you should always connect a camera to the same card, if possible.

In case of problems please check whether all connected cameras are listed under “Imaging devices”. If the operating system does not detect the devices the application software cannot access them, either.

Camera-settings

The cameras have to work without auto focus or any other automatic features during capturing. You can get further details from the manual of the respective camera.

To avoid motion blur you have to limit the exposure time. Common DV-cameras provide shutter settings of 1/100, 1/250 and 1/500 seconds. For fast movements short shutter times have to be set. A short shutter time requires more light.
Often problems occur because the cameras automatically switch to “Standby” and especially Windows 98/Me become very unstable in this case. Some cameras always switch off when there is a tape inserted. In this case you can remove the tape, since it is not needed for capturing with the computer.
Note: The high-speed-modes of the JVC cameras 9x00 are only selectable if there is a tape inserted.
Usage

Please read the manual of your application to learn more about the actual implementation and user interface of the software.

Capture files

During capturing the video streams are always written to one or more hard disks. Therefore sufficient space (one file per camera) has to be reserved on the hard disk, so that no additional administration effort is necessary during capturing.

Each camera produces approx. 3.5 MB per second (=210 MB per minute). This huge amount of data is written directly into the reserved space of the hard disk. Since you should absolutely avoid exceeding the reserved capacity the file sizes should be calculated generously.

After the actual recording you can “save” the video sequences (or parts of it). In fact copies of the capture files are created, because the capture files will be overwritten during the next recording. The copies can also be saved to slow mass storage devices or to the network.

In contrast to that the capture files should be placed on the fastest drives. You should also make sure that these hard disks are not fragmented when you create the capture files. The best choice will be to create capture files on a freshly formatted partition.

The capture files are created automatically from the Simi software, if they are not available or have different sizes. This unique process can take several seconds, with very big files even more than one minute.

The sizes of the capture files remain unchanged, while the saved copies always use only the actually needed space. Both files are in the AVI format and can be played with the Windows media player.
Additional information

Transfer of the AVI-files to other computers

The resulting AVI-files can be played on any computer with Windows 98/Me/2000/XP. Windows NT4 does not support this with the system-inherent means. And since DirectX-8 cannot be installed on Windows NT, you have to use third-party products. Such codecs are available in the internet. The Simi-Team will enjoy helping you.

Frames and fields

The saved AVI files are always full frame videos (NTSC 30 Hz). This format is suitable for real time playback, but not for still images. The typical horizontal stripes appear in every second line of the video image. This effect occurs because the even and the odd lines of a video image were “exposed” at different times. With the Simi-software you can separate odd and even fields and get sharp still images. This way you get twice the number of images per second (60 Hz), but lose vertical resolution since only every second video line is displayed.

NTSC

In northern America the NTSC-system is used:
DV-resolution (horizontal/vertical): 720 / 480
30 frames per second (=60 Hz with field separation)

PAL

In Europe mainly the PAL-system is used:
DV-resolution (horizontal/vertical): 720 / 576
25 frames per second (=50 Hz with field separation)
High-speed-modes

The JVC-cameras of the 9x00 series provide their so called high-speed-modes to record more than 60 fields per second. Twice the frequency (120 Hz) is achieved by halving the resolution, so that the data rate remains the same. JVC’s technical solution is that two different images are assembled in the right and left half of the normal image. So a frame contains as usual two fields, each field a right and a left image. Therefore with 30 frames per second 30x2x2=120 images per second are available.

During live preview and while playing the resulting AVI-files with the media player you can only watch the frames (=assembled fields) and you will not get an impression of the movement with 120 Hz. The Simi-software offers the complete separation of the assembled fields. After selecting the corresponding option all 120 frames are displayed one by one.

Note: The other high-speed modes (120 Hz with horizontal split and 240 Hz with horizontal and vertical split) are supported as well.

Note: The high-speed-modes of PAL-cameras provide 100 or 200 Hz.

Solving common problems

Camera is not detected

Switch off the camera and switch it on again.
Unplug the connection cable to the computer and plug it in again.

Distorted picture (“mosaic”)

Check whether the camera appears in the section “Imaging devices” of the device manager (not “Audio-, Video-, Game controller”). If not please select the driver “Microsoft DV camera and VCR” according to the instructions given in the chapter “Installation”. Make sure that DirectX-8 and the DV-Update are installed before changing the driver.
Lost frames during capturing

See chapter “Operation – Computer-settings”. You should capture with not more than three cameras per hard disk (physical device, NOT partition). Is is also possible that the hard disk is fragmented. In this case you should create a new partition. Perhaps the computer (especially the hard disk) simply is too slow.

Camera switches off

According to the camera model and manufacturer you need to switch off the standby-mode or remove the tape from the camera.

JVC-9x00 camera does not provide high-speed-mode

The high-speed modes are only available with tape inserted. Since the camera then switches to standby-mode after a few minutes you should insert a 60-minutes tape and put the camera to record mode. The camera then only switches off at the end of the tape.

Camera settings change during operation

Most cameras have a DEMO feature which is enabled by default. After a certain amount of time they automatically present various settings. This mode has to be switched off for normal operation. Please follow the instructions given in your camera’s manual.
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Using High-speed Firewire Cameras

Installing the driver
Setting the properties
Saving the properties to a file
  Default file
  Save the properties of all cameras
  Save the properties of a single camera
Loading the properties

Save the properties of all cameras
Save the properties of a single camera
Using High-speed Firewire Cameras

Support for high-speed Firewire cameras (like Basler A301f) has been added to Simi Motion.
All features of the integrated capture module – as described in the manual and in the electronic help system – apply to the high-speed cameras as well.
Although these cameras are quite different from usual DV cameras (camcorders), they appear in exactly the same way within the Simi Motion user interface.

There is only one difference: All camera properties like shutter and white balance have to be set by the software since these cameras do not have any user controls.

Please note: The Windows “device manager” will show these cameras in a separate folder.

Attention: Never disconnect a high-speed camera while it is in use! This may result in a system crash due to the driver software.

Installing the driver

A Basler camera driver setup software is available on the Simi CD. Please install the drivers by double-clicking on the driver setup file.

Setting the properties

Right-click the live preview image and select “Camera properties” to show the corresponding dialog box.
This menu item is not available for normal DV cameras.
All settings will take effect immediately and the camera will save the latest settings to the registry.
Saving the properties to a file

In order to keep the settings for a longer time you may save them to your hard disk.

Default file

You may save a “default” file which will automatically be read each time when the video capture window is opened. Use this option if you want to use the same properties several times.
You may delete the default file if it is not needed anymore.

Save the properties of all cameras

Press the corresponding toolbar button in the video capture window to save the properties of all cameras to the default file or to a user-defined file.

Save the properties of a single camera

Right-click the live preview image and select “Save camera properties” to save the properties of this specific camera.
This menu item is not available for normal DV cameras.

Loading the properties

Previously saved files can be read from hard disk.
Right-click the live preview image and select “Load camera properties” or press the corresponding toolbar button to load the properties of one or more cameras from a user-defined file.
This menu item is not available for normal DV cameras.

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Redlake System
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1. Synchronizing Multi-Camera Systems

Use the Phase Lock feature to synchronize the frames in two or more systems. There is no practical limit of the number of systems that can be synchronized. Refer to section 2 of the Operators Manual for full details.

1.1.1 Connecting the Phase Lock Cables

The Phase Lock feature requires a master system that outputs the initial phase lock signal. This can be a Motion Scope system assigned as the master, or the master signal could come from an equipment source.

1. Select a master system from the systems to be connected, and connect a BNC cable from the Phase Lock Out connector to the Phase Lock In connector on the first slave.
2. Connect the Phase Lock Out connector from the first slave to the Phase Lock Out connector to the next slave.
3. Repeat this procedure for all units are connected.
4. If you are using a trigger signal to stop recording, connect the trigger signal to all units (master and slave) and enter the same trigger settings on all systems.

1.1.2 Setting the Master and Slaves

You may want to designate the camera names such as “Master”, “Slave1”, and “Slave2” etc. using the Setup/Property dialog box. General tab.

1. Right click on the live window of the master system.
2. Click on Sync Mode.
3. Click on Master.
4. Close the window (x).
5. Right click on the live windows of each slave system.
6. Click on Sync Mode.
7. Click on Slave.
8. Close window (x).
2. Operating a Multi-Camera System

Any number of camera windows and file windows can be opened at any time, and the windows can be arranged in a sequential order or in tile format in the application window. Both PCI and e/CAM models operate in the same fashion.

2.1 Recording on Synchronized Cameras

During Record, all control is through the master to the slaves. To record a sequence, the operator must select record on the slaves before entering record on the master system. Click on Stop ([]) with the master window active to stop the recording, then stop the slaves. All systems stop recording simultaneously when they receive a trigger signal.

Follow this procedure to record a sequence on several phase-locked cameras. Designate master and slave systems as described in paragraph 1.1.2 above.

1. Set the same frame Rate on all phase-locked systems.
2. Set the same trigger values on all phase-locked systems.
3. Click on the slave system REC buttons. The slaves will not record any frames (pause mode) until they receive a Phase Lock In signal from the master.
4. Select the master system window and click on the REC button to start recording. The master records at the same frame rate and shutter speed set. The slaves record a frame when they receive a Phase Lock In pulse.

To stop recording

1. Select the master system window and click on stop ([]).
2. The slaves are still in record mode but paused and do not store any frames.
3. You may click on REC again to record another sequence over the previously-recorded sequence, or you may select the windows of each slave in turn an click on stop ([]).
If a trigger stops the record sequence, all systems stop simultaneously.

2.2 Playing Back on Synchronized Cameras

You may view each sequence independently or synchronized from all cameras by selecting the system window and clicking on Play. You may also store each sequence in a file and review the sequence synchronized from the files. Use the Loop button to repeat the sequence.

During Playback, the Sync button links all open windows in the application window, and the active window controls the playback sequence.

CAUTION: Always disable the Sync Mode before changing the Playback frame rate!

2.2.1 Saving the Sequence in a computer file

The sequence in the image memory of each system must be saved in a separate computer file. To record the sequence in a computer file:

1. Click on the camera window.
2. Click on the Save button.
3. Follow the On-Screen instructions to create a file and save the video data in the file.

2.2.2 Viewing each Camera Window independently

1. Click on the camera window
2. Set the playback rate and click on the Play button. The system shows the sequence with each frame number and time for reference frame 0.
3. Alternatively use the Slider to select a frame in the sequence.
2.2.3 Viewing the Recorded Sequence Together

When viewing a synchronized sequence from all cameras, click on a window. The computer takes the playback frame rate from this active window. When you click on Sync, all open windows respond to the controls.

1. Click on an open window.
2. Click on the Sync button.
3. Click on Play. All windows show their video images. Each window shows the same active frame number and elapsed time.
4. Click on Stop ([]) . All reviews will stop playing.

Alternatively you may use the slider to select a frame. All windows will respond and show the same frame number and elapsed time.
Global Tracking Settings

By clicking on *global tracking settings*... the dialog box *global settings* is opened in which adjustments for all markers can be done. The dialog is divided into two parts. They contain settings for trust values and the limitation of the search result at *search*.

(Fig. 1)
With the *trust values* the weighting of the similarity values and the threshold values can be set. The similarity values are a weighting of the total trust. What is given is the medium of the weighting of the similarity values and how high the single values are to be valued.

**The trust values of the similarities are:**

- **Color**
  Similarity of the color of the searched marker with the one of the former found marker

- **Area**
  Similarity of the area of the searched marker with the one of the former found marker

- **Ratio**
  Proportion of the area of the marker to the surrounding area

- **Brightness**
  Similarity of the brightness of the searched marker with the one of the former found marker

- **Saturation**
  Similarity of the saturation of the searched marker with the one of the former found marker

- **Motion path**
  About how far it is a steady or a stochastic movement process

The weightings of the single similarity values depend on the kind of markers that is used (color or black/white), on the movement that is carried out in the video (important for the motion path) and on how big the markers are.

On the right side, next to the field of the similarity values there is the opportunity to have the trust values for the color values calculated by the system *calculate trust values for color*. For that the check box has to be activated. Now the program recommends the weightings for the similarity values. If the option is deactivated the weightings have to be set manually with the scrollbar. This is only possible if the scrollbars are pale grey.
Global Tracking Settings - 3

(Fig. 2)
Remark to the similarity values for color markers (manual adjustment)

(The similarity values are experience values and are to be seen as advise):

- The color similarity should be 100% with color markers
- Two markers with the same color should not lie directly next to each other
- The values for brightness and saturation should be weighted with 100%
- If it is about a steady movement (e.g. swinging around the arms) the similarity values for the motion path can be set to 50%. If it is a volatile movement the pursuance of the marker point is more difficult and the weighting of this similarity value should be chosen lower, at about 10%.
- The two settings area- and ratio similarity should be adjusted with a lower weighting. Recommended is 10%

Remark to the similarity values for black/white markers (manual adjustment)

- In contrast to the color markers the weighting on the value for color similarity is lower and is recommended at 20%
- The same applies to the saturation similarity
- The brightness similarity is to be valued highly because the recognition of the black/white markers must be possible with difficult areas (e.g. when moving into a shadow)

Threshold values

The upper threshold indicates the area in which the markers are recognized well and surely. This one should be over 90% even better is 95%. The value below indicates that until this threshold the marker is recognized. Beneath this value the marker cannot be seen any more. The recommended value here is 75%.
For the limitation of the search result the following adjustments can be done in the part dialog search:

**Maximum marker size**

The maximum marker size is on one hand the size of the marker given in pixels and on the other hand it says something about the size of the search room. For the value of the marker size it is recommended to use 2*x. x is the distance between the center of the found marker and the center of the searched marker in the direction of the x-axis (horizontal). The size of the search room should be taken double that size because of the following reason:

The search room square has in its center the marker and the marker in turn has in its center the coordinate origin of the Cartesian coordinate system. That means that there is the same distance is the x- and the y-directions. With a marker size of 60 pixels (that is 60*60 pixels in x- and in y-direction) the distance from the center of the marker until the edge of the search room square only 30 pixels. But the center of the next marker could lie for example at 60 pixels starting out from the first marker center. The search for the next marker would be unsuccessful. But by choosing 2*x the search room square enlarges by the factor four and the next searched marker will be found no matter in which x- and y-direction it has moved.

**Note**

The marker size should not be chosen too big! By the time the marker becomes almost as big as the entire image the search may take very much time.

**Maximum search time**

The maximum search time is an index for how much time shall be spent on the search for the next equal marker. That means that if the time is expired and no marker was found the program cancels the search and gives the note: *Marker not found* to the user. Therefore it makes sense to limit the search time. It is given in ms. If the maximum search time shall be limited the checkbox *search time limit* must be activated.
**Maximum number of search trials**

The maximum number of trials limits the number of the bad trials. For that the check box *search trial limit* has to be activated. If the maximum number of trials shall be limited the checkbox “search trial limit” must be activated.

**Settings**

At the end of the part dialog field *search* there are still three more entries which can be activated (set a check mark with the left mouse button) or turned off (empty checkbox) with the checkbox. (Fig. 2)
Include extreme values from click in marker search

The first entry *Include extreme values from click in marker search* moves the tolerance range at the search if the option is activated. The tolerance range for the color values is moved into the value range until it finds complete accommodation.

Example
Let us assume there is a value range from 0-1 given and a marker area that moves around 1 and a tolerance of 10%. That connoted for this case that the area moved from 0.95 to 1.05. However the area above 1 does not exist. In order to ensure a tolerance of 10% anyway the area is moved so that it lies between 0.9 and 1.

Maximum tolerance for marker search

The option maximum tolerance for marker search can eliminate brightness fluctuations. This is necessary, if the areas outside the marker are brighter or darker and the search shall be continued though.

Example
Let us assume that a marker is used which is supposed to have a tolerance between 1 and 0 and its area-average moves around 0.8 then the threshold values would be 0.75 and 0.85. In the assumption there are only three other points in the area around the marker, which lie beneath the threshold of 0.75. In this case the scenario will probably not change so much in the following pictures that suddenly the darker points around become brighter than the actual marker. Therefore the upper threshold can be refined so much that it extends to the maximum value area. Of course this has effect on the illumination fluctuations. That means the marker has the possibility to move in this direction without any trouble.

Dynamic search

If the field *dynamic search* is activated the search of the marker in the following image is carried out by the system and this marker then is compared to the former one. In case the marker is not found surely the system takes the found position and recalculates the tolerance. The marker is recognized again
and the system controls whether the trust values improved compared to the previous marker. If it did the operation continues with the new settings. If not it continues with the settings of the previous marker. The second possibility that can occur is that the marker is not recognized. In this case the system goes back one image, defines a new tolerance there and then moves on to the next image.

So with the *dynamic search* the system makes an automatic finding of the markers possible and corrects self-maintained the search settings in case complications appear with the finding. It is recommended to do the first run without the *dynamic search*. It should only be used e.g. if there are heavy illumination fluctuations recognizable in the video.

When all entries on the trust values and the search are done there are the following options available at the end of the dialog box:

**Place all markers again**

After a correction of the global settings the button *place all markers again* makes it possible to use the new settings for all markers and to have the markers set again.

**Default values**

If the button *default values* is used all values are reset and the settings originally given by the program are adopted again. Attention! Individually defined settings are lost afterwards.

**Ok**

With *OK* the new settings are adopted and saved by the system.

**Cancel**

If the button *cancel* is used the dialog is canceled and the dialog window is closed. Current changes are not adopted in this case.
Local Tracking settings

(Fig. 4)

For one selected marker the settings can be changed over the local tracking settings…. The dialog window local marker settings is opened. The structure of this dialog box is similar to the one of the dialog box global tracking adjustments. There are only the following changes:
• It is not possible to activate the check box *calculate trust values for colors*
• *Place all markers again* is replaced by *global settings take over* (serves for adopting settings that were tested at one marker to all markers)

Apart from that the explanations from the global settings are valid.

**Properties**

(Fig. 5)

Under *properties* the properties of the markers can be set and tested. The dialog box shows in the upper half two equally sized, quadratic windows. The
left window shows the original image with marker and the surrounding area. The right window shows the recognized marker. The windows adapt to the size of the marker.

In the lower half the properties of the markers are set. They can be changes by the user. In the list field *color spaces* the *color space components* are listed. The following *color space components* are available

- red, greed, blue, grey
- red/green, red/blue, green/blue
- HSV-H, HSV-S, HSV-V
- HUV-H, HUV-U, HUV-V

The program activates the *color space components* with which the marker is depicted at best.

If a marker is not recognized during the tracking the dialog window *marker properties* is automatically opened by the program and all *color space components* are activated. Now the user is enabled to turn off or activate the check boxes. Next to the listing of the *color spaces* there are scrollbars that indicate the bottom or the top threshold value of the single *color space components* and make it unchangeable.
In order to open further perspectives for the marker image the appearance of the marker surface and its direct surrounding can be changed in the following points:

- **Area of component**
  As soon as a *area of component* is activated the area of the *color space component* is depicted in the window *recognized marker*. This is not the *area of the resulting marker*! The *area of component* appears blue.

- **Area of resulting marker**
  If the checkbox *marker area* is activated the area of the marker is depicted in the window *recognized marker*. The marker area appears
green. Where the *area of resulting marker* and the *area of component* overlap the marker area has a turquoise color.

- **Center of resulting marker**
  By activating the check box *center of resulting area* the center of the marker is shown by a red point in the window recognized marker.

- **Contrast enhancement**
  If the contrast is enhanced the image of the recognized marker is depicted in grey. This setting helps the user to distinguish better between marker- and non marker-area. If the checkbox *contrast enhancement* is activated the marker is depicted stronger in darker grey color.

- **Dynamic marker adjustment**
  Here the dynamic can be turned on and off separately for this marker

**Note**
If the check boxes *area of component* and *area of resulting marker* are activated at the same time the *area of component* which does not belong to the marker is colored blue. The *area of component* which is the *area of resulting marker* is depicted turquoise and the *area of marker* which does not belong to the *area of component* is depicted green.

With the button *reset* any movement of the scrollbars is undone. If the button *reset all* is used the program demands a confirmation. If this is answered with *Yes* the program defines the settings itself

At the end of the dialog box there are three buttons:
- **OK**
- **Cancel**

The meanings of these buttons are described under global tracking settings and have the same impact here.
**Completions to the color spaces**

A color space corresponds to one color model which the computer uses to handle colors or to depict these. Each color space has different properties. These are used differently for the search.

The color space components that are mentioned in the first two paragraphs are self-explaining. These components are especially suitable high contrast markers, no matter if colored or black/white.

In the RGB²-color space the mixing ratio of the colors red, green and blue is regarded. The attempt is that with the illumination change of one color the channels red, green and blue change approximately in equal shares. That means that the mixing ratio of the colors for the marker tracing are regarded. This color space works quite good with rather low contrast, colored markers.

In the HSV color room the marker is searched by the criteria H for hue, S for saturation and V for value.

The H-component of the HSV color space is suitable for colored markers but because of instabilities of the H-component this one rarely comes into operation. The S-component is used well with high contrast markers. The V-component is used with high contrast black/white and colored markers.

The HUV color space is a technical orientated color space. H stands here for the brightness value, just as v does. U and V are different channels which contain only color information. Therefore they should only be applied to with colored markers!

**In general:**

If a good and high contrast picture (with *contrast enhancement*) is shown at one *color space component* in the grey picture at *recognized marker* this *color space component* is suitable for the search. But if a diffuse picture without clear structures appears, this color space component should better be left out.

**Note**

It has no use to select as many components as possible, but only those that posses a really good high contrast structure. Components with a weak structure often influence the search negatively.
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Displaying the Data

Once the movement has been recorded and saved and motion data has been generated, the data can be analyzed. There are two ways of presenting the data.

The first possibility consists of a line drawing in which the movement can be demonstrated in virtual reality and therefore the performance of the movement can be continually monitored.

The second method consists of presenting the data in the form of a graph and analyzing the resulting curves.

It is also possible to export the data for use with other programs.

Line drawing

The movement which has been captured is displayed as a line drawing in this window. It is possible to select whether the system of coordinates is shown or not.

Each of the three axes represents a certain direction or plane: for instance, the xy-plane represents the floor and the z-axis indicates the height.

Clicking with the right-hand mouse button on this window opens a context-sensitive menu with the following options:
Copy

This option copies the line drawing to the Windows Clipboard so that it can then be inserted into all other (MS Office) programs.

Point Tracing

Particular points can be shown up by displaying them in a special way (tracing). The development of the movement is thereby emphasized and possible anomalies can be recognized.

![Trace of points dialog box]

The sequence during which point tracing is to be carried out can be specified to an accuracy of one frame.

The option absolute position specifies whether tracing should be performed dynamically or whether it should be visible from a certain frame on.

This means that if both check boxes are selected, point tracing is displayed within a certain interval. If neither of the check boxes is selected, point tracing is also displayed for several frames before and after the required movement.
“Invisible” deletes the current point tracing from the list box.

**Auto+Light**

The colors of the points in the specification are the default colors used for point tracing. These are shown in a slightly lighter shade to increase visibility of the movement.

**Automatic**

Automatic colors are those colors defined in the specification.

**Default Color**

Standard colors can be defined to suit the user's requirements, e.g. point tracing of the condyle (knee joint of a dog):

![Stick diagram](image)

This option allows quick and easy recognition of special ways of moving or peculiarities of the recorded subject!

**Tracing of Connecting Lines:**

Tracing of connecting lines is basically the same as point tracing. Here, however, it is possible to make these longer connections visible and follow them through the movement. For instance, the connecting line between the hip and knee can be shown up in a different color during a certain phase of the movement.
The timing of the tracing of connecting lines can be specified to an accuracy of one frame.

If high speed video files are used, it is recommended that the interval between frames is increased, since otherwise tracings can conceal each other.

Here the path of the racket when the ball is hit is shown.
Shadow:

A copy of the subject (shadow) is reproduced within the line drawing. This shadow can be displayed in several images and its color defined by the user.

Normal colors
The shadow is displayed in the same colors as the line drawing.

User defined colors
The colors of the shadow can be specified by the user.

Light colors
The colors in the specification are used, but in a lighter shade so that the movement is still clearly visible.

Clear all
Deletes all the existing shadows from the line drawing.
Edit Data rows

This dialog box enables the user to display several line drawings in one window. This provides a good opportunity for the comparison of different test persons.

The offset settings are for positioning the subject.

Any number of data rows can be included in the one window.

Data rows can be selected by dragging and dropping them.
Properties

These settings change the current display of the line drawing in the window. The perspective of the test person can be altered by means of the three axes (x,y,z).

The “Zoom” option allows the size of the subject to be altered.

The subject can be repositioned by moving the line drawing horizontally and vertically by means of the scroll bars.

Interpolated view
Values between the separate frames can be calculated to allow a better representation of the movement.

Shadow visible
The test person casts a shadow on the floor.

Show current position
The line drawing is displayed in the window.
Show system of coordinates
With this option it is possible to choose whether the system of coordinates is displayed or not.

Floor visible
A floor can be displayed in the line drawing window.

Static clip
Line drawing copies of the movement can be made at any time. A static frame series displays these separate images next to each other so that the course of the movement can be studied frame by frame.

Graph
The second method of presenting data rows is in the form of a graph.

Data rows which have been calculated can be displayed and analyzed in a graph. Data rows can be included in the graph by dragging and dropping them. Clicking on the graph with the right-hand mouse button opens a dialog box with the following options:
Copy
This option copies the graph and its contents to the Windows Clipboard. From there it can be exported to all commonly-used programs.

Display Time (F9)

It is possible here to display information about extreme values which have occurred, zero positions and points of intersection of the curves. The exact time at which such phenomena occurred can be displayed.

To do so, position the time near the point and press F9. A dialog box is displayed which describes the type of extreme value and the exact time at which this was measured.

Add data

This dialog box allows data rows to be added to a graph which has already been opened, which enables the easy comparison and analysis of two or more data rows.

The “Category” text box allows the choice of raw data, filtered raw data or, depending on the calculation previously performed, 2-D or 3-D data.

Those points which were defined in the specification, e.g. right knee, right hip, can be entered as data rows. The required coordinates, speeds etc. should be specified in the “Type” field.
It is, of course, simpler to enter the required data row by dragging and dropping it.

**Properties**

All important settings for graphs can be made in this dialog box.

**General**

The graph and background colors can be specified here.

**Display Percentage**

The time-axis of the graph can be displayed in percent. This means that it is possible to compare movements which are independent in time from each other.

**Show data left from Y axis**

If a point of intersection on the axis has been defined, it is possible to choose whether data left of the point of intersection is displayed or not.

**Dynamic plotting**

The construction of the curve is synchronized to match the progress of the movement.
**Dimmed plotting**

The curve is shown in gray in the graph and then plotted dynamically in a different color. In this way the complete curve is displayed but at the same time the current position is highlighted.

![Dimmed plotting diagram](image)

**Legend**

It is possible to choose whether the legend should be displayed above or below the graph.

If “Display Values in Legend” is selected, the value corresponding to the current position is displayed in the legend.

Labels for the axes can be entered in the bottom fields.

![Legend diagram](image)
**X-Scale**

If the automatic option is deactivated, it is possible to select one's own settings.

For instance, the point of intersection of the axis can be shifted in this way.

![Image of X-Scale settings](image)

**Y-Scale**

If the automatic option is deactivated, it is possible to select one's own settings.

**Mouse Controls**

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse Button</th>
<th>Action</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>Left</td>
<td>Drop</td>
<td>Add a data row</td>
</tr>
<tr>
<td>Shift</td>
<td>Left</td>
<td>Move</td>
<td>Read the “coordinates”</td>
</tr>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Click (background)</td>
<td>Display the graph context-sensitive menu</td>
</tr>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Click (curve)</td>
<td>Display the curve context-sensitive menu</td>
</tr>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Click (legend)</td>
<td>Display the curve context-sensitive menu</td>
</tr>
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### Keyboard Combinations

<table>
<thead>
<tr>
<th>Key combination</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>F7</td>
</tr>
<tr>
<td></td>
<td>Shift F7</td>
</tr>
<tr>
<td>Shift</td>
<td>F8</td>
</tr>
<tr>
<td></td>
<td>F8</td>
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<tr>
<td></td>
<td>F9</td>
</tr>
<tr>
<td>Ctrl</td>
<td>LEFT</td>
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<tr>
<td></td>
<td>LEFT</td>
</tr>
<tr>
<td>Ctrl</td>
<td>RIGHT</td>
</tr>
<tr>
<td>Ctrl</td>
<td>RIGHT</td>
</tr>
<tr>
<td>Ctrl</td>
<td>N</td>
</tr>
<tr>
<td>ALT</td>
<td>ENTER</td>
</tr>
</tbody>
</table>
Animation

It is possible to select the speed at which the line drawing and the graph should automatically run in this dialog box. The speed is given in percent and can be changed as required for convenient presentation of the data.

Keyboard Combinations

<table>
<thead>
<tr>
<th>Key combination</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl A</td>
<td>Start the animation</td>
</tr>
<tr>
<td>ALT +</td>
<td>Increase the speed</td>
</tr>
<tr>
<td>ALT -</td>
<td>Decrease the speed</td>
</tr>
</tbody>
</table>

Create templates

If there are certain favorable characteristics in the selected forms of representing the data that you want to use more often, there is the possibility to save this characteristics as templates. This can be done by a right-mouse click on a stick diagram or diagram. In the appearing context menu you can choose save as template and the dialog box save view to template file will open.

The following settings can be selected:

window position

If this function is activated, the new window appears always at the same position.
**window size**
The size of the window can be adjusted here.

**Data properties**
Adjustments that were made in the context menu of a diagram or a button are saved to the template to by this function.

**Data**

*Curses of curves can be saved as template, too!*  

After confirmation of the selected settings with OK they can be saved as *.smv-file. The chosen representation form of the data can also be saved as default template, i.e. by opening any diagram or stick diagram the made adjustments will be adopted in every other project.

By the path *view → open template* or with the button ![open template](image) in the symbol bar the dialog window *open template* will appear. 

In this window you have the opportunity to choose templates. 

The following types can be distinguished:

*(all)*

**Combination of multiple windows**
To create a combination all selected windows must be saved under the name of the first saved file.

Under *open template* you can find the combination.

**Diagram**

**Stick diagram**
The templates of the different representation forms can be opened with OK and can be used in any project.
Create sequence of images

By the path view → new → sequence of images in the menu bar you can open the dialog window sequence of images. Now, different kinds of representation of a motion (stick diagram, diagram, show video…) can be imaged as intervals and can be saved as HTML-document.

The button opens a menu, where you can click on select timetable to open the following dialog window.

In this dialog window you can add single points in time or a sequence with any desired intervals to the current timetable. After confirming the selected settings with OK, the dialog window sequence of images will show marks for the different representations.

Before the representations are shown in the dialog window the corresponding view has to be opened.

If you click on the button on the right top side in the dialog window, you have the ability to click on "select view" in the appearing context menu. You now can see a square with a question mark in it next to the cursor. If you now click into the desired view this appears as a sequence of images in the dialog window.

If you click on the button on the right top side again the result can be saved as an HTML-document by the option "Save as".

Another possibility to choose single points in time for the sequence of images:
Choose e.g. stick diagram, than select frames that should appear in the sequence of images and click on the camera-button at the right top of the dialog box.

**Show video**

Apart from the visualized data the image representation can be displayed simultaneously. You can do this by a right-button-mouse-click on one of the cameras. The image representation can now be chosen in the context menu. The image view can also be called up by drag & drop, by clicking on one camera view and pulling it onto the desk.
Calculation of the data

Calculate envelopes

Envelopes can be calculated for data rows of the same type or for data rows of repeating motions.

If you select project→calculate envelope in the menu-bar the corresponding dialog window will appear.

The data rows have to be placed into Data (drop here) by drag and drop. It is also possible to add the data rows by clicking the add button in the selection box. Selected data rows can be deleted by clicking the delete button.

After that, different values which are calculated automatically can be chosen from a list. (Mean, valid values, Minimum, Maximum, difference Max-Min, standard deviation, mean + standard deviation, mean – standard deviation).

The calculated data row will be saved in a folder. From there they can be displayed in diagrams by drag and drop.

Edit Center of Gravity Model

There are different center of gravity models for different sequences of movements and different test persons or objects. These models are saved as files (*.cgd) and must be loaded before any calculations are carried out.

A certain number of points is required for each model. This means that the specification points must first be assigned to the points in the model. It is not possible to carry out a calculation before all the required points in the model have been covered. If necessary, points which are not quite identical (e.g. heel instead of ankle) can be assigned to each other (with a slight loss of accuracy).

Determining the center of gravity is a mathematical estimation and is based on experience and anthropometric values obtained, for example, from measuring parts of corpses. The exact parameters for calculating the center of gravity are different for each person, so that the use of one model for different types of
people (men/women, adults/children or weight-lifters/long-distance runners) should be treated with caution.

A tool which is optionally available (Simi Anthropo) allows the parameters to be obtained for a certain person on the basis of individual measurements (weight, height, chest measurement, shoulder breadth, leg length etc.).

Points from the specification are assigned to the model in this dialog box and the center of gravity is then calculated.

It is possible to have the points automatically assigned by the system, but this is usually only successful with points which have been created in the specification in Simi Motion 5 with the help of the suggested skeleton points.

**Browse**

The file which contains the required center of gravity model can be selected here. Different center of gravity models can be chosen under
A user-defined description of the center of gravity calculation can be entered below the file name.

**Based on**
All the available groups of 3-D coordinates are displayed in the list box. The data group which contains the measurements to be used in the center of gravity calculation should be selected here.

**Insert in data group**
The data group in which the three-dimensional center of gravity data is to be stored should be selected here.

**Used points**
The left-hand list shows the available points as they were defined in the specification.

**Edit**
It is possible with this command to change directly to the specification window in order to add more points, for instance.

**Points in model**
After the model has been loaded, the points which are required in the model are displayed in the right-hand list.

**Assign**
A point from the specification must be assigned to every point in the “Points in the Model” list. The symbol in front of each entry in the right-hand list shows whether a specification point has already been assigned.

Points can be assigned in the following ways:

a) Select the corresponding entries in the left- and right-hand lists and click on the “Assign” button.

b) Use the mouse to drag the required entry from the left-hand list over to the corresponding entry in the right-hand list.

c) Select an entry in the right-hand list and double-click on the required corresponding entry in the left-hand list. The highlight in the right-hand list then automatically jumps to the next point in that list.
If all points are assigned the input will be validated with one click on the button OK. In the project window appears a new folder called CoG in which the CoG-model is saved.

**Add CoG to stick diagram**

In order to make the CoG visible in the stick diagram you have to add it under `Specifications → Connections`.

Now the folder CoG can be dragged into the stick diagram where the CoG appears as a circle.

**Export**

The center of gravity model which has been loaded - as well as any assignments made - can be written to another file for use with other projects. In this way, it is possible to have the system carry out a correct automatic assignment of points when the model is loaded for other projects which use the same specification.

**New Data**

You can open the dialog window `new data` by clicking on F4 or by selecting `Project → new data` and also with the button.

This dialog box provides a variety of possibilities for editing existing data rows or for creating other data rows.

The following four tabs are available:

„a+b Arith“ „Angle/ Dist.“ „Filter“ „Div“

It is possible, for example, to combine two data rows to form one data row. Or constant values can be added to one or more data rows so that velocities can be added to stationary objects, for instance.
Name

Enter a special name for the new data row here. If possible, this should indicate the type of the data row.

Insert in Data Group

If no entry is made here, a folder with the name “User” containing the newly created data row is saved in the project hierarchy after this window is closed. If a “New Data Group” has been created previously, this is automatically displayed for selection in this list box. If this is the only entry, it is selected automatically.

Data row

The data row which is to be edited has to be put down here. To do so, click on the corresponding data row in the project hierarchy and drag and drop it into this field. If the wrong data row has been selected by mistake, simply repeat this maneuver. The old entry then is deleted and the new data row is displayed in the field.

Depending on the type of operation, the following options can be selected: „a+b Arith“ „Angle/ Dist.“ „Filter“ „Div“
After one of the four options above has been selected, the operation that is to be performed must be specified in the “Operations” list box. Depending on the specific operation, one or more data rows must now be selected or constants specified.

E.g.: subtraction of a data row.
The height of the left shoulder is chosen as the first data row. The second data row which has to be chosen then is the right shoulder and the operation “Subtraction of a data row” is specified. The resulting difference allows conclusions about the posture of the test person.

E.g.: smoothing of a data row.
After motion capture has been performed successfully, it is clear that the graph of the data is not a smooth curve, but is rather. Enter this data row in the listing field ”?” by drag and drop, click on the tab “Filter” and then select the corresponding filter.
The smoothing radius which is entered is decisive for the degree of smoothing of the data.
Click on the “Create” button now and the new data row is saved in the project hierarchy. To display the curve again, drag and drop the new data row into a graph.
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Exporting 3D-Data

The 3-D motion data which has been calculated can now be saved and exported in the required file format.
The following file formats are available:
Text file TXT
Biovision BVH
Biovision BVA
Autodesk DXF
Character Studio CSM
Lightwave LWS
Simi Motion Java Applet SMJ
Maya ASCII Scene
Text File (*.TXT)

Exports the data as a text file.

This file can then, for example, be incorporated in the animation program Maya with the help of the Simi MEL script. If you would like to do this, please be sure to select the options “Write Headers” and “Write Column Headings”.

BioVision (*.BVH)

Exports the data in BVH file format.

The BVH file format is particularly suitable for the transfer of data to animation programs (3D Studio with Character Studio, Metacreations Poser, Maxon Cinema 4D and other software). A plug-in from Maxon is required for importing data to Cinema 4D version 5.x.

Unlike many other file formats, BVH transfers the translation and rotation vectors instead of the coordinates of the identified points. This results in very good scalability and transferability to animated characters after this data has been imported into the appropriate programs.

Note: A certain number of fixed points (specification) is required for exporting data in BVH file format. Please use the "BVH.SMP" file supplied with this software as a template.

The following points are required:

- BVH
- Crown
- L-Ear
- R-Ear
<table>
<thead>
<tr>
<th>Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Collar</td>
</tr>
<tr>
<td>R-Collar</td>
</tr>
<tr>
<td>Chest</td>
</tr>
<tr>
<td>L-UpArm</td>
</tr>
<tr>
<td>L-LowArm</td>
</tr>
<tr>
<td>L-Hand</td>
</tr>
<tr>
<td>L-InnerHand</td>
</tr>
<tr>
<td>L-OuterHand</td>
</tr>
<tr>
<td>R-UpArm</td>
</tr>
<tr>
<td>R-LowArm</td>
</tr>
<tr>
<td>R-Hand</td>
</tr>
<tr>
<td>R-InnerHand</td>
</tr>
<tr>
<td>R-OuterHand</td>
</tr>
<tr>
<td>Hips</td>
</tr>
<tr>
<td>L-UpLeg</td>
</tr>
<tr>
<td>L-LowLeg</td>
</tr>
<tr>
<td>L-Foot</td>
</tr>
<tr>
<td>L-FootTop</td>
</tr>
<tr>
<td>R-UpLeg</td>
</tr>
<tr>
<td>R-LowLeg</td>
</tr>
<tr>
<td>R-Foot</td>
</tr>
<tr>
<td>R-FootTop</td>
</tr>
</tbody>
</table>

If not otherwise indicated, the center of the joint is required.
BioVision Coordinates Format (*.BVA)

Exports the data in BVA file format.
The BVA file format is also suitable for the transfer of data to animation programs (Softimage 3D and other software). This is a simpler version of the BVH file format which basically exports local coordinates.

Note: A certain number of fixed points (specification) is also required for exporting data in BVA file format. See exporting data in BVH format for a description of these points.

Please use the "BVA.SMP" file supplied with this software as a template.

Simi Textexport for the SmJStick Java Applet (*.SMJ)

Exports the data in SMJ file format. This SMJ file format, which has been specially developed by Simi, can be read in by the Simi SmJStick Java applet. This applet allows line drawings from Simi Motion to be displayed in Internet browsers. See www.simi.com for more details and up-to-date information about the applet. A certain number of points in the specification is not required.

Autodesk DXF (*.DXF)

Exports the data in DXF file format. It is only possible to transfer the X/Y/Z coordinates and not any rotation data in this file format. This means that any number of points can be used and defined in the specification. There are many animation and simulation programs (3-D Studio, Softimage etc.) which support the import of DXF files.

Character Studio (*.CSM)

Exports the data in CSM file format.

CSM file format (Character-Studio-Markerfile) is a special format for passing on motion data to animation programs (specifically for Character Studio 2.x). Here the translation and rotation vectors instead of the coordinates of the calculated points are exported. This allows a very good scalability of the skeleton after it has been imported, which means that this can then be easily
transferred to animated characters (in Character-Studio: bipeds). Note: a certain number of points (specification) is required for exporting the data in CSM file format. Please use the "CSM.SMP" file provided with the software as a template.

The following points are required:

<table>
<thead>
<tr>
<th>CSM</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFHD</td>
<td>Left fore of head</td>
</tr>
<tr>
<td>LBHD</td>
<td>Left back of head</td>
</tr>
<tr>
<td>RBHD</td>
<td>Right back of head</td>
</tr>
<tr>
<td>RFHD</td>
<td>Right fore of head</td>
</tr>
<tr>
<td>CLAV</td>
<td>Upper chest</td>
</tr>
<tr>
<td>STRN</td>
<td>Center chest</td>
</tr>
<tr>
<td>LFWT</td>
<td>Left front of waist</td>
</tr>
<tr>
<td>LBWT</td>
<td>Left back of waist</td>
</tr>
<tr>
<td>RBWT</td>
<td>Right back of waist</td>
</tr>
<tr>
<td>RFWT</td>
<td>Right front of waist</td>
</tr>
<tr>
<td>C7</td>
<td>Neck</td>
</tr>
<tr>
<td>T10</td>
<td>Center back</td>
</tr>
<tr>
<td>SACR</td>
<td>Lower back (optional)</td>
</tr>
<tr>
<td>LKNE</td>
<td>Left outer knee</td>
</tr>
<tr>
<td>LKNI</td>
<td>Left inner knee (optional)</td>
</tr>
<tr>
<td>LANK</td>
<td>Left outer ankle</td>
</tr>
<tr>
<td>LHEL</td>
<td>Left heel (optional)</td>
</tr>
<tr>
<td>LMT5</td>
<td>Left outer metatarsus</td>
</tr>
<tr>
<td>LTOE</td>
<td>Left toe</td>
</tr>
<tr>
<td>RKNE</td>
<td>Right outer knee</td>
</tr>
<tr>
<td>RKNI</td>
<td>Right inner knee (optional)</td>
</tr>
<tr>
<td>RANK</td>
<td>Right outer ankle</td>
</tr>
<tr>
<td>RHEL</td>
<td>Right heel (optional)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>RMT5</td>
<td>Right outer metatarsus</td>
</tr>
<tr>
<td>RTOE</td>
<td>Right toe</td>
</tr>
<tr>
<td>LSHO</td>
<td>Left shoulder</td>
</tr>
<tr>
<td>LELB</td>
<td>Left outer elbow</td>
</tr>
<tr>
<td>LILB</td>
<td>Left inner elbow (optional)</td>
</tr>
<tr>
<td>LWRA</td>
<td>Left inner wrist, near the thumb (alternative to LWRE)</td>
</tr>
<tr>
<td>LWRB</td>
<td>Left outer wrist, opposite the thumb (alternative to LWRI)</td>
</tr>
<tr>
<td>LFIN</td>
<td>Left hand</td>
</tr>
<tr>
<td>RSHO</td>
<td>Right shoulder</td>
</tr>
<tr>
<td>RELB</td>
<td>Right outer elbow</td>
</tr>
<tr>
<td>RILB</td>
<td>Right inner elbow (optional)</td>
</tr>
<tr>
<td>RWRA</td>
<td>Right inner wrist, near the thumb (alternative to RWRE)</td>
</tr>
<tr>
<td>RWRB</td>
<td>Right outer wrist, opposite the thumb (alternative to RWRI)</td>
</tr>
<tr>
<td>RFIN</td>
<td>Right hand</td>
</tr>
</tbody>
</table>

If not otherwise indicated, the center of the joint is required. Those points marked "optional" are not obligatory, i.e. they can be deleted from the specification before the data is exported (and also before being captured with Simi Motion).

**Lightwave Scene (*.LWS)**

Exports the data in LWS file format. Export in this file format does not yet support all the possibilities available with a LWS file. Only the coordinates (X/Y/Z) are therefore saved and not any rotation information. This means that any number of points can be used.

**Filtering of 3-D Coordinates**

<table>
<thead>
<tr>
<th>Glättung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keine Glättung</td>
</tr>
<tr>
<td>Geringe Glättung</td>
</tr>
<tr>
<td><strong>Normale Glättung</strong></td>
</tr>
<tr>
<td>Starke Glättung</td>
</tr>
</tbody>
</table>

It is possible to define how the coordinates should be filtered in this menu.
Contents

Contents..........................................................................................................................1

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Installation

DataForce allows analog and digital data to be read into the computer and displayed in Simi Motion.

It supports the product families of the manufacturers

- Data Translation (e.g. DT-3000-series)
- National Instruments (E-series)

Please consult the Simi-Team in order to select the best A/D-converter for your application or to find out whether your existing hardware is supported.

A/D-converters can be connected to the computer in different ways:

- as a PCI-card
- as an external device with USB connection
- as an external device with Firewire (IEEE-1394) connection

Hardware

It is recommended to install the hardware driver first and to connect the A/D-converter afterwards, since then the operating system makes no incorrect automatic plug’n’play assignments.

Please notice that PCI-cards often need an interrupt of their own.

Note for the Data Translation DT-3000-series:
If (using Win2000) – especially with sampling rates of 1000 Hz or more – the system is very unstable (blue screen), the computer should be set to “Standard PC” (not ACPI), and a hardware interrupt should be exclusively assigned to the Data Translation card.
Data Translation

The latest drivers are available on the Simi installation CD or on the internet (www.datatranslation.com/support).

Start the “setup” which is suitable for you operating system (98/2000/ NT4) and follow the instructions. If there is more than one Data Translation card in the system you may select a card or change its name in the control panel. In this case the desired card name has to be written to the INI-file (see appendix) as well.

By default the first card in the system is used.

National-Instruments

The latest drivers are available on the Simi installation CD or in the internet (www.ni.com). Start the “setup” and follow the instructions.

Software

Simi-Software

Please take the exact order of the software installation from the “Readme”-file on the Simi installation CD.

Settings in the “SmImpDT.ini” configuration file

The file SmImpDT.ini is shipped on your Simi installation CD as SmImpDT.org. With the first usage of Data Force it is renamed to SmImpDT.ini automatically and usually saved at “C:\Program Files\Common Files\Simi”.

This file contains information about the connected devices (Force platforms, EMG, …) and has to be adopted to the available measurement configuration. The detailed options are described in the appendix of this manual.
Using Simi DataForce

DataForce is the Simi Motion module for analog data acquisition. Analog signals are converted to digital data by means of an A/D converter board. In this way analog data from force platforms, EMG or treadmills can be imported into and edited in Simi Motion.

Data Acquisition

After A/D board has been installed and all the settings in the SmImpDT.ini file have been specified, measurements can be carried out and the data subsequently processed in Simi Motion.

The Acquire Data command in the Project menu opens the A/D Import dialog box.

In this dialog box the device configuration can be selected. Channel assignments and defaults for each configuration are specified in the SmImpDT.ini file.
The duration and the frequency of the measurement can be entered here. Click on the button Next to proceed.

If a Kistler force platform is included in the selected configuration, a dialog box appears to select the amplifier’s ranges, as explained in the Kistler manual.

![A/D Import](image)

You may use a trigger to start your measurement. In this case the system is waiting for the vertical ground reaction force to become more than/less than a specified number (in Newton). Data acquisition will start automatically as soon as this condition becomes true.

Pre-trigger time allows to collect data a certain time before that event. Click on the Next button to proceed.
This box consists of a preview window in which the current measurement is displayed. This way the user can check a measurement immediately and decide whether it is usable or not. In the lower half of the box are buttons to control the measurement.

1.1.1.1.1 Start
Starts a measurement with the previously defined duration. During the measurement this button (with the caption “Stop”) is used to stop the measurement. A new measurement overwrites previously collected data.

1.1.1.1.2 Start (infinite)
Starts an infinite measurement. This measurement can be stopped (caption changes to “Stop”) at any time. After stopping the last captured data is available. A new measurement overwrites previously collected data.

1.1.1.1.3 Reset
The amplifiers can be reset before a measurement is started (especially Kistler force platforms). This button only appears when manual reset is activated in the device configuration (SmImpDT.ini).

1.1.1.1.4 New measurement
This button only appears when the corresponding option is activated in the device configuration (SmImpDT.ini). An additional measurement is initialized and all settings are taken over. The previous measurement remains preserved. The measurement itself has to be started with “Start” or “Start (infinite)”
1.1.1.1.5 Close

Closes the measurement dialog box.

Data analysis

All collected data is saved in appropriate folders in the project tree. For example, there are two folders for force platforms: one is the folder which contains the raw data and the other is a folder which contains the calculated force platform data.

All data can be processed with the Simi Motion functions and displayed or exported as any other data.

Create a force vector

Right-click the folder with your calculated force platform data and select “Create 3D force vector”.

Simi DataForce - 7
A new folder will appear in the project tree. You can drag this folder to the desktop to open a stick diagram of the vector.

Hint: Use “Trace of Connections” in your stick diagram to visualize the vector.

**Processing of EMG data**

Simi Motion offers a special EMG module. Please learn more about it from the corresponding manual.
Settings in SmlImpDT.ini

The file is usually located in

C:\Program Files\Common Files\Simi

and has the same structure as any other Windows INI file. It can be edited using any text editor.

For each device there is a section (at the end of the file) which describes for example the name of the channels and the type of the device.

Examples: Force platform, EMG, goniometer

The “configuration” section corresponds to a measurement configuration, i.e. a combination of devices.

Examples:
- Force platform
- EMG
- Force platform and EMG
- EMG and goniometer
- 2 force platforms and EMG

General Settings (“General”)

This section includes basic settings as well as the A/D-converter and its options.

<table>
<thead>
<tr>
<th>[General]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Version=100</td>
<td>Version number (reserved)</td>
</tr>
<tr>
<td>ValuesChangedInterval=200</td>
<td>Interval in [ms] for display refresh</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DefaultDirectory=D:\</td>
<td>Default directory</td>
</tr>
<tr>
<td>Log=</td>
<td>Filename for protocol file</td>
</tr>
<tr>
<td>Pulse=1,100,50</td>
<td>Signal generation (e.g. for triggering cameras)</td>
</tr>
<tr>
<td></td>
<td>type, hertz, percentage</td>
</tr>
<tr>
<td></td>
<td>type: 0=off, 1=low-high, 2=high-low</td>
</tr>
<tr>
<td></td>
<td>percentage: ratio low/high</td>
</tr>
<tr>
<td>ADConverter1=DT</td>
<td>Possible values:</td>
</tr>
<tr>
<td>ADConverter2=</td>
<td>DT=Data Translation</td>
</tr>
<tr>
<td></td>
<td>NI=National Instruments</td>
</tr>
<tr>
<td></td>
<td>TESTMODE=no hardware</td>
</tr>
<tr>
<td></td>
<td>(simulation)</td>
</tr>
<tr>
<td></td>
<td>If only one board is available</td>
</tr>
<tr>
<td></td>
<td>“ADConverter=” without any index can be used.</td>
</tr>
<tr>
<td>Board1=</td>
<td>Possible values:</td>
</tr>
<tr>
<td>Board2=</td>
<td>National Instruments boards:</td>
</tr>
<tr>
<td></td>
<td>Number of the board as displayed in the NI-configuration utility program</td>
</tr>
<tr>
<td></td>
<td>Data Translation boards:</td>
</tr>
<tr>
<td></td>
<td>Name of the board as displayed in Windows control panel (e.g.</td>
</tr>
<tr>
<td></td>
<td>“DT3002(00)”</td>
</tr>
<tr>
<td></td>
<td>If only one board is available</td>
</tr>
<tr>
<td></td>
<td>“Board=” without any index can be used.</td>
</tr>
<tr>
<td>FirstChannel1=1</td>
<td>For multiple boards only: First channel of each A/D board.</td>
</tr>
<tr>
<td>FirstChannel2=</td>
<td></td>
</tr>
<tr>
<td>BufSizeHigh=50</td>
<td>(Data Translation only) Buffer size for data transfer from the A/D board to</td>
</tr>
<tr>
<td></td>
<td>the software. Defines how many times per second a data block is sent.</td>
</tr>
<tr>
<td></td>
<td>It is recommended to decrease this</td>
</tr>
</tbody>
</table>
Available Configurations

All available configurations are described in this chapter. All descriptive names are user defined.
If the value 0 is given, the configuration is hidden, if 1 is selected it is displayed.

<table>
<thead>
<tr>
<th>Configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td>KMP1=1</td>
</tr>
<tr>
<td>KMP2=0</td>
</tr>
</tbody>
</table>

Configuration Details

A separate section is required for each configuration specified in the “Configurations” section. Each section has the same name as the configuration.

<table>
<thead>
<tr>
<th>[KMP1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name=2 force plates</td>
</tr>
<tr>
<td>Text=Channels 1-8: force plate 1</td>
</tr>
<tr>
<td>Channels 9-16: force plate 2</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>DefaultSeconds=3</td>
</tr>
<tr>
<td>DefaultXY=0</td>
</tr>
<tr>
<td>DefaultZ=0</td>
</tr>
<tr>
<td>DefaultTrigger=0,0.2,10,3</td>
</tr>
<tr>
<td>ShowData=1+2+3, 4+5+6, 7+8+9, 10</td>
</tr>
<tr>
<td>ShowDataFactor=1, 1, 1, 2</td>
</tr>
<tr>
<td>ShowDataName=Fz,Fy,Fx,Motor</td>
</tr>
<tr>
<td>ShowDataColor=255/0/0, 0/128/0, 0/0/255, 128/0/0</td>
</tr>
<tr>
<td>DiaYMin=-10</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>DiaYMax=10</td>
</tr>
<tr>
<td>DiaColor=224/224/224</td>
</tr>
<tr>
<td>DefaultTC=0</td>
</tr>
<tr>
<td>TimeConstOn=1</td>
</tr>
<tr>
<td>LEDOn=1</td>
</tr>
<tr>
<td>RangeXY=0,1,2,3</td>
</tr>
<tr>
<td>RangeZ=0,4,8,12</td>
</tr>
<tr>
<td>RangeNameXY=1000 pC,5000 pC,10000 pC</td>
</tr>
<tr>
<td>RangeNameZ=50000 pC,5000 pC,1000 pC</td>
</tr>
<tr>
<td>Reset=1</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Offset=0</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>NewMeasurement=0</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>AutoName=1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>TimeFormat=</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
The following is a list of devices used. Two lines must be entered for each device: Device# and Channels#, whereby # is a consecutive number beginning with 1.

<table>
<thead>
<tr>
<th>Device1=DEV_KISTLER</th>
<th>Section name of the device (see “Device details” below). This name can be chosen by the user.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channels1=1,2,3,4,5,6,7,8</td>
<td>List of the A/D board channels used for this device.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device2=DEV_EMG</th>
<th>Section name of the second device.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channels2=9,10,11,12,13,14,15,16</td>
<td>Channels for device 2.</td>
</tr>
</tbody>
</table>

### Device Details

<table>
<thead>
<tr>
<th>[DEV_KISTLER]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name=Force platform</td>
<td>Device name</td>
</tr>
<tr>
<td>Magic=0x524C5046</td>
<td>Magic number (see note)</td>
</tr>
<tr>
<td>DefaultFrequency=300</td>
<td>Acquisition frequency (default value)</td>
</tr>
<tr>
<td>NumberOfChannels=8</td>
<td>Number of channels</td>
</tr>
<tr>
<td>Channel1=Fx12</td>
<td>Name of Channel 1</td>
</tr>
<tr>
<td>Channel</td>
<td>Name of Channel</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Channel 2</td>
<td>Fx34</td>
</tr>
<tr>
<td>Channel 3</td>
<td>Fy14</td>
</tr>
<tr>
<td>Channel 4</td>
<td>Fy23</td>
</tr>
<tr>
<td>Channel 5</td>
<td>Fz1</td>
</tr>
<tr>
<td>Channel 6</td>
<td>Fz2</td>
</tr>
<tr>
<td>Channel 7</td>
<td>Fz3</td>
</tr>
<tr>
<td>Channel 8</td>
<td>Fz4</td>
</tr>
</tbody>
</table>

Samples from each channel can be manipulated using the following formula:
\[
\text{value} = (\text{value + offset}) \times \text{factor}.
\]
Different offsets and factors can be specified for each channel. (Default=0)

<table>
<thead>
<tr>
<th>Offset</th>
<th>Factor</th>
<th>Gain</th>
<th>Operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,0,0,0,0,0,0,0</td>
<td>10,10,10,10,10,10,10,10</td>
<td>1,1,1,1,1,1,1,1</td>
<td>1</td>
</tr>
</tbody>
</table>

See “Offset” (Default=1)

Defines the gain of the A/D converter.
Data Translation: ignored
National Instruments: -1 (0.5), 1, 2, 5, 10 etc.

Defines which signal (0,1) triggers the „Operate“ state (Reset is the other value)

The following ONLY applies to Kistler force platforms (Magic=0x524C5046)

<table>
<thead>
<tr>
<th>DefaultOffsetX</th>
<th>Distance in the X-direction in mm of the plate origin to the common origin for systems with more than one plate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DefaultOffsetY</td>
<td>Distance in the Y-direction.</td>
</tr>
<tr>
<td>DistanceX</td>
<td>Distance in the X-direction in mm of the force sensors from the plate.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Distance Y=210</td>
<td>Distance in the Y-direction in mm of the force sensors from the plate origin.</td>
</tr>
<tr>
<td>Distance Z=-45</td>
<td>Distance in the Z-direction in mm of the force sensors from the plate origin.</td>
</tr>
<tr>
<td>Version=1</td>
<td>Version number (only for Kistler force platforms)</td>
</tr>
<tr>
<td>Sens X=-3.71</td>
<td>Calibration value for X-forces. This is defined in the Kistler calibration sheet. Only valid for version=0</td>
</tr>
<tr>
<td>Sens Y=-3.71</td>
<td>Calibration value for Y-forces</td>
</tr>
<tr>
<td>Sens Z=-3.87</td>
<td>Calibration value for Z-forces</td>
</tr>
<tr>
<td>Range 4=1.907;1.925;1.937;1.899;0.969;0.957;0.960;0.970</td>
<td>8 calibration values for range 4; these are defined in the Kistler calibration sheet. Only valid for version=1</td>
</tr>
<tr>
<td>Range 3=3.814;3.850;3.875;3.797;1.938;1.914;1.920;1.941</td>
<td>8 calibration values for range 3</td>
</tr>
<tr>
<td>Range 1=38.114;38.486;38.579;37.821;19.310;19.082;19.127;19.337</td>
<td>8 calibration values for range 1</td>
</tr>
</tbody>
</table>
## Device type (“Magic”)  

The “magic” numbers define the device type and thereby the resultant data type:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x524C5046</td>
<td>Kistler force platform, 8 raw data channels from which the software calculates the force, torque and point of application of the force.</td>
</tr>
<tr>
<td>0x495454D1</td>
<td>AMTI force platform, 6 data channels</td>
</tr>
<tr>
<td>0x2D474D45</td>
<td>EMG device, any number of channels. The software can automatically apply various EMG-specific operations.</td>
</tr>
<tr>
<td>0x324C5046</td>
<td>Special design: treadmill containing two force platforms, 18+2 raw data channels, from which the software calculates the force.</td>
</tr>
<tr>
<td>0x344C5046</td>
<td>Special design: treadmill containing four force platforms, 12+4 raw data channels from which the software calculates the force.</td>
</tr>
<tr>
<td>0x524A4B53</td>
<td>Special design for ski jumping.</td>
</tr>
<tr>
<td>0x52455355</td>
<td>Data without any special automatic processing, user-defined number of channels.</td>
</tr>
</tbody>
</table>
Simi Motion Manual : Triggerbox
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Chapter 1. Overview

Capturing synchronously is an essential part of exact and high-quality analyses. High speed capturing of video data is supported directly in Simi Motion using high speed industry cameras from manufacturers like Basler, Vosskuhler and others. If more than one camera is used, each picture must be taken exactly at the same point of time in every camera. To do this, an external trigger signal is used. It tells the cameras to capture one frame and reaches every camera at the same time. The trigger signal is generated from the Simi Triggerbox, which must be connected to each camera separately. This manual describes how to connect the cables and to make the correct settings in the software.
Chapter 2. Step-by-step guide

Setup

This guide will enable you to connect the hardware easily so that you can quickly start with your first analysis. The hardware setup consists of installing the driver and connecting the cables.

Installing the driver

The first thing to do is to install the device driver for the triggerbox. The device driver can be found on the CD that you received with your Simi product. To install the driver, double-click on the appropriate executable. A window like the one in figure 1 will appear. Now, follow the instructions on the screen and finish the driver installation.

**Caution**

Please do not connect any cables yet. Install the driver first.

---

![Figure 1. Driver installation](image)

Connecting the triggerbox
Connect the triggerbox to the computer by using the USB cable that is supplied with the triggerbox. Plug one end of the cable into the triggerbox and the other one into an USB port on your computer (see figure 2).

Figure 2. Connect the USB cable

If you plan the use more than one computer for capturing the cameras, you can connect the triggerbox to any of these computers.
Figure 3. New hardware detected

After connecting the USB cable to the computer, a window like the one in figure 3 will appear. Choose “Install software automatically” and follow the instructions on the screen to install the new hardware. When the setup of the hardware has finished, you can make sure the triggerbox is installed correctly by checking with the device manager. To do this, click on the Start button, then on Settings and on Control Panel and on the System icon. After that, click on Hardware and on Device manager. The triggerbox should appear as shown in figure 4.
Connecting the cameras

In the last step of the hardware setup, connect the cameras to the triggerbox with the trigger cables. Connect every camera separately to the port of the triggerbox shown in figure 5.
Capturing in Simi Motion

Now the hardware setup is complete. To use the trigger to capture video from the cameras, you will have to make some final settings in Simi Motion. These configuration settings will be described in the following paragraphs.

Settings in Simi Motion

In Simi Motion, open the video capture window by pressing F10 or clicking on the Capture video button in the main toolbar. In the capture window, click on the button Camera-trigger configuration. A new window will open up which is used to configure the trigger signal. Please see figure 6 to get an overview.
Figure 6. Configure trigger signal

Select the option Capture one image at a time on trigger signal so that each frame will be triggered by the signal individually. Then, choose "DT9817" as the device and set the frequency to the value that the cameras support, e.g. "100,00 Hz" with Basler 600 series cameras.

These settings apply to the computer where the triggerbox is connected to. On any other computers with cameras, choose "External signal" as device.

The other settings ("Signaled ratio" and "Timer/counter") should be left as they are, normally with "1%" and "0".

Testing the settings

The settings can be tested by using the Start and Stop buttons. If these succeed, the values are correct and can be used for capturing.

Capturing video

The video capture process with triggered cameras does not differ from the untriggered normal video capture process.
How to set up the real-time force vector overlay

1. Calibration
   1. Capture a video image from your calibration frame positioned on top of the force plate and register it as 3D calibration video. It is important to know the relative position of the force plate to the calibration frame. Your force plate’s center will be the origin of the coordinate system.
   2. Calibrate the camera: enter the coordinates of your 3D calibration system. There are two important things to take into account:
      a. Make sure to enter the coordinate system with its origin in the center of the force plate.
      b. Make sure to match the direction of the force plate’s coordinate axes. This is important for correct positioning and orientation of the force vector. Note: Many force plates have the z axis pointing down. In order to have the z axis point up it is required to turn one axis by 180° (in this case the x axis).

![Force plate coordinate system.](image-url)
Calibrated coordinate system with z-axis pointing up.
Coordinates of the calibration system from the example.
2. Force Vector Overlay

1. Once you have performed the calibration, you can open the video capture screen again to view the live video stream.
2. Additionally, open the data acquisition window and choose the configuration of your force plate.
3. Start analog data acquisition in infinite mode. You should now see the live preview in the diagram.
4. Start the live overlay with the button shown in the screen shots.
5. You can now check easily if you calibration is correct. Just step on either of the four sides of the force plate – the force vector should go to the center of pressure. If your coordinate axes are pointing in wrong directions, the vector will go to the opposite side. You can easily change this in the coordinates of your calibration system and do the check again.
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Introduction

Since it is not possible to measure internal forces in humans without surgical procedures, Inverse Dynamics is used to estimate the forces and torques in the joints of the human body. To calculate the internal forces and torques, the human body is divided into 15 segments. The segments are the foot, shank, thigh, upper arm, lower arm, head, upper torso and lower torso connected by the joints of interest. The orientation and position of each segment is determined video-recording the marker set described in chapter six.

Internal forces and torques can be calculated using only marker positions as input (Winters, 1990). This method tends to produce noisy joint torques because angular accelerations are typically determined by twice differentiating motion data with respect to time and the differentiation process tends to amplify measurement noise. Introducing additional measurements in form of ground reaction forces, which are typically less noisy, the resultant joint torques tends to be more precise. It is not necessary but it is highly recommended to use this program in combination with one or two force plates.

The individual human properties such as joint axis locations and segment lengths are determined during a static standing trial. During the standing trial temporal markers are attached to the body, which can be removed during the dynamic trial.

The manual is divided into six chapters. The second one introduces the coordinate systems used to describe the body segment locations. The third chapter explains the input parameters and the fourth the output time curves and their clinical relevance. The fifth chapter outlines the protocol used to calculate Inverse Dynamics, which is the most important for the user. The last chapter describes the anatomical landmarks on the body where the markers are attached.

For a quick start it is recommended to go through the measurement protocol described in chapter five and look up the necessary references to the other chapters.
Coordinate Systems

The calibration frame determines the **global coordinate system** in which the three dimensional marker positions are described. The markers placed on anatomical landmarks on the body (chapter 6) determine the joints locations and the center of mass for each body segment. Further from the markers positions a **local coordinate system** is defined for each body which origin is in the centre of mass of the respective segment. These local coordinate systems for all bodies are shown in figure 1. They are determined based on four markers belonging to the respective segment with the following procedure: two vectors are defined vector A from the first to the second marker and vector B from the third to the fourth marker (the third and the first marker can be the same). The Z-axis is in the direction of vector A. The cross product between vector A and vector B determines the X-axis. The Y-axis is obtained by the cross product between the Z and the X-axis. In the default configuration (figure 1) the axis Z direction points in distal-proximal direction. The X-axis points from dorsal to frontal and the Y-axis direction is lateral to medial and medial to lateral for the right limbs and the left limbs respectively. It is possible to change the default axis directions, by changing the order of the markers to determine vectors A and B. For detailed information contact Simi GmbH.
Figure 1
The output data curves can either be described relative to the body local coordinate system or the global coordinate system. In the case of the local coordinate system the time curves are often easier to interpret, e.g. when the knee extension flexion angles are described in the local body coordinate system of the shank, the calculated angles can be compared to the angles measured with a goniometer attached to the shank and the thigh. When the joint angles are described in the global system, the output depends on the actual running direction.
Input Datasets and Parameters

Digitized marker coordinates

First of all the recorded markers must be digitized. For the static standing trial the digitized marker trajectories are averaged so that at least the markers of one time step must be completely digitized. During the dynamic trial it is not necessary to digitize the whole video sequence. In the case one force plate is used it is enough to digitize the swing phase before the foot is in contact with the force plate (figure1 left side) until the swing phase after ground contact with the force plate (figure 1. right side). Using two force plates you would start to digitize before the right leg touches the right force plate until the left leg leaves the left force plate. The program automatically chose the time interval when the first time all markers 3D coordinates are digitized to the point when a certain amount of markers are not digitized any more (the amount of markers is given by the parameter “Markers missing to stop”). When data points are missing in between, the gaps are filled up automatically using a 5th order spline interpolation. Setting the parameter “Markers missing to stop” to zero no gaps in between are allowed.
When using one or two force plates, the location of the force plates with respect to the calibration frame must be determined. This is done during the standing trial putting four markers on each edge of the force plate. During the digitizing process the four markers must then be assigned so that their back to front direction is along the positive Y direction of force plate given by the manufacturer. The right to left direction is along the positive X force plate direction. In figure two there are two force plates shown which are from different manufacturers defining their force plate coordinate systems in different directions so that at the second plate for the left leg, the back to front direction markers are not any more aligned with the running direction. The markers on the force plate are temporal, they are only required during the standing trial and can be removed during the dynamic trial.

The forces of the right and left force plate are applied to the right and left leg respectively so that it is important to check that the right leg touches the right force plate and the left leg the left force plate.

The manufacturers force coordinate system must be “right handed” with Z direction pointing into the ground. The center of pressure of the plate must be
defined relative to the center of the force plate in the directions described above.

**Figure 2**

**Subject name**
Name of the subjects performing the trials is used to name the recorded trials.

**Body height**
This is the whole body length of the subject in units **Meter**. The body height is used to calculate segment dimensions based on NASA regression equations (NASA Reference Publication, 1978).

**Body mass**
This is the whole body mass of the subject in units **Kilogram**. The body mass is used to calculate the segment masses and Inertia properties based on NASA regression equations (NASA Reference Publication, 1978).
Subject gender
Since the segment mass calculation mentioned in the previous parameter is different between man and woman the gender must be given “w” means woman, man is “m”.

Marker radius
To calculate the surface of the force plate the marker radius of the force plate markers must be known (attention not the diameter!!) it is given in units Meter.

Markers missing to stop
When not the whole sequence is digitized the calculation is limited to a time window where the first time all markers exist until a certain amount of markers in absolute values given by this parameter is not available anymore. E.g. markers missing to stop are two then the calculation time frame ends when more than two of the markers are not available any more. E.g. using eight markers in the dynamic trial, the timeframe starts when all eight markers are visible the first time and ends at that time when less than six markers 3D coordinates are digitized.

Force threshold
This value given in Newton is used to detect force plate contact. When the absolute value of the force vector is lower than the threshold given, the moment arm of the external force is set to zero. This is done because the center of pressure is not zero when the force plate is unloaded. You can observe the effect of this parameter setting it to zero and plotting the external force moment arm.

Model stiffness
This Parameter changes the model based filtering and with that says something how stiff a model is. With other words this setting defines how far a marker can move away - with fixed expenditure of force - from its segment. The value lies between zero (lose) and one (firm) and is to be seen as a percentage value for the surface integrity of the object.
Output datasets and how they are calculated

From the inverse dynamics calculation resulting 10 output datasets over time, the datasets are calculated during a certain time window dependent on the amount of digitized markers described in chapter three. The angles, forces and torques output are in local or global coordinates (chapter two), however local coordinates are recommended.

The angle output is in cardan angles alpha, beta, gamma which rotates around the X, Y and Z axis respectively (Shabana, 2001). Cardan angles have the unpleasant property to be singular when beta is a multiple of 90 degrees. This is not a problem for the calculated forces and torques since the inverse dynamics calculation is based on the use of rotation matrices (Shabana, 2001). The singularity is only a problem for the output function calculating cardan angles from rotation matrices. A solution is given in the documentation of the joint angles dataset in the following.

The internal constraint forces, torques and muscle torques are calculated determining the Newton-Euler equations (Shabana, 2001) for each body segment and solving the coupled equations for all bodies including the external forces of the force plate. However, the introduction of additional force data provides more equations than can be satisfied. This over determinacy is avoided by discarding the acceleration measurement of the head segment. Joint Centers:

Center of mass:

The location of the center of mass is determined with respect to the joint centers based on regressions equations (NASA Reference Publication, 1978). The centre of mass acceleration is obtained differentiating the data set twice with respect to time. These accelerations are then used in the Newton equations (Shabana, 2001) to determine the internal constraint forces. Since the differentiation process tends to amplify measurement noise the noise found in the center of mass accelerations is also found in the internal force data sets.
when the mass of the segment of interest is considerably high and the point of force application is not very close to this segments e.g. the hip constraint forces are considerably noisy compared to the foot because the mass of the thigh is higher than those of the foot. The unit is **Meter**.

### Joint center:

The location of the joint centers for the ankle, knee elbow and wrist joint are determined as the midpoint of a line connecting the lateral and medial marker of the respective joint.

The remaining joints at Hip Shoulder, Neck and between pelvis and abdomen and abdomen and thorax are each treated in a more complex way explained in the following.

### Hip joint:

The hip joint centre is derived using a hybrid method based on an experimental review of a number of previously used methods (Bell, 1990). This method uses the left and right anterior spina iliaca superior (ASIS) markers, L4 marker, and the greater trochanter markers.

First we must account for the radius of the markers placed on the left and right ASIS. The real marker centroid is not at skin level, so that intermediate virtual markers on the skin level are created and used for the calculation instead of the real ASIS markers.

Then an ASIS coordinate system figure 4 is created with the origin in the left ASIS skin level marker and the XY plane in the plane of the skin level left and right ASIS and the L4 Markers.

The location of the hip joint centre is located in the ASIS coordinate system in Y direction 14% medial of the ASIS skin level marker. In Z direction 30% distal of the ASIS skin level marker. The length is normalized on the inter-ASIS distance. The X direction is those of the respective greater trochanter marker described in the ASIS coordinate system.
**Lumbar spine joint:**

The joint between the body pelvis and the body lumbus is calculated using a virtual marker midasis located the middle of a line connecting the right and left asis markers. The lumbar spine joint is positioned in the middle between midasis and l4.

**Thoracic spine joint:**

The joint between the body lumbus and the body thorax is located in the middle between markers processus xiphoideus and Th 8.

**Neck joint:**

The joint between Thorax and the Head is located in the middle between markers
manubrium sterni and c7
Shoulder joint:

The shoulder joint centre is derived by using data provided by de Leva (1996b). The joint centre is 10.9% of upper–arm length below the acromion process. The upper-arm length is defined from the elbow joint centre to the top of the acromion process (figure 5).

**Figure 5**

Some of the markers required for the joints center determination e.g. the medial knee marker, are disturbing the movement during motion. For this reason the temporal blue markers shown in figure 4 are required. The position of these temporal markers is determined during a static trial, after this static trial they can be removed. During the dynamic trials the position of the
temporal markers can be calculated from the position of the non temporal markers.

**Body angles:**

The center of mass gives the location of the segments coordinate system with respect to the calibration frame. The body angles determine the rotation of the segment coordinate system with respect to the calibration frame. They are clinical not relevant but along the same line as for the center of mass the differentiated rotation matrices for the determination of the body angles are used in the Euler equations to determine the constraint and muscle torques. The angles are **cardan angles** (see definition above) and the unit is **Degrees**

**Joint angles:**

These angles are the cardan angles between two adjacent segments coordinate systems. They are normalized on the joint angles during the standing trial. This means that during the standing trial all joint angles are zero. Clinically most relevant are the knee and ankle joint angles in the body sagittal plane (cardan Y axis in local coordinates) and the ankle joint angles in the frontal plane (cardan X axis in local coordinates). These angles represent the foot plantar dorsal flexion, knee extension and flexion and the foot eversion inversion angles respectively. During gait, the joint angles do usually not approach 90 degrees where the singularity problem of the cardan angles appears. However to avoid this problem in other movement situations you can change the zero joint angle definition during the standing trial to a seated trial so that e.g. the new knee angle zero position is not the extended it’s a flexed knee. Another possibility would be to switch to Euler angles close to the singular point, or use helical axis approach (Woltring, 1994). Since these angle definitions are rather mathematical of nature and difficult to interpret they are not implemented to avoid too much program input overhead for the user. The unit is **Degrees**.
External forces:

This is nothing else than the ground reaction force acting on the left or right foot. Using two force plates you can check again if the force of the right and left force plate is applied on the right and left leg respectively.

External momentarm:

This is the distance between the point of application on the force plates and the center of mass of the respective foot segment.

External torques:

The external torque on the foot caused by the ground reaction force is the cross product between the moment arm and the ground reaction force, plus the free moment in Z direction of the force plate acting on the body.

Internal joint constraint forces:

These forces are acting between two body when their motion is constrained by a joint. When the output option is switched to local, all internal forces are given with respect to the local coordinate system of their distal body, e.g. for the hip joint constraint forces are given with respect to the thigh and the ankle joint forces with respect to the foot.

Internal joint constraint torques:

The constraint torque is the cross product of the distance of the segments center of mass to the joint center and the constraint force.

Internal muscle torques:

Beside the passive constraint forces that would be in any mechanical system connected by spherical joints, there exists additional torques due to active muscle actions. These are the resultant joint torques summed up over all
muscles acting around a joint. Resultant means when the joint torque output is zero the muscles can still have a lot of force when the agonist and antagonist generate the same torques in opposite directions. This parameter can be used to discuss the mechanical torque necessary to move the body in a certain way.

Inverse dynamics computation of constraint forces and resultant muscle torques in **highly dynamical movements** often leads to improper peaks in the constraint forces which can not be generated from the human body in this short time (van den Bogert 1996). The Authors suggest to use an appropriate filter for the ground reaction forces. However in case of improper peaks we first suggest the user to check the consistency of the ground reaction forces. Eg. the required force Plates center of pressure is sometimes out of the plate dimensions or oscillates during ground contact due to fixation of the force plates.
Measurement Protocol

Calibrate the cameras with a calibration frame.
Put the markers (chapter six) on the body and check if you did not forget one, count eleven markers on the subject recording a single leg and 53 using the whole body.

Record one static trial with all markers attached to the body additional four markers must be on the edges of each force plate. The person must stand still in its neutral joint angle position shown in figure 3.
Remove temporal markers and force plate markers.
Record all running trials videos and force plate datasets.
Digitize the static trial, be careful with the force plate markers directions (chapter three). **Check the position of the digitized markers** e.g. that the left heel marker is really positioned at the left heel otherwise erroneous results can occur.

Digitize the dynamic trials videos during the time sequence of interest. It is recommended to **check the position of the digitized markers**.
Create 3D marker coordinates.
Set input parameters subject mass and gender and calculate inverse dynamics, the output datasets would then appear in the left window.
Marker-set

For the whole body model forty-five real markers are worn for the static trial plus four markers must be positioned on each force plate. Following this, all force plate markers are taken away and 12 markers are removed from the subject before the moving trials are performed. The markers, which can be removed, are indicated in blue color and brackets in the following list. In **practical applications** you are not interested in a whole body analysis e.g. when you are interested in the ankle, knee and hip joint angles and muscle torques of the right leg you can **reduce the amount of the markers** worn at the body to eleven. In this case you use marker one to eleven from the following list for the right leg in the static trial and remove three of them so that only eight markers are left in the dynamic trial and less cameras and digitizing time is required. The program detects the amount of available markers and automatically returns only the angles, forces, and torques for the leg where you put on the markers.

**Forefoot right/left:** directly over the 2nd metatarsal, approximately one or two centimeters posterior from its head so as to allow for the metatarso-phalangeal joints to flex without the marker being disturbed.

**(Foot tip right/left):** on the tip of the second toe, or on the front tip of the shoe.

**Heel right/ left :** on the posterior surface of the calcaneus with the marker hovering just above floor level when the foot is flat against the ground.

**Maleolus lateralis right/left:** tip of the lateral malleolus of the fibula.

**(Maleolus medialis right/left):** 5mm distal to the tibial malleolus.

**Shank right/left:** approximately half way up the anterior surface of the shank.

**Condylis lateralis right/left:** on the posterior convexity of the lateral femoral epicondyle.

**(Condylis medialis right/left):** on the posterior convexity of the medial femoral epicondyle.

**Spina iliaca anterior superior right/left:** directly on the anterior superior iliac spine.

**L4 :** on the lower back, mid-way between the posterior superior iliac spines.

**(Trochanter major right/left):** on the lateral hip placed over the greater trochanter.
**C 7:** on the superior palpable point of the spinous process of the seventh cervical vertebrae.

**Manubrium sterni:** on the front of the neck centrally on the collarbone (or clavicle) just below the throat, in level with the 7th cervical vertebrae.

**Processus Xiphoideus:** on the lower end of the breastbone.

**Th8:** placed on approximately the middle of the back directly opposite the Processus Xiphoideus marker.

**(Acromion right/left):** placed on top of the acromion process.

**Triceps right/left:** on the posterior surface of the upper arm, approximately 10-12 cm down from the glenohumeral joint (depending on length of arm).

**Biceps lateral right/left:** placed approximately in the middle of the lateral side of the upper–arm when the arm is held in the anatomical position.

**Head front side right/left:** the front head markers should be placed above the temples. It is recommended constructing a headband with all four head markers with all the markers equally distant to each other.

**Head backside right/left:** diagonally opposite the front head markers.

**(Elbow medial right/left):** placed on the medial epicondyle of the humerus.

**Elbow lateral right/left:** placed on the lateral epicondyle of the humerus.

**Wrist medial right/ left:** placed on the medial side of the wrist joint, near styloid process of ulna.

**Wrist Lateral right/left:** placed on lateral side of wrist joint, near styloid process of ulna.

**Hand:** just before the distal end of the 3rd metacarpal bone.

**(Right Force plate right front) on the right front edge of the force plate. See chapter three for the definition of front, back left right directions of the force plate .**

(Right Force plate left front) …

(Right Force plate right back) …

(Right Force plate left back)…

(Left Force plate right front) …

(Left Force plate left front) …

(Left Force plate right back) …

(Left Force plate left back) …
Figure 4
Literature


3D Ankle kinematics
Manual

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1. Introduction

To calculate the kinematics of the ankle joint, the human body is divided into four segments. The segments are the Hallux, Rearfoot, Talus, and Tibia connected by the joints of interest. The orientation and position of each segment is determined video-recording the marker set described in chapter five.

The individual joint axis locations are determined during a static standing trial. During the standing trial temporal markers are attached to the body, which can be removed during the dynamic trial.

The manual is divided into five chapters. The second one introduces the coordinate systems used to describe the joint center locations. The third chapter explains the calculation of the joint centers. The fifth chapter outlines the protocol used to calculate the ankle kinematics. The fifth chapter describes the anatomical landmarks on the body where the markers are attached.

2. Coordinate Systems

The calibration frame determines the global coordinate system in which the three dimensional marker positions are described. The markers placed on anatomical landmarks on the body (chapter 4) determine the joints locations and the center of mass for each body segment. Further from the markers positions and the joint centers, a local coordinate system is defined for each body which origin is in the proximal joint center of the respective segment. The local joint coordinate systems are determined based on four markers belonging to the respective segment with the following procedure: two vectors are defined, vector A from the first to the second marker and vector B from the third to the fourth marker (the third and the first marker can be the same). The Z-axis is in the direction of vector A. The cross product between vector A and vector B determines the X-axis. The Y-axis is obtained by the cross product between the Z and the X-axis. Then the X, Y and Z directions can be changed (+X+Y-Z) means the Z direction is negative. (+Y+X-Z) means X and Y are changed relative to the algorithm explained before. More information about orthogonal coordinate systems can be found in Shabana 2001.
Body | Triad Markers | Triad Rotation
--- | --- | ---

3. Joint center calculation

The location of the joint centers for the ankle, knee elbow and wrist joint are determined as the midpoint of a line connecting the lateral and medial marker of the respective joint. The remaining joints at Hip Shoulder, Neck and between pelvis and abdomen and abdomen and thorax are each treated in a more complex way explained in the following.

Knee joint:

The knee joint centre is derived as the midpoint of a line connecting the marker Condylus lateral and condylus medial.

Tibiotalar and Talocalcaneal Joint:

According to measurements of Inman (Inman 76), both The Tibiotalar and Talocalcaneal joint axes can be treated as hinge joints. The location of the joint centers as well as the direction of the joint coordinate system of this calculation is based on the measurements of Inman. The Axis of the Tibiotalar joint is oblique in the coronal plane and passes slightly distal to each maleolus. The axis passes through a point 11 mm frontal and 12 mm distal from the lateral maleolus with respect to the sagital plane, and 1 mm frontal and 16 mm distal from the medial maleolus. The definition of the sagital plane of the foot is shown in figure 1. Keep in mind that for an appropriate definition of the sagittal plane, markers Calcaneus posterior and Metatarsal23 are on the same level with respect to the ground. Marker Metatarsal0 and Metatarsal6 should also have the same level with respect to the ground. The position of the joint center is midway between the lateral and medial maleolus points with the corrections described above.
Fig 1. The sagittal plane of the foot is spanned by vector A (midline of the foot) and the cross product C between vector A and B. The Talocalcaneal axis is rotated about 23 deg. with respect to the midline of the foot.

The Joint center of the Talocalcaneal joint is 3.5 mm below the Tibiotalar joint, the Talocalcaneal joint axes is rotated 23 deg around vertical Vector C (figure 1) and 42 deg. around vector D (figure2).

Fig 2. The sagittal plane of the foot is spanned by vector A and C. between vector A and B. The Talocalcaneal axis is rotated 42 deg. around vector D.
**Hallux joint:**

The Hallux joint centre is located on the line connecting the marker Metatarsal0 and Metatarsal6 at 21% of the line length starting from Metatarsal0.

**4. Data output**

Body angles:
The body angles determine the rotation of the joint coordinate system with respect to the calibration frame. The angles are **cardan angles** (see definition above) and the unit is **Degrees**

Joint angles:
These angles are the cardan angles between two adjacent segments coordinate systems. They are normalized on the joint angles during the standing trial. This means that during the standing trial all joint angles are zero. The joint angles do usually not approach 90 degrees where the singularity problem of the cardan angles appears. However to avoid this problem in other movement situations you can change the zero joint angle definition during the standing trial to a seated trial so that e.g. the new knee angle zero position is not the extended it’s a flexed knee. The unit is **Degrees**.
5. Measurement Protocol

- Calibrate the cameras with a calibration frame.
- Put the markers (chapter six) on the body and check if you did not forget one, count eleven markers on the subject recording a single leg and 53 using the whole body.
- Record one static trial with all markers attached to the body additional four markers must be on the edges of each force plate. The person must stand still in its neutral joint angle position shown in figure 3.
- Remove the temporal markers
- Record all running trials videos and force plate datasets.
- Digitize the static trial, **Check the position of the digitized markers** e.g. that the left heel marker is really positioned at the left heel otherwise erroneous results can occur.
- Digitize the dynamic trials videos during the time sequence of interest. It is recommended to **check the position of the digitized markers**.
- Create 3D marker coordinates and joint angles.
### 6. Marker-set

For the ankle kinematics 13 real markers are worn for the static trial. Four markers are removed from the subject before the moving trials are performed. The markers, which can be removed, are indicated in blue color and brackets in the following list.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Marker</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hallux</td>
<td>On the first toe nail</td>
</tr>
<tr>
<td>2</td>
<td>(Metatarsal0)</td>
<td>medial beside of the first Metatarsal</td>
</tr>
<tr>
<td>3</td>
<td>Metatarsal23</td>
<td>between the second and third metatarsal, approximately one or two centimeters posterior from its head so as to allow for the metatarso-phalangeal joints to flex without the marker being disturbed.</td>
</tr>
<tr>
<td>4</td>
<td>(Metatarsal6)</td>
<td>lateral beside the sixth Metatarsal on the same height as Metatarsal0 from the ground.</td>
</tr>
<tr>
<td>5</td>
<td>Naviculare</td>
<td>In the area of the naviculare on the back of the foot. Exact positioning is not required since it is not used as an anatomical landmark.</td>
</tr>
<tr>
<td>6</td>
<td>Calcaneus lat</td>
<td>Lateral on the Calcaneus. Exact positioning is not required since it is not used as an anatomical landmark.</td>
</tr>
<tr>
<td>7</td>
<td>(Calcaneus posterior)</td>
<td>On the midpoint of the Heel on the same height as the Metatarsal23 from the ground.</td>
</tr>
<tr>
<td>8</td>
<td>Malleolus lateral</td>
<td>Tip of the lateral malleolus of the fibula</td>
</tr>
<tr>
<td>9</td>
<td>(Malleolus medial)</td>
<td>On the tip of the medial tibial malleolus.</td>
</tr>
<tr>
<td>10</td>
<td>Tibia</td>
<td>Approximately half way up the anterior surface of the shank</td>
</tr>
<tr>
<td>11</td>
<td>Tuberositas</td>
<td>Below the Patella on the lateral side.</td>
</tr>
<tr>
<td>12</td>
<td>Knee Condylus lateral</td>
<td>On the posterior convexity of the lateral femoral epicondyle.</td>
</tr>
<tr>
<td>13</td>
<td>(Knee Condylus medial)</td>
<td>On the posterior convexity of the medial femoral epicondyle.</td>
</tr>
</tbody>
</table>

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MANUAL

Simi Phaser

Reality Motion Systems GmbH
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Simi Phaser

With the phases model, movement flows can be divided, marked and compared into always recurring phases and cycles. There is a phase model for every movement. The corresponding model can be loaded at:

```
project→import→phases – model
```

Example: gait analysis

A new symbol will be added to the tool bar.

The dialog window Phase

This window will be opened if you click on the new button.

![Phase Dialog Window](image)
The exact determination of a starting point can be calculated in this window. If you activate the option „user defined“ the exact value appears at the marked spot (marked spot = stoke in the diagram).

Subsequently the corresponding phase of a group is selected.

In a specific group could be almost as many phases as you want. The movement limits the amount of phases in a group. After definition of all phases, these will be as follows; represented in the diagrams.

The different colors mark different phases.

As a further form of representation, you can indicate the phases also as rectangle.

To do this select Properties in the context menu of the diagrams. It opens itself a dialog window, in that you can click on the tab General in the combo box

*Indicate phases as a rectangle*
The phases window

To view the phases in tabular form, a window can be opened by clicking on \textit{view} \rightarrow \textit{new} \rightarrow \textit{phases}. This gives you the possibility to overview the phases.

![Phase Table]

The actual phase of the moment is emphasized in color.

The phases which are not needed anymore can also be deleted in this window. By right-clicking in this window, the following options can be selected.

\textbf{Delete}

The marked phase will be deleted.

\textbf{Delete all phases from here}

All the phases beginning with the marked one will be deleted.
Properties

Tool bar
The icons in the tool bar can be used for a better view of the phases. Phases can be deleted or it can be jumped to another phase by clicking on them.

Dialog window „cut into phases“

Data rows can be cut into phases in this window.

Procedure:
The data rows can be moved into the area Data \textit{(drop here)} by Drag and Drop. Data rows can also be added and removed by clicking on \textit{Add} or \textit{Delete}. The standard settings for the maximum number of cycles can also be changed. After all the details have been entered, the calculations for cutting into phases will be activated by clicking OK.
The dialog window „calculate envelope“

If a data row has already been cut into phases or cycles, the so called envelope can be calculated, e.g. the minimum or maximum of the phases or cycles, or the standard deviation.

Procedure:
Selection of the data row or even complete data trees. Enter the desired values and start the calculation by clicking OK.
The calculated values can be visualized in diagrams now.

Minimum, maximum and mean average value of a phase are shown in the diagram above.
Simi EMG

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Simi EMG

Data Acquisition

More details on this chapter can be found in the manual for the module „Simi DataForce‟.

After the installation of an A/D converter and the configuration of the SmImpDT.ini file data acquisition and data processing can be done.

According to your configuration EMG data can be collected separately or together with other data (force plate, goniometer, acceleration sensors).

Please start data acquisition by pressing the toolbar button „Acquire data‟ or by selection the menu item “Project – Acquire data”.

In both cases the dialogbox “A/D Import” appears.

Select your EMG device configuration and enter additional information about your measurement (duration in seconds, frequency).

Press “Next” to proceed.
The dialog box presents a diagram to preview the current measurement. You can easily and quickly decide if the measurement was successful.

At the bottom are the buttons to control the measurement. Operation and configuration of these buttons are described in the 'Simi DataForce’ manual.

Measured data will appear in your project tree in their appropriate folders and may be processed by special EMG functions or by all other functions featured in Simi Motion.

**Display Data**

EMG data can easily be displayed using diagrams: Drag and drop the data item to an empty place on your desktop in order to open a new diagram or to an existing diagram in order to add the item to this diagram.

A popup menu appears and offers two options: “Raw signal” and “Rectified signal”. The rectified signal is computed using the absolute value (full wave) of the measured data.
After calculation of additional (filtered) data, these new items can be displayed in the same way.

**Calculation of Additional Data**

Right-click any raw data item, select “EMG-processing” and a dialog box will appear, offering various operations to filter and process your data. Select one of the filter and processing options from the „Operation“ list.

**Preprocessing**

Signal quality can be enhanced by performing one or more steps of pre-processing.

**Highpass filter**

There are several predefined filter frequencies available. A highpass filter eliminates low frequencies, e.g. movement artifacts.

**Base line correction**

Removes a constant offset from the signal. The system determines the mean value for the complete signal and subtracts this value from each sample.

**Rectify (full wave)**

Calculates absolutes values of the signal’s samples. This option is predefined for most operations.
Operations

**LowPass Filter**
The lowpass filter (Butterworth filter) is applied twice (forward/backward) to eliminate phase shifting. The rectified signal is used for input.

**LowPass Filter 2nd Order**
The second order lowpass filter (Butterworth filter) is applied twice (forward/backward) to eliminate phase shifting. The rectified signal is used for input.

**Root Mean Square**
Average of the square values. Block size can be chosen without restrictions. The rectified signal is used for input.

**Mean Absolute Value**
Average of absolute values. Block size can be chosen without restrictions. The rectified signal is used for input.

**Signal Power**
Integrated frequency spectrum. Block size is automatically adjusted to a power of two. The raw signal is used for input.
A block size of 32 or 64 values is often used together with windowing (e.g. Hamming) to calculate an envelope graph.

**Median Frequency**
The median frequency is defined as that frequency that divides the power density spectrum in two regions having the same amount of power.
Block size is automatically adjusted to a power of two. The raw signal is used for input.

**Mean Frequency**
The mean frequency is that frequency where the product of the frequency value and the amplitude of the spectrum are equal to the average of all such products throughout the complete spectrum.
Block size is automatically adjusted to a power of two. The raw signal is used for input.
No Operation
No additional calculations are made. Use this option to do preprocessing or scaling only.

Parameters

Some operations require parameters like scaling, frequency, block size and windowing:

Scaling
There are several scaling options available:

None
Maximum of signal
The resulting graph is scaled in a way that its maximum value is equal to the maximum value of the input signal.
Percent
The resulting graph is scaled in a way that its maximum value is 100%.
Maximum of scaling value (%)
The resulting graph is scaled in a way that a given value is equal to 100%. The scaling value is specified in “Edit- Scaling”. This can be used to normalize the data to a MVC value.

Filter frequency
This is the cut-frequency for lowpass filtering.
Often values of about 30 Hz are used.

Block size
The block size specifies the number of values which are used for one instance of the operation. Please note that the block size has to be a power of two for signal power, median and mean frequency.
The option „Move blockwise“ reduces the amount of data.
The operations root mean square and mean absolute value are often used with block sizes of 50ms-100ms. For long measurements sometimes 1000ms are used.

Windowing
Windowing describes the weight of each value in your block of interest.
None (rectangle)
All values in the block (window) have the same weight.

*Triangle*

The center of the window is weighted with 100%. The values to the left and right are weighted less using linear decrease.

*Welch, Hamming, Hanning*

The weight of the window’s values is according to the respective authors.

*Sine*

The weight of the window’s values is according to a sine function.

**Menu**

**File**

All operation parameters can be saved as a „configuration“ (*.smc file) and reloaded with “Load configuration” in order to reuse them for another measurement.

If a configuration is needed for a sequence of measurements it can be set as the “Standard configuration”. For all subsequent measurements the specified operations will be automatically computed.

**Edit**

*Scaling*

A dialog box appears which allows editing of the scaling values.

You may enter user defined percentage values using the modify button or import these values from another measurement within the same project or from another project.

All settings can be exported for repeated usage.

Often an EMG signal is normalized to its percentage of a MVC value (maximum voluntary contraction). This value is determined by a separate measurement.

*Rename data*

*Delete data*

**View**

There are options to display raw data and/or calculated data. These options show effect in the preview diagram at the bottom of the dialog box.
Add EMG Data

After entering all parameters you can apply this operation on all raw data items by clicking “Add”. After changing the parameters you can modify the selected item by clicking “Apply”. Close the dialog box to create a new folder “Calculated EMG data” in your project tree.

Right-click the “Calculated EMG data” folder and select “EMG processing” to modify the parameters of your operations or to add more items.

Import of Noraxon files (optional)

Native Noraxon files can be imported. Select „Project-Import-Import Noraxon“ to load the measurements. You may then apply all operations on this data.
FastScan
Simi FastScan Foot Pressure Measurement

It is possible to trigger a video camera with a FastScan foot pressure measurement. To do so, a special trigger box is necessary. The option of producing an external trigger signal is available with the FastScan foot pressure measurement. This can be defined in the FastScan Recording Parameters. The external trigger signal can be connected to either of the serial ports COM1 or COM2. This trigger signal is converted to a high TTL signal using a special “Sync Box” from Simi. This TTL signal is then passed on to the audio input of the AV Master or another similar audio recording device. The TTL signal can then be recognized on the audio track of the video recording. This audio track is displayed in Simi Motion when the starting frame is defined. Using the audio track the video frame can be synchronized exactly with the beginning of the foot pressure measurement.

Making a video recording with a camera and foot pressure measurement

First of all the video frame as well as the foot pressure measurement must be calibrated as described in the instructions. Then FastScan must be set up for external triggering. To do so, select external triggering in the recording parameters. The serial port for the trigger signal (COM1 or COM2) must be selected next and the trigger box must then be connected to this port. The trigger signal is sent from the port to the trigger box, and the converted signal is then passed on from the trigger box to the audio input of, for example, the AV Master. The video camera is likewise connected directly to the video board using the appropriate input channels. It is important to ensure that the sound is recorded when the video recording is made. The setting for this should be selected in the capture software. To begin recording the movement with synchronized foot pressure measurement, use the video board, for example the AV Master, to start the
video camera. Once the video recording is running, the FastScan measurement can be started. As soon as the foot pressure measurement has been started, the system sends the trigger signal to the serial port and from there to the audio track of the video recording which is being made. The performance of the movement can be started when the foot pressure measurement has begun.

**Processing the Video with Simi Motion**

The normal procedure should be followed in the Simi Motion program. First of all a specification detailing the points to be captured and their connecting lines must be created. Then the video has to be calibrated. Before motion capture is carried out, the user is required to specify a starting frame. To do so, the audio track of the recorded video can be displayed. The start of the foot pressure measurement can be recognized by the trigger signal on this audio track. The system sends one HI signal per recorded frame, i.e. if a recording speed of 50 frames per second has been defined in the FastScan recording parameters, then 50 HI signals in a second will be recorded on the audio track. In Video Mode it is possible to select either complete frames (25 frames per second) or fields (50 fields per second) for the video image. This should not be changed after the starting frame has been specified and thereby the video synchronized with the foot pressure measurement, since the starting frame of the video would no longer match the starting frame of the foot pressure measurement. Once motion capture has been completed, this can be played through synchronously with the foot pressure measurement. To display the FastScan data, open the Tekscan/FastScan View in the View menu. An empty FastScan window is displayed. Click on this window with the right-hand mouse button to display a context-sensitive menu. Use the Properties command to load the relevant fsx files. This is done by clicking on the “...” button; in this way the appropriate file for the right and left side can be loaded. Since the video frame was synchronized with the FastScan measurement when the starting frame was specified, no further manual adjustment by means of the time offset is necessary. The foot pressure measurement matches the video frame and the line-drawing exactly when the captured movement is played through.
Medilogic

By the path View → New → Medilogic view you can open the still empty medilogic-window. If the medilogic data base cannot be found the path still has to be adjusted. If you now choose Open database in the context menu, a new dialog window appears in which the group and the name of the patient can be chosen. There even is the possibility to search for measurements by key points. The measurements which belong to the selected patient appear. If you mark one of the measurements and afterwards click on the button OK, the chosen measurement turns up in the representation window. Furthermore the medilogic properties which can be called up by the context menu can be adjusted.

With the scrollbar time offset it is possible to correct a deviation of time between the beginning of the video and the beginning of the pressure measurement.

In addition you can choose between the following kinds of representing:

Sensor representation
Landscape r
Landscape l
Landscape m
Isobaric representation
Content

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Pan, Tilt & Zoom

When doing open field analysis it is sometimes quite helpful to have the option to pan, tilt and zoom your camera.

- Pan (rotation of the camera around its vertical axis (“left-right”))
- Tilt (rotation of the camera around its horizontal axis (“up-down”))
- Zoom (enlargement or reduction of the camera’s view port)

The P/T/Z module allows all or single options to be used at the same time. It has been developed in cooperation with Dr. Volker Drenk, Leipzig, Germany.

Video recording

The reconstruction of correct 3D coordinates requires additional points (“reference points”) for each camera that is panned, tilted and/or zoomed.

You have to install additional markers (e.g. on the ground) in your movement’s space. These markers have to be measured according to the system of coordinates which is defined by your calibration system.

Make sure that two or more reference points are visible at any time during your movement. If one reference point disappears another point has to be selected. Reference points should be wide spread in your camera’s view.

Hint: Install enough additional markers to be sure that three or more points are visible in each frame of your recorded sequence. Then you have more options in case of hidden points or poor point positions (in an algorithmic point of view).

Hint: Use different markers (e.g. colors) in order to simplify the identification of your reference points.

Hint: Draw a detailed outline of your trial setup (position of calibration system and reference points) and note all metrics.
Initialize your camera object for P/T/Z

Settings are made for each camera individually. It is allowed to use one, several or all cameras within a project together with the P/T/Z-option.

Module activation

Please open the dialogbox “Edit 3D calibration system”. The P/T/Z module is activated when at least one of the “Pan/Tilt/Zoom”-options is checked. When all checkboxes are unchecked the module gets deactivated and all existing information about P/T/Z is discarded.

Camera calibration

The Calibration for P/T/Z-cameras is identical to the process for normal cameras. The P/T/Z calculation is dependent on an accurate calibration. Please use the “Camera constants” (in the 3D calibration menu) to check your calibration. Pay attention in particular to the calculated camera position and the principal point with “Optimization” turned off. Because of the additional requirements for panned or zoomed cameras you should make an effort to use all options of calibration optimization. Please enter the exact position of your camera and the principal point.

Additional information: “Camera position”

The camera position (coordinates according to the calibration system) is calculated automatically during the calibration process, but if the exact position has been measured it should be entered. This information is optional and you can also enter only one component (e.g. the height of the camera) and leave all other textboxes empty.
Additional information: “Principal point”

The camera’s principal point is calculated automatically during the calibration process, but if the exact values are known they should be entered. The principal point is usually close to the center of the image. According to circumstances the default values “0.5 / 0.5” are sometimes good enough to achieve an improved accuracy.

There is also the possibility to measure the exact position of the principal point. It is not dependent on the camera’s position, rotation or setup but on the optics and the cameras itself.

Please contact the Simi support for a software tool to measure the principal point of your camera.

Digitizing

Digitizing (tracking) of your normal markers is done as usual. Additional points (“reference points”) appear for each camera that has been activated for P/T/Z.

For digitizing these reference points are treated as usual markers and at least two of them have to be specified by manual clicking or automatic tracking in each frame.

Additionally all measured coordinates of the respective reference points have to be entered: Right-click one of the reference points and select “Reference coordinates” to open the corresponding dialog box.

Dialogbox “Reference coordinates”

Here you have to enter the coordinates and a description to identify each reference point without problems.

You can enter and modify this information manually each time one of your reference points changes, but a predefined set of reference points is offered for quick and easy modifications. Please press the “Edit” button to open the dialog box “Edit reference coordinates”.

A reference point remains valid for consecutive frames until you define a new point or select a predefined point from the list.
Dialogbox “Edit reference coordinates”

You may enter as many reference points as you like. They appear in a list and can be sorted upwards or downwards.

All points from the list can be selected during the digitizing process. It is recommended to add all reference points to the list in order to achieve security and efficiency.

You can save the list to a file and reuse it for several trials with the same setup without entering the same information again.

Press “Export” to save the list to a file with the extension “*.coo”.

3D calculation

3D coordinates are calculated as usual. P/T/Z information is used automatically.

P/T/Z parameter

You may want to check the P/T/Z module and display the results in a diagram.

Right-click a camera in the project tree and select “Calculate panning parameters” and you will get the desired information.

*Panning angle, Tilting angle, Zoom and Residuum* describe the calculated camera movement.

*Panning* and *Tilting angle* are given in degrees and the camera’s position during the calibration process defaults to 0°. For *Zoom* the value for the camera setup during calibration is 1.

*Residuum* allows an estimation how accurate the results have been calculated. This value should be as close to zero as possible, usually in a range below 0.05.
Display complete panning information

The optional module „Report“ is needed for this function. Open a report (“View – New – Report”) and select a template to display camera and calibration information.

You will get a table with all reference point assignments and all calculated panning parameters; You may print this table or save it as a HTML file.

Please use this table to check your reference point assignments and to find any errors in the P/T/Z data.
Simi Motion Manual

Laser Calibration
Simi Laser Calibration

Simi Motion Manual : Laser Calibration
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Chapter 1. Overview of Simi Laser Calibration Technique

Whether using a calibration cube or the laser calibration technique, both involve:

1. Placing control points in the filming space
2. Filming the control points
3. Determining the coordinates of the control points if unknown
4. Providing the software with the control point coordinates

The control points with this laser calibration technique are reflective markers mounted on one vertically aligned pole. The pole is moved and held in three or more locations throughout the filming space, thereby providing a dispersion of control points. The vertical coordinates (z) of the control points are measured directly with a tape measure. The horizontal coordinates (x, y) of the control points are calculated trigonometrically by Simi Motion after it is provided with two measurements; distance to the pole and the horizontal sweep angle of the laser tripod. The distance is measured with a laser distance meter and the sweep angle is measured electronically by the leveled tripod on which the laser distance meter is mounted.

The X and Y axes of the laser coordinate system form a horizontal plane at floor level and the Z axis is perpendicular to the floor. The vertical (z) coordinates of the reflective markers are their heights from the floor (bottom of the pole). These are measured by hand with a tape measure. These coordinates are assumed to be the same at each pole position.
Chapter 2. Step-by-step guide

This manual will guide you through the steps necessary for conducting a successful calibration using the hardware and the software provided by Simi. During the process, the calibration tripod has to be placed in the four corners of the space that needs to be calibrated, measured with the laser pointing device and recorded with the camera.

Preparations

First of all, some preparations are required before the calibration can be started.

Equipment requirements

The following equipment is needed to place control points in the filming area, film them and determine their three dimensional coordinates.

1. Calibration pole (segments)
2. Calibration pole reflective markers
3. Tape measure
4. Laser distance meter
5. Laser distance meter tripod, equipped with levels and an electronic horizontal angle meter
6. Two or more stationary cameras

Hardware preparations

Set up two or more cameras whose fields of view capture the filming space. These cameras should remain stationary and their settings (e.g. zoom) unchanged once calibration has been completed. Attach the laser distance meter to the tripod and provide electrical power to the tripod. Set the laser tripod off to one side of the filming space so the laser can be focused on the pole at each pole position. Level the tripod. Attach as many segments with reflective markers to the pole as desired. Using a tape measure, measure the heights (z coordinates) of the markers on the calibration pole. Record these in millimeters on a copy of the Calibration Sheet in Appendix A.

Software preparations

In this step, you will enter the height values for the markers in the software. To do this, please edit the `marker.ini` file that is created during installation of the Simi Software. This file can usually be found in the folder

C:\Program Files\SIMI\Motion\Tools\SmLaserCalib

Open the file in a text editor like Notepad or WordPad. What you see should look like figure 2 (lines starting with a semicolon are comments and can be ignored).

```
[SIMI_LASERCALIB]
Type=SIMI_MARKER
Version=102
Description=Test-Markerset
Offset=10

[MARKER1]
Position=200
Name=bottom

[MARKER2]
Position=1000
Name=middle
```
Figure 2. Contents of file `marker.ini`

This is what you should see in the marker configuration file when you open it with a text editor. All paragraph names are enclosed within brackets, e.g. `[MARKER1]`. The first paragraph `[SIMI_LASERCALIB]` contains public information of which only the Offset value is interesting. It has a default value of 10 millimeters and it automatically subtracted from each value you measure.

What exactly does this offset value do? The distance you will measure with the laser is actually a bit longer than the real distance to the center of the marker. The offset value represents this distance. You can calculate the offset using the formula:

\[
\text{(diameter\_of\_marker} / 2) - \text{ (thickness\_of\_pole} / 2)
\]

The next paragraphs contain the height data for each marker. They must be named `[MARKER1]`, `[MARKER2]`, `[MARKER3]` and so on. The Position value indicates the height above ground that you noted before, and the Name value is a name for the marker that you can chose freely. Please enter the values as you wrote them down before, adding more marker paragraphs if needed. Remember, the numbers are millimeters.

After that, saved the file and close it.

**Calibration**

The calibration process is ready to begin when you have set up the hard- and software as shown in the chapter before. It consists of moving the pole to the four positions that define the edge of the space that you want to calibrate.
Figure 3. Setup for the calibration process

The calibration will consist of these parts:

- Moving the pole to the extents of the calibration space and recording picture and measurement data
- Creating a calibration description file
- Calibrating in Simi Motion

Capturing the data

In the first step, you will define the space to be calibrated by moving the pole to the edges of this space and record the data by (i) capturing the video data with Simi Motion and (ii) using the laser to determine distances and angles.

First of all, see figure 3 to get an overview of the procedure. Place the pole at the first position and check again that the
laser device will be able to point at the pole and that the pole is hanging down.

While filming, the pole should be moved to and held in at least three positions but preferably four; each corner of the filming space. The pole can be moved to and held in as many additional positions in the filming space as desired. In general four positions are sufficient and there is little advantage to holding the pole in more than five positions.

Then, place the cameras so that they will be able to see as many markers as possible. Make sure that a marker has to be visible from at least two cameras at all times.

Now you are ready to start the capture process within Simi Motion. To do this, please start Simi Motion and open the video capture window. The cameras must capture the pole at each of its positions. So set a lengthy capturing period and start the capturing process just before you start positioning the pole, and measuring the distances and angles. See figure 4 how to make these settings.

In figure 4, we chose a setting of 180 seconds which should be enough for the entire process with four pole positions. Before you click on the capture button, print out or copy the calibration sheet from the Appendix and use it to write down the values you measure with the laser pointer.

Now, start the capturing and perform the following steps:
1. Point the laser to the pole. Attention: Be sure not to tilt the laser, use only the rotation device to rotate it.

2. Measure the distance from the laser to the pole by pressing the large button on the laser distance meter and the horizontal sweep angle by rotating the tripod mounted angle device.

3. Write the values (distance and angle) down in the calibration sheet (see appendix). The angle value for the first position is always 0°.

4. Move the pole to the next position and repeat steps 1 to 3 until you have measured all positions and captured in the video.

When you are finished with all positions, press Esc in Simi Motion to stop capturing or click on the camera icon again. When the program asks you to register the video clips, register them as calibration videos. In the next step, you will use the values that you wrote down during this step to create a calibration configuration file.

Creating a calibration file

In this step, a calibration configuration file will be created using the SmLaserCalib tool. You can run it from the start menu or directly from the folder where it is installed (see chapter “Software preparations”). When you open the tool, you will see a window like the one shown in figure 5.

![SmLaserCalib main window](image)

Figure 5. SmLaserCalib main window

Enter the values you noted on the calibration sheet using the following procedure and figure 6:

- Click on the Add pole... button
- Enter distance (in meters), position (in degrees) and name of the pole
- Click on OK

Repeat those steps until you have entered all the values from your calibration sheet.
In the next step, set the origin for the coordinate system using the Set origin command from the Origin menu. Set the origin to be at one of the poles, not the laser device. In addition, define the x or y axe to run to one of the other bar positions as shown in figure 7.

After that, save your data by choosing Save as... from the File menu and entering a file name. Remember where you saved it to so that you will be able to load it from Simi Motion in the next step.
Calibrating in Simi Motion

The last step of your calibration includes loading the calibration file in Simi Motion and clicking on the corresponding points in the video. To do this, open your project in Simi Motion or create a new one and add your cameras. Open the 3D calibration window. Please see the appropriate section of the Simi Motion manual on how to do this.

When you click on the 3D calibration button for the first time, you will be prompted a choice on defining a coordinate system. Later, you can access this window by clicking on the properties button next to the scrollbar and selecting Edit calibration system from the menu.
You will get to the window shown in figure 8. Click on the Import button and select the saved calibration file from the last step. After that, the calibration system will look like the one in figure 8. Now, click on the Exit button.

After that, you will be taken to the main calibration window where you have to click on the markers in the video. To finish your calibration, repeat the following steps:

1. Scroll the video to the position where the first pole position is visible using the scroll bar at the top
2. Select the first point (probably the bottom one) from the list
3. Click in the middle of it into the video
4. Repeat steps 2 and 3 for the rest of the markers (probably the middle and the top marker)
5. Scroll the video to the next position of the pole
6. Repeat from step 1 until all markers appear in green

Repeat the procedure in this chapter for every camera. When every marker in every camera is green in the list, you are finished with the calibration.

Congratulations, you just finished your first laser based calibration!
Appendix A. Calibration sheet

Make a copy of this sheet and use it to record the z coordinates of the reflective markers as determined with a tape measure, and the distance and horizontal sweep angle to the pole at each pole position as determined by the laser and laser tripod.

<table>
<thead>
<tr>
<th>Trial name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marker</th>
<th>Height (mm) of marker on pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position</th>
<th>Distance (m)</th>
<th>Angle (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B. Unit conversion

Use this table to convert values from the imperial to the metric system.

<table>
<thead>
<tr>
<th>To convert from...</th>
<th>...to</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>mile (US)</td>
<td>kilometer (km)</td>
<td>1.609347</td>
</tr>
<tr>
<td>inch (in)</td>
<td>millimeter (mm)</td>
<td>25.4</td>
</tr>
<tr>
<td>inch (in)</td>
<td>centimeter (cm)</td>
<td>2.54</td>
</tr>
<tr>
<td>inch (in)</td>
<td>meter (m)</td>
<td>0.0254</td>
</tr>
<tr>
<td>foot (ft)</td>
<td>meter (m)</td>
<td>0.3048</td>
</tr>
<tr>
<td>yard (yd)</td>
<td>meter (m)</td>
<td>0.9144</td>
</tr>
</tbody>
</table>
Content

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  Stick diagram ............................................................................................... 3
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# Keyboard shortcuts

List of abbreviations:
Ctrl = “control” – key
Shift = upper/lowercase key
NumPad = numeric pad on the right of the keyboard

## General

<table>
<thead>
<tr>
<th>Keyboard shortcut</th>
<th>Command</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F1</strong></td>
<td>Help menu</td>
<td></td>
</tr>
<tr>
<td><strong>F2</strong></td>
<td>Data acquisition (DataForce module)</td>
<td></td>
</tr>
<tr>
<td><strong>F3</strong></td>
<td>Open template file</td>
<td></td>
</tr>
<tr>
<td><strong>F4</strong></td>
<td>Create new data</td>
<td></td>
</tr>
<tr>
<td><strong>F5</strong></td>
<td>Refresh</td>
<td></td>
</tr>
<tr>
<td><strong>F7</strong></td>
<td>New time position: Start of selected range</td>
<td></td>
</tr>
<tr>
<td><strong>Shift</strong> + <strong>F7</strong></td>
<td>Marks the start of the selected range</td>
<td></td>
</tr>
<tr>
<td><strong>F8</strong></td>
<td>New time position: End of selected range</td>
<td></td>
</tr>
<tr>
<td><strong>Shift</strong> + <strong>F8</strong></td>
<td>Marks the end of the selected range</td>
<td></td>
</tr>
<tr>
<td><strong>F10</strong></td>
<td>Video capture</td>
<td></td>
</tr>
<tr>
<td><strong>Alt</strong> + Enter</td>
<td>Show properties of selected object</td>
<td></td>
</tr>
<tr>
<td><strong>Alt</strong> + / - (NumPad)</td>
<td>Adjust speed of automatic playback (animation)</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl A</strong></td>
<td>Start/stop automatic playback (animation)</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl C</strong></td>
<td>Copy to clipboard</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl V</strong></td>
<td>Paste from clipboard</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl X</strong></td>
<td>Cut to clipboard</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl Z</strong></td>
<td>Undo</td>
<td></td>
</tr>
<tr>
<td><strong>Left</strong> / <strong>right</strong></td>
<td>Move time position (1 step)</td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl Left</strong> / <strong>right</strong></td>
<td>Move time position (several steps)</td>
<td></td>
</tr>
<tr>
<td><strong>End</strong></td>
<td>Move time position to the end</td>
<td></td>
</tr>
<tr>
<td><strong>Home</strong></td>
<td>Move time position to the start</td>
<td></td>
</tr>
</tbody>
</table>
## Stick diagram

<table>
<thead>
<tr>
<th>Keyboard shortcut</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>F12</td>
<td>„Shadow“ Normal colors</td>
</tr>
<tr>
<td>Shift F12</td>
<td>„Shadow“ user defined colors</td>
</tr>
<tr>
<td>Ctrl F12</td>
<td>„Shadow“ bright colors</td>
</tr>
<tr>
<td>Shift + Ctrl F12</td>
<td>Removes all shadows</td>
</tr>
<tr>
<td>Ctrl N</td>
<td>Standard stick diagram</td>
</tr>
<tr>
<td>Ctrl + / - (NumPad)</td>
<td>Changes pen width</td>
</tr>
</tbody>
</table>

## Diagram

<table>
<thead>
<tr>
<th>Keyboard shortcut</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>F9</td>
<td>Determine point in time</td>
</tr>
<tr>
<td>Ctrl L</td>
<td>Show/hide grid lines</td>
</tr>
<tr>
<td>Ctrl N</td>
<td>Restore default format („normal“)</td>
</tr>
<tr>
<td>Ctrl + / - (NumPad)</td>
<td>Modify pen width for selected data row</td>
</tr>
<tr>
<td>Ctrl+ Shift + / - (NumPad)</td>
<td>Modify pen width for all data rows</td>
</tr>
<tr>
<td>Ctrl PgUp / PgDown</td>
<td>Zooms x axis section</td>
</tr>
</tbody>
</table>
Mouse handling

Explanation of abbreviations

Ctrl = “control” – key
Shift = upper/lowercase key
Drag = Pull item (while mouse button is pressed)
Drop = Release mouse button (after “Drag”)
Move = Move mouse pointer without pressing a mouse button
Wheel = Rotate mouse wheel (if available)

General

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse button</th>
<th>Action</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Click</td>
<td></td>
<td>Select object</td>
</tr>
<tr>
<td>Right</td>
<td>Click</td>
<td></td>
<td>Display context menu</td>
</tr>
<tr>
<td>Wheel</td>
<td>Forw / backw</td>
<td></td>
<td>Move position in time</td>
</tr>
<tr>
<td>Left</td>
<td>Drag</td>
<td></td>
<td>Move objects, open view by dropping items on desktop window</td>
</tr>
</tbody>
</table>

Digitization/Video view

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse btn</th>
<th>Action</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Click</td>
<td></td>
<td>Set point (tracking mode only)</td>
</tr>
<tr>
<td>Shift</td>
<td>Left</td>
<td>Drag</td>
<td>Move x and y section</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Right</td>
<td>Click</td>
<td>Zoom-In</td>
</tr>
<tr>
<td>Ctrl + Shift</td>
<td>Right</td>
<td>Click</td>
<td>Zoom-Out</td>
</tr>
</tbody>
</table>
## Stick diagram

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse btn</th>
<th>Action</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>Left</td>
<td>Hor. Drag</td>
<td>Rotation around Z axis</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Left</td>
<td>Hor. Drag</td>
<td>Zoom</td>
</tr>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Hor. Drag</td>
<td>Rotation around X axis</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Right</td>
<td>Hor. Drag</td>
<td>Rotation around Y axis</td>
</tr>
</tbody>
</table>

| Shift    | Left      | Hor. Drag| Move left/right/up/down   |
| Ctrl     | Right     | Hor. Drag| Add data (2D/3D data only)|

## Diagram

<table>
<thead>
<tr>
<th>Keyboard</th>
<th>Mouse btn</th>
<th>Action</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Click (Back-</td>
<td>Context menu: diagram</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Right</td>
<td>ground)</td>
<td></td>
</tr>
<tr>
<td>Shift</td>
<td>Right</td>
<td>Click (data</td>
<td>Context menu: curve</td>
</tr>
<tr>
<td>Ctrl</td>
<td>Right</td>
<td>curve)</td>
<td></td>
</tr>
<tr>
<td>Ctrl+ Shift</td>
<td>Right</td>
<td>Click (legend)</td>
<td>Context menu: curve</td>
</tr>
</tbody>
</table>

| Shift    | Right     | Drag          | Select X-section             |
| Ctrl     | Right     | Drag          | Select Y-section             |
| Ctrl+ Shift| Right    | Drag          | Select X and Y section      |
| Alt +Ctrl| Right     | Drag          | Move X-section               |
| Alt +Ctrl +Shift| Right | Drag       | Move Y-section               |
| Alt+Ctrl + Shift | Right | Drag    | Move X and Y section        |
Operations

Arithmetic Operations

Add constant value
Adds a constant value to each sample of a data row. \([A+c]\)
Parameters: data row and addend (floating point number)
Example: Runner on a treadmill, the speed of the treadmill is added to the speed of the runner.

Multiply with constant value
Multiplies each sample of a data row with a constant number \([A*c]\).
Parameters: data row and factor (floating point number)
Example: Conversion from m/s to km/h (factor=3.6)

Divide by constant value
Divides each sample of a data row by a constant number \([A / c]\)
Parameters: data row and divisor (floating point number)
Example: Conversion from N to kg (divisor=9.81)

Add data row
Add the corresponding samples of two data rows \([A+B]\).
Parameters: Two data rows
Example: Addition of left force and right force results in total force.

Subtract data row
Subtract the corresponding samples of two data rows \([A-B]\).
Parameters: Two data rows
Example: Subtract the shoulder height of the left side (Z coordinate) from the shoulder height of the right side to get the shoulder gradient.
Multiply with factored data row
Multiplies the corresponding samples of two data rows and a factor \([A*B*c]\)
Parameters: two data rows and a factor (floating point number)
Example: calculation of a torque (force*distance).

Divide by factored data row
Divide the corresponding samples of two data rows (and a divisor) \([A/(B*c)]\)
Parameters: two data rows and a divisor (floating point number)
Example: Ratio of two forces (left and right)

Absolute value
Creates the absolute value for every sample \([|A|]\)
Parameter: data row
Example: Rectifying an EMG signal

Percentage of total data
Provides the ratio of two data rows in percent \([(A/B) * 100]\)
Parameters: two data rows
Example: The right leg’s percentage of the total force.

Percentage of summarized data \((A/(A+B)*100)\)
Provides the ratio of a data row and the sum of this data row with a second one in per cent \([(A/(A+B) * 100]\)
Parameters: two data rows
Example: The right leg’s percentage of the total force (when the right and the left force are given)

Tangent
Creates a new data row (straight) which touches the data row in a given place.
Parameters: data row, position X (the position, where the tangent has to be calculated, floating point number), and the start and the end of an time interval (used to draw the line, floating point number)
Example: Visualization of a gradient.
Function (equation \( y = mx + c \))

Creates a new data row with the function equation \([y = mx + c]\).
Parameters: \(m\) (slope) and \(c\) (constant offset), floating point numbers
Example: Visualization of a bisecting line in a diagram (\(m=1, c=0\))

Angles and distances

Angle (3 Points)
Calculates an angle which is defined by one point on each leg and the vertex.
Parameters: Leg point, vertex, leg point
Example: Angle between ankle, knee and hip (knee angle).
Remark: angles do not have an orientation in 3D (e.g. counterclockwise).
Therefore the result is always the smallest angle (less than 180°)

Angle (4 Points)
Calculates an angle where both legs are defined by two points. The legs do not have to have an intersection, the projection is used instead.
Parameters: Leg 1 (points 1 + 2), Leg 2 (point 3 + 4)
Example: Angle between wrist/elbow on the right and wrist/elbow on the left (angle between the forearms).
Remark: angles do not have an orientation in 3D (e.g. counterclockwise).
Therefore the result is always the smallest angle (less than 180°)

Angle with X/Y-plane, X/Z-plane, Y/Z-plane
Calculates the angle between a plane and a straight defined by two points.
Parameters: two points
Example: The angle of a javelin in the moment of ground contact.

2D-angle (3 Points)
Calculates an angle, which is defined by one point on each leg and the vertex.
Parameters: Leg point, vertex, leg point
Example: Angles between ankle, knee and hip (knee angle).
Remark: Only the X and Y coordinates (2 D) are taken into account. The angle is measured counterclockwise and the resulting angle is between 0° and 359°.
2D-angle (4 Points)
Calculates an angle where both legs are defined by two points. The legs do not have to have an intersection, the projection is used instead.
Parameters: Leg 1 (points 1 + 2), Leg 2 (point 3 + 4)
Example: Angle between wrist/elbow on the right and wrist/elbow on the left (angle between the forearms).
Remark: Only the X and Y coordinates (2D) are taken into account. The angle is measured counterclockwise and the resulting angle is between 0° and 359°. Attention: This calculation has often problems in 2D.

2D angle with horizontal line
Calculates an angle which is defined by two points and a horizontal line.
Parameters: Two points
Example: Angle between ankle/knee and horizontal line (angle of the lower limb to the ground).
Remark: Only the X and Y coordinates (2D) are taken into account. The angle is measured counterclockwise and the resulting angle is between 0° and 359°.

2D angle with vertical line
Calculates an angle which is defined by two points and a vertical line.
Parameters: Two points
Example: Angle between hip/shoulder and vertical line.
Remark: Only the X and Y coordinates (2D) are taken into account. The angle is measured counterclockwise and the resulting angle is between 0° and 359°.

2D/3D distance
Calculates the three-dimensional distance between two points (suitable for 2D, too).
Parameters: Two points
Example: Distance between ball and tennis racket

Distance in X direction
Calculates the distance between two points regarding the X axis (suitable also for 2D analysis).
Parameters: Two points
Example: Distance between ball and tennis racket in playing direction.
**Distance in Y direction**
Calculates the distance between two points regarding the Y axis (suitable for 2D, too).
Parameters: Two points
Example: Distance between ball and tennis racket orthogonal to the playing direction.

**Distance in Z direction**
Calculates the distance between two points regarding the Z axis.
Parameter: Two points
Example: Height difference between right and left hip (pelvis position).

**3D distance from a constant point**
Calculates the distance between a point and a constant point (suitable for 2D, too).
Parameters: One point and 3 coordinates (X,Y,Z, floating-point number)
Example: Distance between the tiptoe and the long jump bar.

**Angle ArcTan(A/B)**
Calculates the angle with the arc tangent of a quotient [arctan(A/B)]
Parameters: Two data rows
Example: Calculation of the take-off angle in long jump, given the horizontal and vertical velocity

**2D distance**
Calculates the distance covered by a point in the X/Y plane.
Parameter: Data row
Example: Hand movement during breaststroke in swimming.

**3D distance**
Calculates the distance covered by a point in 3D space.
Parameters: Data row
Example: Covered distance of the center of mass during running, including the vertical and lateral movements.
Filtering and smoothing

Smooth with moving average
The smoothing radius determines the number of the adjacent points (on both sides) which are included in the calculation (e.g. radius 3 = smoothing with 7 points)
Parameters: Data row and smoothing radius (integer)
Example: Slight smoothing of raw data to eliminate noise (smoothing radius 1 or 2)

Filter with Low-pass

Filter with double Low-pass

Filter with 2nd order Low-pass
Frequency parts above the filter frequency (threshold value) will be damped or eliminated using a Butterworth filter.
Parameters: Data row and filter frequency (floating point number)
Example: Filtering 3D coordinates (human movements (Filter frequency e.g. 10 hertz)

Filter with Low-pass (percentage)

Filter with doubled Low-pass (percentage)

Filter with 2nd order Low-pass (percentage)
A FFT will be calculated and integrated in order to determine the filter frequency which corresponds to the given percentage. Then the data is filtered with this frequency. This is done for each data row separately (i.e. for X, Y and Z, too).
Parameters: Data row and percentage value (floating point number)
Example: Smoothing of 3D data (e.g. with 85%)

Filter with Highpass
Frequency parts below the filter frequency will be damped or eliminated.
Parameters: Data row and filter frequency (floating point number)
Example: Eliminate low frequencies in EMG signals which are often movement artifacts.
Filter with Bandpass
Applies a lowpass and a highpass filter at the same time.
Frequencies outside the given range will be damped or eliminated.
Parameters: Data row, lower and upper filter frequency (floating point numbers)
Examples: EMG processing: Eliminate movement artifacts (very low frequencies) and noise (high frequencies) at the same time.

Filter with Splines
“Quintic Splines” are used to describe the data and allowed to differ slightly from the original data. The resulting curve is smooth and can be derived several times.
Parameters: Data row and error variance (floating point number).
The error variance is a number between 0 (no filtering) and 1 (infinite filtering), typically between 0.1 and 0.0001. Negative values make the system determine the optimal error variance automatically.
Example: Smoothing of 3D.

Div
Copy (identical mapping)
Creates an identical data row.
Parameter: Data row
Example: Create several copies, to compare different operations applied on them.

Time offset
Move the data row in time.
Parameters: Data row and time offset (floating point number)
Example: Kinetics and kinematics have not been recorded synchronously. Use this operation to move one set of data in time to synchronize both measurements.

Scale values
Scale data to be within a new co-domain.
Parameters: Data row, new minimum and maximum value (floating point values)
Example: Normalize data in order to compare different trials or subjects.
**Interpolate missing values**
Interpolates missing values with a „cubic spline“. Only gaps are filled, that are smaller as or equal to the maximum interpolation interval. This avoids mathematical correct interpolation without any relation to reality.
Parameters: Data row and max. interpolation interval (integer)
Example: Sometimes during a 3D recording the right hand is only visible in one camera. For a 3D calculation, however, the information of two cameras is necessary. So the gaps of the envelope of the second camera are filled with (mathematical) sensible values. Be careful, because the result is an approximation and no real measurement!

**Cut part (same frequency)**
Extracts a certain portion from the data row. The given time values are automatically rounded to the nearest samples.
Parameters: Data row, start and end time (in seconds, floating point number).
Example: A force platform delivers data during support phase only. All other data can be discarded.
Please note: the fragment carries its time information and is therefore still synchronous to other data

**Resampling**
Converts a part of the data row into another frequency.
Parameters: Data row, start and end time (floating point number) and the number of samples (integer)
Example: A force platform has been sampled with 1000 Hz. In order to reduce data a time range from 2.3 to 4.3 seconds is selected and resampled with 500 samples. The resulting data row lasts two seconds and has a frequency of 250 Hz.

**Envelope of minimum / maximum / mean values**
Calculate a blockwise minimum/maximum/mean value and create a new data row with these values.
Parameter: Data row and block size (integer)
Example: Calculate the minimum and the maximum envelope to get an overview of the movement’s amplitude in each phase of the movement.

**X/Y Data rows**
Creates a special data row which is not shown versus time but versus another data row.
Parameters: Two data rows
Example: Projection of the movement of the tennis racket on the ground (X data row = racket X; Y data row = racket Y)
Example: A diagram with a graph “force vs. acceleration”

**Derivation d/dt**
Calculates the first derivation of time [d/dt].
Parameter: Data row
Example: Calculate angular velocity from a given angle.

**1\textsuperscript{st}/2\textsuperscript{nd} derivative (Spline)**
Calculates the first or the second derivative of time [d/dt]. The error variance determines the smoothing of the original data. Refer to “Filter with Splines” for more information.
Parameters: Data row and error variance
Example: Calculation of the velocity, respectively acceleration of a coordinate.

**Integral**
Calculate the area between the curve and the X axis.
Parameter: Data row
Example: Integrating force data delivers the impulse (force x time)

**Integral (A-B) area between graphs**
Calculates the area between two graphs
Parameters: Two data rows

**FFT (upsampling by Splines)**
**FFT (padding with zeros)**
Calculates the “Fast-Fourier-Transformation” of the given data row. The number of samples has to be a power of two or will be padded by zeros or interpolated by splines.
Parameter: Data row
Example: Frequency spectrum of EMG signals
Accumulated FFT (upsampling by Splines)

Accumulated FFT (padding with zeros)
Calculates the “Fast-Fourier-Transformation” of the given data row. The number of samples has to be a power of two or will be padded by zeros or interpolated by splines. The frequencies’ amplitudes are summed up and normalized to 100%.
Parameter: Data row
Example: Determination of the 80% / 85% / 90% limit (frequency value) for further usage in lowpass filters.

3D sinuosity
Calculates the radius of curvature of three-dimensional movements.
Parameter: Data row
Example: Rotation during hammer throwing. If it was possible to move the hammer on a perfect circular path, the radius had to be constant. The resulting graph would be a horizontal line.

Radius of 2D circle

Center X of 2D circle

Center Y of 2D circle
Calculate the radius respectively the center of the 2D circle defined by three points in a plane.
Parameters: 3 Data rows (2D)
Example: Three points of the spine (cervical vertebra, chest vertebra, lumbar vertebra) deliver information about the bending of the upper torso.

New position for system of coordinates
Move the data (or the system of coordinates) in space.
Parameters: Data row, offset in X, Y and Z direction (floating point numbers)
Example: The system of coordinates should be moved so, that the X axis is congruent to the long jump bar (e.g. Y greater than 0 means that the bar has been passed).
Move system of coordinates continuously

Moves the system of coordinates continuously in space during the movement (i.e. the distance between the location of the movement and the system of coordinates varies).
Parameters: Data row, offset (in meters per second) in X, Y and Z direction (floating point numbers)
Example: A runner on a tread mill is recorded. The tread mill’s speed is 3 m/sec. In the video recording the runner is always at the same position. When the system of coordinates is moved with 3 m/sec to the opposite side, the runner seems to run with his real speed.

Turn system of coordinates around X, Y Z axis

Turns the data in space around an axis (respectively turns the system of coordinates).
Parameters: Data row, turn (in degrees, floating point number)
Example: The system of coordinates should be turned in a way that the X axis is congruent to the movement’s direction.
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## Settings in SmTMill.ini

This file has the same structure as other Windows INI files. It can be edited using any text editor.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>[Simi Treadmill]</strong></td>
<td></td>
</tr>
<tr>
<td>Version=100</td>
<td>Version number. Do not change this number!</td>
</tr>
<tr>
<td>Type=Lenze</td>
<td>Type of drive. Possible values: Heynau, Lenze</td>
</tr>
<tr>
<td>COM=0</td>
<td>Serial port (0=test while disconnected)</td>
</tr>
<tr>
<td>Mode=baud=9600 parity=E data=7 stop=1</td>
<td>Serial port parameters, see MS-DOS 'MODE' command</td>
</tr>
<tr>
<td>Animation=1</td>
<td>Switches animation on (1) or off (0)</td>
</tr>
<tr>
<td>TimerInterval=200</td>
<td>Adjustment speed in milliseconds</td>
</tr>
<tr>
<td>Stop=2</td>
<td>Stop switch mode: hidden (0), immediate stop (1), normal breaking speed (2)</td>
</tr>
<tr>
<td>MaxSpeed=1.0</td>
<td>maximum speed</td>
</tr>
<tr>
<td>UserSpeed=0.1, 0.2, 0.3, 0.4, 0.5</td>
<td>Possible values (max. of 10)</td>
</tr>
<tr>
<td>UserSpeedDefault=4</td>
<td>Selected value</td>
</tr>
<tr>
<td>CorrectionOffset=0.02</td>
<td>Offset correction value for the 'Faster' and 'Slower' switches</td>
</tr>
<tr>
<td>IncAdjustSlow=0.04</td>
<td>Adjustment value when (slowly) increasing speed per unit of time (see TimeInterval)</td>
</tr>
<tr>
<td>IncAdjustFast=0.10</td>
<td>Adjustment value when (quickly) increasing speed</td>
</tr>
<tr>
<td>DecAdjustSlow=0.02</td>
<td>Adjustment value when (slowly) decreasing speed</td>
</tr>
<tr>
<td>DecAdjustFast=0.05</td>
<td>Adjustment value when (quickly)</td>
</tr>
<tr>
<td></td>
<td>decreasing speed</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>FastAdjust=0</strong></td>
<td>Fast adjustment on (1) or off (0)</td>
</tr>
</tbody>
</table>