

**EML 5595 – Section 5576**  
**Mechanics of the Human Locomotor System**  
*B. J. Fregly*

**Course Project Proposal**

**Jeff Reinbolt**  
[reinbolt@ufl.edu](mailto:reinbolt@ufl.edu)

**Date Due: Wednesday, October 29, 2003**  
**Date Submitted: Wednesday, October 29, 2003**

**Title:** Deformable Ground Contact Modeling: An Optimization Approach

**Team Members:** None, rather collaborating with J.D. Yamokoski on a full-body forward dynamic simulation of gait to eventually combine the current project (P.I. – Reinbolt) along with a “hand of God” stabilization project (P.I. – Yamokoski).

**Rationale:** One of the most important choices made in creating a multi-body dynamic model of human gait involves how to handle the foot-ground interface. Ground contact models are essential to modeling changes in ground contact conditions (i.e., single support versus double support) and different human movement tasks (i.e., gait versus jumping). There are two main options for modeling ground contact: 1) constraint-based models and 2) deformable models. Constraint-based methods confine the feet to the floor using revolute joints or weld joints. This approach requires separate models for different ground contact conditions. Constraint-based models permit determination of constraining reaction forces and torques and facilitate analysis of induced acceleration and induced power. Deformable ground contact methods use spring-damper elements as constraints. This approach allows the use of a single model regardless of changing ground contact conditions. Deformable models permit determination of discrete spring forces that prevent the foot from excessively penetrating the floor. However, these models complicate the induced acceleration and induced power analyses. To reproduce experimental ground reactions with a deformable ground contact model, given the experimental motion, one must choose the optimal spring and damper parameters.

**Specific Goals:** This project will develop a deformable ground contact modeling approach to reproduce experimental ground reactions given the experimental motion. Moreover, optimization techniques will be implemented to determine a set of optimal spring and damper parameters.

**Steps & Deadlines:** The following two phase approach will be used.

***Phase 1 – Working Simulation:***

- Compile experimental data and existing Matlab and Autolev code (by 11/7/03)
- Perform inverse dynamics analysis to determine joint reactions (by 11/7/03)
  - Separate foot from full-body model if necessary
- Create two segment foot model with discrete spring attachment points (by 11/14/03)
- Implement linear spring, nonlinear damping, and coulomb friction models (by 11/21/03)
- Determine a nominal set of spring and damper parameters (by 11/21/03)
- Given the experimental motion, compute nominal forces for each discrete spring (by 11/28/03)
- Carry out replacement to determine the ground reaction forces and torques about the electrical center of the force plates (by 11/28/03)

***Phase 2 – Successive Enhancements:***

- Apply optimization techniques to determine a set of optimal spring and damper parameters to reproduce the experimental ground reactions given the experimental motion (by 12/5/03)
  - Cost function – minimize the errors between the experimental and simulated ground reactions
  - Design variables – spring and damper parameters