Lecture 16

Ground Contact Modeling

EML 5595

Mechanics of the Human Locomotor System

Outline

- Motivation
- Methods
- Journal Article Review

  Neptune et al. (2000)

Outline

- Motivation

Why Ground Contact Models?

- Important human movements such as gait involve changes in ground contact conditions (e.g., single support vs. double support).
- Different movement tasks involve different ground contact conditions (e.g., compare gait and jumping).
- Constraint-based ground contact requires different models for different tasks or changing the model when ground contact conditions change.
- Deformable ground contact permits use of a single model regardless of changes in contact conditions or task (e.g., one model for gait and jumping).

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Modeling Methods

Constraint-based ground contact:

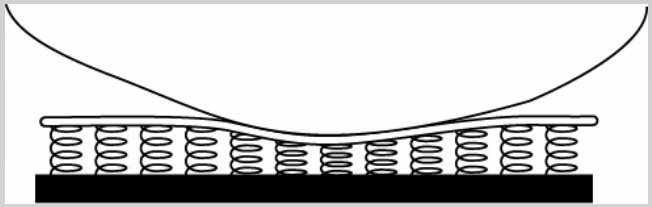
- Joints (typically weld or pin) used to constrain foot to remain in contact with the ground
- Internal reaction forces and torques can be calculated in constrained directions
- Facilitates induced acceleration or power analyses
- No numerical stiffness added to system

Deformable ground contact:

- Discrete springs typically used to prevent foot from penetrating floor excessively
- Spring forces can be calculated at each discrete location given the current amount of interpenetration
- Complicates induced acceleration or power analyses
- Can make the system numerically stiff

Deformable Ground Contact

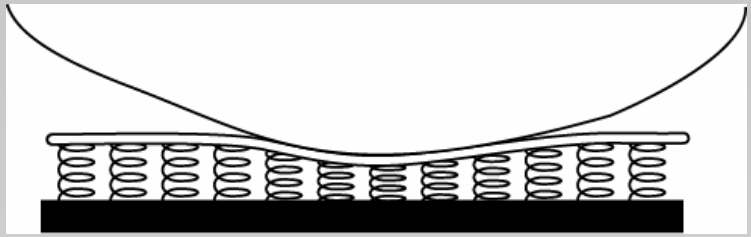
Concept: Prevent the foot from excessively penetrating the floor by placing stiff springs at discrete locations across the floor surface.



For each spring,

$$F_{norm} = kx^n$$

Deformable Contact Issues



$$F_{norm} = k x^n$$

1) How do we pick *k*?
2) Is *k* the same for every spring?
3) How do we pick *n*?
4) How do we account for damping?
5) How do we account for friction?

How to Pick *k* and *n*?

1) Linear elastic contact model (*n* = 1)

$$F_i = p_i A_i$$

where

$$p_i = \frac{(1-\nu)E_i}{(1+\nu)(1-2\nu)h_i} x_i$$

so

$$k_i = \frac{(1-\nu)E_i}{(1+\nu)(1-2\nu)h_i} A_i$$

2) Experiments with shoes
3) Optimization

How to Account for Damping?

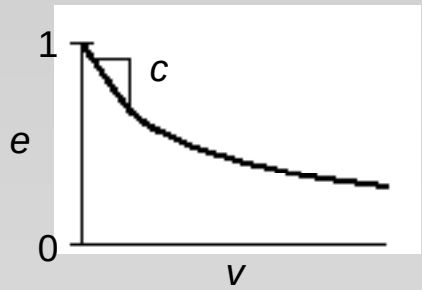
Linear Damping

$$F = kx^n + c\dot{x}$$

Why does this commonly-used method produce unrealistic forces at contact initiation?

Nonlinear Damping
(Hunt and Crossley, 1975)

$$F = kx^n(1 + c\dot{x})$$



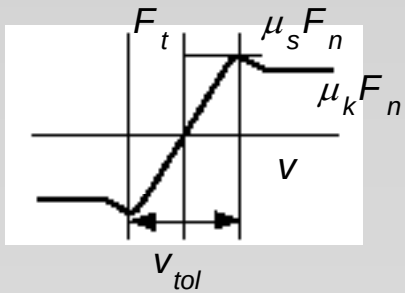
How does this damping formulation eliminate unrealistic forces at contact initiation?

How to Account for Friction?

Coulomb Friction

$$F_{\tan} = \mu F_{norm}$$

applied opposite to the local sliding direction



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Published Contact Model

1) What ground contact model formulation did Neptune et al. (2000) use?

2) What are the strengths of this formulation?

3) What are its weaknesses?

4) What ground contact model would you use, and why?