2D motion analysis

Only one camera is necessary for kinematic measurements when the main movement of the body or of some parts of it is performed in a plane, such as

- gait analysis (on a treadmill)
- counter movement jumps
- high bar gymnastics
- weight lifting

Most of these movements can be analysed from a lateral view where angles at the ankle, knee and hip can be measured. Additionally the position of the center of mass can be determined within the movement plane.
If the camera is far away from the movement all segments appear to be in a single plane. Small differences in distances from the camera can be neglected for most purposes.
Often cameras from different perspectives are used to allow more detailed measurements (e.g. both lateral views).

2D calibration

Calibration is simple as long as the camera is perpendicular to the movement plane. When the aspect ratio of the cameras pixels is known a simple distance with any orientation within the movement plane can be used to scale the pixel information to metric information.
More sophisticated algorithms, such as the 2D DLT, allow measurements even if the camera is not perpendicular to the movement plane.
2D calibration can be completed within less than 60 seconds.

3D motion analysis

A three-dimensional analysis has typically to be done for complex, rotating or simi- lar movements:

- **golf swing**
- **hammer throwing**
- **tennis**
- **judo**
- **martial arts**

Scientists in sports biomechanics and medicine often use 3D analysis in order to describe a body's movements in three dimensional space. If you want to do a simi- lar motion analysis you have to use more than one camera, because each anatomic landmark (marker) has to be identified in at least two cameras.
Although 3D motion analysis can be done using only two cameras, most movements require four or more cameras.

With 3D coordinates six degrees of freedom (6 DOF) can be computed, i.e. rotations around all three axes of a segment or a joint can be determined as well as the exact spatial position.

3D calibration

Two different methods are commonly used in commercial motion capture systems:

Static calibration frame

For a static calibration an object with known dimensions (e.g. a cube, cuboid or simi- lar object) is placed into the cameras field of view. The size of the calibration frame should cover the total movement space.
The objects shape is then digitized using manual or automatic marker detection for the calibration points.
For most algorithms it is not necessary that all cameras see the same set of calibration points.
A static calibration needs approx. 1-3 minutes per camera.

Dynamic calibration (wand calibration)

During dynamic calibration the user moves a pole with attached markers which have to be seen by all or a subset of the cameras.
The pole is moved until the complete movement space is covered.
A dynamic calibration needs a couple of minutes or more, depending on the systems detailed requirements and its real-time tracking capabilities.

Video analysis procedure

The following paragraphs outline a typical analysis procedure using Simi Motion.

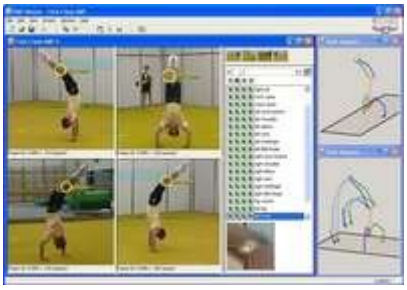
Specification
A set of markers for the analysis can be selected from the predefined number of points on a skeleton or user-defined points can be added. You can also import marker sets from previous projects or from a template file.

Camera setup
Select the number and position of your cameras. For 2D at least one camera and for 3D at least two cameras must be used. Most 3D movements require three or more cameras to avoid occlusion.

Calibration
Capture a known calibration object (e.g. a cube for 3D) to calibrate the cameras. The system identifies the positions and settings of the cameras.
Simi Motion provides several methods of verifying the accuracy of the calibration.
As long as the cameras remain fixed, this calibration can be used for several tests.

Video capture and analog data acquisition
Capture the movement with several cameras. Simi Motion provides tools for cutting and saving the video clips from all the cameras in a single step.
Analog data can be acquired at the same time.
The video recording can be triggered by an analog signal (e.g. touching a force plate or triggering a light barrier).
You can also import existing video footage in any common format (AVI, MPEG, MOV).

Tracking / digitization / motion data capture
Select the start frame and digitize the movement frame by frame.
If you have used markers to tag the points on your test object, automatic tracking can be used. This automatically identifies and tracks white or colored markers.
Simi Motion also provides a pattern matching algorithm for markerless tracking.



Calculation of 2D or 3D coordinates
Use default settings or select your own filter and interpolation settings to calculate the 2D/3D data from the raw data.

Import
Additional data from other devices (e.g. insole measurement from MegaScan, Novel, Medilogic or Paromed) can be imported via their native file formats or as text or C3D files.

Analysis
Angles, distances and centers of gravity can now be calculated. Arithmetic and trigonometric algorithms and a wide variety of other functions (integration, frequency analysis, transformations etc.) are available to compute more information.
The results can be displayed in tables and diagrams, stick-figure animations and 3D virtual reality representations. Extensive or recurring calculations can be saved as calculation templates for use in further tests.

Export
Data can either be exported in full or partially to spreadsheet and statistics applications (SPSS, Origin, MatLab, Excel) for further manipulation.
Special file formats for common animation programs such as Maya, 3ds max, Cinema 4D, Lightwave 3D, Softimage|XSI or Poser are available.

All diagrams and images can be saved to hard disk (BMP, JPG, PNG etc.) or copied to the Windows clipboard.

Report
Reports can be produced using predefined or customized templates and be printed out or saved as HTML files.

Alternatives

Simi Motion can also be used for other types of analysis: kinematics can be completely omitted and the synchronized video clips can be used instead for a qualitative video analysis.

As another alternative 2D or 3D still image measurements can be carried out: select a video frame and you can measure an angle or distance with a few mouse clicks.

Simi Motion is also a fully featured EMG analysis software and a perfect tool for evaluating data from force plates. These two variations are particularly useful in combination with a simple video analysis or a still image measurement.