

Designing Control Systems for Prosthesis-Aided Walking on Varied Terrains

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Motivation: Prosthesis Underuse

1.9 million

Americans live with limb loss.

86 percent

of all amputations are of the lower extremity.

173,000

Americans use a lower extremity prosthesis.



Motivation: Varied-Terrain Walking



Image Source: Smithsonian Magazine

Key Issue: Prostheses perform poorly on varied terrains

Background: Prosthesis Control



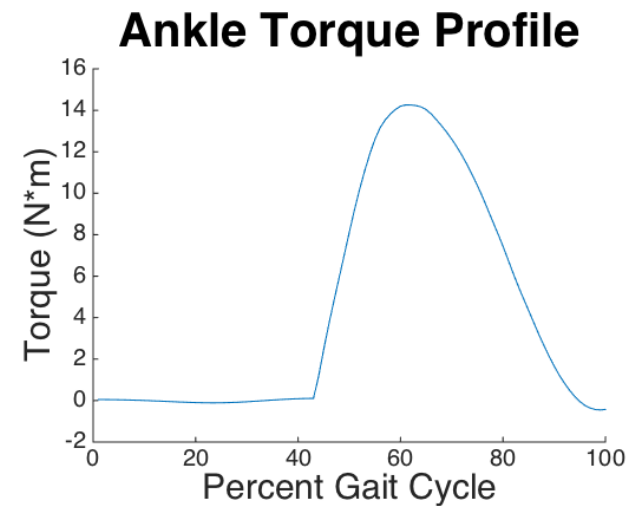
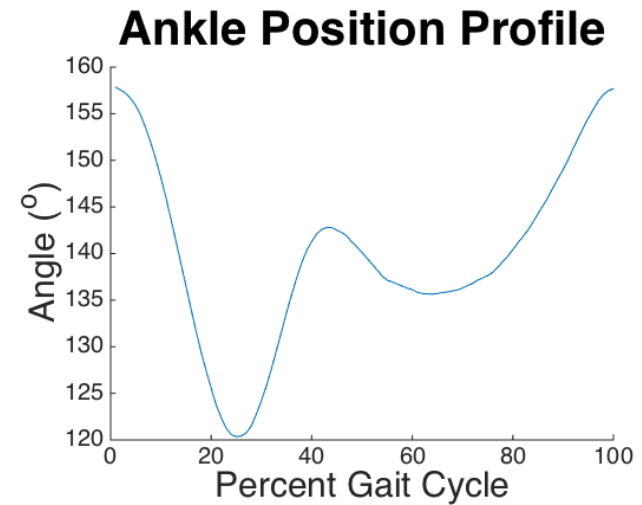
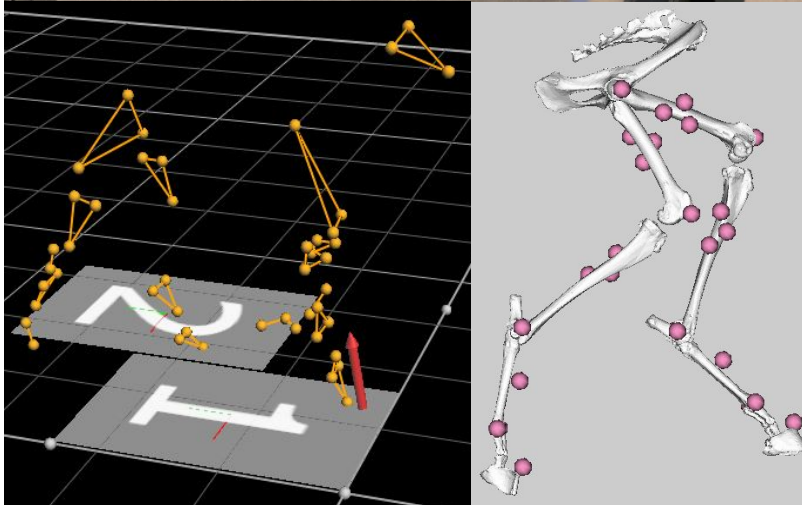
Approach

1. Characterize goat walking across varied terrains
2. Design control system to match observed gait characteristics
3. Optimize control system parameters

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Gait Characterization



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Human Ankle Prosthesis Control

Swing 1
Position
Control

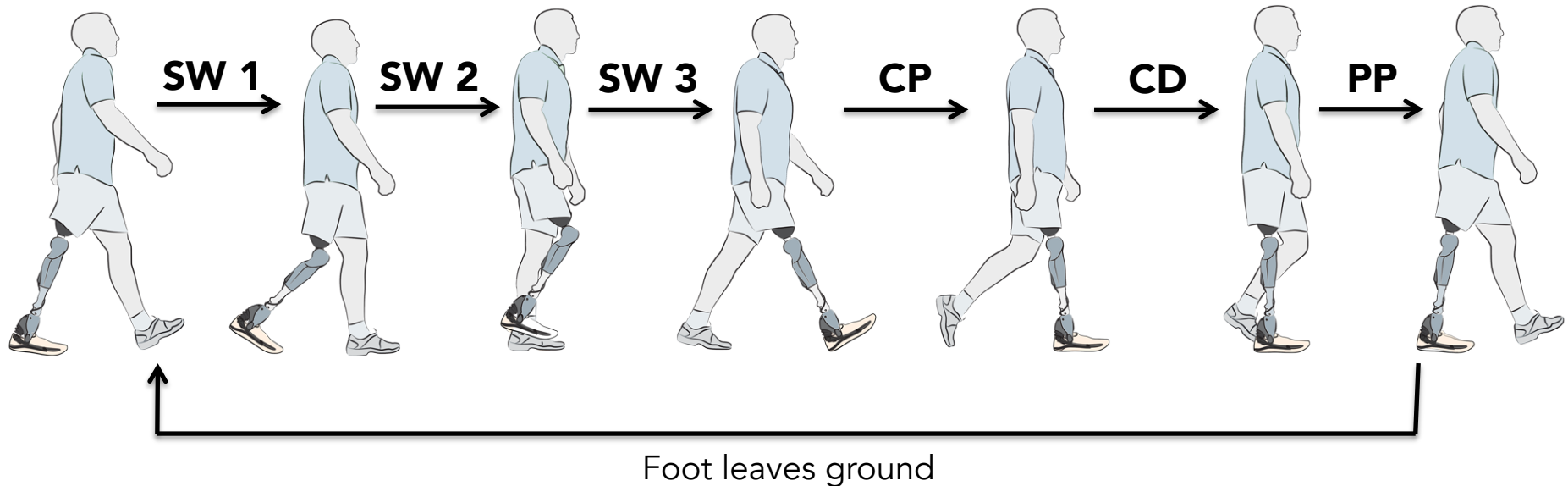
Swing 2
Position
Control

Swing 3
Position
Control

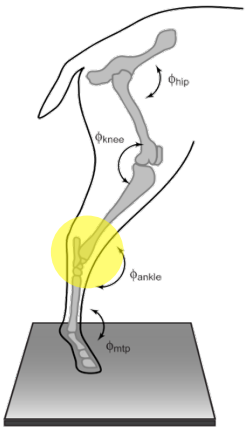
**Controlled
Plantarflex.**
Impedance
Control

**Controlled
Dorsiflex.**
Impedance
Control

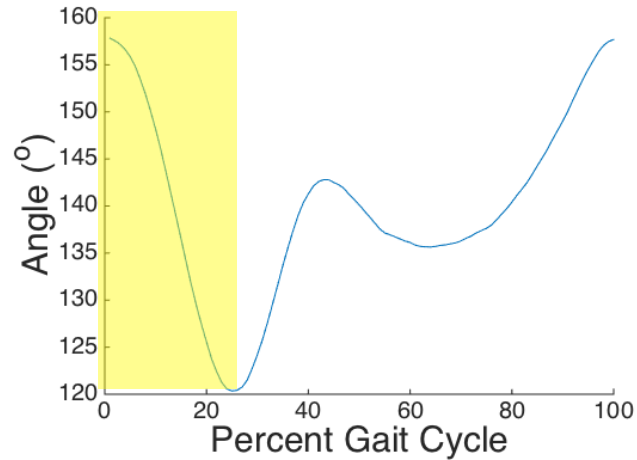
**Powered
Plantarflex.**
Impedance
Control
+Torque



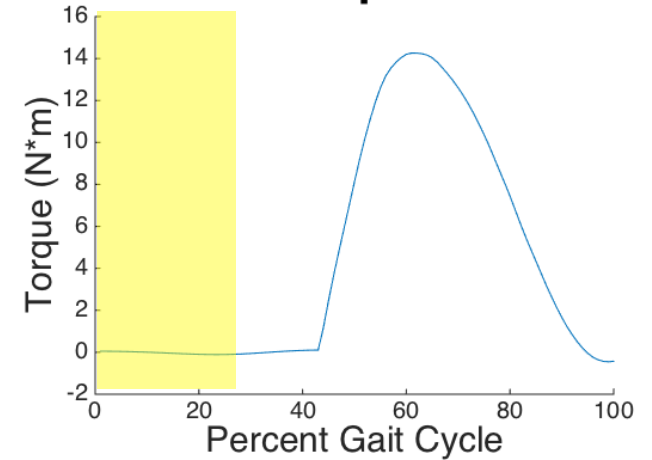
Control System Design



Ankle Position Profile

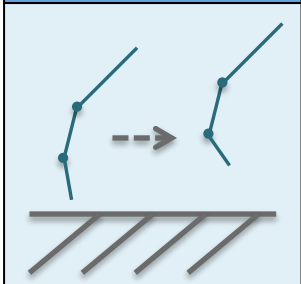


Ankle Torque Profile

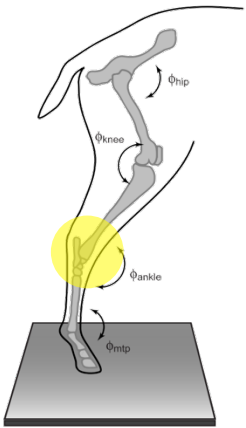


SW 1

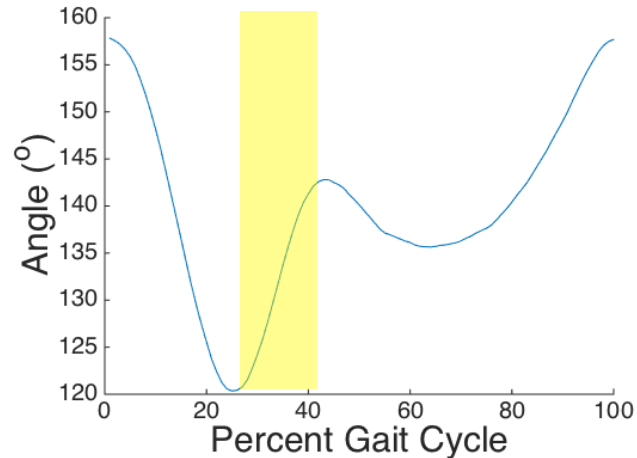
Swing 1
Position
Control



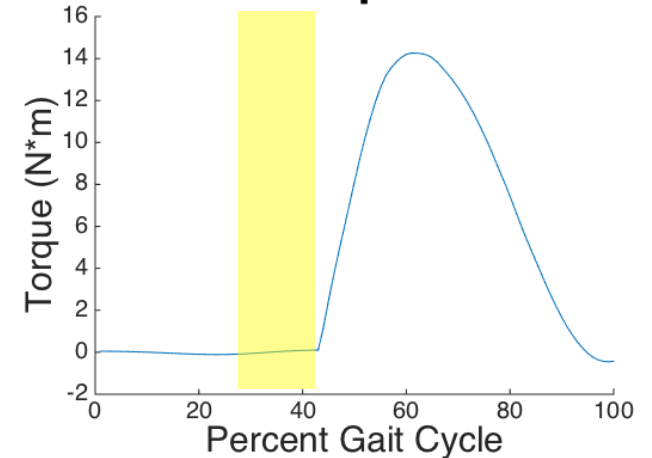
Control System Design



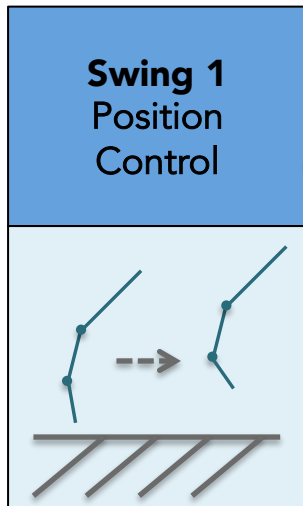
Ankle Position Profile



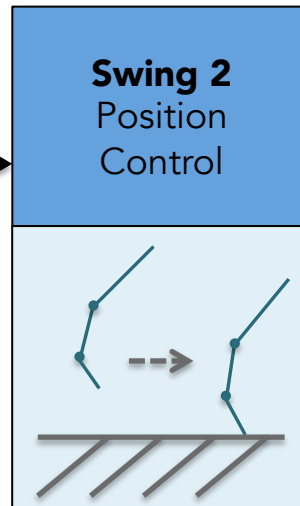
Ankle Torque Profile



SW 1

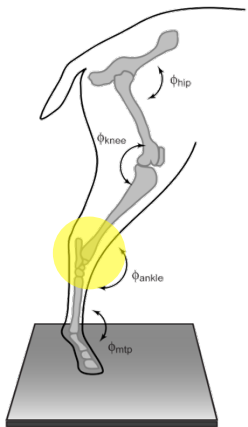


SW 2

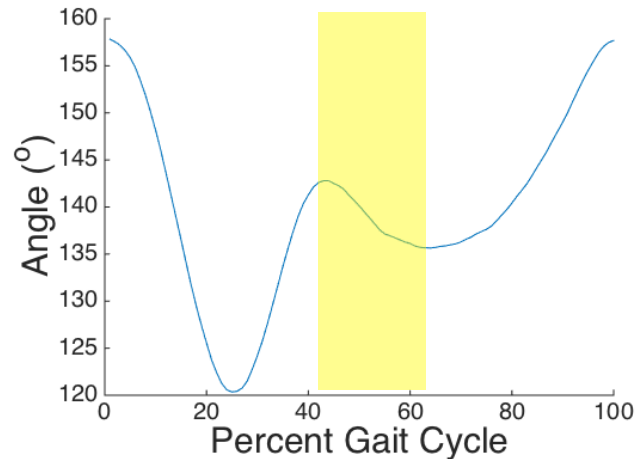


Ankle
angle
reaches
threshold

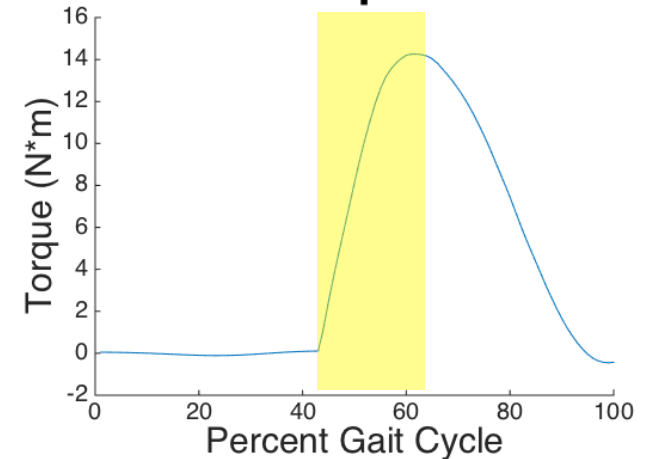
Control System Design



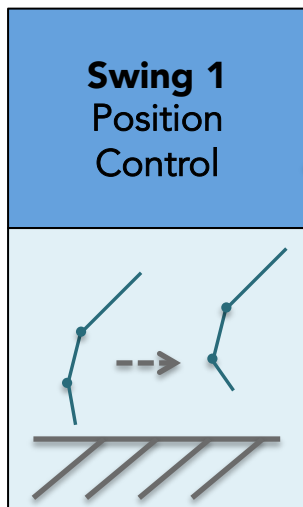
Ankle Position Profile



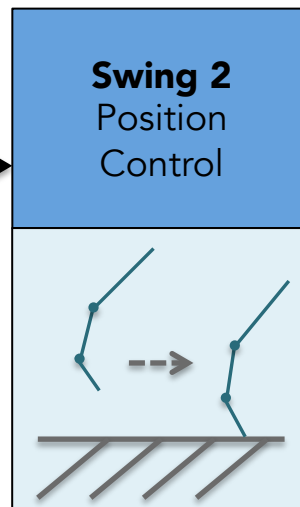
Ankle Torque Profile



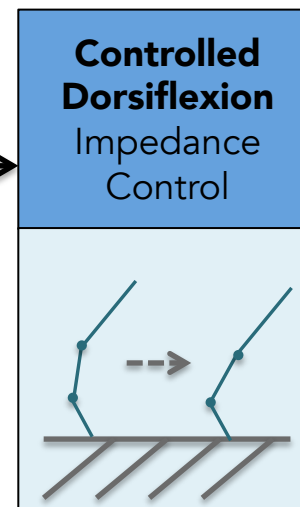
SW 1



SW 2



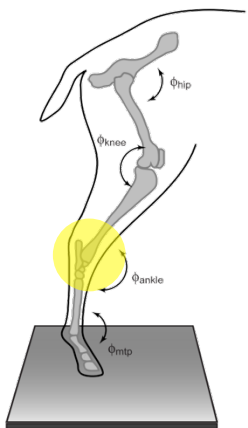
CD



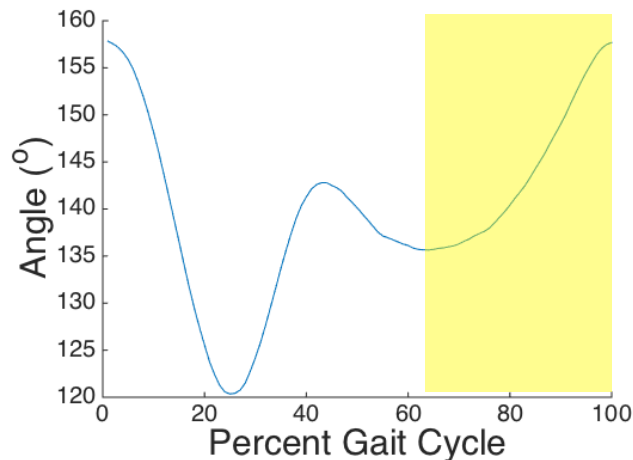
Ankle angle reaches threshold

Foot touches ground

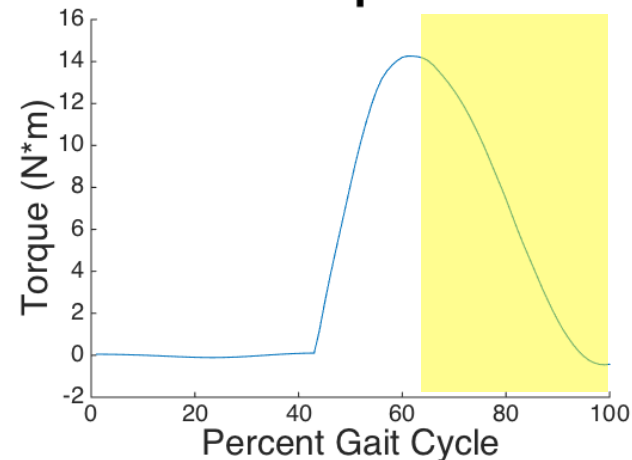
Control System Design



Ankle Position Profile



Ankle Torque Profile

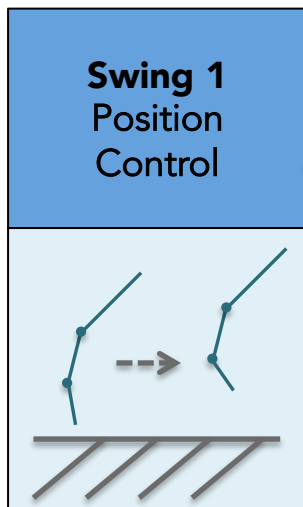


SW 1

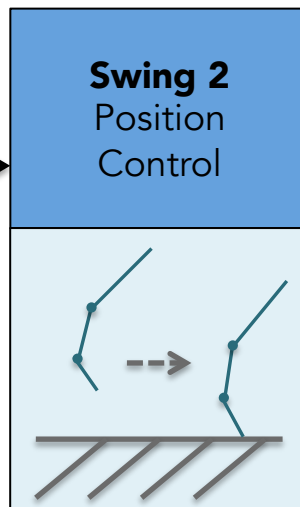
SW 2

CD

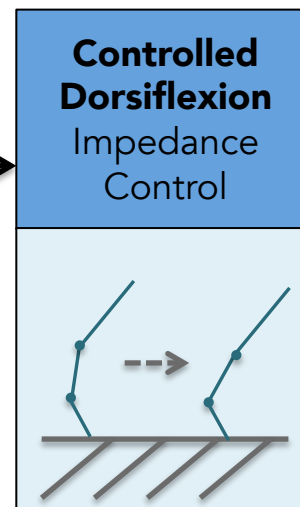
PP



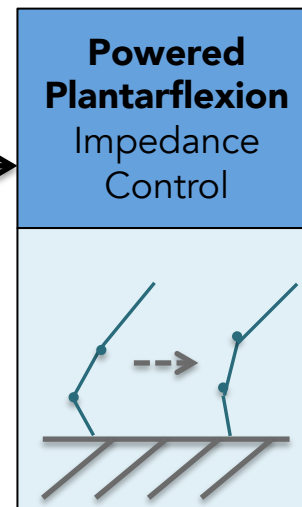
Ankle angle reaches threshold



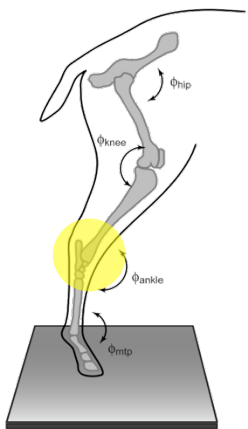
Foot touches ground



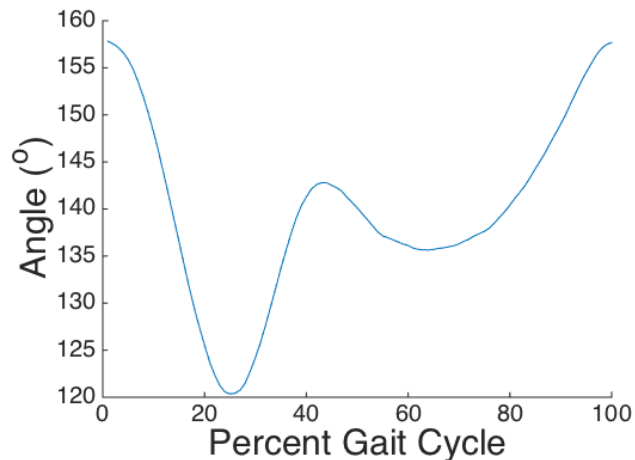
Ankle torque reaches threshold



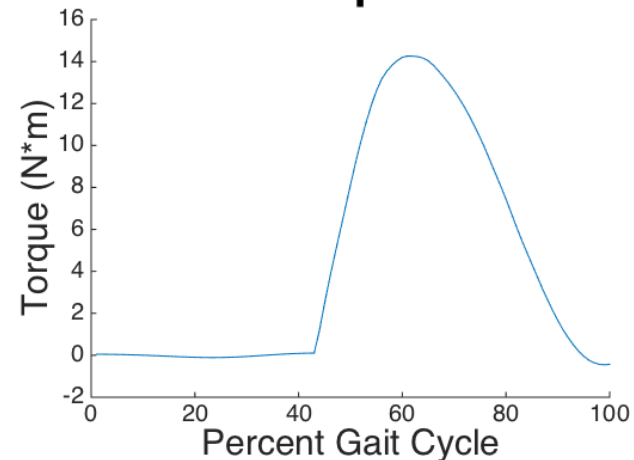
Control System Design



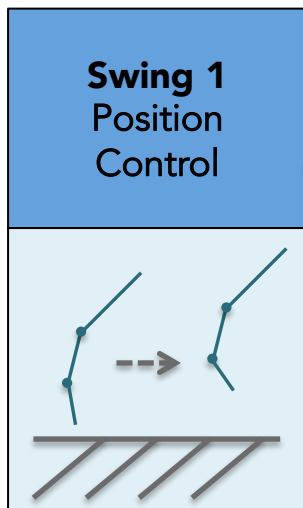
Ankle Position Profile



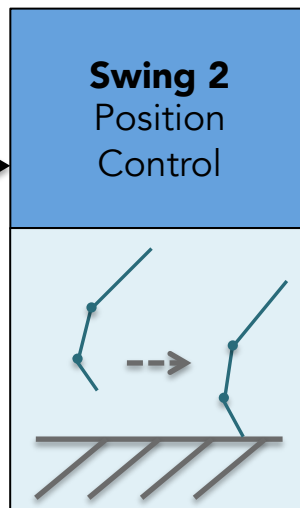
Ankle Torque Profile



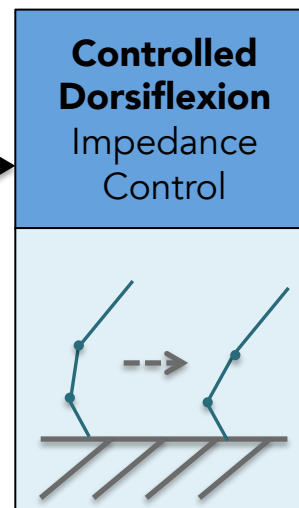
SW 1



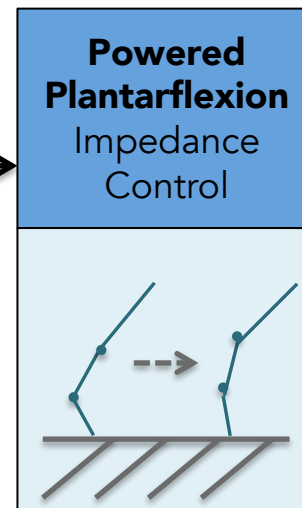
SW 2



CD



PP



Ankle angle reaches threshold

Foot touches ground

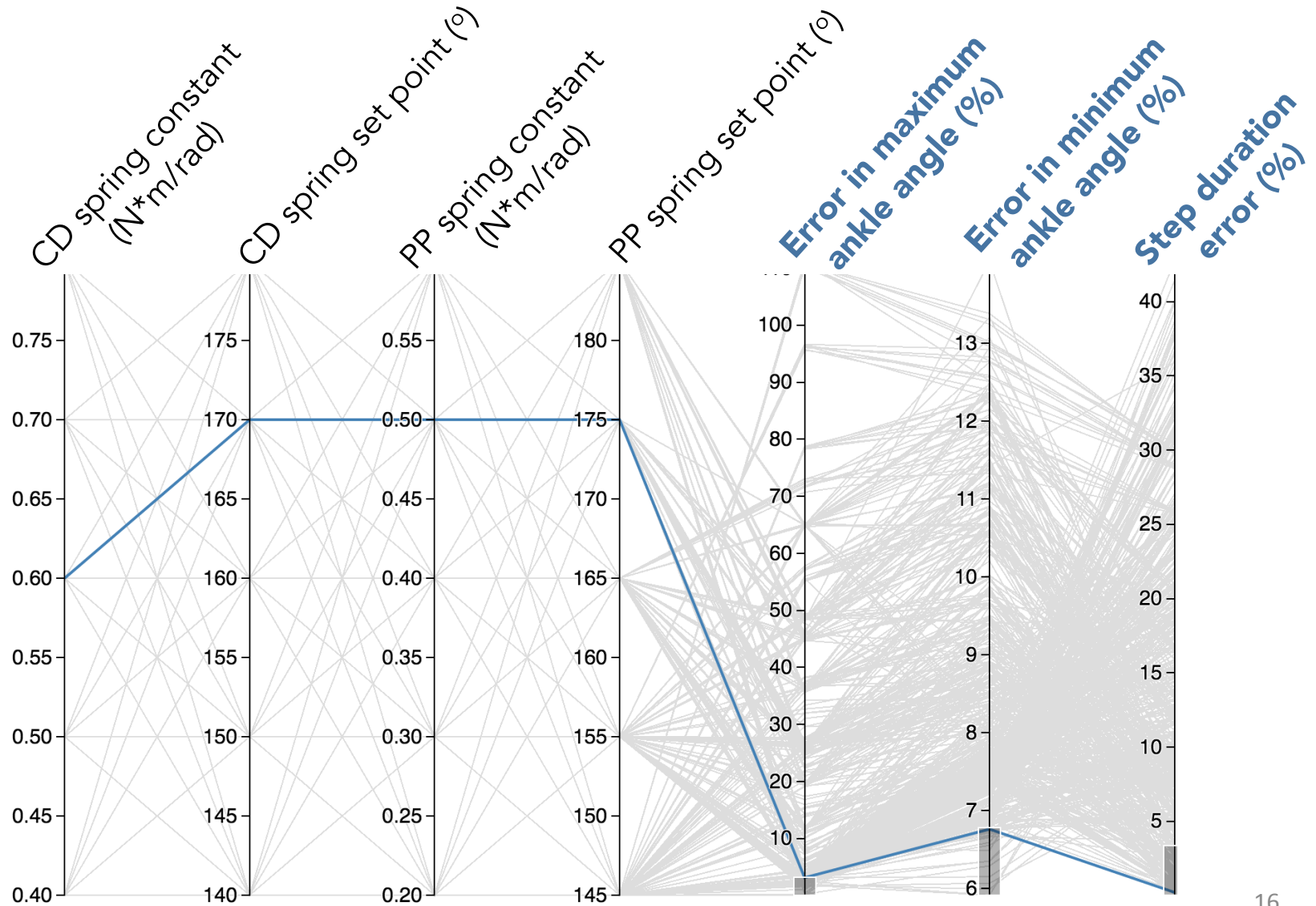
Ankle torque reaches threshold

Foot leaves ground

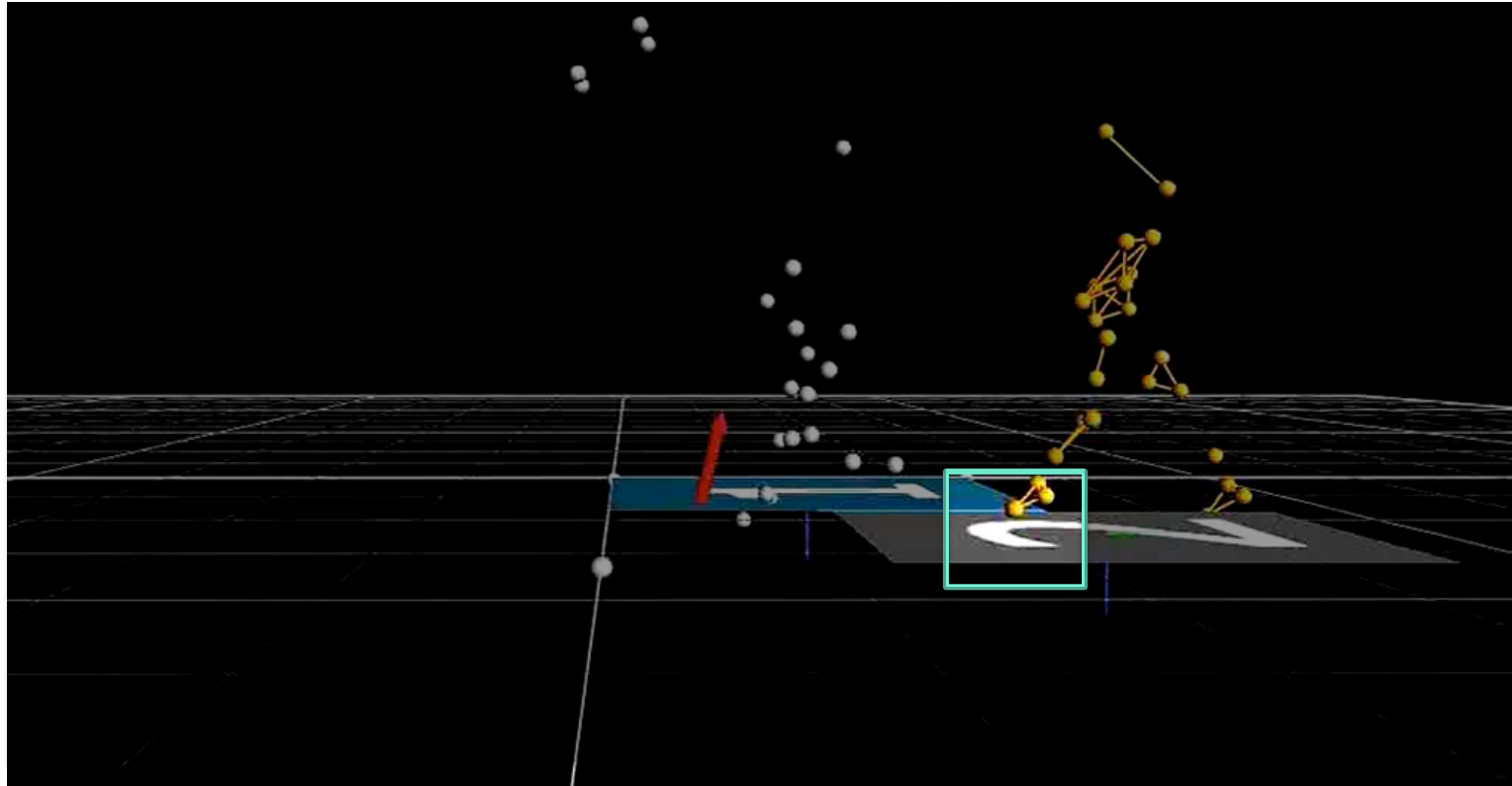
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Simulation and Optimization



Current Work: Terrain-Specific Control



Acknowledgments

- Hugh Herr, PhD
- Tyler Clites
- Allison Arnold-Rife, PhD
- Eric Kline
- Karl Baranov