COMPUTER SIMULATION OF A HUMAN SKI JUMPER - A COMPLETE TRIAL

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INTRODUCTION

Recent computer simulation results make a good contribution to understanding human movements [2,4]. But the control algorithms used there, are very complex and numerically more expensive. The purpose of this contribution is to present a robust method to model and simulate a complex human movement with aerodynamic interaction. In detail the squat position control at start-up and the calculation of lift and drag forces during the complete ski jump are considered.

METHODS

The ski jumper model was created on the bases of a HANAVAN [3] model (height: 1,78m, weight: 60kg) consisting of 17 rigid bodies. Each joint has a 1-dof rotational spring damper representing stiffness and elasticity of the real body joints except for the following joints: ankle, knee, hip, upper body, shoulder and neck. These joints are the actuators of the model. To create and solve the equations of motion we used DySim, a self-coded rigid body simulation package. The animation of the data was made with AniDySim also self-coded using OpenGL.

The actuators are built with 1-dof rotational spring dampers (ARSDA) with adaptable resting length. Therefore we created a control algorithm to switch between different states to adapt the resting length to the desired motion. The torque produced by the spring is directly transmitted to the body mechanics. In this presented simulation we used eight different angular configurations (states/resting lengths) for the complete trial.

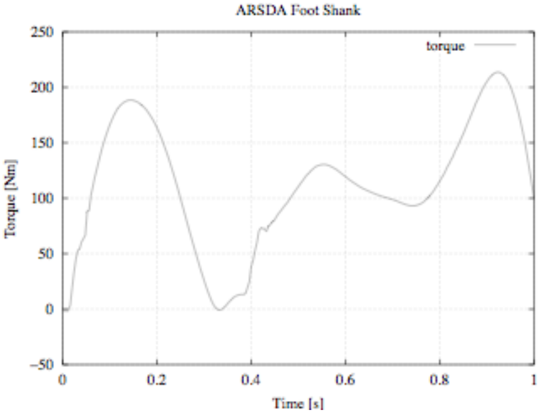

Figure 1: Movement control of the foot-shank joint: The control algorithm switches between two states, one to bring the ski jumper more to the front and the other more to the back (positive and negative torque changes).

During the start-up and the landing phase the ground reaction forces were modeled with contact elements between the skis and the jumping hill. In the flight phase we used a newly written aerodynamic algorithm. Lift and drag forces where calculated separately with drag force $\underline{F}_D = 0.5 \cdot c_R \rho_A A_R \underline{v}^2$ as a standard formula. The lift force, largely dependent on the variable aerodynamic conditions like position and surface conditions, was estimated by the modified formula $\underline{F}_L = 0.5 \cdot c_L \rho_A A_W \underline{v}^2$.

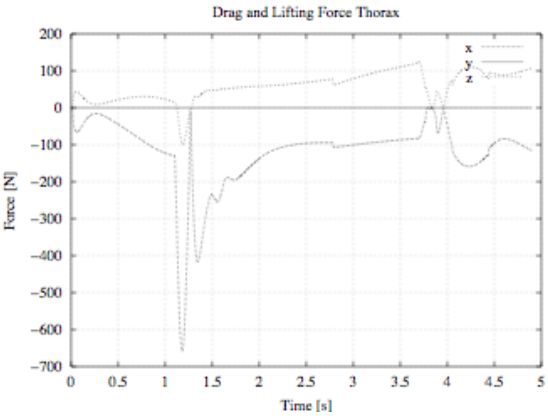

Figure 2: Aerodynamic forces in x-, y-, z-direction. Where -x marks the drag direction and z marks the lift direction.

RESULTS AND DISCUSSION

The result of this computer simulation is an entire ski jumping trial, encompassing the start-up and the landing including the calculated aerodynamic forces. Figure 1 displays the ankle torque for the movement control during the start-up phase. The swift-like regulation between forward and backward position is clearly observable. Figure 2 shows the lift and drag forces of the thorax body calculated for the entire trial. At t~1,2s the takeoff of the jumping movement takes place, thus high drag forces are considerable.

This example of a entire and complex movement model on the basis of realistic physical constraints demonstrates a powerful tool for better understanding of complex biomechanical structures. However, the validation of the results is still in progress using detailed position and velocity data from real ski jumper collected with a GPS receiver.

CONCLUSIONS

Even with this approach to model human movement we showed that a complex computer simulation could be done according to the λ-model [1]. Furthermore it is obvious that modeling of aerodynamics of a dynamic multibody system enables to identify the most critical flight phases in relation to optimize horizontal velocity.

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