# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago

NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## Challenge

- Humanoids lack the ability to move in constrained environments
- Humanoid lack the ability to change their speed and directions quickly.
- Humanoids have high degrees of freedom which makes real-time control challenging

## Solution

- Closed-form, low dimensional quadratic polynomial models using data-driven approaches
- Formulating and solving quadratic programs for real-time control

## Scientific Impact

- Creation of tools for building simple, yet accurate models for control.
- Creation of tools for fast online optimization
- Creation of tools for experimental evaluation and benchmark

## Broader Impact

- Humanoid robots for future applications
- Control methods useful for other systems with contact such as manipulators, legged systems, and prosthetics.
- Research and training opportunities to minorities in STEM
- Spread awareness about STEM careers in Chicago area.

# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago

NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

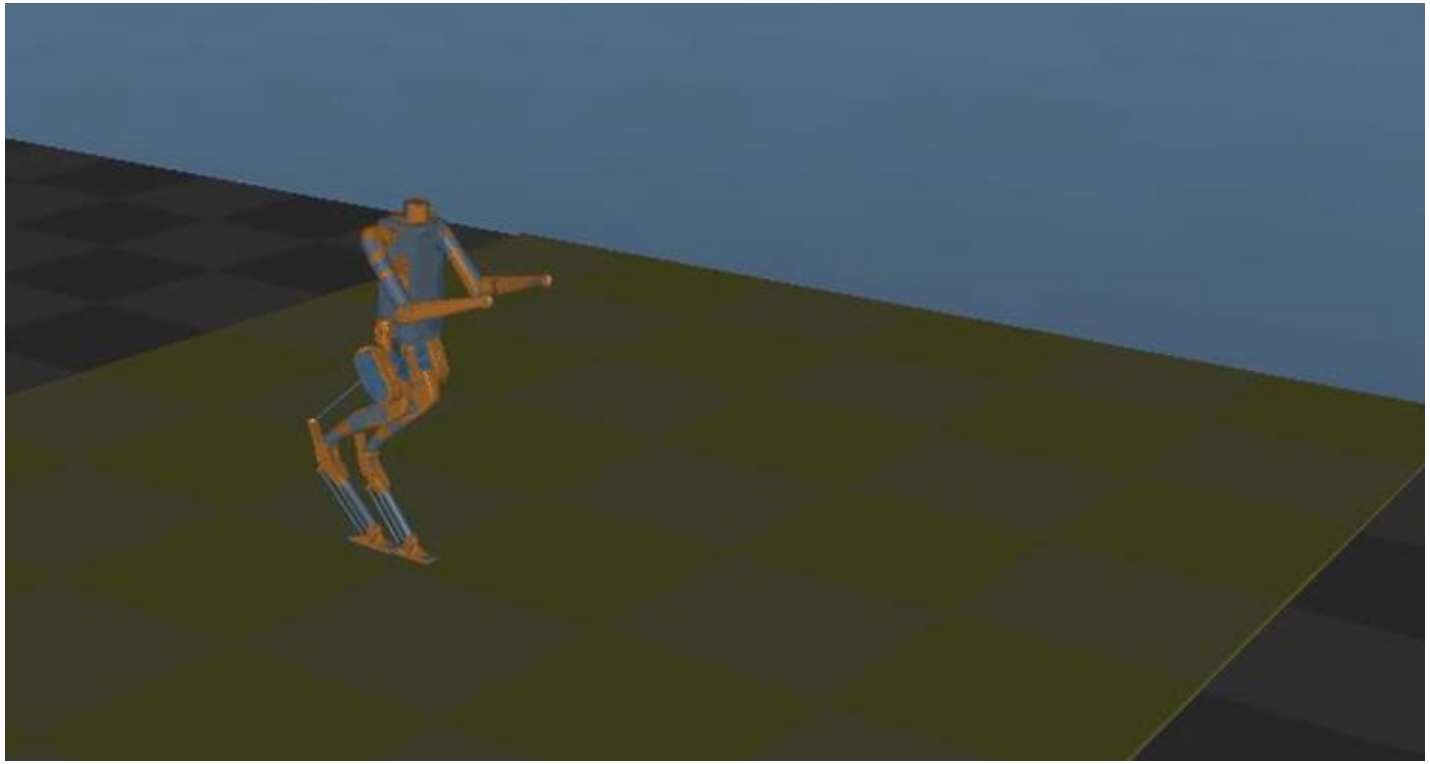
- Foot placement and walking speed are important for stepping over obstacles

# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago

NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

- Most walking robots are underactuated
- Orbital stability may be achieved passively

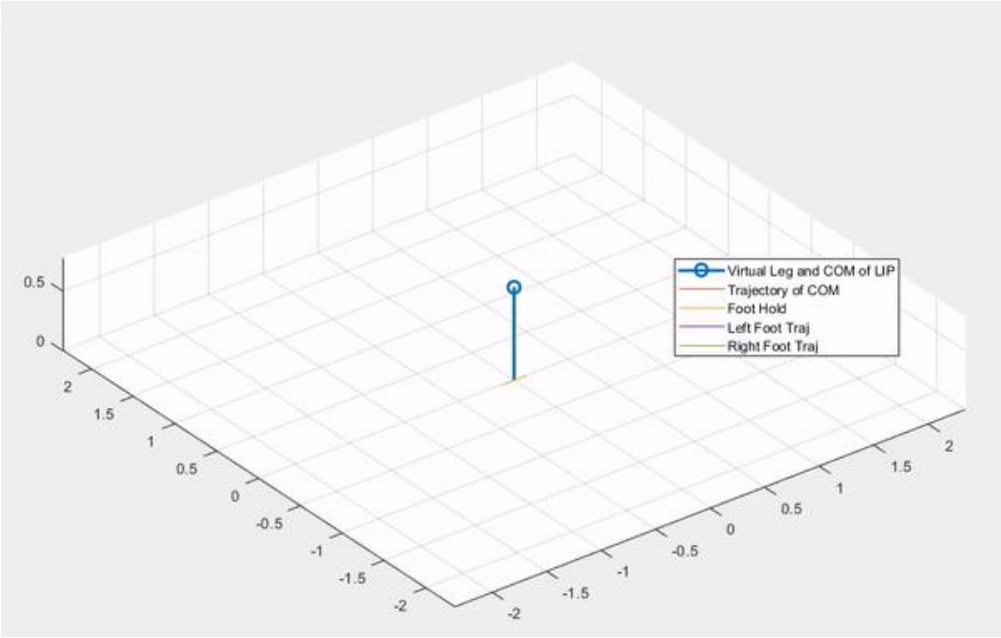


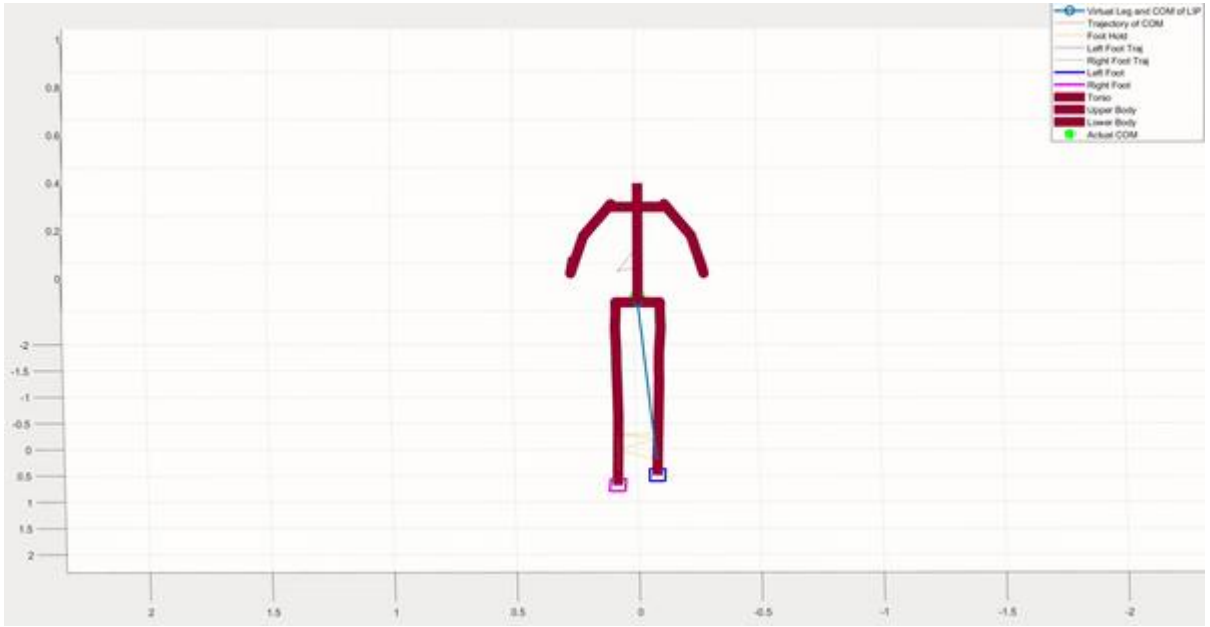
# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago

NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## 3D Linear Inverted Pendulum Model



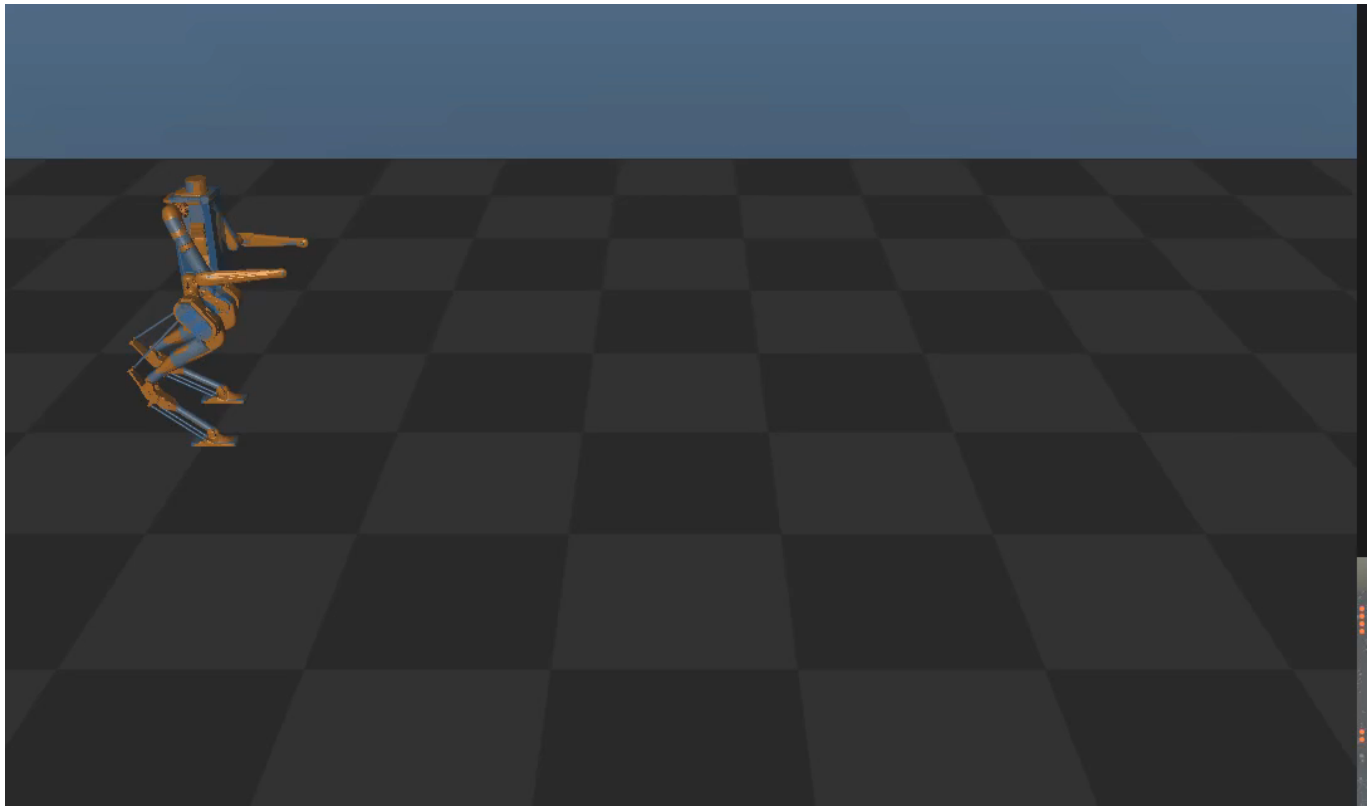



# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago

NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## 2D Linear Inverted Pendulum Model

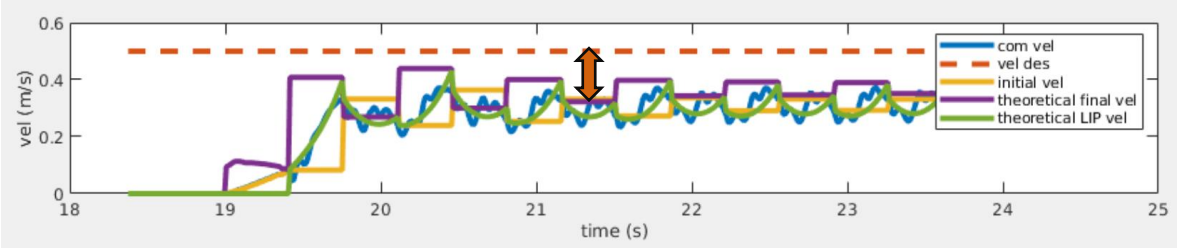


# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago
NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## 2D Model

- Actual robot step-to-step dynamics is not the same as LIPM
  - Error term
- If the error is small → Still design a stable controller
- Having heavy links and torso and compliant joints adds further complexity to the physics model and diverges from the LIPM

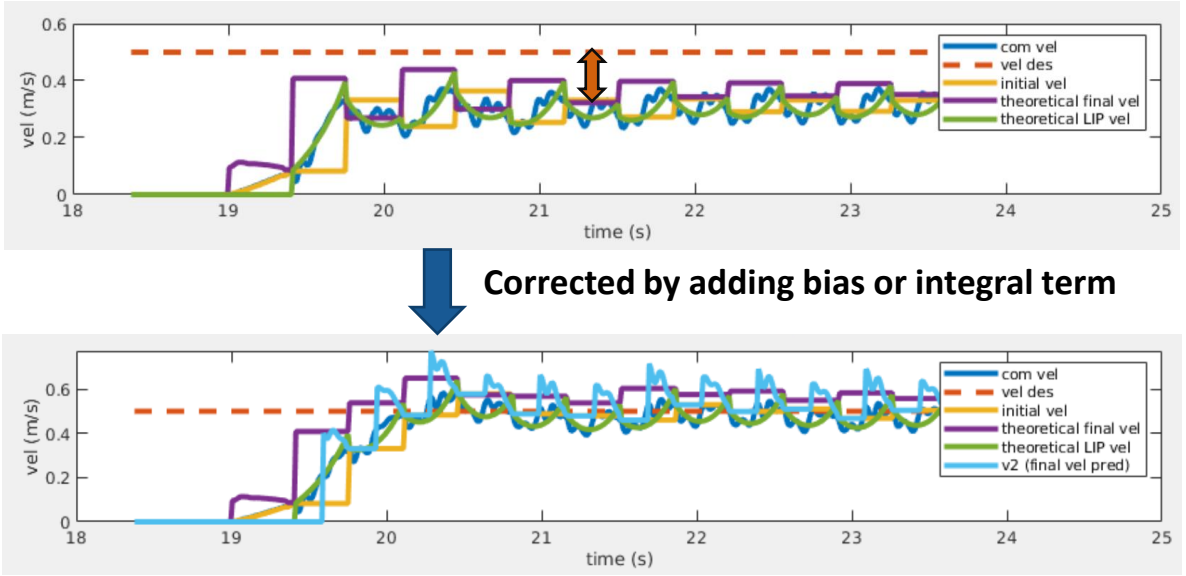


# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago
NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## 2D Model

- Actual robot step-to-step dynamics is not the same as LIPM
  - Error term
- If the error is small → Still design a stable controller
- Having heavy links and torso and compliant joints adds further complexity to the physics model and diverges from the LIPM



# Asymmetric Gait Generation for Legged Locomotion in Complex Environments via Off-Line Model Reduction and Real-Time Optimal Control

Pranav A. Bhounsule, Dept. of Mechanical Engineering, University of Illinois at Chicago
NSF award link: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2128568&HistoricalAwards=false

## Future Work

- **3D LIPM** stepping controller to use on hardware
- Explore alternative step-to-step dynamics map using data driven approaches
  - Use full body dynamic model
  - Simplified Poincare map