# 3D MOTION RECONSTRUCTION FROM UNCALIBRATED VIDEO SEQUENCES – APPLICATION TO SKIING KNEE INJURIES

## Purpose of the study

The purpose of this study was to assess the accuracy of a new model-based image-matching technique for reconstruction of human 3D motion from one or more video sequences.

## Materials and methods

A laboratory trial was performed to compare the accuracy of a new model-based image-matching technique based on regular video recordings with a seven-camera 240 Hz marker-based optical motion analysis system (ProReflex, Qualisys, Inc.) as the gold standard. Three ordinary video cameras – placed in front, to the side and to the rear of the subject – were used to record the motion of one test subject performing a side-step cutting maneuver. This gave a total of seven matchings (three single camera matchings, three double camera matchings and one triple camera matchings)

The commercially available 3D modeling program Poser® provided the interactive environment for the image matching from the video tapes. The matching procedure consists of the following steps:

- Measuring the anthropometry of the subject and building a customized computer-model (e.g. by changing segment dimensions of an existing model).
- Measuring landmarks (e.g. floor, walls, lines, objects) in the background and building a virtual environment similar to the original.
- Importing the video sequence(s) into Poser as background for the virtual environment and model.
- "Calibrating" the Poser-cameras at each time step (e.g. adjust the translation, orientation and focal length parameters at each point in time to make them similar to the original), by matching the virtual environment to the background reference
- Matching the model to the background person.
- Exporting the necessary joint rotations and translations for further biomechanical analyses

## Results

Good agreement was found for the support leg flexion angles in the hip and knee for all the matchings compared to the ProReflex measurements, with root mean square (RMS) differences ranging from 3 to 12°. Hip adduction RMS differences ranged from 12-14°, while varus angles of the knee were in the range of 3-5°. Rotation angles were clearly most variable in both the hip and knee, and RMS differences ranged from 6 to 16°.

Velocity estimates were generally good (RMS differences in all three directions ranging from 0.1 to 0.6 m/s). Accelerations were only acceptable for the matchings that contained perpendicular views, with the triple camera matching as the best (RMS differences of 2.8-4.9 $m/s^2$).

## Conclusions

We found that 3D motion could successfully be reconstructed with adequate precision in all the studied situations. The accuracy, however, improved with the number of camera views available. The largest source of error seemed to be the pelvic matching, which gave a shift in hip adduction of about 13°. It is, however, difficult to interpret the results from the joint angle estimates, since observations suggested that the error partly resulted from significant skin movement artifacts in the marker-based analysis system, our gold standard. For the velocities we observed that movement in the depth direction of the camera view is difficult to estimate, and thus a minimum of two cameras is required for good estimates. Accelerations can also be estimated with adequate presicion, but due to low frame rate (50 Hz for PAL videos), the high frequency acceleration peaks are not captured.

The results suggest that the method has sufficient accuracy to be used to analyse and categorize video tapes of knee injury situations in freestyle and alpine skiing. It is also our intention to use the kinematics estimates for input in more advanced mathematical models.

Acknowledgements
The Oslo Sports Trauma Research Center has been established at the Norwegian University of Sport & Physical Education through generous grants from the Royal Norwegian Ministry of Culture, the Norwegian Olympic Committee & Confederation of Sport, Norsk Tipping AS, and Pfizer AS.