SIMULATION OF SKIING TURNS

[1]Werner Nachbauer, [1]Martin Mössner, [1]Dieter Heinrich, [2]Herwig Schretter, and [3]Peter Kaps
[1]Departmet of Sport Science, University of Innsbruck
[2]HTM Tyrolia Schwechat, Austria
[3]Department of Engineering Mathematics, University of Innsbruck
email: werner.nachbauer@uibk.ac.at

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.

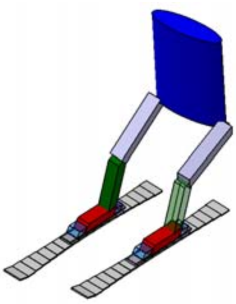

Figure 1: The model of the skier with skis.

The skier was built up of 7 segments: trunk, thighs, shanks, and feet. The trunk-segment 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 consists 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 ski measurements. 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 a field test a skilled skier skied on a plain slope to complete two turns defined by four gates. 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 of the video data [3].

Figure 2: The field test with the skier.

RESULTS AND DISCUSSION

The skier´s trajectory, given by the computer simulation model, was in relatively good agreement with the experimental field data. It was possible to simulate each single turn, but not the whole turn combination. The skier´s movement in the transition phase between the two turns was incomplete described by the implemented driver constraints. Additionally, the slope is an inclined plane in the simulation whereas the slope inclination decreased from 20° for the 1st to 16° for the 2nd turn in the field test.

CONCLUSIONS

The model is a valuable tool in 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 calculate resultant knee joint forces and moments and to assess the risk of knee ligament ruptures using a knee joint model.

ACKNOWLEDGEMENTS

The study was partly supported by HTM Tyrolia Schwechat and the INTERREG IV project: SkiProTech.

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