SIMULATION OF SKIING TURNS

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INTRODUCTION

Simulation of skiing is a challenging task. In prior work a simulation model for a sledge on two skis was presented and parameter studies were conducted [1,2]. Since the sledge does not allow skier specific movements, the model had to be improved. The purpose of this study was to implement a more realistic model for the skier and to compare simulation results with 3-d data of a real skier.

METHODS

A multibody model for a skier with skis was implemented in the simulation software LMS Virtual.Lab Motion (LMS International, Leuven, BE).

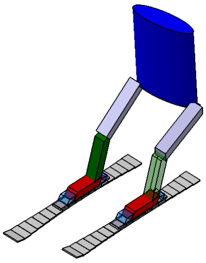

Figure 1: The model of the skier with skis.

The skier was built up of 7 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 consisted of 19 segments, which were linked by two revolute joints with 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.

For establishing ski turns in the simulation driver constraints were implemented. One driver for the knee joint and two drivers for the hip joint were installed for each side to control knee and hip flexion/extension as well as hip abduction/adduction.

In the field test a skilled skier skied two complete turns. 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.

Figure 2: The field test with the skier.

RESULTS AND DISCUSSION

The model of the skier was successfully implemented to simulate a sequence of turns. The simulated skier's trajectory was in relatively good agreement with the experimental field data. It was possible to simulate each single turn, but not the whole turn combination. Differences occurred because of the incomplete description of the driver constraints during the transition phase between the two turns. Additionally, the slope is an inclined plane in the simulation whereas the slope inclination decreased in the field test from 20 to 16°.

CONCLUSIONS

The model is a valuable tool for the simulation of Alpine skiing. It can be used for assessing effects of ski materials (geometry, stiffness) as well as effects of the ski-snow interaction (carving vs. skidding). The implemented skier model allows the investigation of basic movements like edging, weighting, 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 a detailed knee joint model for the calculation of the joint forces and moments and to assess the risk of knee ligament ruptures.

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