17 Application: Gait analysis

The software Simi Motion® allows the recording, digitization and visualization of different kinds of movement. One main goal to be accomplisihed is the analysis and interpretation of the data. Further the software allows due to different configurations simple recordings up to complex scientific analysis. The purpose of this manual is to be a help on the one side for the software and provide a step-by-step guideline in order to create basic movement analysis. The chronological provided steps should allow to conduct efficient and reproducible analysis.
The first part of this manual provide the basic preparations which need to be done for good measurement, e.g. camera position and camera settings. The next part will provide information about the recording and the calibration of the system. The last part describes the steps which need to be taken to create 3^D-data, the post-processing and analyzing options.
Exemplarily this manual describes a simple gait analysis, as this is one of the most common and simple movements which is of big interest in sports and medicine. The described guideline can easily be transferred to more complex movements.

System agreement

This manual has been written with the use of certain components, distributed by *Simi Reality Motion Systems GmbH*. The camera system used for this guideline was selected in a way to fit the best the used laboratory at *Simi Reality Motion Systems GmbH*. This may lead to certain differences with your system, however the general approach will not be affected by that.

Example

In order to get flicker-free images due to pulsing light it is common to use multiples of 50 fps for acquisition in Germany as the frequency of light is 50 Hz. In the US it would recommend to use multiples of 60 fps for capturing as the light frequency is 60 Hz

Used components and settings:

Cameras:

- Type: 8 Basler scA640-120gc
- Frequency: 100 Hz
- Exposure Time: 3 ms

Wand calibration:

- T-Wand: 80 cm
- Floor offset: 1 cm

Force plate:

- Kistler 9286AA

Marker:

- Diameter: 15 mm
- Amount: 23

Software:

- Simi Motion® 9.2.0 build 355

Important buttons

To be able to use standard functions the most important buttons are briefly explained below. Detailed explanations can be found in chapter

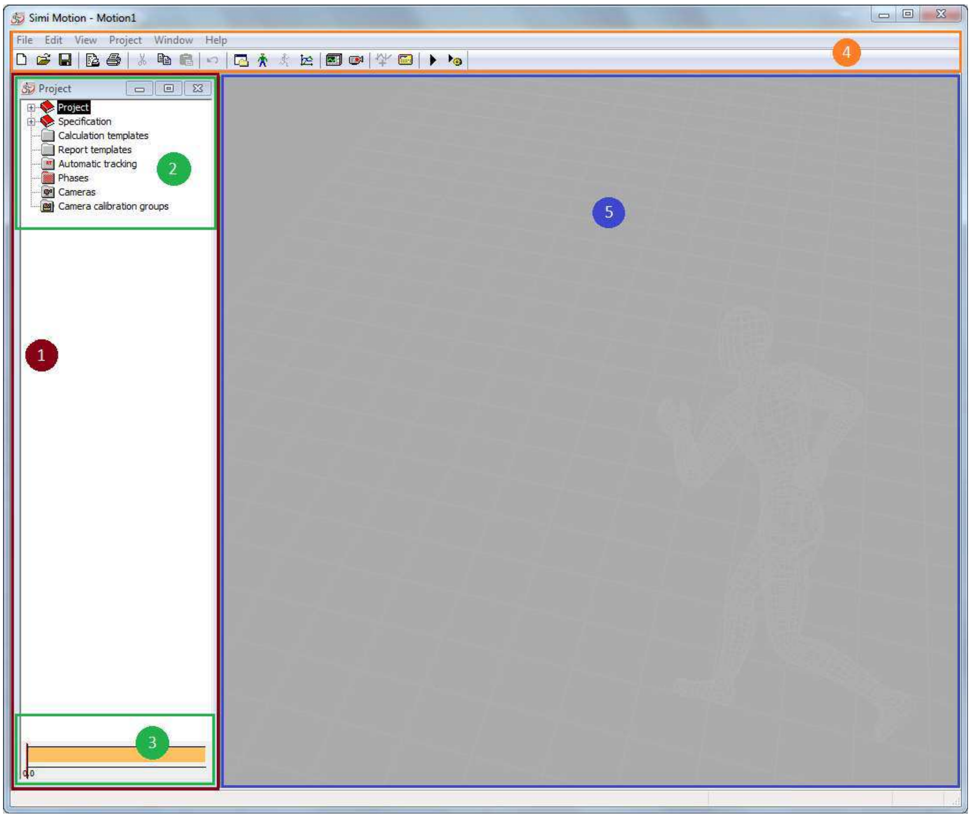


Figure 17.1: *Simi Motion Menu*: 1. Project window; 2. Project-Tree; 3. Time bar; 4. Menu-Bar; 5. Working environment

Icon	Function
	Switch live and play mode: Switches between the live image and the recorded image
	Search for devices...: Searchs for available cameras and displays them
	Edit available devices...: Displays available cameras
	Record video: Opens camera environment or starts the recording of a video
	Camera-trigger configuration: Settings of the trigger-box
	3D view: Displays 3D view of the coordinates
	New data: Creates a new stream of data (filters, interpolation, mathmatical operations...)
	Acquire data: Opens and starts the recording of the force plate
	Animation: Plays the 3D view or a video of a camera
	Configure animation: Settings of the animation (i.e. speed of animation)

Table 17.1: Table of icons

17.1 Preparations

This chapter describes which steps need to be taken in order to conduct a successful gait analysis. Almost all these steps are also relevant for other movements and applications.

17.1.1 Assembling the ring-lights

If you are running the system for the very first time, attach the ring-lights on the cameras. Attachment of the ringlights is described in section **??**.

(a) Ringlight-build on camera v.1 (b) Ringlight-build on camera v.2 (from 2015 on)

Figure 17.2: Two possibilities of attaching the LED-ringlights

Instruction

Attach the ringlight to the camera v1:

- Mount the L-section on the camera by using M3 screws
- If the inner pin isn't premounted, put the internal pin in the hole without a thread and fix it with one M5 screw
- Now attach the extension-pin to the L-section by using the third M3 screw
- Fix the ring-light to the extension-pin with the second M5 screw

Attach the ringlight to the camera v2:

- Open the three screws on the ringlight, so it fits over the lens.
- Fasten the ringlight onto a rigid part of the camera lens by tightening the screws.

Tip

Make sure the ringlights v2 do not change the lens setting through their own weight. If there are setscrews on the lens, fasten them.

17.1.2 Connecting the cables

Assure that all cameras are connected with the desired cables. Each cameras needs to be connected with a Trigger- respective Supply-cable (Power and Sync) and a GigE network cable. The Trigger- and Supply-cable leads to the Sync/IO-Box (Triggerbox) and the ethernet cables are being connected to the PC directly. If further a force plate or other different analog devices are being used make sure to connect them to the IO box as well to allow in sync recording of all devices.

17.1.3 Force-plate

If a force-plate is being used with the camera system attention needs to be paid to the correct orientation of the coordinate system of the force-plate. Check the manual of the force-plate or it's description for further information if the orientation is unknown.
It is recommended that the orientation of the coordinate system of the force-plate and the camera system match (cf. 17.3).

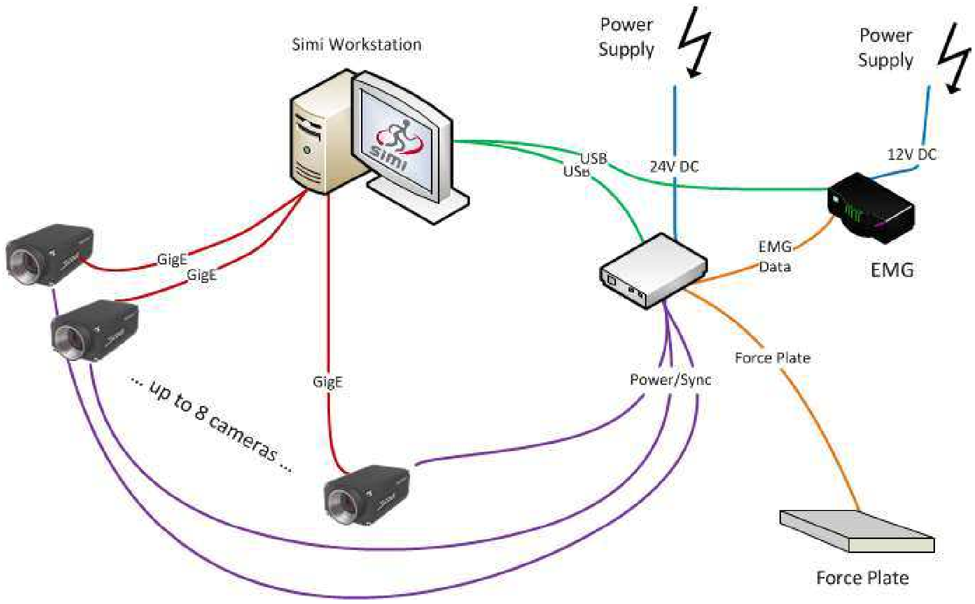


Figure 17.3: Assembly of a Simi Motion System

17.1.4 Power on

Power on the Triggerbox of the cameras and the LED ring-lights. If additional analog devices are being used ensure that those are powered on as well.

17.1.5 Camera connection

Assure that all cameras are being recognized correctly.

Instruction

To check the camera connection following options are available:

1. Click Capture Video in Simi Motion®. Now you should see the images of all cameras in the resulting window (cf. figure 17.4).
2. Open the Basler Pylon Viewer and check if the cameras are being recognized. (cf. fig. 17.5)
3. Using the Basler IP Configuration Tool check if all cameras are being recognized or if any IP-conflicts are present (cf. fig. 17.6).

Note

Steps 2 and 3 are only necessary, if some cameras in Simi Motion® were not recognized correctly

Note

Pylon Viewer and Pylon IP Configuration Tool are software-tools which are installed with Simi Motion®. Both tools can be found on the desktop or in the program-folder of the computer.
For the regular use of the Simi Motion system usually no settings have to be changed in the Basler software. Your system is already pre-installed and -configured. If you make changes in the Basler software it can intefere with the Simi software.

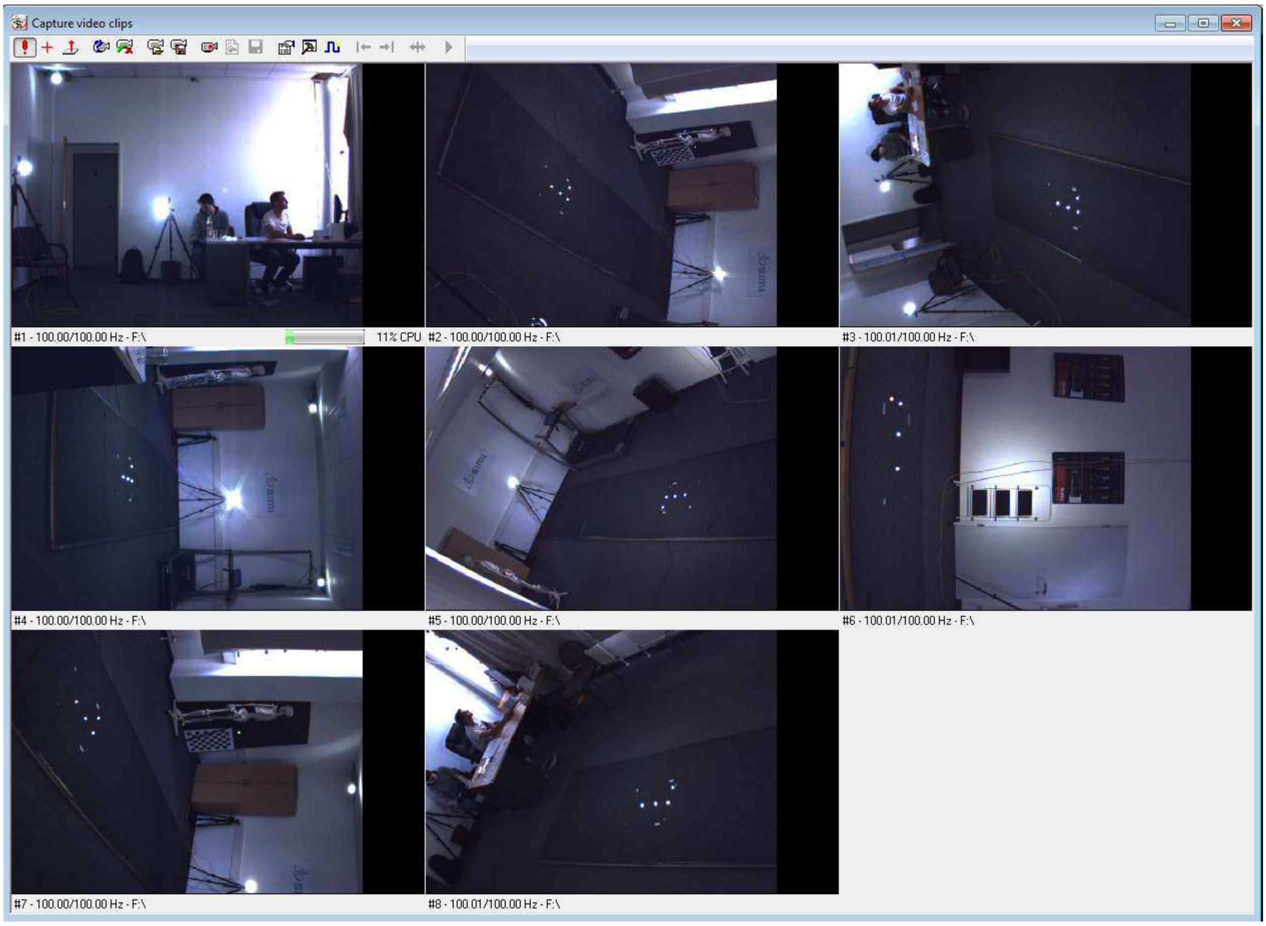


Figure 17.4: Recognition of 8 Cameras in Simi Motion

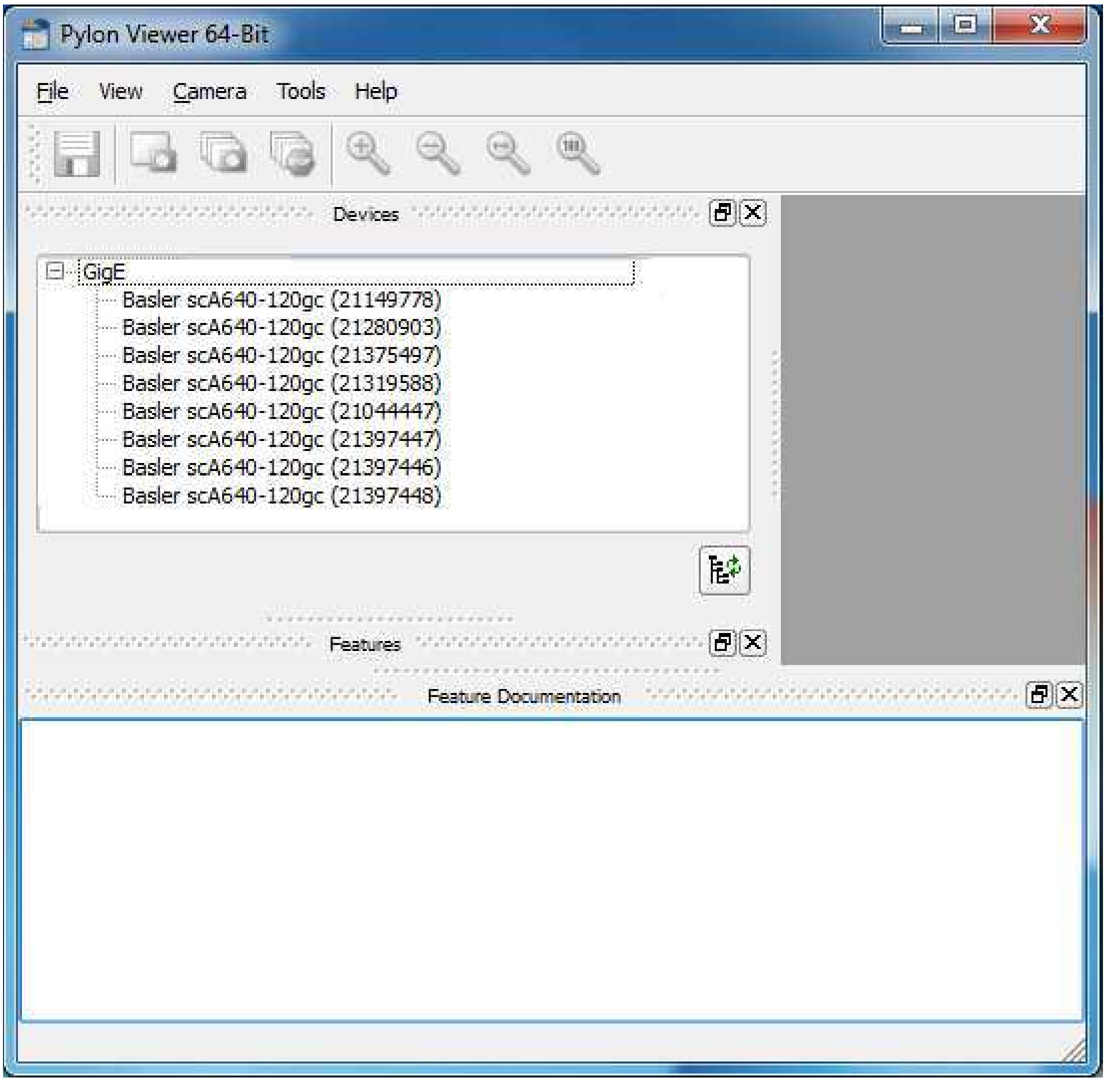


Figure 17.5: Recognition of 8 Cameras in Pylon Viewer

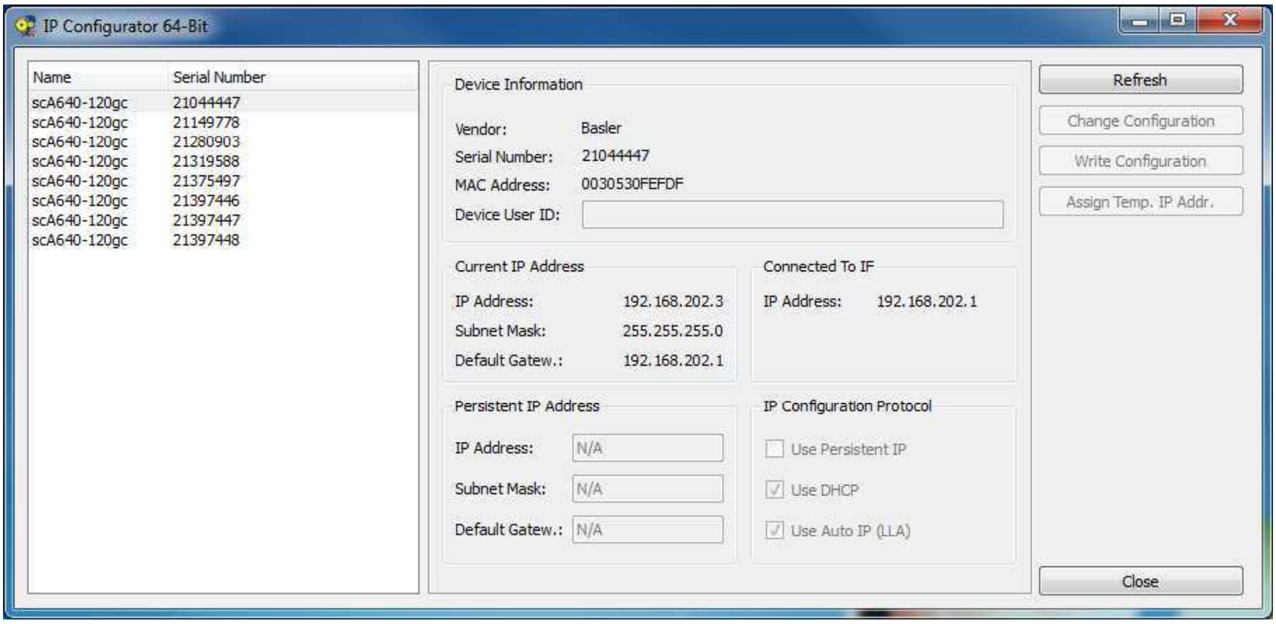


Figure 17.6: Recognition of 8 Cameras in Pylon IP Configuration Tool

Instruction

If some or all cameras are missing follow the steps in top down order:

- Missing in Simi Motion®: Click Find devices in the window *Record video...*
- Missing in Simi Motion®: Click Edit available devices... in the window *Record video...* and add accidentally disabled devices by checking the box in front of the device (17.7)
- Missing in Pylon Viewer: Possible IP-Conflict. Check the IP configuration in the Basler IP configuration tool.
- Missing in IP Configuration Tool: Check if all cameras are connected properly with the IO Box and the PC and if they are powered on (cf. 17.1.2).

17.1.6 Camera field of view

A capture space which is too big can lead to missing marker during tracking or additional tracking information without any special use. A capture space which is selected too small can lead to missing movement information.
Check the field of view of the camera:

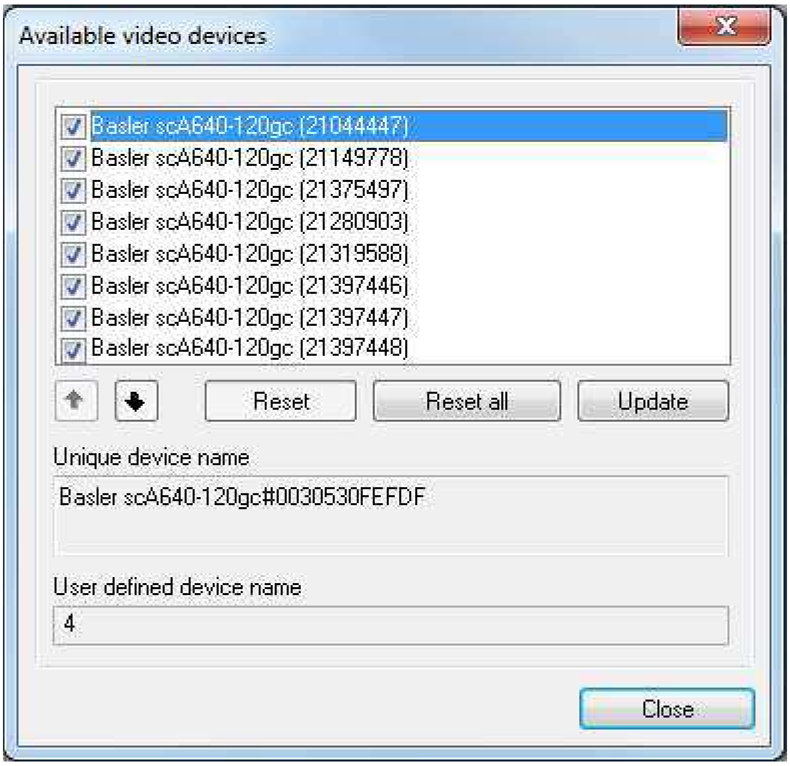


Figure 17.7: Selecting available devices

Instruction

- Click Record video...
- Align all cameras in a way that the movement space matches with captured space the best
- If possible use the zoom of the camera (cf. figure 17.9) and the possibilities offered by the tripod.

Tip

1. Adjust the cameras in a way that the LED ring-lights of the other cameras are not seen. Also pay attention to the correct setting of aperture and focus of the cameras (cf. section 17.1.7)
2. If needed, e.g. to record the walkway completely, it is recommended to rotate the camera 90° using the tripod (cf. figure 17.8)
3. During setup place a marker into the field of view respective movement area to assure the correct marker recognition (cf. figure 17.8).

Figure 17.8: Rotated camera with a marker in the field of view

17.1.7 Focus and aperture

As important as the correct placement of the cameras is the correct setting of focus and aperture. The aperture can be modified directly at the lens (cf. figure 17.9). Attention needs to be paid that the markers as well as the video image can still be recognized well.

Figure 17.9: 1. Aperture ; 2. Zoom; 3. Focus

To adjust the focus of the image the according lever needs to be moved (cf. figure 17.9). Images being not sufficient can lead to wrongly tracked markers.

Instruction

Make sure the video does not look blurry, but also not too dark:

- Open the aperture completely and close it slowly until the desired setting is found
- Set the cameras to clear images for the capture-/movement area

17.1.8 Camera properties

The correct settings of the cameras properties are also an important part in order to receive valid data. The camera properties can be accessed by right-clicking the camera view in the *Record videos...* window (cf. figure 17.10).

Note

Make sure you get the best 'physical' image from the cameras before adjusting the digital image with software settings in the camera properties.

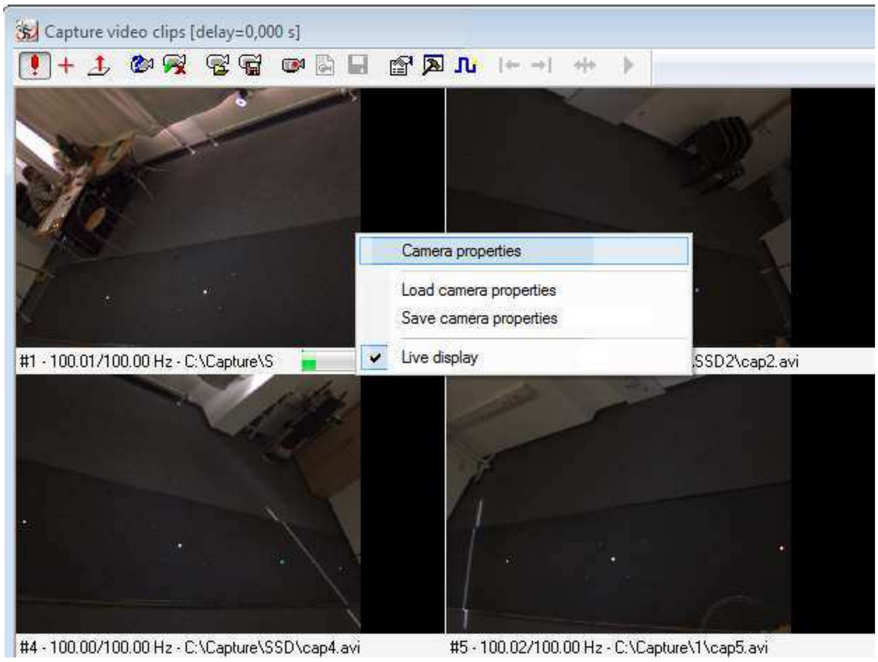


Figure 17.10: How to open the camera properties

Gain and Brightness

Gain and *Brightness* adjust certain image properties directly via software.
Brightness adjusts the amount of black within the image. An image with a high brightness carries only a little black.
On the other hand *Gain* describes the digital amplifying of the pixel. Raising the *Gain* results in a brighter image, however some noise can disturb the image due to the modification of the gain.

Instruction

Both slide-rulers should be set as low as possible, to allow a good marker tracking. If the image is to dark, it is recommended to raise the gain maximum to the middle of the available range, otherwise the quality of the image can be insufficient.

Note

To adjust the brightness of the image it is recommended to use the options provided by the lens (= aperture) first, afterwards by adjusting the exposure time. Modifying the Gain should be the last option in order to get brighter images.
After the video recording the videos can still be adjusted to look brighter for a visual reference.

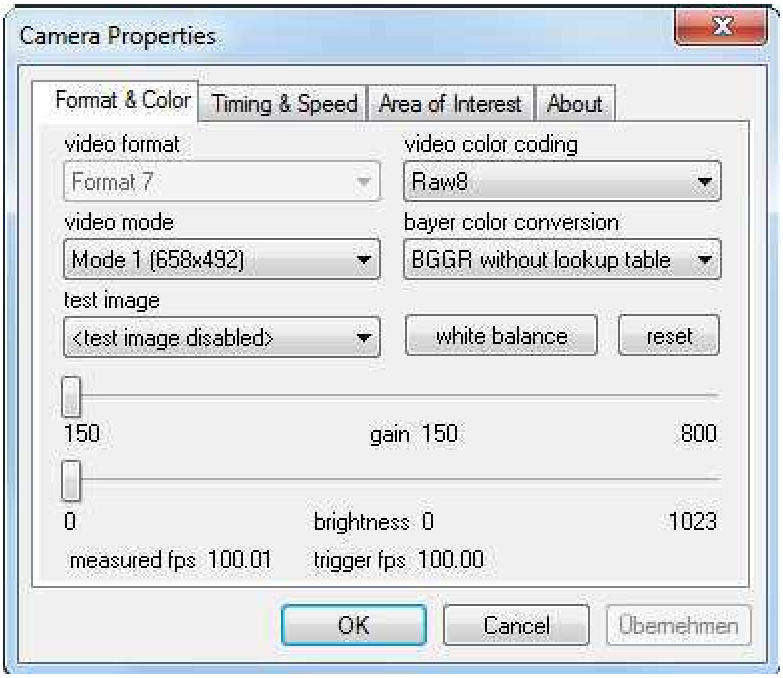


Figure 17.11: Camera properties - Format & Color

White Balance

The *White Balance* is being used to adjust the camera to the color-temperature of it's captured area. Make sure the colors you can see on the videos do match the colors you can see with your eyes.

Instruction

If there is something close to white in the capture area the *White Balance* can be executed without any further actions. Otherwise put a piece of white paper in front of the camera and execute the White Balance hitting the according button.

Exposure Time

The *Exposure Time* describes the time the camera-sensor is being exposed to light. For the recordings it is important that the circular markers still appear circular in the videos. If the Exposure Time is being set to high and the movement is too quick, circular markers can appear as an oval, blurring can be seen in the video and the tracking can become inaccurate.
As already mentioned, the correct setting of the *Exposure Time* depends on the speed of the captured movement and the set frame rate (cf. ff). For gait analysis with normal gait speed it is common to use 50 fps capture speed with 4 ms Exposure time (Richards).

Instruction

For the gait analysis with 100 fps 3 ms Exposure time are a common setting. This option can be found at *Timing and Speed* in the camera setting.

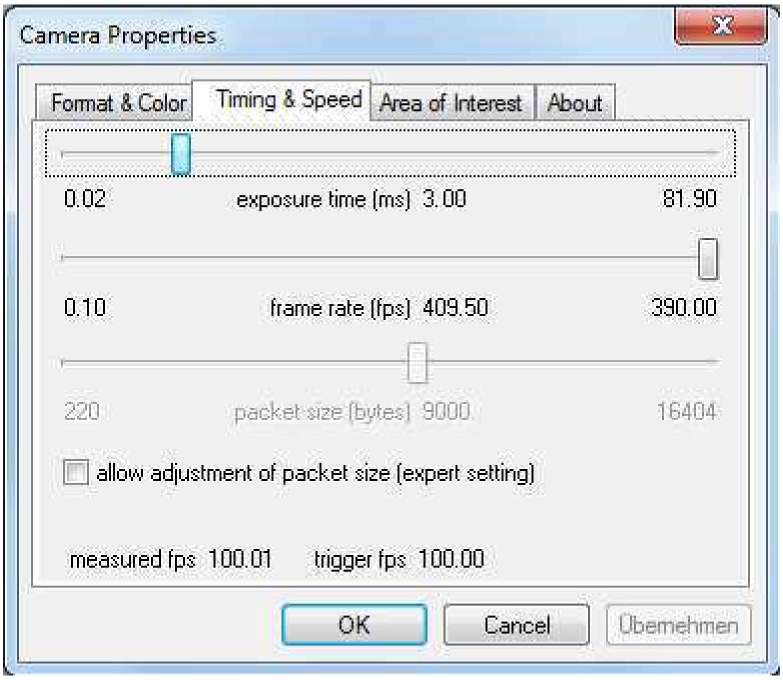


Figure 17.12: Camera properties - Timing & Speed

Frame rate and Packet size

The frame rate expresses the amount of images taken per second. The frame rate should be set as high as possible to allow the best analysis possible. Using the Sync option for cameras it is assured that all cameras record the same amount of images. If no Sync options are available each camera should at least be set to the same fps (cf. 17.1.9).

The *Packet size* should be set to 9.000 for all cameras. This setting adjusts the size of packages during the data transfer and can be modified using the slide ruler after activating the option *Allow adjustment of packet size (expert setting)*. However this setting can only be modified if the Network adapters allow the usage of *Jumbo Frames* and the setting is on 9024KB.

Note

If cameras are synched make sure the internal frame rate is set at least one frame higher then the desired synch frame rate.
All systems configured by Simi Reality Motion Systems are always configured to it's needs regarding IP and network settings. No further action needs to be taken.

17.1.9 Trigger setting

If multiple cameras are being used, all cameras have to be synchronized, otherwise the resulting 3^D-Data will not be valid. To ensure this, an event for synchronization is being introduced. This is carried out by the Sync/IO-Box.
At *Camera-Trigger configuration* in the window *Record videos...* one can adjust the settings for this property (cf. figure 17.13):

Figure 17.13: Trigger settings

Instruction

- Ensure that *Record one image per Sync signal* is activated
- Device should name the connected sync device (here: *USB-6218*)
- Set the desired frequency to 100 Hz
- Settings: compare figure 17.14

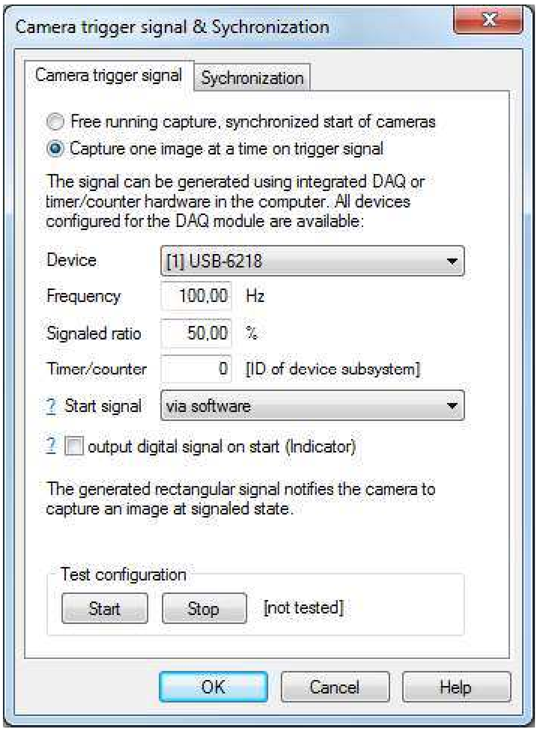


Figure 17.14: Trigger settings: USB-6218 and 100 Hz

17.1.10 Set of markers

The next step is to prepare the markers for the measurement. The gait analysis conducted for this manual uses a set of markers for the lower extremities of the Inverse Dynamics, which uses 23 markers:

- 1 Big toe tip right/left (optional)
- 2 Forefoot right/left
- 3 Heel right/left
- 4 Inner ankle bone right/left
- 5 Outer ankle bone right/left
- 6 Shin right/left (optional)
- 7 Inner Condyle right/left
- 8 Outer Condyle right/left
- 9 Thigh right/left (optional)
- 10 Greater trochanter right/left (optional)
- 11 Anterior superior iliac spine right/left
- 12 Mid SIPS

Instruction

Attach the markers to the patient according to figure 17.15.

Note

Not all markers of the set are compulsory for a correct measurement of a gait. Optional markers as greater trochanter, thigh, shin and big toe can be attached to receive additional information of a gait. **IMPORTANT**: If you are using the big toe markers, you have dismount them right before the dynamic trial. Because of the close proximity to the forefoot markers, that can lead to false assignment of the markers.

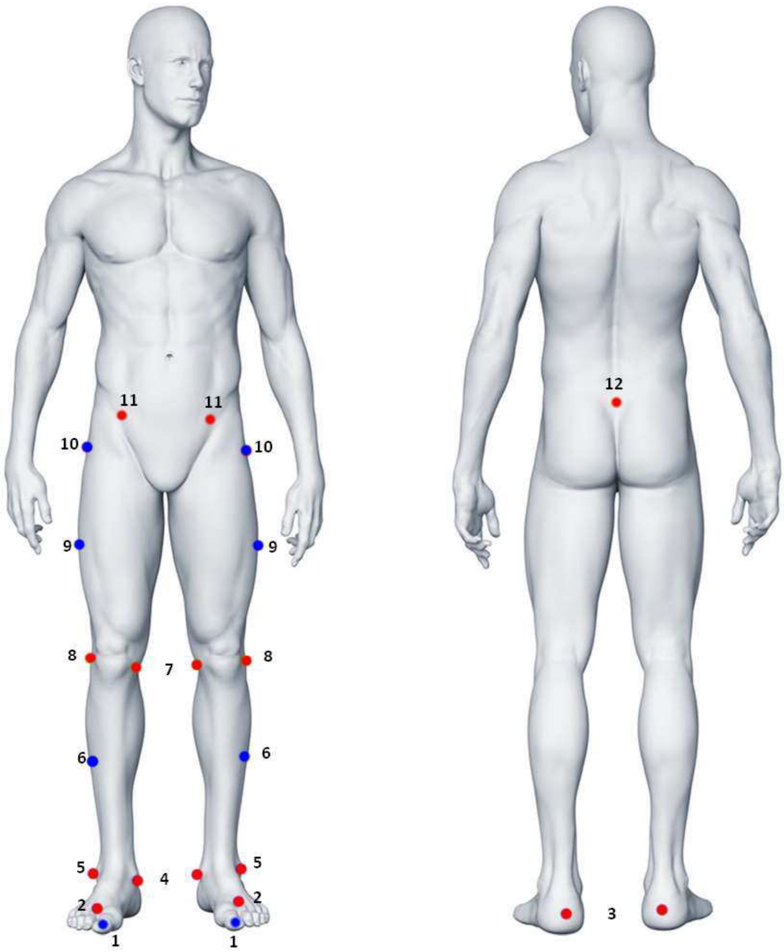


Figure 17.15: Set of markers for Inverse Dynamics with compulsory (red) and optional (blue) markers. The big toe marker is usually not tracked in the dynamic trial.

17.1.11 Recording- and Recognitiontest

Before the movement analysis is being performed, it is recommended to do a short test acquisition.

Instruction

- Start the acquisition by hitting Record video...
- Move an arbitrary marker around the capture area and place it in a way that all cameras can 'see' the marker.
- Stop the recording by hitting Record video... again or by hitting ESC
- Check if the marker is recognized well in each camera view. If not, recheck the settings of the cameras
- Save the recording temporarily by using Save.... Select the option *Assign as movement video* and put the cameras to the folder *Video*.
- Do a tracking-test by selecting 🖱 » Cameras » Automatic 3D tracking...
- Start the tracking by hitting Start tracking and check the resulting tracking, if the marker is being recognized well (further information can be found at 17.4.4.3)
- After a successful test the test project can be closed and a new project can be started

(a) Marker recognized (b) Marker not recognized

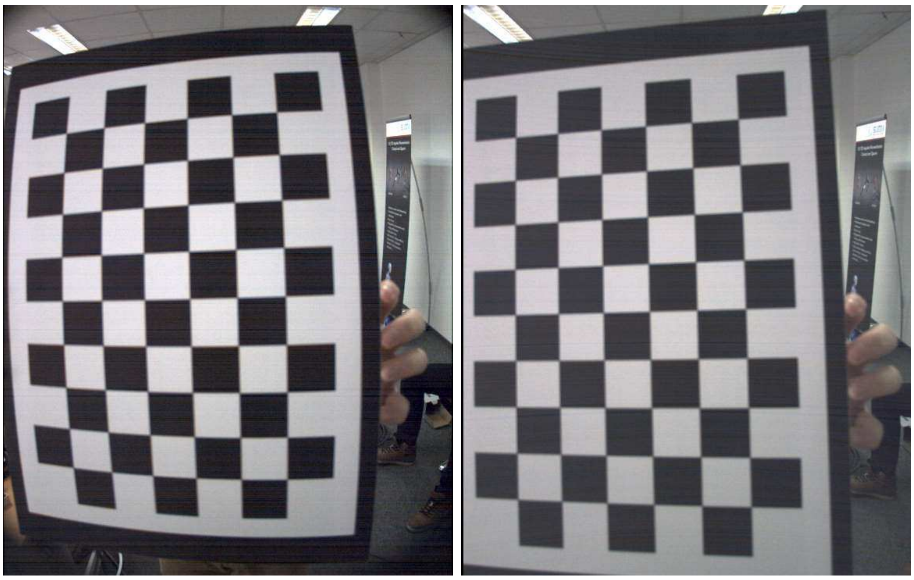
Figure 17.16: Recognition test of a marker

17.2 Distortion correction

Note

The correction of distortion is optional. The higher the quality of the lenses the less is the need for correction of lens distortion. If a lot of zoom is applied to the lens, only the middle area of the lens will be used and the distortion can be limited and a correction might not be needed.

Lens distortion is a projection error on the image which can occur due to different reasons concerning the lens. Most common for lens distortion are pincushion or barrel wise distortion which leads to 'straight lines being not straight anymore'. Starting from the principal points the 'projection-rate' decreases as in the direction of the boarder of the image.
Correction of such distortion can be done by two different ways: The first possibility is to correct it by the wand data, which is recorded in the calibration section. The second one is to determine distortion parameters by recording chessboard movements. This way of correction is in contrast to the other less comfortable but more accurate. **Simi recommends to conduct the correction of distortion by wand data, since it saves time and in connection with a good calibration, it is good enough for even the highest standards.** If the distortion correction by wand is not good enough, the distortion correction by chessboard can still be done afterwards.



(a) Original camera view (b) Camera view undistorted

Figure 17.17: Distortion correction on camera views

Info

Figure 17.17 shows two images of the same camera. On the one hand the original camera view can be seen (a) with a barrel distortion, which can be seen easily on the left hand side, illustrated by a solid red line. On the right hand side the corrected image can be found (b).

17.2.1 Distortion correction by wand data

To correct videos by wand data is an easy and comfortable way of distortion correction. The most significant advantage of this correction method is, that you only have to record calibration videos, which you have to capture either way. Minor disadvantage is that the correction by chessboard data is a little bit more accurate than this method. The computation of distortion parameters is conducted in section 17.3.4 and the correction of distortion is applied to the videos automatically.

17.2.2 Distortion correction by chessboard videos

Tutorial

For this section, a video tutorial can be found at `https://www.youtube.com/watch?v=uvUQKI-n1fY`

If you are not using wand data for the correction of your videos, you have to record chessboard videos. How to do this is described in the following sections.

17.2.2.1 Create project and record chessboard video

Instruction

- Create a new project, name it *Gait analysis* and save it
- Open the camera view by clicking *Capture video*.
- Call the option Edit available devices... and select just the first camera
- Open the view of the camera by clicking Capture video
- Record a video using Capture video
- During the recording move the chessboard into all corners of the camera view. Pay attention, that the chessboard is as parallel to the camera as possible (cf. Note)
- Save the video as *2D calibration video clip* and name it 'Camera 1'
- Create a new Camera group 'Calibration cameras' and a new camera object
- Repeat those steps for every camera and save the videos in new camera object in the group 'Calibration cameras'

Note

Following positions should occur in the chessboard video:

- Chessboard centered as close as possible to the camera
- Chessboard centered covering only the middle area of the camera
- Chessboard in each corner of the camera view, covering approximately 1/4 of the camera view
- Chessboard close the boarder of the camera view, horizontal centered for the top and bottom boarder, vertical centered for left and right boarders
- Chessboard tilted horizontal and vertical (4 directions)
- Chessboard rotated

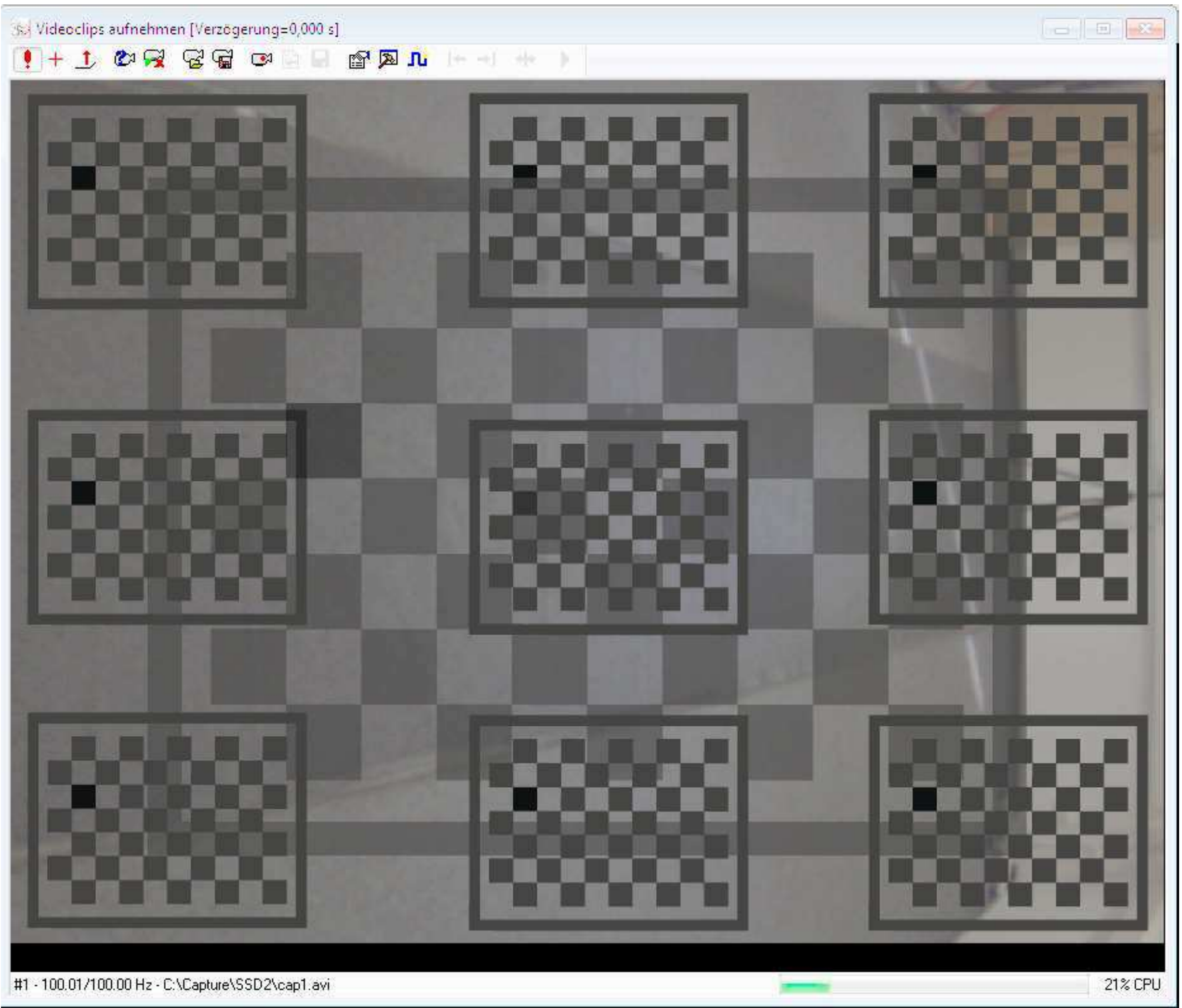


Figure 17.18: Positions of the chessboard for a successful distortion correction

17.2.2.2 Computing distortion parameters

Instruction

- Right click on 'Camera 1' and click Calculate Distortion parameters
- Click Start
- Save the computed parameters
- Repeat those steps for all cameras

Tip

The calculation of distortion parameters can be computed for all cameras at once. However, it may be difficult to see if all chessboards have been recognized correctly and one might have to recapture videos.

Tip

If the calculation fails due to some missing chessboard patterns two options are given. The distortion correction can be computed anyway and validated by visual inspection or a second video can be recorded and the new data can be appended to the existent. This option will automatically ask if this should be executed when the 'Determine distortion parameters' function is called.

17.3 Calibration

Tutorial
For this section, a video tutorial can be found at `http://youtu.be/Qn4NeejeEIE`

A T-wand and a L-frame is required in order to create a valid 3^D-calibration. The calibration will create a reference system for the measurement (= global coordinate system). The T-wand is used to apply a known size to the system for metric calibration. The L-Frame provides two different shanks which indicate the Y-axis (long shank) and the X-axis (short axis) of the global coordinate system. Perpendicular to both axes the Z-axis will be that, which will result in a right hand coordinate system.

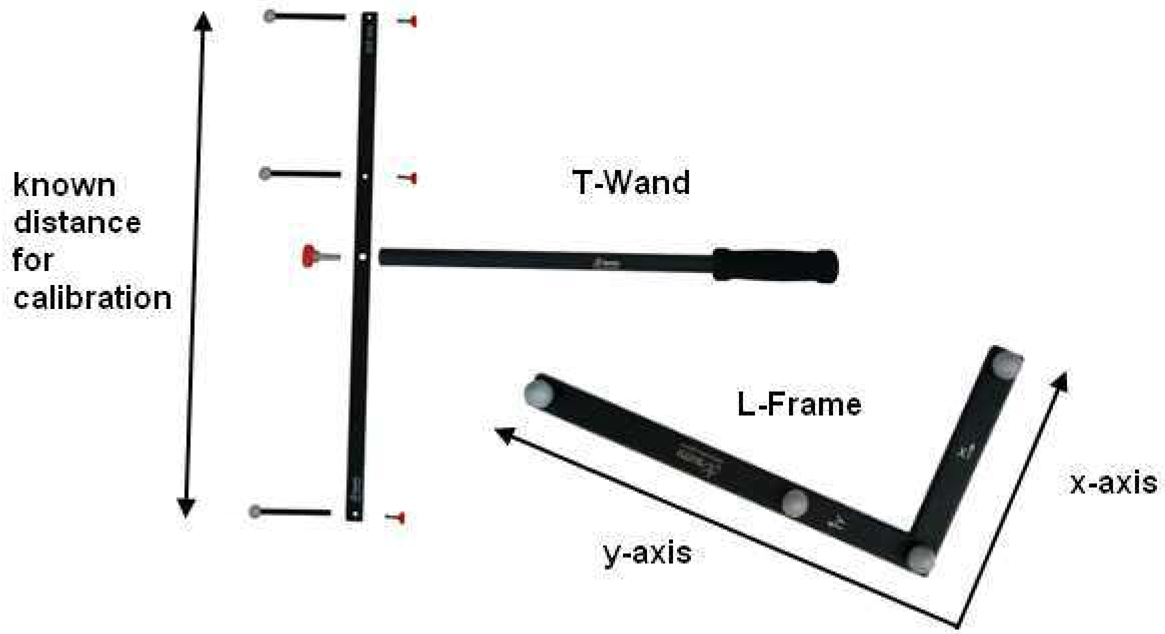


Figure 17.19: Calibration Tools: T-Wand and L-Frame

17.3.1 Capture calibration videos

The capturing of the calibration videos is more or less equal to capture movement videos (cf. 17.4).

Instruction

- Position the L-Frame at the starting point of your movement, so that it is visible for at least two cameras
- Align the L-Frame in a way, that the Y-axis (cf. 17.3) equals the direction of movement
- Start the capturing with [Capture video]
- Move the T-frame around the capture space and move for at least 30 seconds. Pay attention to cover the whole capture space and move it in a arbitrary pattern
- Save the video by hitting [Save...]
- Select the directory to save in and name the videos *Calibration%d* (% ensures consecutive numbering of the recorded videos)
- Choose *3D calibration video clips*
- Assign those videos to the existing camera group 'Calibration cameras'

Tip

Pay attention that on the one hand the videos for the calibration are not too short or on the other hand too long. Recommended is a duration of at least 30 seconds, however the whole capture area should be covered by the wand dance.

17.3.2 Automatic 3D wand tracking

Instruction

Open the automatic 3Dwand tracking for the calibration videos, in order to track the markers of the calibration-devices:
[mouse] » Calibration cameras » Automatic 3Dwand tracking... (cf. figure 17.20)

The approach for the automatic 3Dwand tracking for calibration is very similar to the automatic 3D tracking of movement videos. The only difference is the tracking mode, which is set to *Wand calibration*. Disturbing values like reflexions, or visible ring-lights of other cameras should be excluded using the *Area of interest*. The excluded area will be shaded out and avoids falsely tracked wands.

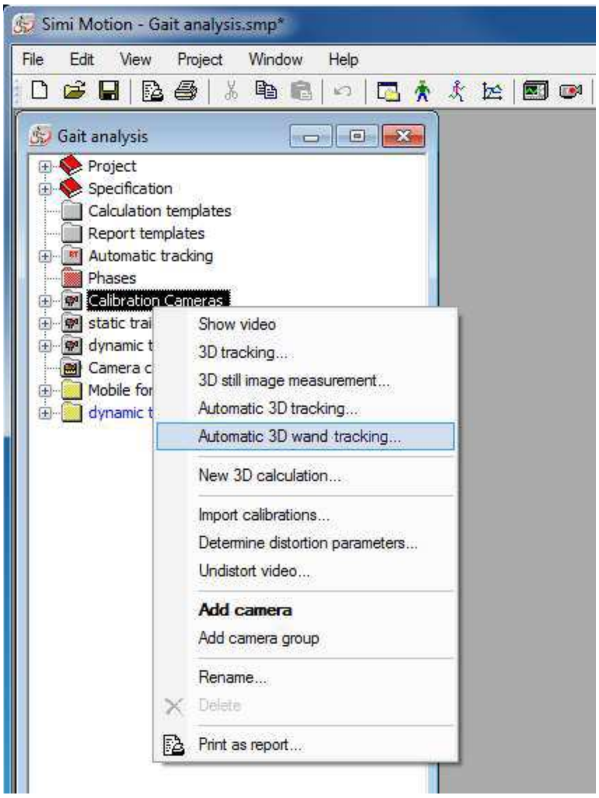


Figure 17.20: Automatic 3D wand tracking

Instruction

- Check the Area of interest and exclude the parts of the video image which should not be included to the tracking
- Save the Area of interest, as it can also be used for the dynamic movement tracking
- Start the tracking by hitting Start Tracking
- Click on Assign markers and check if the tracked markers:
  - If the markers are recognized well
  - If the L-frame was recognized well and assigned correctly
  - If the traces (trajectories of the markers) are mostly constant
  - If to many 'Ghost-marker' appear (Markers that are actually not there)
  - For a first guess take the number of found marker in account
- Tracking Options might be adjusted if markers are not been recognized (cf. 17.3.3)
- Export the tracked markers to raw data with Export to raw data
- Close the automatic 3Dwand tracking window and save its tracking.

Tip

If the camera setup is being used for further measurements, it is recommended to save or set the area of interest as standard

17.3.3 Options for automatic 3D wand calibration

If the 3D-Tracking does not recognize the desired markers, there are several options for modifying and improving the tracking, which can be found in Options on the right side of the *Automatic 3D-Tracking* window:

- Marker sensitivity
- Apply image processing settings

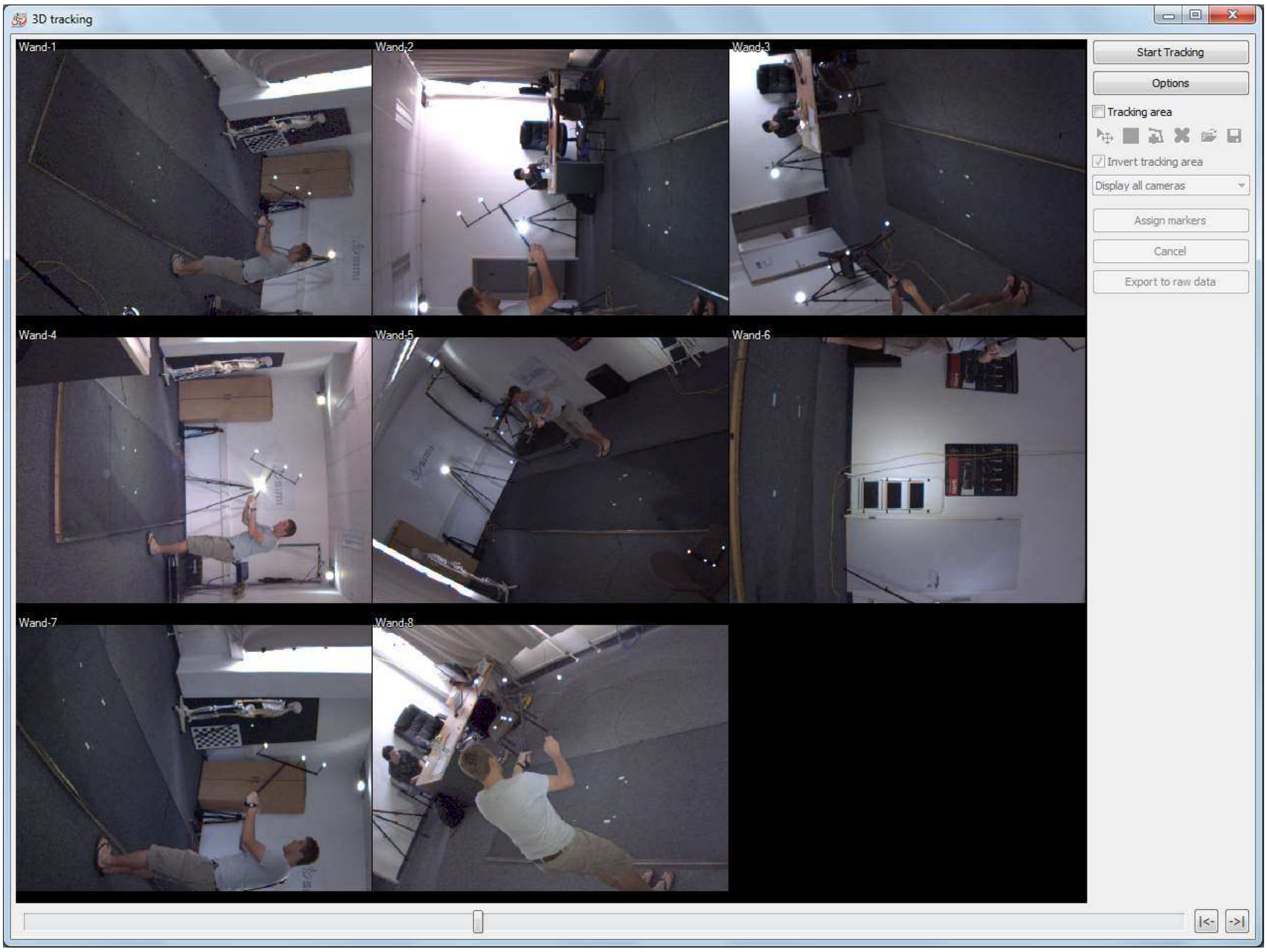


Figure 17.21: Working area for automatic 3D wand tracking

Tip

It could be useful to shortly start the tracking process to discover and denote possible problems. To do so, click on *Start Tracking* and to stop the tracking click on *Cancel*

The optimal settings are found if:

- All markers are recognized
- Not too many Ghost-markers have been detected
- Nearly no disturbing values like reflections occurred

After changing the setting for the tracking options and a good results can be reached, the tracking should be finished (cf. 17.3.2).

Marker sensitivity

If the marker sensitivity is set too low, this can lead to markers being not detected. The higher the marker sensitivity is set, the easier markers will be recognized. However, if the marker sensitivity is set to high, the chance of detected false markers increase. Thus a good level needs to be found which allows the detection of all markers, but no Ghost-markers.

Apply image processing settings

With this option you can apply image processing settings. You can adjust these settings by right-clicking a camera view in the Automatic tracking window.

17.3.4 Camera calibration groups

After conducting the *automatic 3^D wand tracking* a new wand raw data will appear in the camera folders of the 'Calibration cameras' camera group. To finish the calibration a new *camera calibration group* is required.

Instruction

- on *camera calibration group*
- Choose `new wand calibration group`
- Name it 'Calibration'

Now the information provided by the L-frame and the T-wand has to be transferred to the system. This information consists of the wand length and the floor offset. The wand length is set by the distance of the two outer markers and the floor offset is defined by the distance between the markers of the L-frame and the actual floor.
A window will open where these information is required. Furthermore the least amount of used cameras to be used for calibration needs to be set. E.g. if 5 cameras are set to be used for calibration, the systems searches for samples which shows the wand data in at least 5 cameras at the same time. All other samples will be ignored.
If you haven't recorded chessboard videos for the correction of distortion, you are able to compute distortion parameters here by using the wand data instead of the chessboard data. After computation of these parameters, distortion correction will be applied to all your recordings automatically, as the parameters are saved in this *camera calibration group*.

Instruction

- Set the wand length (here: 800 mm) and the used floor offset (here: 10 mm)
- Select the least amount of cameras to be used for calibration (select 3 cameras)
- Furthermore set the check mark at *Compute distortion parameters* (if you want to correct distortion by wand data)
- Press Ok to calibrate the system

Note

If you are working in a project with already existing distortion parameters, don't set the check mark at *Compute distortion parameters*. Otherwise new parameters will be calculated and the old ones will be overwritten.

17.3.5 Testing calibration

17.3.5.1 Calibration validation

Tutorial

For this section, a video tutorial can be found at `http://youtu.be/0EA8hFljGxg`

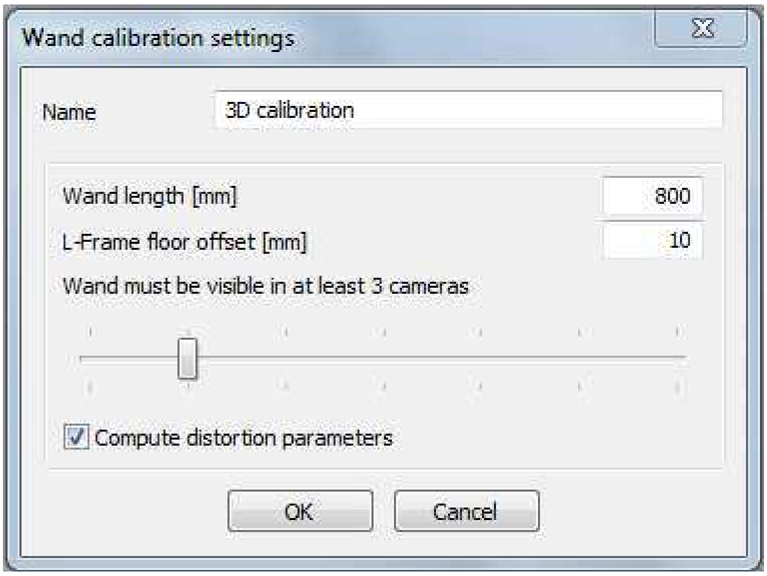


Figure 17.22: Settings for wand calibration

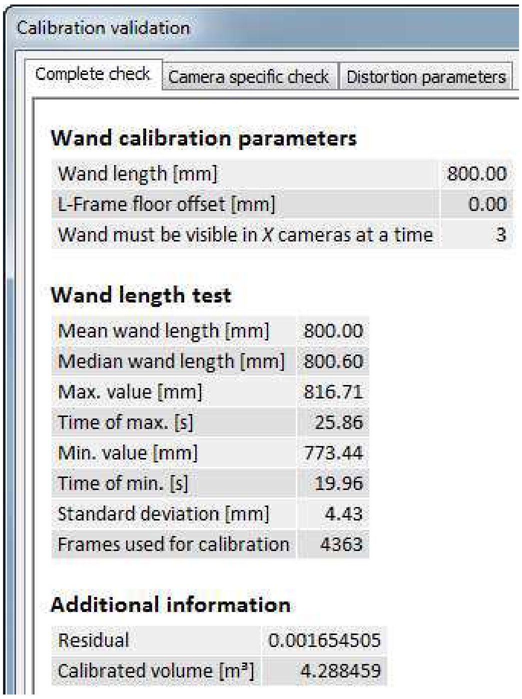
After computing the calibration a window, 'Calibration validation', will appear which provides information to prove the calibration. It shows the parameter of the floor offset and of the T-wand length which were entered by the user in the previous step. Furthermore the computed mean wand-length, its standard deviation and the amount of used frames can be found. Another important criterion for the calibration, the residual, is also displayed.

Tip

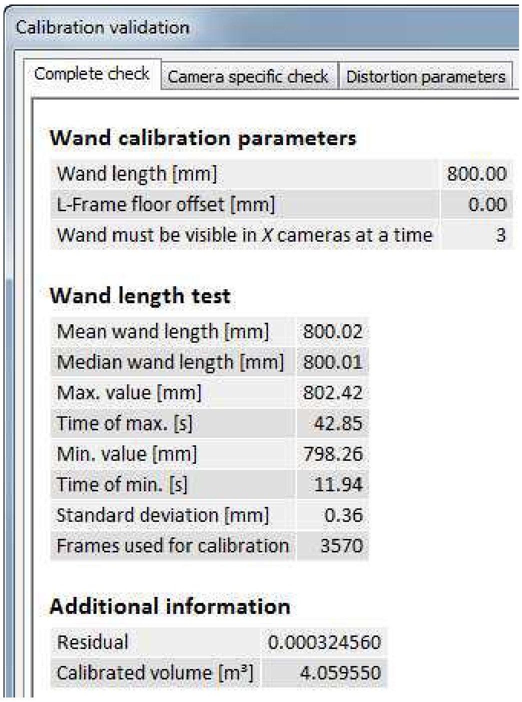
For a good calibration the following parameters should be (cf. 17.23):

- Mean wand length: Close to the entered value (80 cm)
- Standard deviation: < 1 mm (for corrected videos)
- Amount of used frames: A realistic value in relation to the recoding time (**correct**: 40 sec (4000 frames) and about 3500 used frames; **wrong**: 40 sec (4000 frames) and about 100 used frames)
- Residuum: <0.01

  This 'Calibration validation' window can be opened in the calibration-groups afterwards by [mouse] > Calibration > Validate...



(a) Values of a bad calibration



(b) Values of a good calibration

Figure 17.23: Proving quality of calibration by Mean wand length, maximum value and standard deviation

17.3.5.2 Still image measurement

By using the *Still image measurement* the quality of your calibration can be checked visually. The clicked points will be projected on the projection lines to the other cameras. If the desired point is clicked in all images the projection lines should intersect in the middle of the marker in each camera if the calibration is good.

Instruction

- Calibration cameras > 3D still image measurement (cf. figure 17.24)
- Check if in the drop-down menu the right video type (movement video, 2D calibration...) and the *camera calibration group* is selected
- Select one marker which is visible in as many views as possible
- Click the middle of the marker in one camera
- Activate the option *Show virtual line*
- Check if the virtual line hits the marker in all camera view (cf. figure 17.25). Increase the zoom to 200% by into the image view of each camera and selecting Set zoom 200%

Tip

This method is also very practicable to check if a calibration is still valid or not, because one camera might have been moved. In this case the virtual lines don't intersect on the marker. Consequently a new calibration has to be recorded.

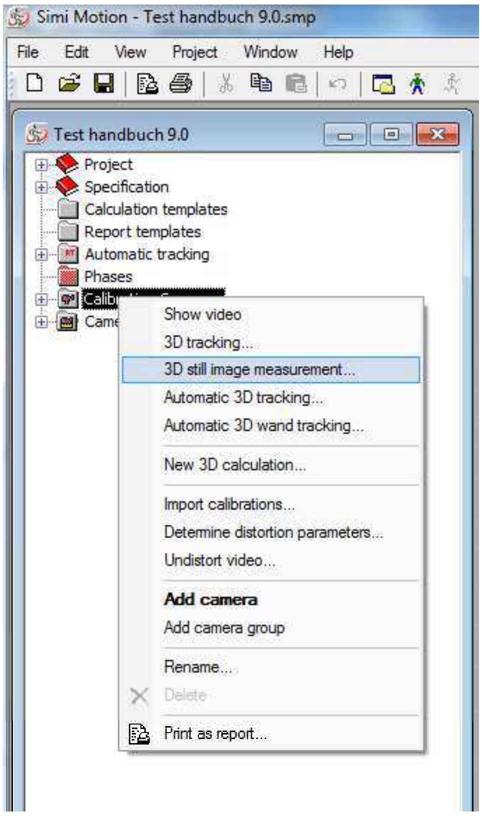


Figure 17.24: 3D still image measurement

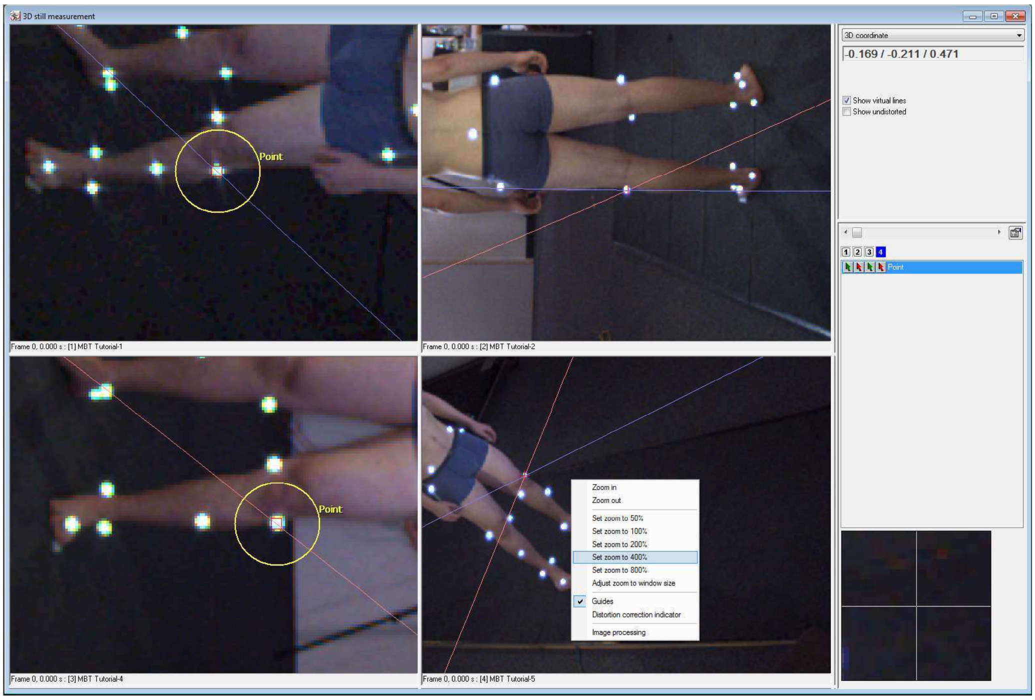


Figure 17.25: Zooming virtual line in still image measurement

17.4 Video capturing

After successfully doing all preparative steps and conducting a 3D-calibration, the capturing of movement videos can be started. Assure that you are working in the project intended for the gait analysis.

17.4.1 Specifications

Before markers can be digitized, the set of markers to be used needs to be specified in Simi Motion®.

Instruction

Select [mouse] › Specifications › Import from model. . . and choose the model *Lower extremities* to be able to calculate the Inverse Dynamics as well as execute the gait analysis report.

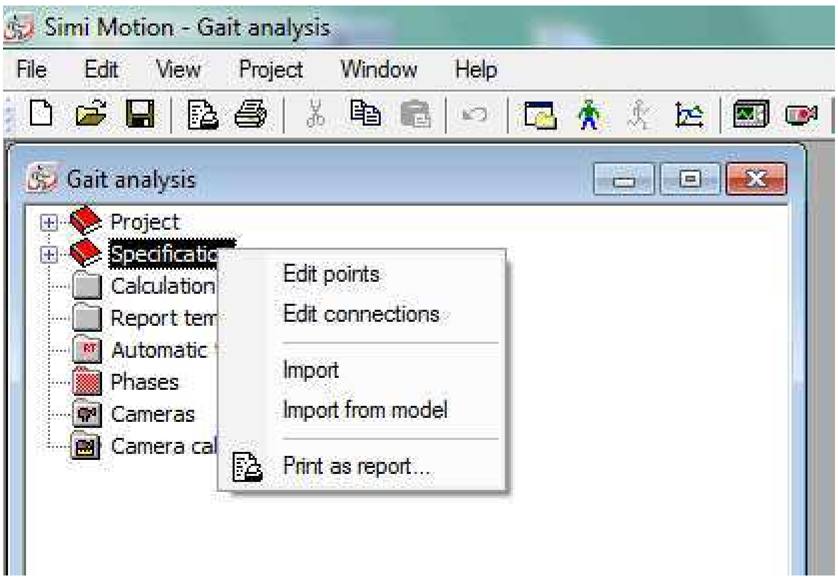
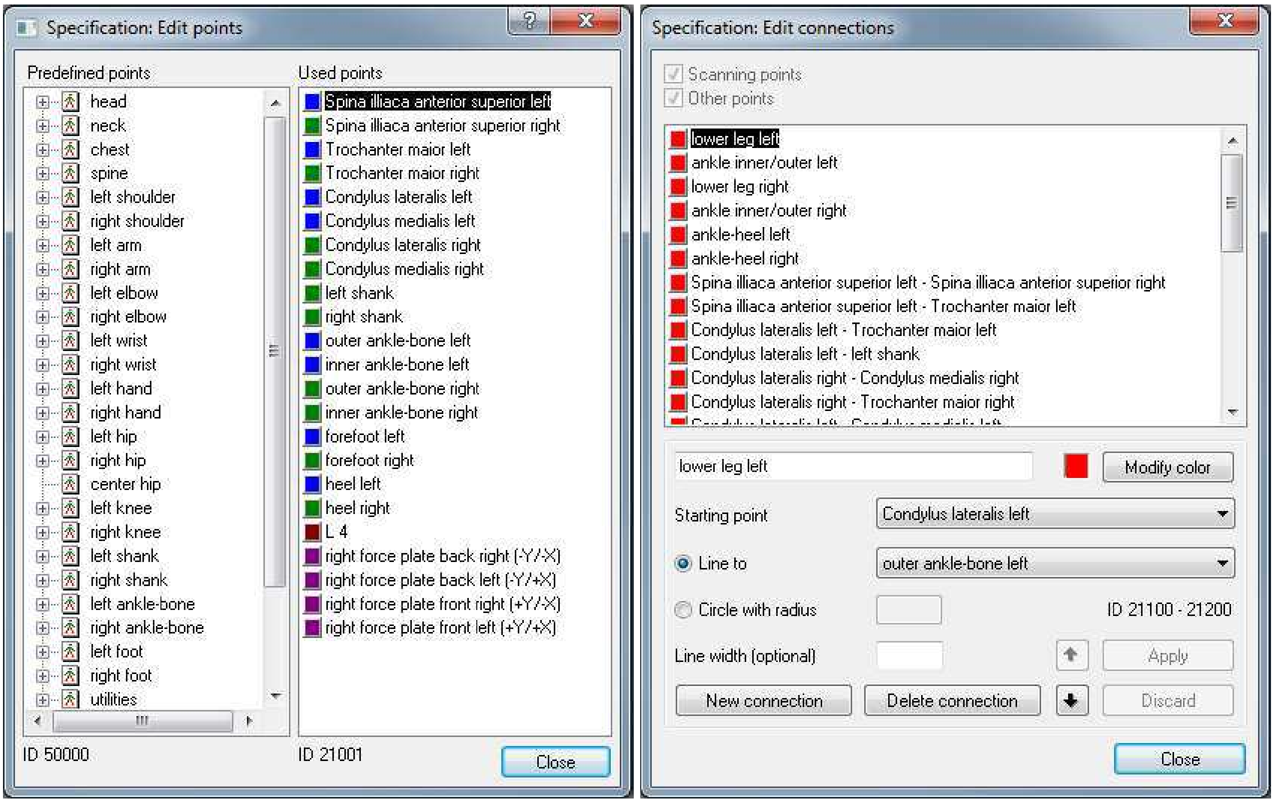


Figure 17.26: Importing specifications by project or model

To use different marker-setups the specifications can easily be adjusted by importing the specifications from a different project or creating new *Points* and *Connections*. The *Points* represent anatomical landmarks, which are used for the digitization. The *Connections* are used to connect certain digitized points for the visualization with the *Stick view* or *3D-view*.

Note

- Each marker to be digitized needs to have a corresponding defined image point in the specifications, including an unique ID (cf. figure 17.27)
- The used markers must comply with the *Model Based Tracking*-model (cf. section 17.4.4.3) and the Inverse dynamics.



(a) Image points for the markers (b) Connections of single image points

Figure 17.27: Specifications: image points and connections

17.4.2 Static trial

First a static recording for initialization of the inverse dynamics needs to be done. The static recording takes a short shot of the patient in neutral standing position. Additionally the force-plates can be initialized for the software.

Note

If you do not want to compute the gait analysis report or the Inverse Dynamics, you can ignore the static trial.

17.4.3 Starting capture and editing

Instruction

- Put 4 markers on the corners of the force-plate.
- Click Capture video.
- After capture starts remove the markers from the force-plate corners and record a short sequence of the patient standing in neutral position.
- Finish the recording by hitting either ESC or Capture video again.

Using the blue arrow-keys in the top right corner of the capture window, the video can be cut. E.g. the beginning and ending of the video file can be cropped to avoid large video files with a lot of unneeded information (cf. **??**).

17.4.3.1 Save recording

Following the captured video files have to be saved.

Instruction

- Click Save...
- Create a new folder in the desired directory and name the video files *Static trial%d*

After saving the videos, one can decide if the videos should be linked to the existing camera-group or a new camera group should be created. If a new camera-group should be created, select *New camera-group*.

Instruction

- Create a new camera group
- Call it ’Static trial’
- Choose *Movement video* for the saving options (cf. figure 17.28)

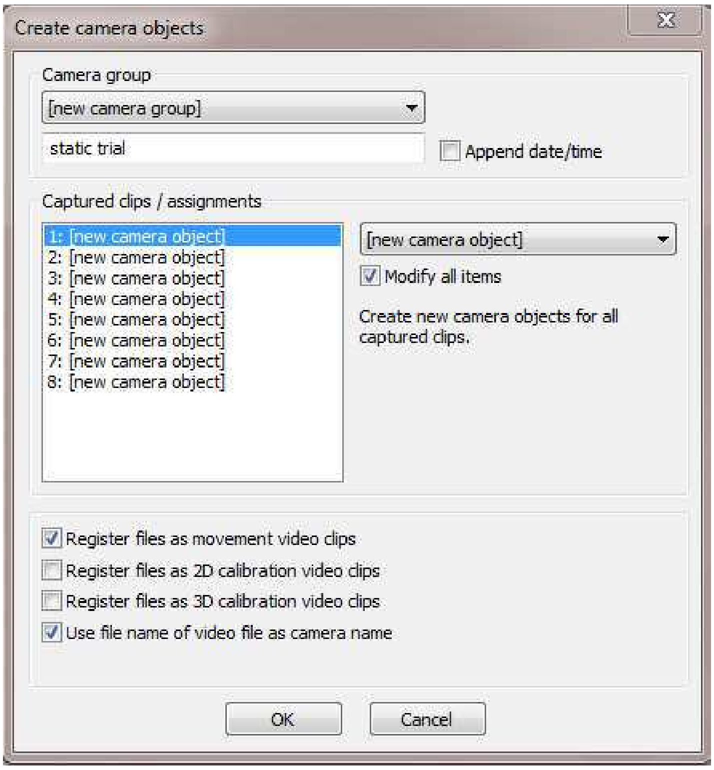


Figure 17.28: Saving captured videos in a new camera group as Movement videos

17.4.3.2 3D-Tracking

Now the the anatomical landmarks which have been indicated by the markers on the patient need to be digitized.

Instruction

- Select [mouse icon] Static Data 3D-Tracking... (cf. figure 17.29)
- Assign each marker to the according specified point in the list on the right hand side. Assign each marker with a left-click in at least two cameras (cf. figure 17.30)
- Make sure to click the middle of the desired marker
- Assign the marker of the force-plate corners in at least 2 cameras in one frame
- Close the *3D-Tracking*

Tip

The minimum requirement for the *3D-Tracking* is two cameras, to allow the computation of valid 3D-data. Assigning the marker in more cameras can increase the accuracy, however the positive effect will be very small for the fourth and following cameras.

Move the mouse-courser to the marker to be tracked in the video view and push down and hold the left mouse button. Doing this will lower the mouse-speed and the image-point will be zoomed in the magnifier on the bottom right hand side to accurately set the point. Releasing the left mouse button will set the digitized point.
To simplify the assignment select cameras, which display (mostly) all markers at one time.

17.4.3.3 Computing 3D data

Now the recorded marker data can be transferred to 3D-Data. This step allows to set the amount of cameras which should be used for the calculation of the 3D-Data. Always use the amount of cameras which has been used in the *3D-Tracking*.

Instruction

- Select [mouse icon] Static trial New 3D calculation... (cf. figure 17.31).
- Choose the right calibration group ('Calibration') in the drop down menu

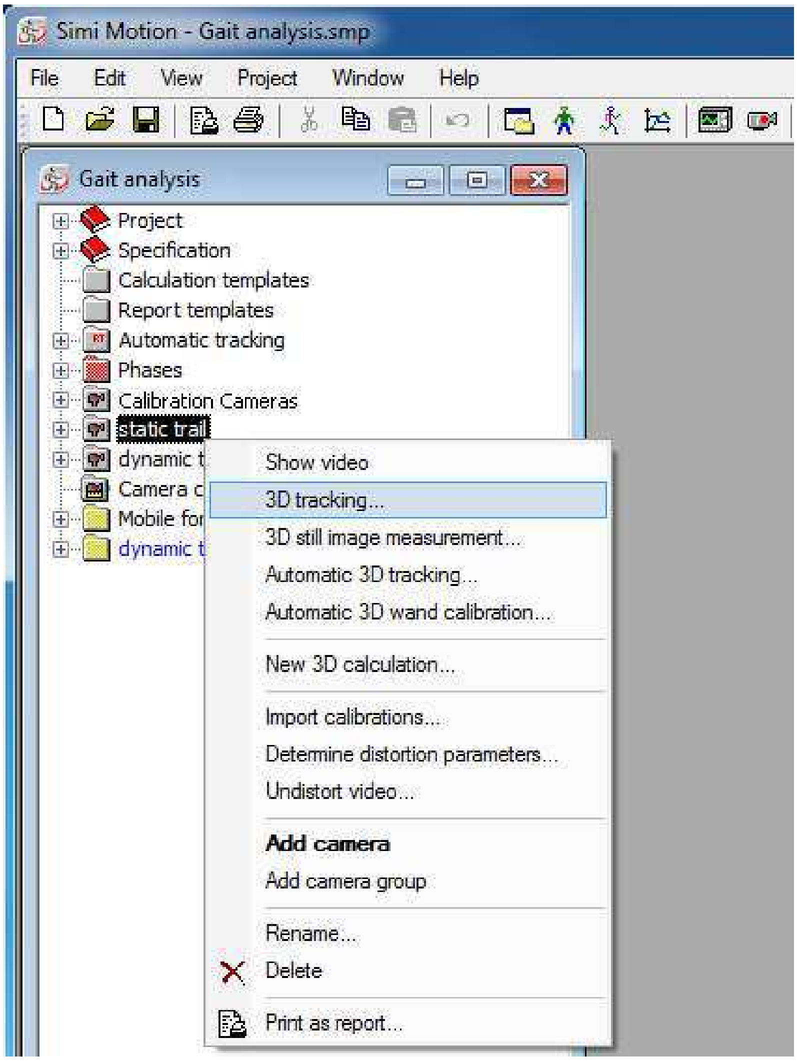


Figure 17.29: 3D Tracking

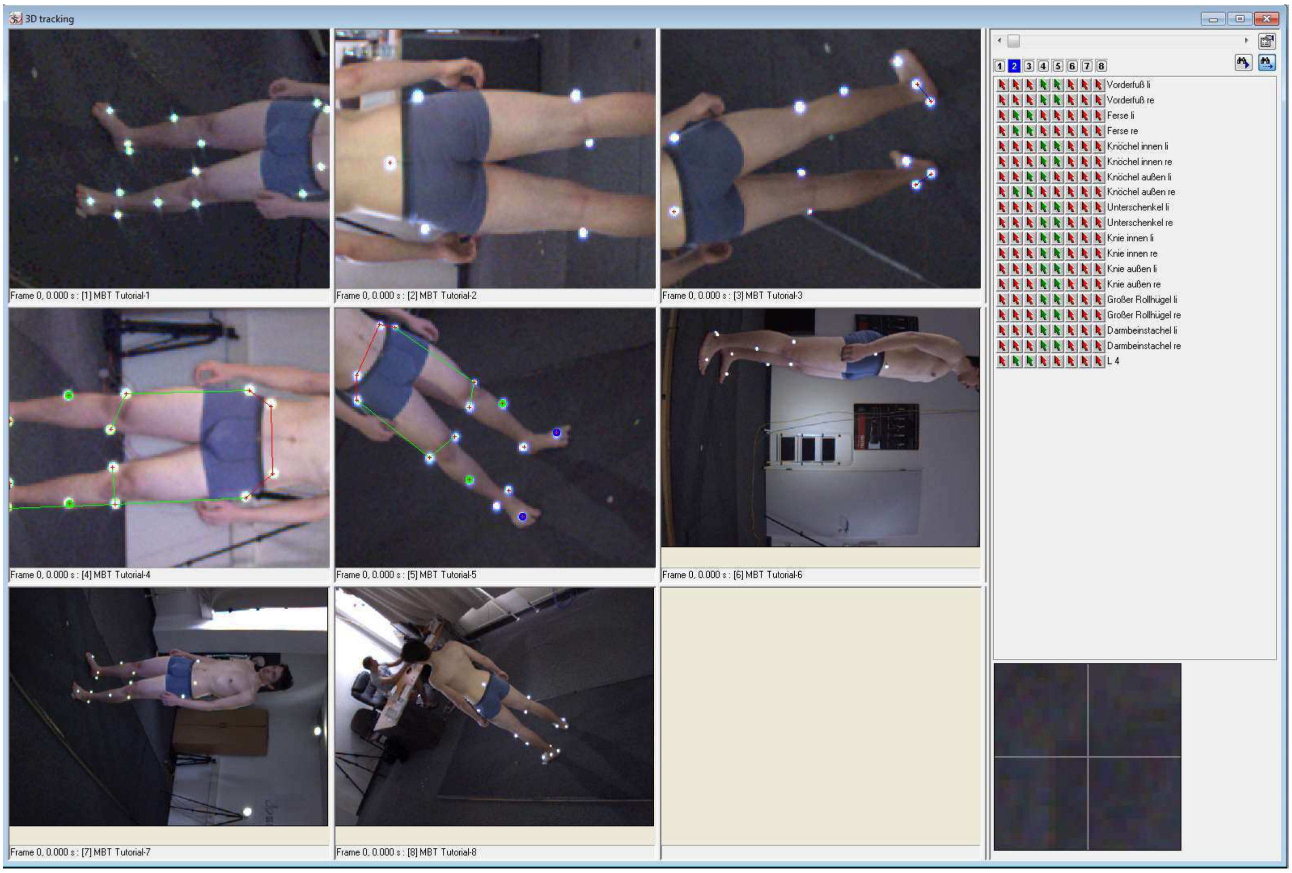


Figure 17.30: Tracking markers for static trial

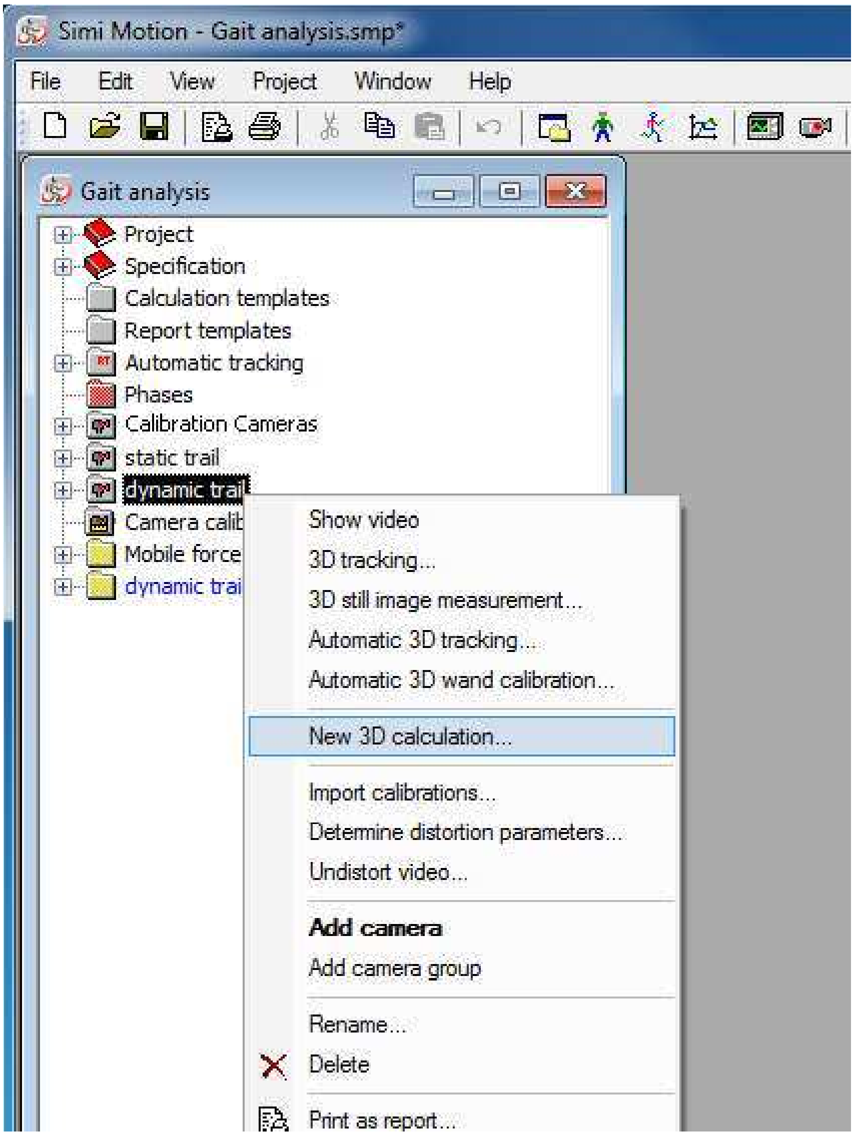


Figure 17.31: New 3D calculation

Following the result should appear in the project-tree called *Static trial-3D-coordinates*.

Tip

The setting of the used cameras can also be modified belated by 🖱 › Static trial-3D-coordinates › Properties (cf. figure 17.32). Blue highlighted data groups represent 'dynamic' data groups which will be updated whenever the raw-data, calibration or settings are adjusted.

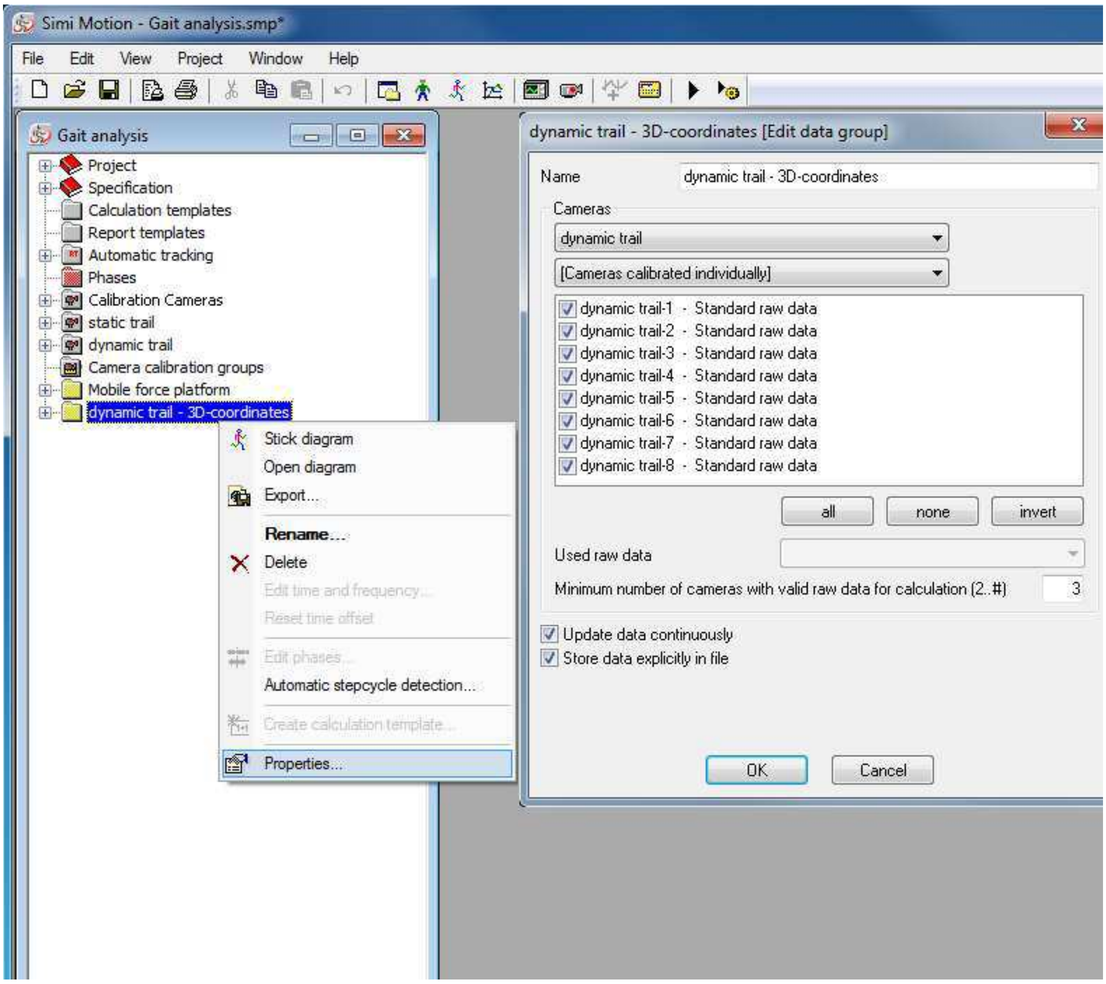


Figure 17.32: Properties of 3D-Data

17.4.4 Dynamic trial

The dynamic recording equals the actual movement recording of the analysis. For a correct gait analysis record the patient in a way that at least two complete gait cycles have been captured and each leg (left&right) have hit the force-plate once. The set of markers remains the same as in the static trial.

Note

If you have attached markers to both big toes in the static trial, dismount them now. Otherwise it can cause errors with assignment because of the proximity to the forefoot markers (cf. 17.1.10).

17.4.4.1 Capture and save movement video

Instruction

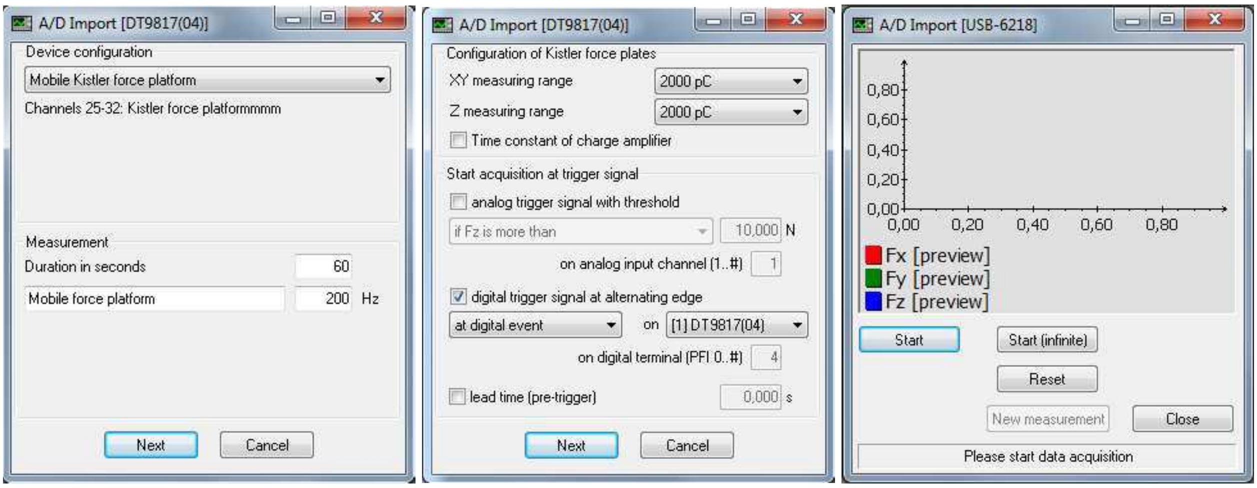
- Activate the recording of the force-plate (Analog data) by clicking Acquire data (cf. figure 17.33). By starting the capture of the video files the data acquisition will start automatically.
- Record the gait cycle of the patient as described in 17.4.3
- Save the videos as movement clips as described in 17.4.3.1
- Select the directory to save in and name the videos *Dynamic trial%d*
- Create a new camera-group and name it 'Dynamic trial'

Figure 17.33: Recording force data

17.4.4.2 Creating a initialization frame

Tutorial

For this section, a video tutorial can be found at `http://youtu.be/1vTgVFNpVs8`



(a) Force-plate selection (b) Force-plate configuration (c) Force-plate ready to acquire

Figure 17.34: Settings for Forceplate

For the later assignment of the markers by model based tracking an initialization frame is required. For this you act analogue to the static trial and assign every marker in one frame in at least two cameras (cf. 17.4.3.2).

Instruction

- Select [mouse] » Dynamic Data » 3D-Tracking....
- Scroll to a moment of time, where the subject is possibly standing in the center of all camera views and the markers are visible in all cameras. Remember the number of this frame.
- Assign each marker to the according specified point in the list on the right hand side. Assign each marker with a left-click in at least two cameras (cf. figure 17.30).
- Make sure to click the middle of the desired marker.
- Close the *3D-Tracking*.

As soon as all markers are assigned, create a new 3D-calculation of the dynamic trial.

Instruction

- Select [mouse] » Dynamic trial » New 3D calculation....
- Choose the right calibration group ('Calibration') in the drop down menu

The result can be found in the project tree named *Dynamic trial 3D-coordinates*.

Tip

To check the 3D-data, drag the data row into the work environment and find the frame where you clicked the markers with the help of the time bar and the cursors. With the connections between the markers and your knowledge of where they should be you can find possible assignment errors. In the 3D-Tracking you can correct those errors quick and easy as soon as you know which markers where clicked incorrectly.

If all Markers are assigned correctly and the 3D-calculation is completed, you can create the model initialization.

Instruction

- Dynamic trial 3D-coordinates » save as model initialization
- Enter the frame number, in which you clicked the markers twice in the 3D-tracking.

17.4.4.3 Automatic 3D-Tracking

Tutorial

For this section, a video tutorial can be found at `http://youtu.be/I7hUYu_EX9o`

After an initialization has been created for the tracked model, the software can track the markers automatically.

Instruction

Open the automatic 3D-Tracking with Dynamic trial » Automatic 3D-Tracking...

Minor details or disturbing reflections, e.g. LED ring-lights, can be excluded with the *Area of interest*. The excluded area will be shaded out.

Instruction

Apply an *Area of interest* or load the one used for the calibration

17.4.4.4 Start tracking and assigning

Instruction

- Start the tracking by Start tracking
- As soon as the tracking is finished, make sure the option model assignment is deactivated, then click *Assign markers*.
- Scroll the video to check if:
  - the markers are recognized well
  - the traces (trajectories of the markers) are mostly constant
  - not too many 'Ghost-marker' appear (Markers that are actually not there)
  - For a first guess take the number of found marker into account (if the number of markers in a camera is extremely high, the tracking was usually not very good).

Tracking Options might be adjusted if the tracking is not good and markers were not recognized correctly (cf. 17.4.4.5).
Otherwise continue with:

- Set the check mark at Marker association.
- Now choose the right model for the measurement (here: Lower extremities).
- Then select your initialization frame in the *Init project* frame.

After selecting an initialization project yellow crosses will appear in each camera. These crosses refer to the initialization frame.

- Search with the time-bar at the bottom of the tracking window a moment where the markers are coincident with the yellow crosses.
- Now click Assign markers to start the assignment.
- Accept the assignment with OK.
- Export the results of the tracking to raw data using Export to raw data.
- If already raw data exists in the cameras, you will be asked how to proceed with the new data. It is recommended to choose *Only overwrite tracked samples*.
- Close the automatic 3D-Tracking.

Figure 17.35: Perfect match of yellow crosses with initialization frame

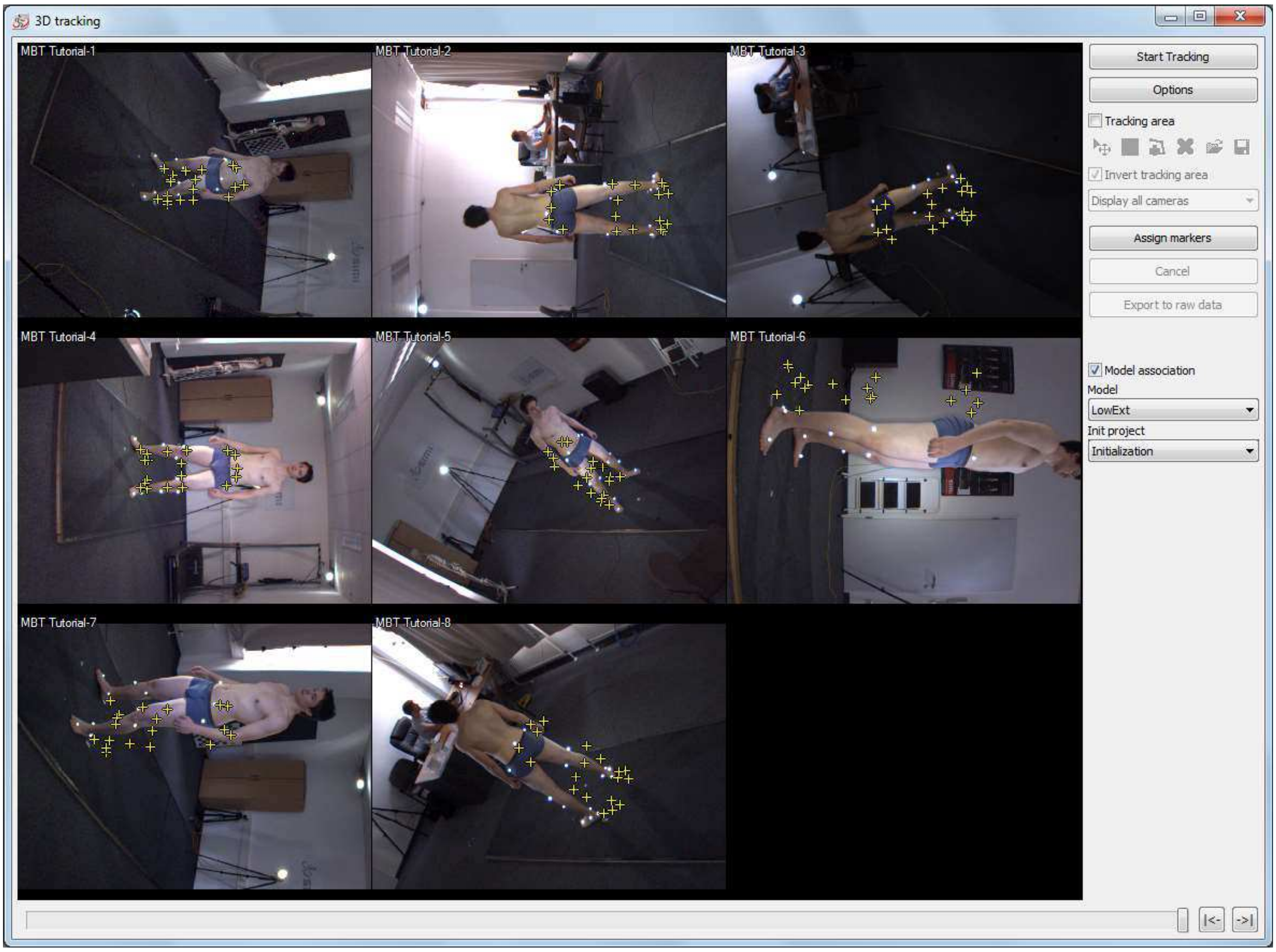


Figure 17.36: Bad match of yellow crosses with initialization frame

17.4.4.5 Tracking Options

In addition to the tracking options of section 17.3.3, you are able to adjust the settings according to:

- Recovering sensitivity
- Post processing sensitivity
- Use colored LEDs
- Calculate 3D-correspondences
- Increase marker size artificially
- Delete temporal static artifacts

Recovering sensitivity

The recovering sensitivity will recover temporarily hidden markers. E.g. if the hip marker is temporarily covered by the moved arm, the software tries to reassign the newly found marker as the hip marker.
Also for this option it is very important to find the right level. If the recovering sensitivity is set too low, the amount of found markers can skyrocket. If the value is set too high, markers which obviously don't belong together could be mixed up.

Post processing sensitivity

The post processing sensitivity tries to eliminate wrongly assigned markers e.g. ankle bone and forefoot. This options checks the trajectories of the detected markers. The higher the value, the more possible problems arise and will be split into different markers.

Use color LEDs

This option can be activated if colored LEDs, like for Simi Aktisys®, are used. This might be a possible option if you extend your set of markers with color LEDs or import Simi Aktisys® videos.
E.g. if a red LED marker is used for the Hip and set as a red marker in the specification (cf. 17.4.1) it can be assigned automatically if this option is activated.
This option can help to decrease the time of post processing for the marker assignment.

Tip

Active LED marker and passive retro-reflective markers can also be mixed. In this case the reflective markers will appear as blue markers most of the time.

Calculate 3D-correspondences

The 3D-correspondence calculation can be used if a valid calibration already exists in order to support and improve the automatic merging of markers and reduce the amount of resulting markers to be assigned.

Note

The option Calculate 3D-correspondences should be activated *always* for 3D-calculations as it improves the accuracy of the results.

Increase marker size artificially

This options offers another possibility to detected forgotten markers. Markers might be not detected as markers because they appear to small for the tracking algorithm. Activating this option the software artificially increases possible markers and small markers might be detected.

Note

Increasing the marker size artificially could lead to inaccuracies computing the center of the marker.

Delete temporal static artifacts

If disturbing values still exist, even though they have been excluded using the area of interest, this option might take care of small artifacts.

Note

Explanations of the two other tracking options (*marker sensitivity* and *apply image processing settings*) can be found in section 17.3.3

17.4.4.6 Dynamic 3D-data

The 3D-data can be verified by dragging one camera into the workspace and [mouse] Videomix and Overlay.

17.4.4.7 Edit 3D Data (optional)

Simi Motion® provides some further options to edit the calculated data. For example one can filter or interpolate the measured values. Furthermore exist several options for creating new data rows.

Note

The options for editing 3D-Data are not mandatory and should only be executed with a good knowledge of the operations.

Create new data row

Tutorial

For this section, a video tutorial can be found at `http://youtu.be/D8xdBOM9GTM`

The option *New data row* provides different mathematics operations. Further information on this topic can be found in chapter 14.1.

- Open *New data row* by hitting F4 or the icon New data row in the top bar.
- Enter the name of the newly created data row.
- Select via Drag&Drop the desired data, e.g. *Dynamic 3D coordinates* into *Data row* and choose the components *Coordinates (XYZ)* (cf. figure 17.37).
- Select the desired operation.
- The calculated result can be found in the project-tree.

Tip

Highlight the values to be used for computation and open *New data row*. Thus will save the step for of selecting the data needed for computation as they are already filled into the form.

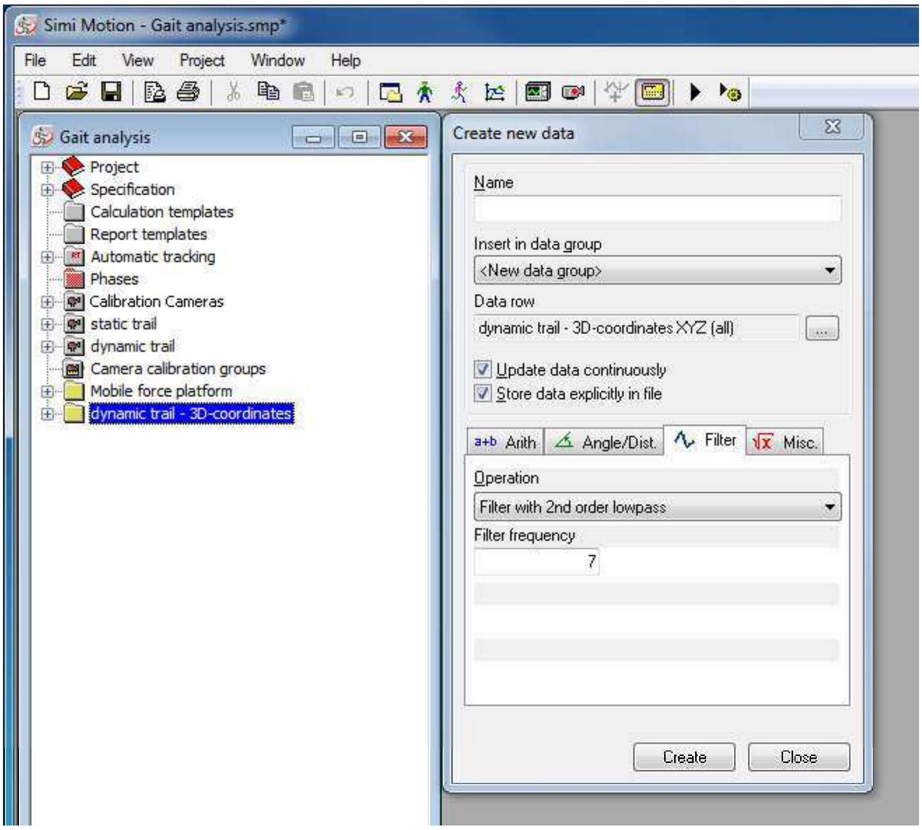


Figure 17.37: Opening of a new data row

Filter and Interpolation

Various filter-operations can modify the measured values with respect to their frequency or amplitude. Interpolation is a tool to fill up gaps between measured values by mathematical operations. Nodes are used to create a approach to a linear or spline function to fill the gaps.

New data row

Common filter in biomechanical research or gait analysis, like a low-pass or *Butterworth* filter, can be applied as described in section 17.4.4.7 *Create new data row*

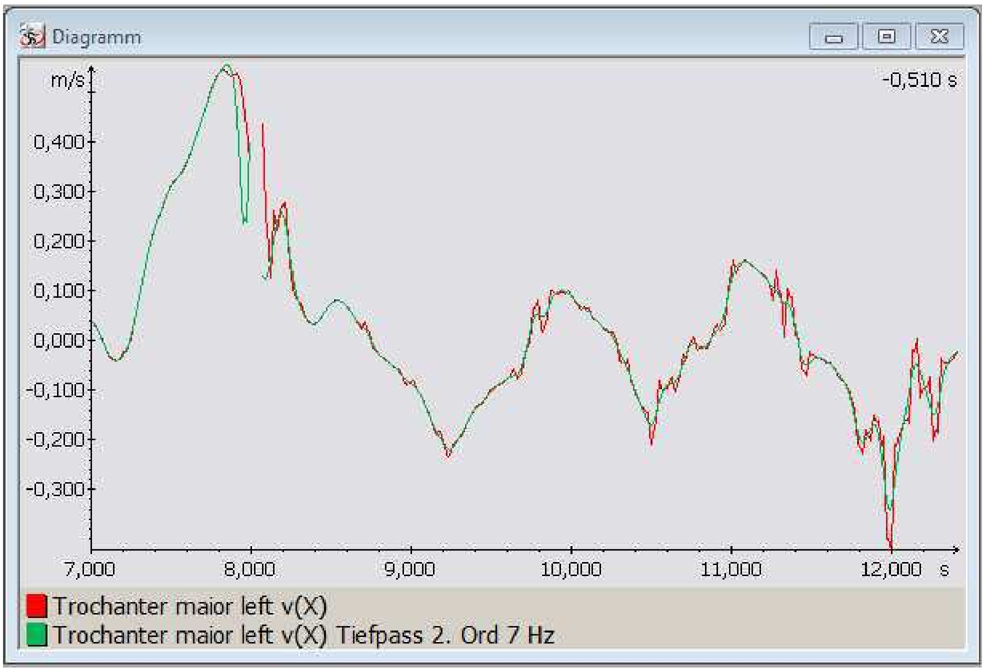


Figure 17.38: Filtering with a low-pass 2nd order with 7 Hz cut-off frequency

Filtered raw data

Filter- or interpolation-functions can also be applied to raw data. The result is being called *Filtered raw data* by Simi Motion®. The appropriate folder can be found in the project-tree (e.g. *Dynamic Trial\Camera1\Filtered raw data*). Right-clicking this folder will lead you to *Properties*, where the settings for the filter and interpolation options can be modified. Given options are:

Filter:

- Smoothing with Moving Average (Enter the Smoothing radius)
- Filter with low-pass (Enter the filter frequency)
- Filter with low-pass 2nd order (Enter the filter frequency)

- Smoothing with Spline (Enter the error variance)

Interpolation:

- linear interpolation
- Spline-interpolation

If filtered data should be used, this has to be set for each camera-object. Further one has to define the *Filtered raw data* as *Standard*. To do so, [mouse] › Filtered raw data › Use as standard. Afterwards the 3D-coordinates have to be computed newly.

Note

Please note, that by applying filters measured values could be slightly biased. Further note, that errors are greater in the derivations of a data row, since it multiplies during the derivation of filtered coordinates. Also is the interpolation of missing values only a approximation of the true value.

17.5 Inverse Dynamics

The *Inverse Dynamics* describes a biomechanical method aiming at the determination of joint-torques and muscle forces. To determine those values the body is divided into 16 different segments: Foot, lower leg, upper leg, upper arm, lower arm, hand, head, lower trunk, upper trunk and pelvis. Those segments are connected with several joints. The torques and forces are being computed from a combination of the recorded kinematic parameters and data from the force-plate. Utilizing the inverse dynamics global coordinates are transfered to local coordinates of the patient. However, to be able to compute inverse dynamics external forces must be known, otherwise only inverse kinematics can be computed

17.5.1 Computing the Inverse Dynamics

Instruction

To compute the inverse dynamics go to Project › Inverse Dynamics.

Following a window pops up (cf. figure 17.39), which holds several fields of information needed for the computation.

Model

Different inverse dynamic models can be selected for the computation

Instruction

For the model (set of markers) used in this manual use the option *Full body, static(2015)*.

Description

Name the computation of the *Inverse Dynamics*

Static 3D-Data

To allocate the static trial two options are possible:

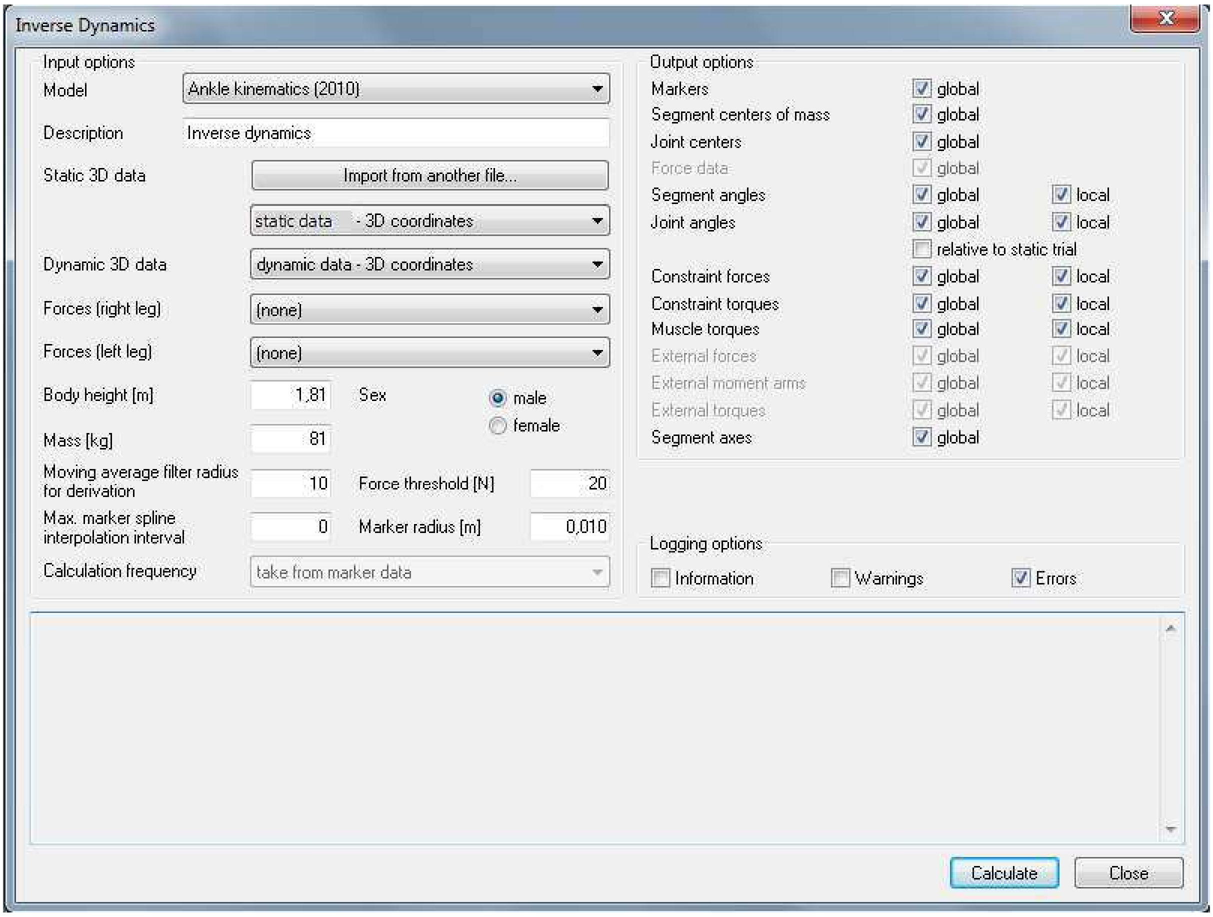


Figure 17.39: Working area for inverse dynamics

Instruction

- Select the static trial from a different Simi Motion®-project. Click Import from other file
- OR: Select the static trial 'Static 3D coordinates' from the current project from the drop down menu

Dynamic 3D-Data

Instruction

Select the dynamic data from the movement trial 'Dynamic 3D coordinates new'.

Forces right/left Leg

The data for the option *Forces right/left leg* can be found in the recording of the force-plate. Those data can be found lower in the project-tree.

Patient data

Provide several information of the recorded patient. Those parameters help to determine the size and weight of the individual segments and the following inverse dynamics.

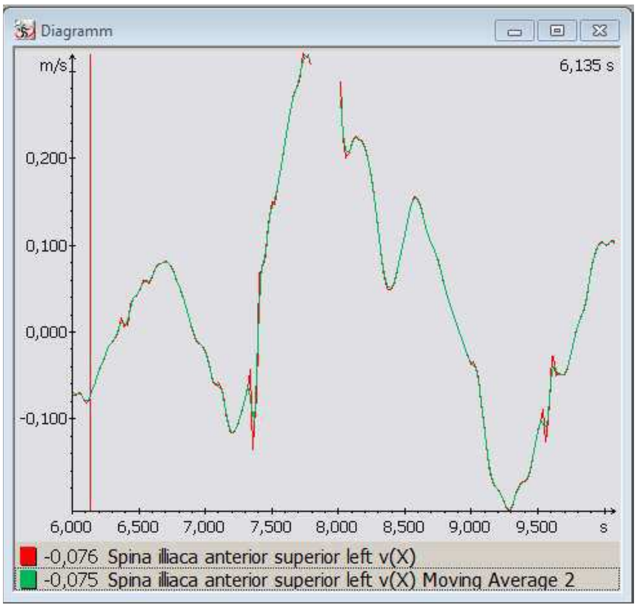
Instruction

Transmit the following parameters:

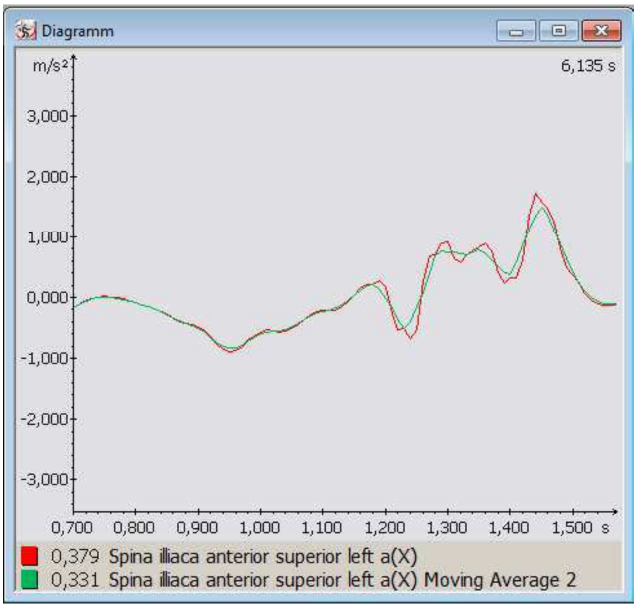
- Body height [m]
- Sex
- Body weight [kg]

Filter radius for derivation

The strength of the filter radius for the derivation can be set. The smoothing-filter will be applied on the derivation, thus it will affect the speed and acceleration results.
Setting the radius to '1' will use 3 values for the smoothing of one value.



(a) Velocity



(b) Acceleration

Figure 17.40: Filtering using Moving average with radius 2

Note

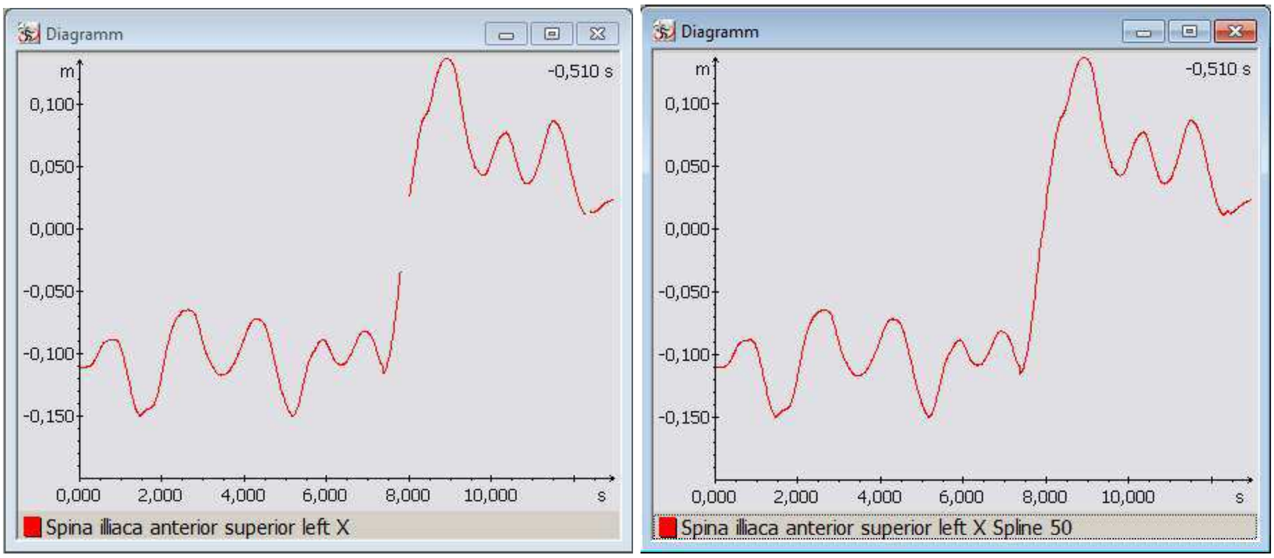
Choose the selected radius carefully. If the radius is too big, the curvature might appear smooth, but the measurement could be biased. Further, can good results appear for the speed, but due to a second derivation the results of the acceleration could be falsified due to an exponential error growth.
Data filtering can also already be executed before the inverse dynamic is computed.

Force threshold

The value set [N] is used to eliminate small noise during the measurement. If the absolute value of the force is smaller than the threshold, the external forces and torques will be set equal Zero. This will result in forces being used for the inverse dynamics only if they exceed the threshold.

Marker interpolation

If gaps exist in the measured values, those can be filled by interpolation. For the inverse dynamics interpolation via Splines is used by default. Providing a value for the interpolation interval sets the size of gaps to be filled. Setting the value 0 will not perform any interpolation. Interpolation is not a mandatory task for the inverse dynamics.



(a) Original (b) Interpolated

Figure 17.41: Spline interpolation with Interval 50

Note

Interpolation can already be performed to the measured values before the inverse dynamics module is started (cf. section 17.4.4.7).

Marker radius

Provide the size of the marker radius. If this value is set wrongly, the computation of the join-centers can be falsified.

Calculation frequency

Provide the frequency for the computed data.

Output options

The *Output options* for the inverse dynamics can be displayed depending on the global as well as the local coordinate system. The global coordinate system is represented by the calibration system (cf. section 17.3. The local coordinate system has its origin in the center of gravity of the corresponding body segment, which is defined by the attached markers.
Available output options:

- *Marker global*: Describes the marker in the global coordinate system

- *Segment centers global*: Describes the center of the segment with respect to the global coordinate system
- *Joint centers global*: Describes the center of joints with respect to the global coordinate system
- *Forces global*: Describes the forces, split into ground reaction force, torques and center of pressure
- *Segment rotation global / local*: Describes the rotation of the segments
- *Joint rotation global / local*: Describes the rotations between the two joint coordinate systems (proximal and distal)
- *Constraint forces global / local*: Describes forces which occur if the movement of a joint is limited by two segments
- *Constraint torques global / local*: Describes the cross-product of constraint force with the distance of the center of gravity of the segment with the joint center
- *Muscle torques global / local*: Describes additionally to the constraint forces the torques occurring due to muscle rotation
- *External forces global / local*: Describes the ground reaction force of the right/left leg
- *External moment arms global / local*: Describes the center of pressure on the force-plate and the distance to the center of gravity of the according foot.
- *External moments global / local*: Describes the moments, created by the ground reaction force
- *Segment axes global*: Describes the position of the segment axes with respect to the global coordinate system

Note

Commonly the local segment rotations, Joint rotations and local constraint forces are of interest.

Calculate

If all parameters are set click on Calculate
The result can be found, added as a new folder, in the project-tree.

17.6 Gait phases and Report

17.6.1 Gait phases

To analyze a gait cycle correctly, it is important to examine the different phases of a gait cycle. For a Simi gait report 3 phases are used: Initial contact, pre swing and terminal swing.

(a) Initial contact (b) Pre swing (c) Terminal swing

Figure 17.42: Phases for a Simi gait report

Phase model

The phase model describes the classification of the different gait phases. For the gait analysis report both a left and right step have to be defined to make sure all data can be produced. The defined steps should be directly after another since otherwise some data can not be calculated correctly. The gait analysis report supports up to 3 steps of each leg. When using more than one step, the kinematic data is averaged.

Instruction

- Open Import phase model... via:
  - Phases in the project-tree,
  - **Or**: Go to Project » Edit phase model... and select Import
- Navigate to *C:\Program Files (x86)\Simi\Motion 9.x.x\Templates\GaitAnalysis*.
- Select the file *GaitAnalysisPhaseModel.sph*.
- Accept with Open.

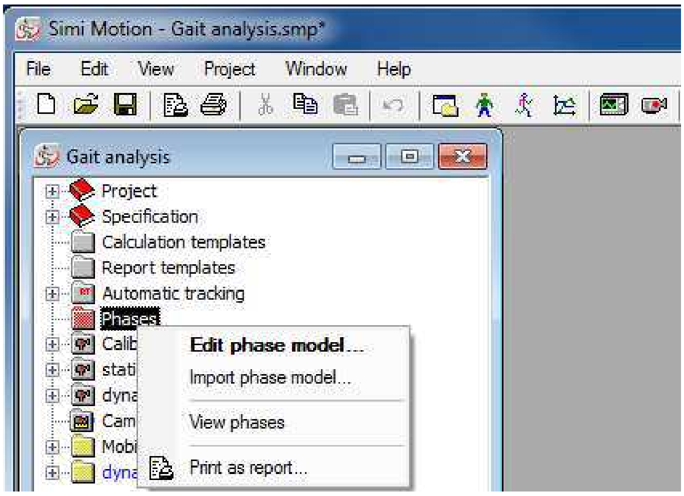


Figure 17.43: Phase model

Add phase

Instruction

- Open a video by Drag&Drop a camera into the workspace.
- Find the frame (by using the time bar or the arrow keys) where the *Inital contact* occurs.
- Select Add phase in the top bar or by hitting F11.
- Select the correct group and appropriate phase
- Add the phase by clicking OK
- Repeat this step for all phases. Always define the end of a phase group (terminal step).

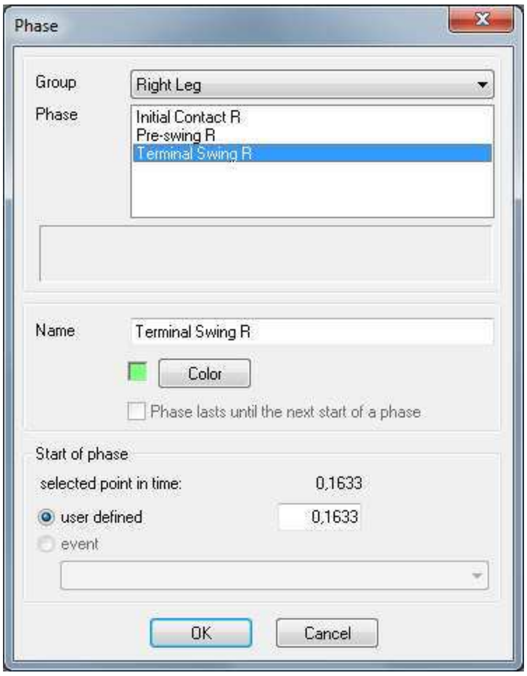


Figure 17.44: Creating new gait phases

17.6.2 Report

At the end of the recording it is possible to create a report of the gait analysis in order to get a well-arranged result.

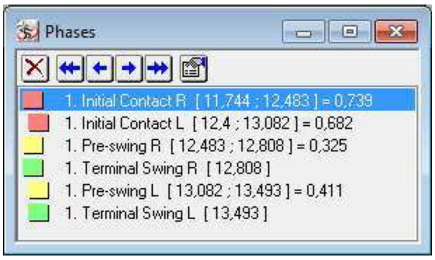


Figure 17.45: Setting different phases

Calculation templates

To create the gait analysis report you need to further process the data after you finished the steps described before. Therefore the three gait analysis calculation templates need to be imported and executed.

Instruction

- Calculation templates in the projekt tree.
- Select Add calculation template. . . .
- Navigate to *C:\Program Files (x86)\Simi\Motion 9.x.x\Templates\GaitAnalysis*.
- Choose *GaitAnalysisCalculations1.smt* and accept with Open.
- Repeat those steps two times with *GaitAnalysisCalculations2.smt* and *GaitAnalysisCalculations3.smt*.

With that all necessary calculations are imported and ready to be executed.

Instruction

- Execute *Calculations Page 1* by:
  - Calculations Page 1 in the project tree beneath *Calculation templates* and select *Berechnungsvorlage anwenden*,
  - **Or**: Doubleclick *Calculations Page 1*.
- If all inputs are marked green, accept with OK. If the inputs are not marked green, one of the steps before has not been performed correctly.
- Repeat those steps in correct order with *Calculations Page 2* and *Calculations Page 3*.

Import of Reference values

To compare the gait of the subject with a healthy gait the according reference values have to be imported. The reference values differ with the weight of the subject. Select the file with the weight closest to the subject's.

Instruction

- Navigate to Projekt » Import » Import special files. . . .
- In the dropdown menu select *Simi Reference data*.
- Navigate to *C:\Program Files (x86)\Simi\Motion 9.x.x\Templates\GaitAnalysis\Data*.
- Select the file *xx kg InvKinDyn.rfd* with similar weight as the subject and accept with Open.

subsubsection*Display of report
As soon as all calculation templates are executed correctly the report can be displayed.

Instruction

- » Report templates and select Print as report. . . .
- In the dropdown menu scroll to *Gait Analysis Report - full*.

17.7 Control of data

After recording the measured data, the stream of data should be proved.

Instruction

- Pull the desired camera from the project-tree into the working environment.
- Right click on the image region.
- Click on Video mix and -overlay...
- Choose your data *dynamic 3D coordinates new* in the drop-down-menu *3D overlay* and confirm by clicking Close.

Then the video is superposed with the dynamic 3D coordinates. Now errors can be found easily.

Note

If you want to activate the option *video mix and -overlay* for more than one camera, you have to do this for every camera separately.

Furthermore it is possible to compare 3D overlay and 2D data. Activate for this purpose the stick view.

Instruction

- Right click on the image region of the camera in the working environment.
- Choose this time Show stick diagram.
- Prove if overlay and stick view are superposed.

If overlay and stick view are coincident, the 3D is correct. If not respectively markers were aligned falsely, this can be recognized by the 3D view or by intense deflections in the data curves of the single marker.

If an error occurs only in a small range of data, this range of data can be erased and interpolated.

Instruction

- Search for the incorrect camera and open it.
- raw data › edit raw data.
- Choose the respective marker which shall be edited.
- Go to the moment when the false alignment occur.
- Erase the value by clicking delete and interpolate by clicking fill (spline).
- Afterwards close the window and confirm the alteration.

If an error occurs in a bigger range of data, it is recommended to track the marker by hand.

Instruction

- Search for the incorrect camera.
- on the respective camera and choose *2D tracking*.
- Choose *click manually* for the marker that should be edited. (For the other markers have to be selected *do not track*)
- Edit the incorrect range of data.

17.8 Finishing the project: Moving and compressing videos

Tutorial

For this section, a video tutorial can be found at `http://youtu.be/rEq-YiHpm-8`

With finishing the project it is recommended to move and compress all videos.

Instruction

- Choose File › Ressource administration
- Choose *Move* in 'video files'
- Set checkmarks at *update video links* and *recompress video data*
- Select *Move* in 'project file' as well
- Click Collect data...
- Choose *Xvid MPEG-4 Codec* in the drop-down menu
- Click configure...
- Set the "'Target Quantizer"' to *1.70* (cf. Fig. 17.46) and confirm with *Ok*
- With the pressing Ok a window with a directory appears. Choose the desired directory for saving your video files

Note

Compressing video files leads to loss of data, but in this case raw data is affected marginally. So do this only if you are certain all data is already recorded and 3D is correct.

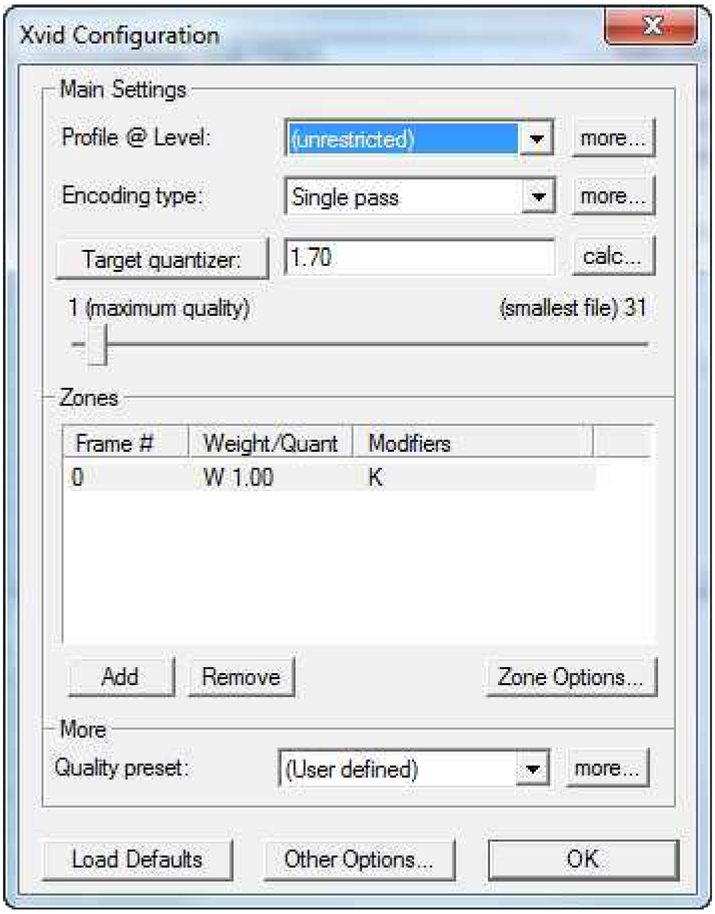


Figure 17.46: Configuration of compressing settings

17.9 Checklist

This chapter provides a very compact overview of the needed steps to conduct a successful gait analysis. The detailed steps are described in in the referenced sections.

Tip

Print out this Checklist. After finishing one task the box ☐ in front of the step can be checked. Thus no step will be left out and the analysis can be conducted successfully.

17.9.1 Preparations

- ☐ Assembling the ring-lights (Sec. 17.1.1)
- ☐ Connecting all cables (Sec. 17.1.2)
- ☐ Checking the Force-plate (FPL) (Sec. 17.1.3)
- ☐ Switch on LED-ring-lights and FPL (Sec. 17.1.4)
- ☐ Camera connection (Sec. 17.1.5)
- ☐ Setting the camera field of view (Sec. 17.1.6)
- ☐ Setting focus and aperture (Sec. 17.1.7)
- ☐ Adjusting camera properties (Sec. 17.1.8)
- ☐ Checking the trigger settings (Sec. 17.1.9)
- ☐ Preparing the set of markers (Sec. 17.1.10)
- ☐ Testing the recording and recognition (Sec. 17.1.11)

17.9.2 Correction of distortion

- ☐ Distortion correction by chessboard, if you are not using wand data for correction
- ☐ Create a project and record chessboard-videos (Sec. 17.2.2.1)
- ☐ Computing distortion parameters (Sec. 17.2.2.2)

17.9.3 Calibration

- ☐ Recording calibration videos (Sec. 17.3.1)
- ☐ Automatic 3D wand tracking (Sec. 17.3.2)
- ☐ Camera calibration groups (Sec. 17.3.4)
- ☐ Testing the calibration (Sec. 17.3.5)

17.9.4 Video Capturing

- ☐ Defining the specifications (Sec. 17.4.1)

17.9.4.1 Static trial

- ☐ Performing a static trial recording (Sec. 17.4.2)
- ☐ Starting the capture (Sec. 17.4.3)
- ☐ Saving the static trial (Sec. 17.4.3.1)
- ☐ 3D-tracking for static trial (Sec. 17.4.3.2)

17.9.4.2 Dynamic trial

- ☐ Performing a dynamic trial recording (Sec. 17.4.4)
- ☐ Starting the capture for the dynamic trial (Sec. 17.4.4.1)
- ☐ Automatic 3D-Tracking (Sec. 17.4.4.3)

☐ Recalculating dynamic 3D-data (Sec. 17.4.4.6)

☐ Edit 3D Data (optional) (Sec. 17.4.4.7)

17.9.5 Inverse Dynamics (Sec. 17.5)

☐ Calling the inverse dynamics

☐ Selecting the model

☐ Include static and dynamic data

☐ Select force data for left/right leg

☐ Providing patient data

☐ Setting of filter and interpolation properties

☐ Selecting threshold and marker radius

☐ Inserting the frequency of computation

☐ Selecting output options

☐ Compute inverse dynamics

17.9.6 Gait phases and report

☐ Select phase model (Sec. 17.6.1)

☐ Adding a phase

☐ Create a report (Sec. 17.6.2)

17.9.7 Control of data (Sec. ??)

☐ Pull desired camera in the working environment

☐ Open *video mix and -overlay*

☐ Choose *dynamic 3D coordinates new* for 3D-overlay

☐ Activate *stick view*

☐ Compare *video mix and -overlay* and *stick view*

17.9.8 Finishing the project: Moving and compressing videos (Sec. ??)

☐ Move video files and recompress