"DYNAMIC TRACKING", A METHOD FOR SMOOTHING KINEMATIC DATA

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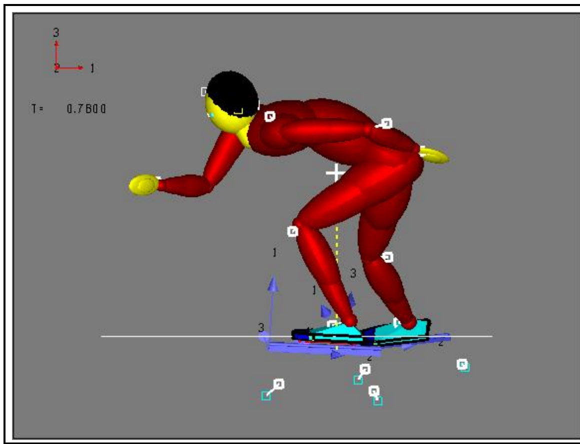
One basic problem in biomechanical modelling is the transfer of a real motion to a model. Here the motion of an ice speed skater should be transferred to the *alaska* 3D MBS man model DYNAMICUS. To find an optimal description for the motion of the man model Dynamic Tracking has been used and investigated. The results show that this method is a useful possibilty to recieve time histories for the inner co-ordinates close to reality.

KEY WORDS: dynamic tracking, data smoothing, biomechanical modelling

INTRODUCTION: In order to be able to solve inverse problems using biomechanical modelling, it is important to describe the motion which is under consideration by high accuracy. Only if it is possible to describe motions with close-to-reality and artifact-poor time histories for the inner co-ordinates – i.e. relative co-ordinates between the adjacent segments - the internal forces can be calculated for the model. A method is shown that can be used to receive smoothed kinematic data for the inner co-ordinates on the basis of video-captured data.

METHODS: The Dynamic Tracking (see Wolf et al. 2000) is based on the absolute 3D co-ordinates of defined markers fixed at the surface of the filmed ice skater which are a result of the videometry. By these data the inverse kinematic is executed, i.e. the time histories for the spatial co-ordinates of the man model DYNAMICUS are calculated as well as the appropriate velocities and accelerations. For the Dynamic Tracking model-fixed points are defined, which correspond to the digitized markers of the filmed skater. In these points the man model is connected viscoelastically with the markers. This leads to a dynamic adjusting of the man model with the moving marker cloud. Due to the linear elasticity used to connect the markers this approach is equivalent to linear filtering. Thus the motion of the real ice skater is transferred to the man model.



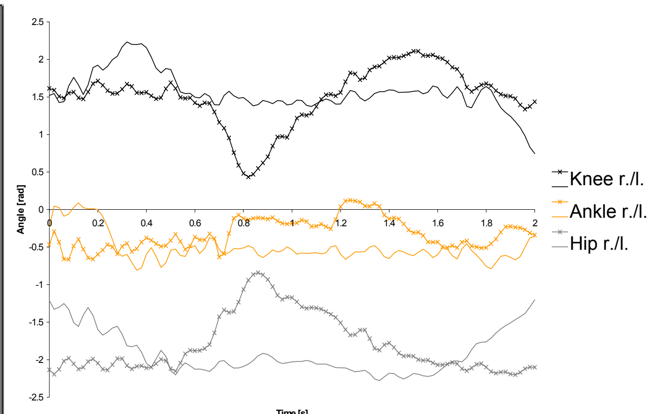


Figure 1 - *Alaska* man model in marker cloud. **Figure 2 - Angles of hip, knee and ankle.**

Dynamic adjusting (integration of the motion equations) already leads to a natural smoothing and averaging of the time history of the position, velocity and acceleration of the inner co-ordinates. However, this smoothing procedure is frequently not sufficient in case of spacious motions (see figure 2). The oscillations regarding amplitude and frequency induced by the viscoelastic coupling in the man model can be kept small by selecting the parameters of the force coupling in consideration of the relatively large masses in the man model. In the following the angles for hip, knee and ankle in direction of flexion and extension are shown as example. The output sampling rate for the determined joint angles is 0.02 s corresponding to the sampling rate given by the videometry. For the simulation of the speed skating motion time histories of the inner co-ordinates are obtained by the inverse kinematics. The angles still contain oscillations due to the Dynamic Tracking, so that these co-ordinates do not correspond well enough to reality. Therefore different possibilities of motion control based on the results shown above have been tested and compared. In order to eliminate these oscillations, different sampling rates were used for the specification of the functions of the inner co-ordinates. Subsequently the functions controlling the inner co-ordinates were interpolated by cubic splines. For the available ice skating motion the following sampling rates have been selected and tested with respect to the motion quality: 0.02 s, 0.04 s, 0.08 s, 0.1 s, 0.15 s, 0.2 s.

RESULTS AND DISCUSSION:

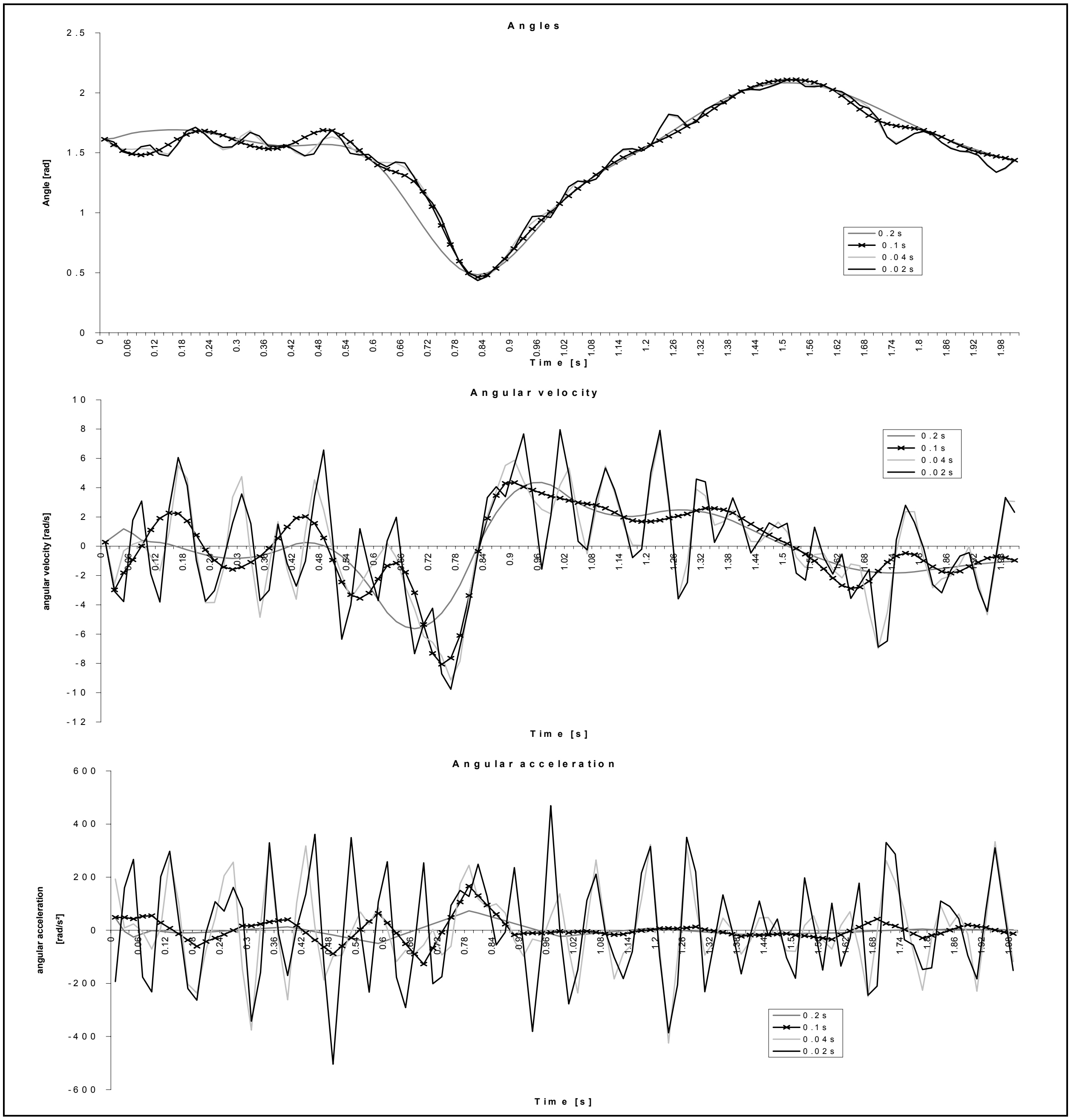


Figure 3 - Angles, angular velocities and angular accelerations of right knee with different sampling rates.

Figure 4 shows the influence of different sampling rates on the functions of the inner co-ordinates, their velocities and accelerations. These highly influence the calculation of the joint forces of the model by inverse dynamics
After pointing out, how the sampling rates influence the specification of the functions of the inner co-ordinates, the quality of the motion has to be checked up. To what extent the total motion of the man model is influenced by different function specifications? In order to investigate the effects of different sampling rates, the following assessment metrics were considered:

- point distances, between all markers and corresponding points on the model;

- root means square, determined over all distances of markers and corresponding points on the model;

- integral of the variance, determined over all distances of markers and corresponding points on the model.

Table 1 Results of the Motion Quality Check

sampling rate	Max. variance	Max. variance squared	root mean square	integral of variance
0.02	0.015	0.12	0.073	0.0108
0.04	0,01	0,1	0,069	0,0099
0.08	0.01	0.1	0.068	0.0095
0.1	0.007	0.08	0.069	0.0097
0.2	0.01	0.1	0.073	0.0113

CONCLUSION: By means of the angles, angular velocities and angular accelerations it could be shown that a specification of the inner co-ordinates with higher sampling rates than given by the videometry have a smoothing effect. This is achieved by the Dynamic Tracking in conjunction with a down sampling via cubic splines

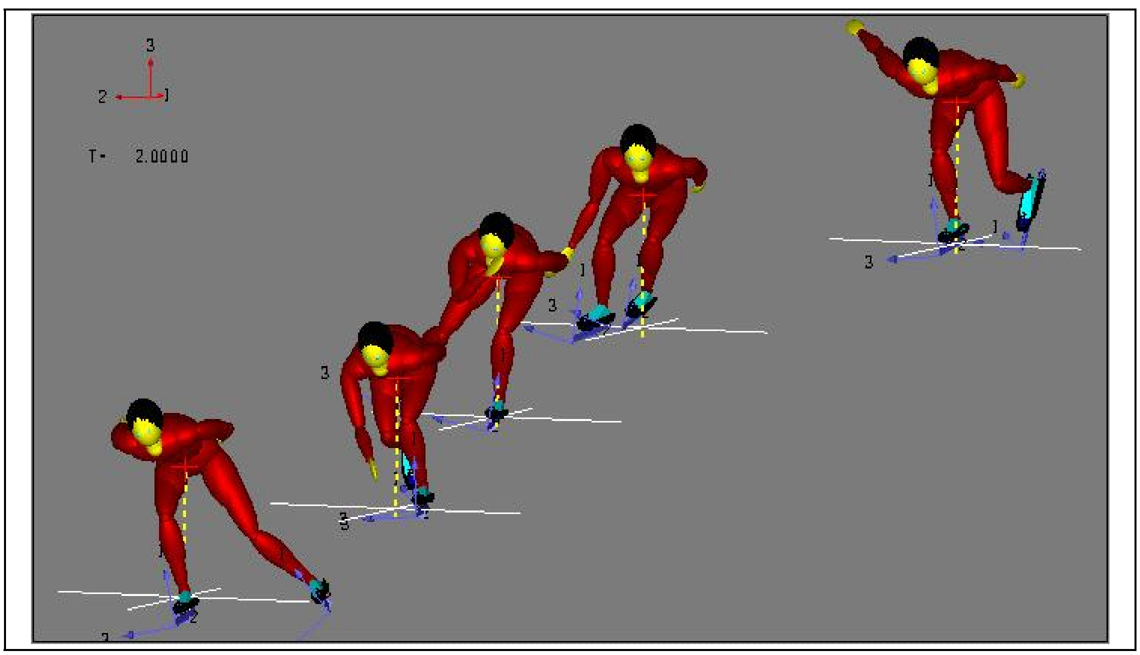
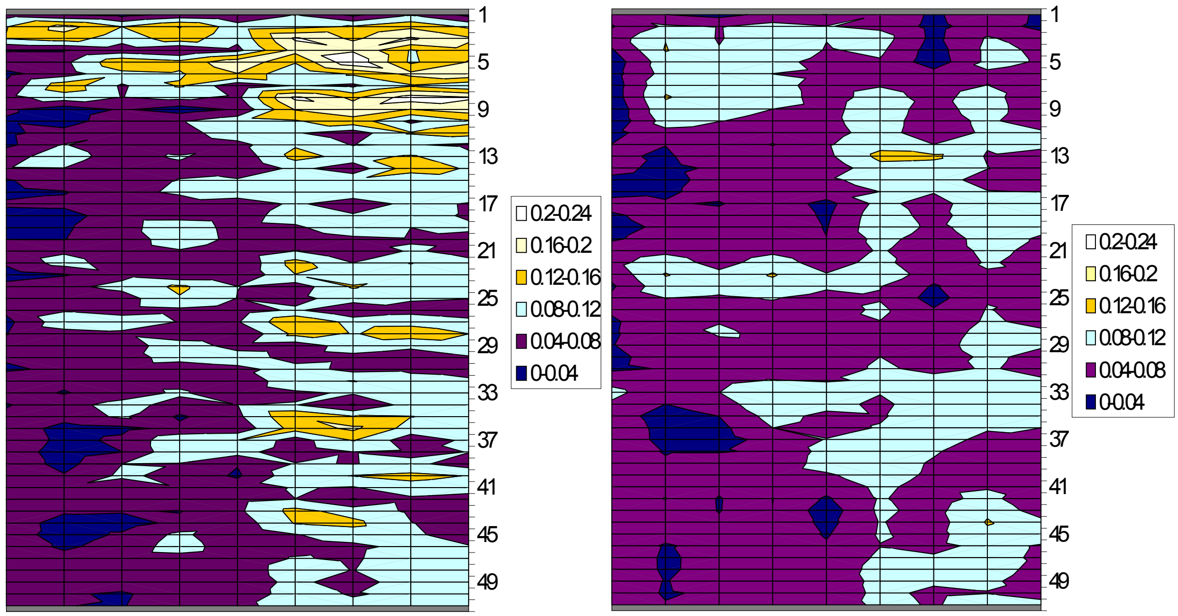


Figure 4 - Simulation of the ice speed skating motion.

Considering the root mean square and the time integral of the variance it is obvious that the motion quality may be improved in addition to the smoothing. This effect is due to averaging effects of the spline interpolation I.e., the deviations of the markers and corresponding points on the model decrease for almost all sampling rates. Only at the sampling rate of 0.2 s a the values are higher.



Sampling rate of 0.02 s

Sampling rate of 0.1 s

Figures 5 and 6 - Distances of markers and corresponding points on the model at a sampling rate of 0.02 s and 0.1 s shown in a surface mesh grid.

This effect is also depicted in Figures 5 and 6 for the respective distances between the markers and their corresponding points on the model. When the sampling rate is set to an optimum of 0.1 s the light parts in the diagrams, which display a large deviation, decrease.
The Dynamic Tracking method enables to transfer a video-captured motion on to a model, as foundation to solve inverse problems in biomechanics in sports. The inverse dynamics are directly influenced by the provided information. As such the sampling rate has to be adjusted in accordance to achieve a minimum difference of simulated and measured motion and a maximum smoothing.

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