SIMULATION OF SKIING TURNS

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Purpose: The aim of this study was to develop a simulation tool to simulate consecutive skiing turns.

Introduction

Simulation of skiing is a challenging task. In a first step a simulation model of a sledge on two skis and the ski-snow contact was developed and parameter studies were conducted [1,2]. In the second step the simulation model was extended by a model of the skier to investigate skier specific movements.

Methods

A multibody model for a skier with skis (Fig. 1) was implemented in the simulation software LMS Virtual.Lab Motion (LMS International, Leuven, BE). The model of the skier consisted of seven segments: upper-body, thighs, shanks, and feet. The upper-body was modeled as an elliptic cylinder and represents head, trunk, and arms of the skier. Thighs, shanks and feet were modeled as cuboids. Segment dimensions, mass, and inertia properties of these segments were derived from the total mass and from anthropometric data of a real skier. Each ski was divided into 19 segments and adjacent segments were linked by two revolute joints with integrated spring-damper elements – one for bending and one for torsional deformation. The stiffness properties for these spring-damper elements were adjusted using measurements on a real ski. The ski bindings were modeled by bracket joints for the front pieces and translational joints for the heel pieces of the bindings.

For the ski-snow contact snow-penetration, snow-shear, and snow-friction forces were implemented. The snow-penetration force was modeled by a hypoplastic constitutive equation, which takes into account that snow deformations remain. The snow-shear force was modeled based on machining theory. Finally, snow-friction force was represented by Coulomb friction and a velocity dependent friction term.

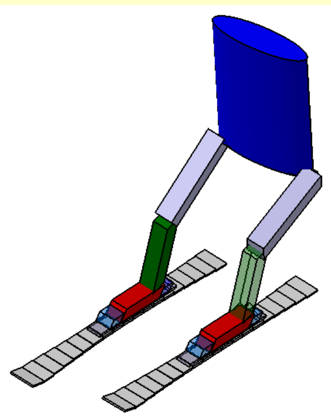

Figure 1: Model of the skier .

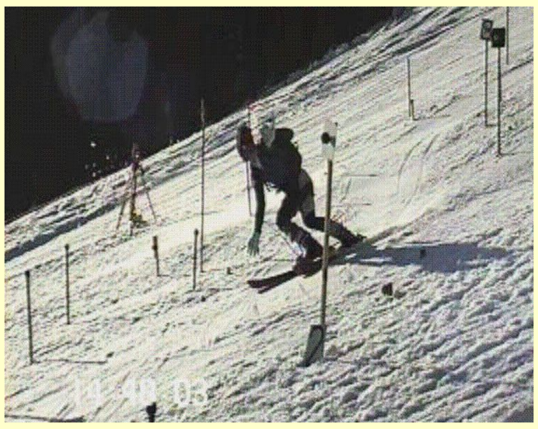

Figure 2: Field test with the skier.

To simulate ski turns, driver constraints were implemented in the joints of the skier. One driver for the knee joint and two drivers for the hip joint were installed to control knee and hip flexion/extension as well as hip abduction/adduction of both legs. To assess the influence of knee flexion/extension and hip angulation parameter studies were done.

To evaluate the simulation model of the skier, field tests were conducted. In the field test a skilled skier skied two complete turns (Fig. 2). During the runs the skier was recorded by three cameras at 50 fps. In the lab 3-d coordinates for the skier's landmarks were calculated by DLT reconstruction from the video data [3]. The simulation results of the trajectory of the skier were compared with the field tests.

Results and Discussion

The model of the skier was successfully implemented to simulate a sequence of turns. To keep the skier in balance the inward lean had to be selected in such a way that the resultant force on the skier's center of mass pointed between both skis.

The parameter study showed that without angulation the trajectories of the skier and the former sledge model agree. Increased hip angulation caused increased edge angles and therefore smaller turn radii (Fig. 3).

In a further step the skier's trajectory was compared to the experimental field data. It was possible to simulate each single turn (Fig. 4), but not the whole turn combination. Differences occurred because in the simulation the slope was modeled as an idealized inclined plane whereas the slope was not perfectly plane and the inclination decreased from 20 to 16° in the field test. Furthermore homogenous snow conditions were assumed in the simulation.

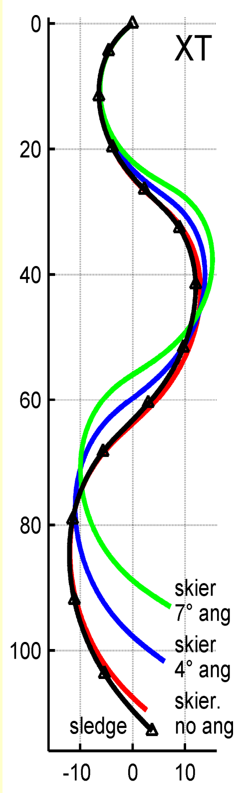

Figure 3: Trajectories of the sledge model as well as the skier model with 0, 4, and 7° hip angulation.

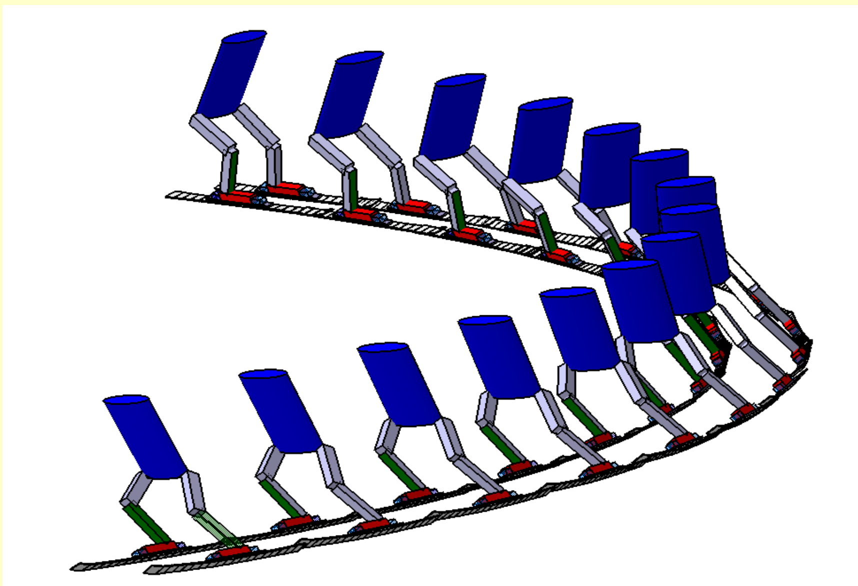

Figure 4: Single turn of the simulation.

Acknowledgements

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References

[1] Mössner M, et al. J ASTM Int 5(8), 2008.

[2] Mössner M, et al. Science and Skiing IV, Meyer & Meyer Sport, UK, 374-388, 2009.

[3] Nachbauer W, et al. J Appl Biomech 12, 104-115, 1996.

Conclusions: The model of the skier is a valuable tool for the simulation of Alpine skiing. It can be used for assessing effects of ski properties (geometry, stiffness), snow properties and the ski-snow interaction (carving vs. skidding) as well as basic movements of the skier like edging, weighting/unweighting, angulation, and forward/backward lean. However, improvements of the model are still necessary, especially for the analysis of injury mechanisms. It is planned to include muscle forces and moments in the simulation and to assess the risk of knee ligament ruptures based on a detailed model of the knee joint.

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