A 3D Multi-body Model to Investigate Postural Stability in Dynamic Human Locomotion

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Abstract: Human gait performed on slopes, in particular with prosthetic devices can be considered as a dynamic motion which is difficult to stabilize. In our work, we seek for a measure that can be used to quantify postural stability, i.e. a human walker's ability not to fall and to recover from small perturbations during dynamic locomotion. For our investigation we developed a detailed human-like 3D multi-body model where the major body-parts are represented by rigid bodies connected by ball and socket joints. The multi-body model is composed of 13 rigid bodies with 34 degrees of freedom. Since upper-body movement has a strong influence on the net angular momentum, we include segments for the arms and head into our model.

Our experiments in the gait lab involve subjects with and without lower limb amputation. Their gait is monitored on level ground and slopes. The subjects' individual constitutions as well as the properties of the prosthetic devices are carefully recorded and included into the model to gain precise knowledge about the strategies underlying stability and balance control.

Optimal control methods allow to determine motions for our dynamic model that best match the experimental data from the gait lab. We transform the trajectories of the measured marker positions into joint angle trajectories that correspond to the structure of our 13-segment model's generalized coordinates. The measured motions are imposed on our model by fitting the joint-angle trajectories using least-squares criteria. Biomechanical constraints on joint-angles and foot-to-floor interaction ensure realistic motion in the simulation.

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