Towards Improving Rapid Acceleration in Legged Robots

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DATE: 18TH OCTOBER 2018

UCT MECHATRONICS

University of Cape Town • iYunivesithi yaseKapa • Universiteit van Kaapstad

SPES BONA

Lecture Contents

- Background to my Research
  - Aims and Objectives of Research
- Optimisation to Inspire Design
- Template Identification
- Controller Design
- Research Vision
- The Bigger Picture

Background to Research

- Animals exhibit superior agility
  - Don't fully understand animal locomotion
  - Robotic platforms cannot compete
- Current robotic focus
  - Short time horizon problems (Steady state/periodic steps)
  - Energy efficient locomotion

[1]

[2]

[3]

Our Research Group

Dr. Patel

Me

State Estimation

Sensing

Bio Mechanics

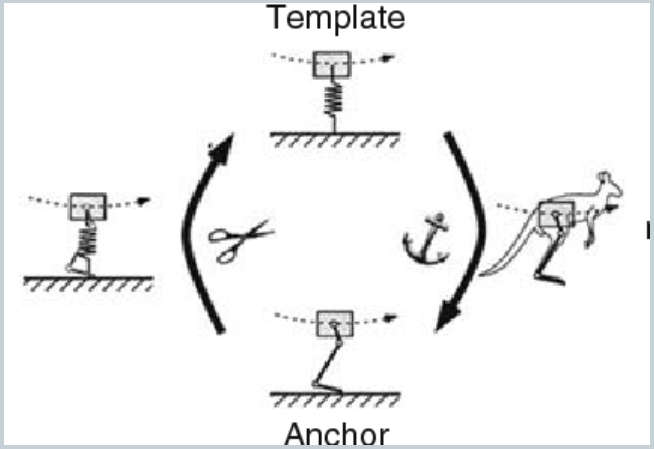
Trajectory Optimisation

Feedback Control

Mech Design

Aims and Objectives of Research

- Improve the agility of legged platforms
  - Focus on rapid acceleration and deceleration
  - Novel mechanical designs inspired by trajectory optimisation
  - Development of novel templates and control algorithms
  - Requires improving optimisation techniques



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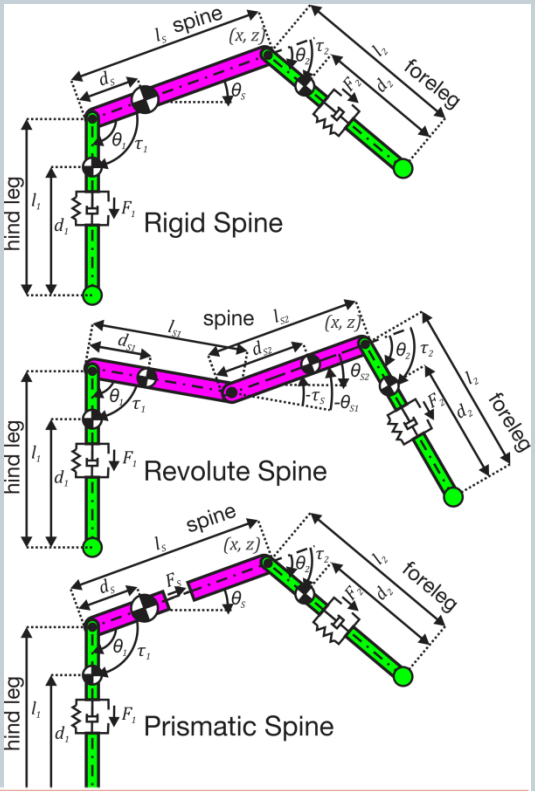
How is Optimisation Used to Inspire Design?

- Large scale Monte Carlo Simulations
  - Investigate optimal spine morphology
  - 100 randomly generated robot parameters
  - Planar robots
    - Bound gait
    - One rear and one front leg
- Spine morphologies:
  - Rigid Spine
  - Revolute Spine
  - Prismatic Spine
- Hybrid dynamics
  - Prescribed phase order
- Results inspired the design of a novel platform



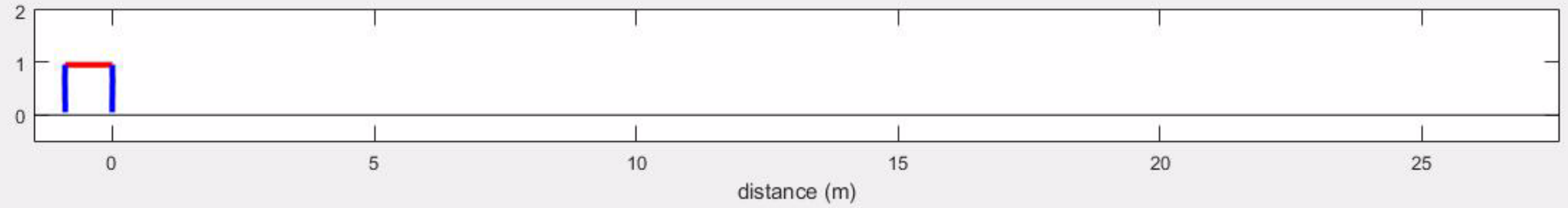
Spine Morphology	Percentage best	Convergence Rate
Rigid Spine	18.2%	15.4%
Revolute Spine	6.1%	8.4%
Prismatic Spine	75.8%	9.9%

Extension of Research

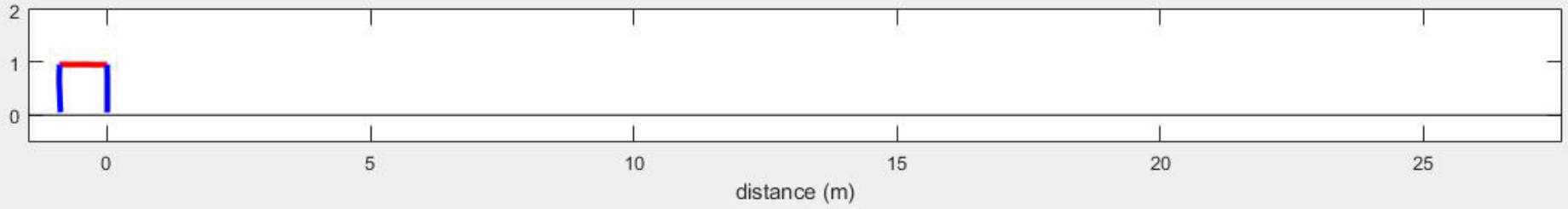
- Through contact methods [5]
  - Optimiser picks contact order
  - Slipping is allowed:
    - Friction cone
- Long time horizon problem
  - Start and end in rest configuration
  - Travel 30 spine lengths
  - Acceleration and Deceleration phase
- Improved optimisation methods
  - 3 point collocation
- Also looking at leg bend direction (collaboration)

Initial Results

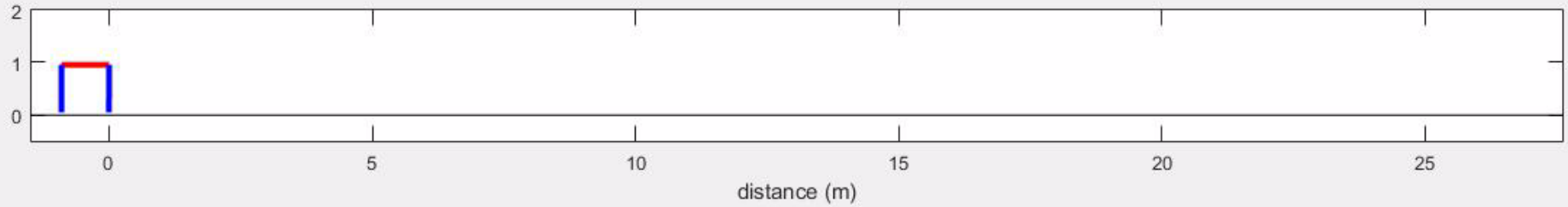
Rigid Spine



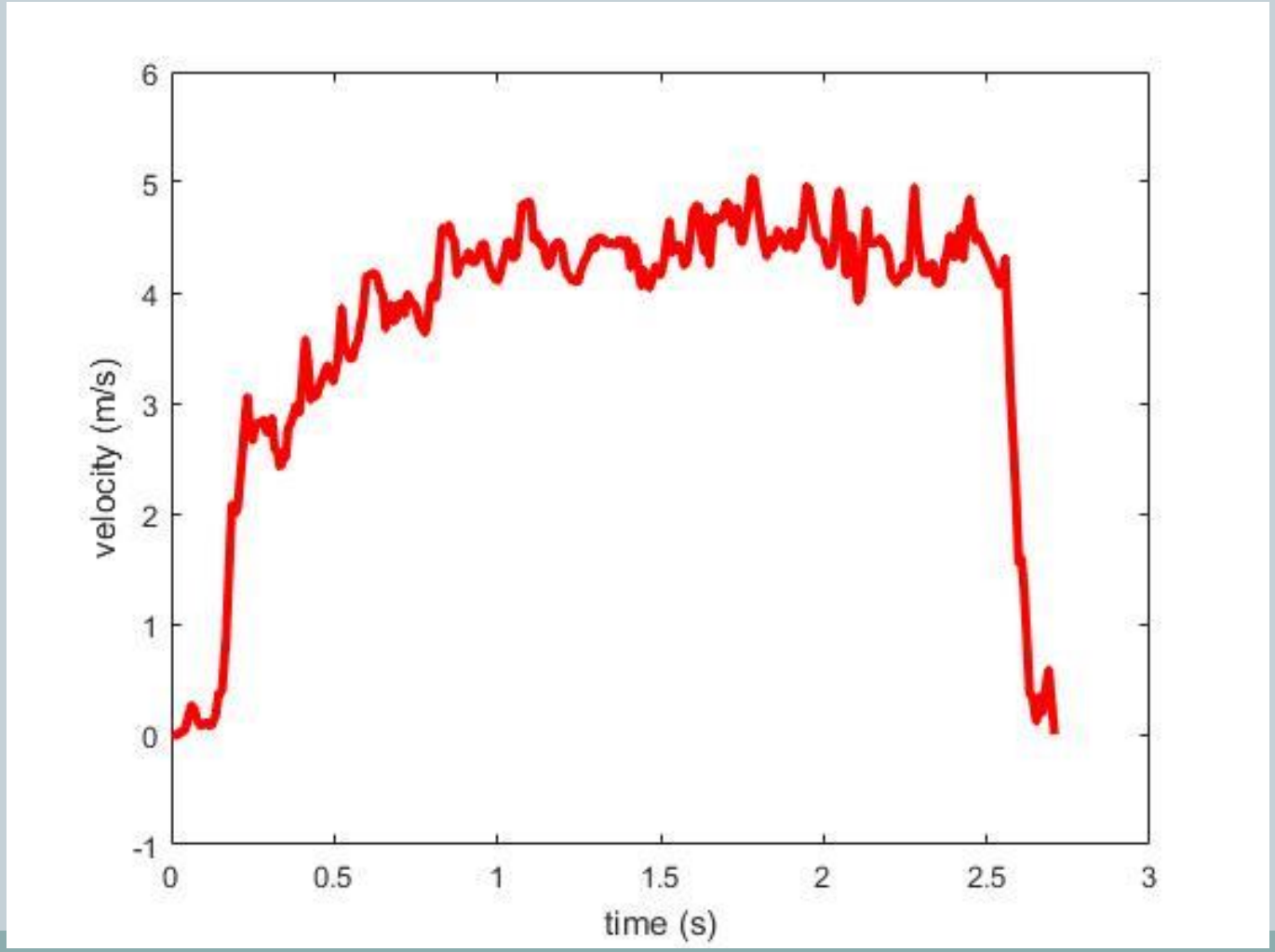
Revolute Spine



Prismatic Spine

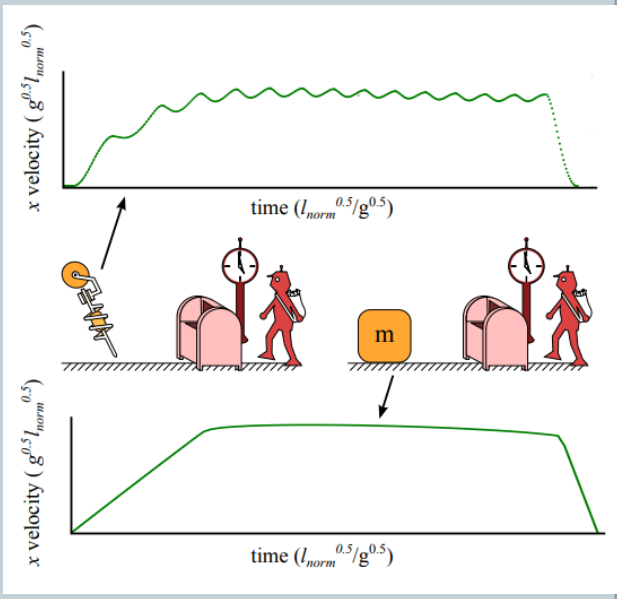


Initial Results

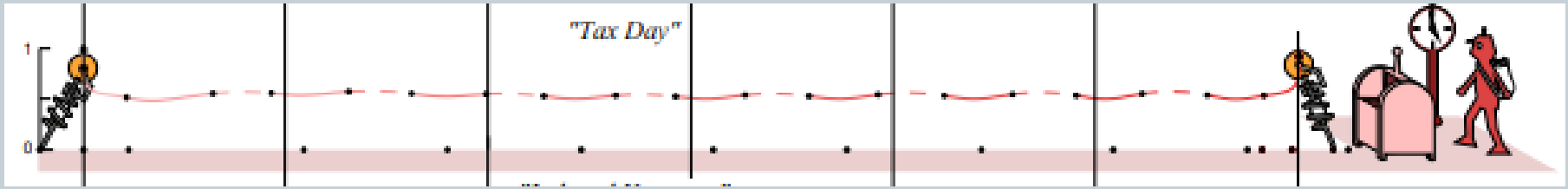


Template Identification

- A/Prof. Hubicki [6]:
  - Investigated long time horizon problems
  - Using simple monopod
  - Sliding mass (viscous friction subject to a time varying force
  - Approximation for scheduling velocities for optimal locomotion planning
  - Hypothesized it will hold for more complex legged models



- Collaborating to test this hypothesis



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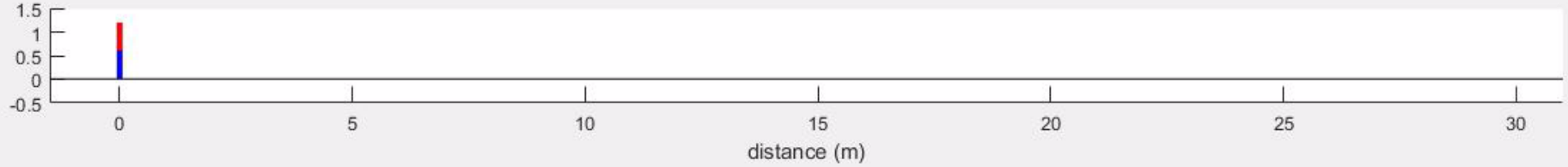
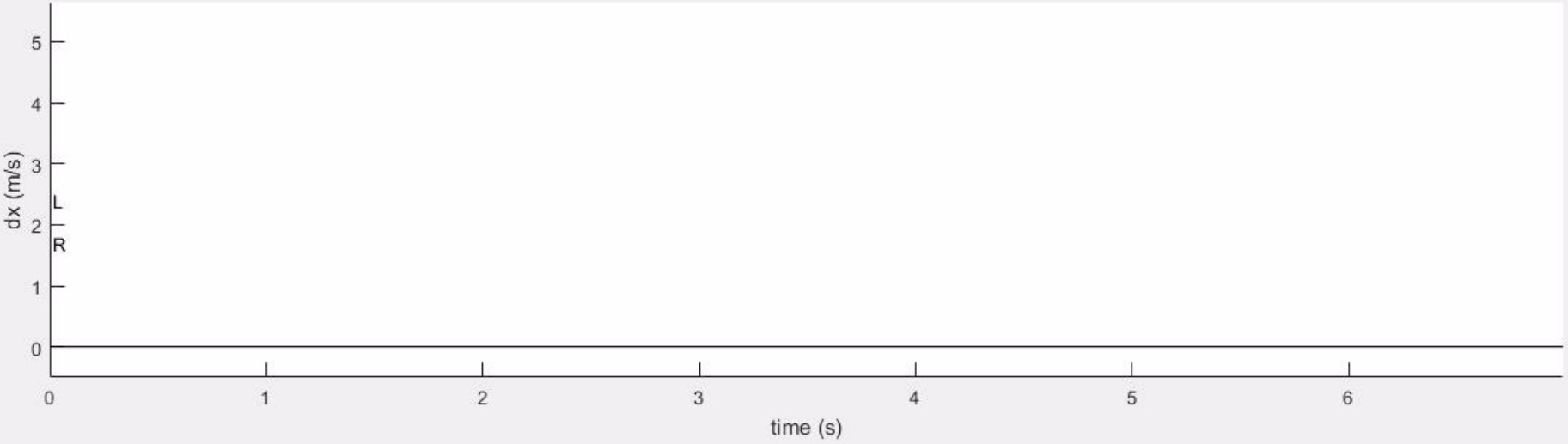
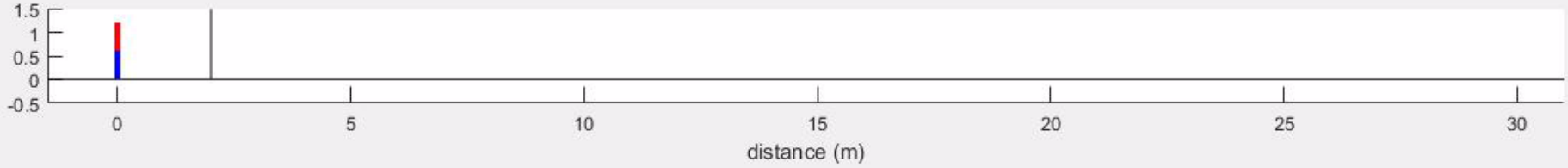
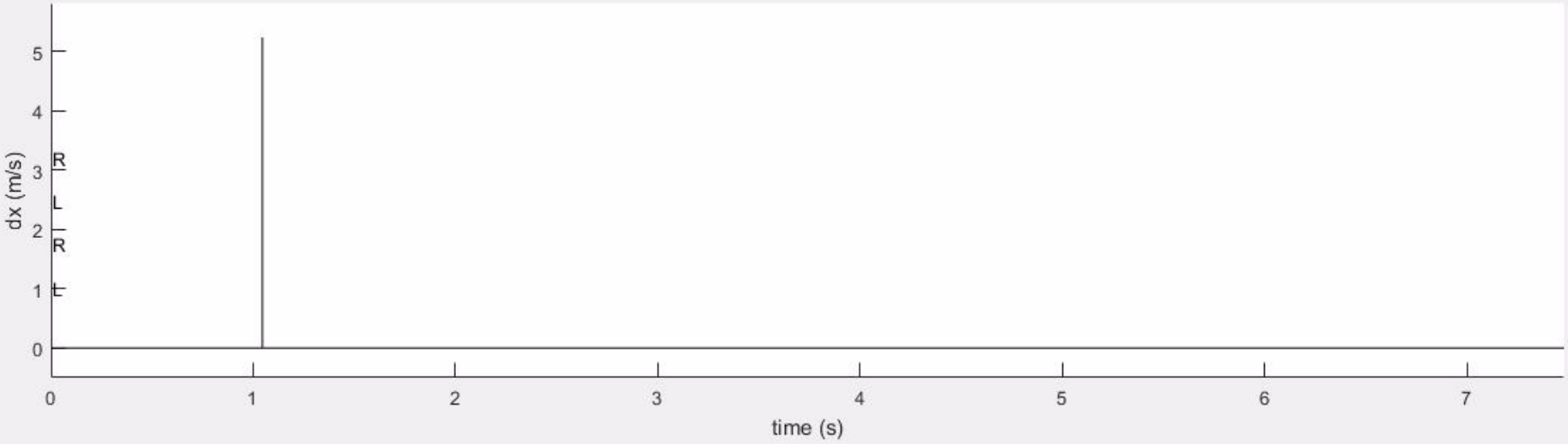




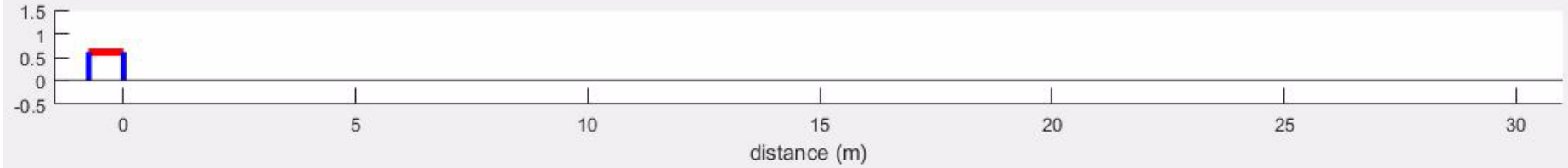
Disturbance Analysis



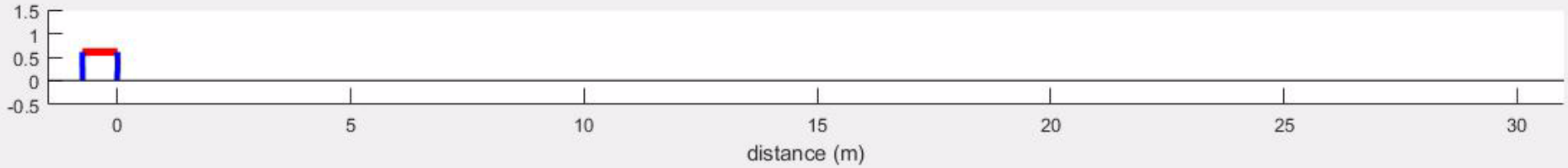


Initial Results

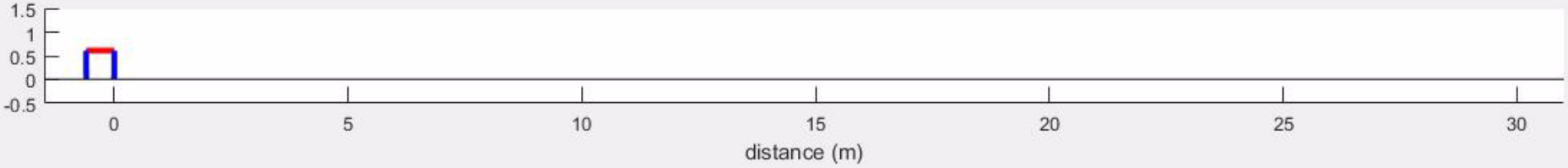
Rigid Spine



Prismatic Spine

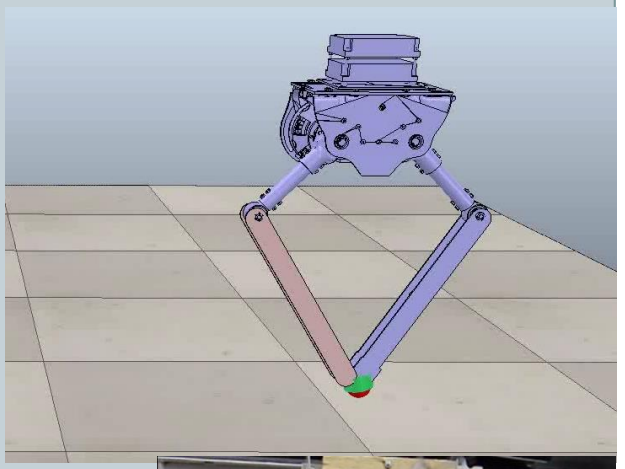


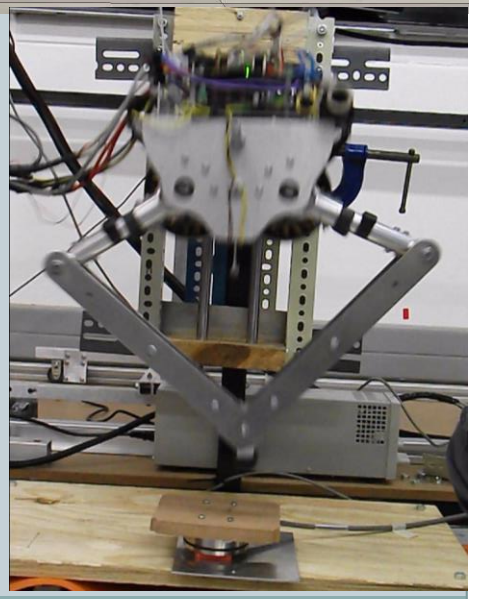
Revolute Spine



Controller Design

- Trajectory optimisation inspired
  - PFL controller
  - Using sliding mass template for velocity commands
- Test in Simulation
  - Initial tests done in a physics engine
  - Test on Platform



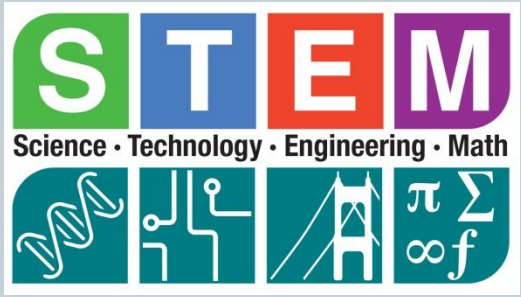


My Vision

- PhD goals:
  - Planar Quadruped
  - Rigid and Prismatic spine
  - Test and compare acceleration
- Future goals:
  - 4 legged quadruped
  - 2 DOF spine
  - Investigate
    - Galloping gait
    - Rapid acceleration and deceleration
    - Turning

Fit in With Africa: Global Picture

- Developed algorithms and techniques are transferable to other fields
  - Optimisation used in multiple fields
- Large potential for patents:
  - Will result in job creation
  - In the process of patenting with Dr. Patel (NDA)
- New method to understand control
- New technique to inspire robot design
- Most importantly:
  - Inspire the pursuit of STEM at a school level
  - Demonstrate the robot at schools and UCT open day



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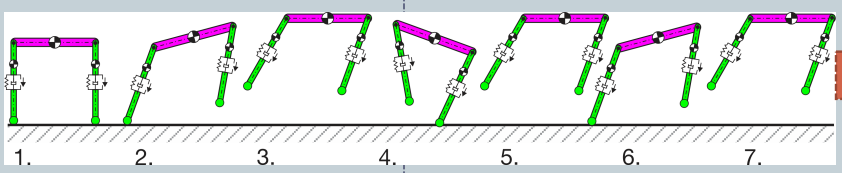
How do I align with the EEE Department?

Mechatronics lab

- Investigating animal locomotion
- Trajectory optimisation
  - Lab's focus: bipeds and quadrupeds

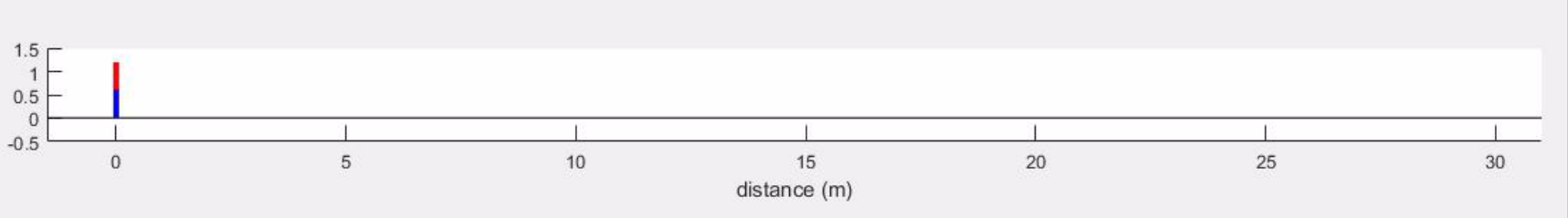
EEE Department

- Mechatronics Engineer
- Hands on and practical experience
- Leading the development of the robot



Thank you for listening!!

- Any questions?



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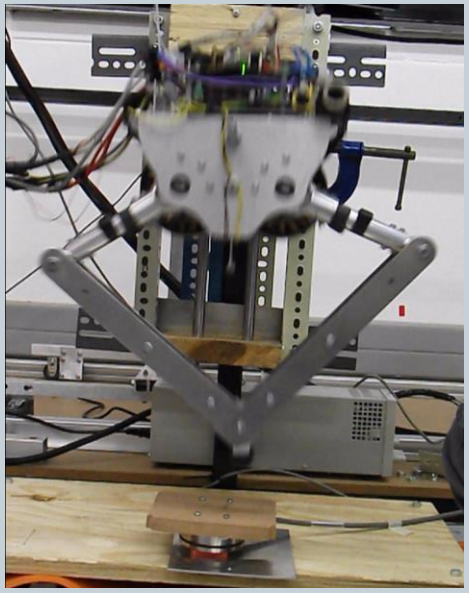

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References

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- [3] https://www.youtube.com/watch?v=NtU9p1VYtcQ
- [4] Turvey, Michael T. and Sérgio Teixeira da Fonseca. "Nature of motor control: perspectives and issues." *Advances in experimental medicine and biology* 629 (2009): 93-123.
- [5] M Posa, C Cantu, R Tedrake, 'A Direct Method for Trajectory Optimization of Rigid Bodies Through Contact' 2013
- [6] C Hubicki, M Jones, M Daley, J Hurst, 'Do Limit cycles matter in the long run? Stable orbits and sliding-mass dynamics emerge in task-optimal locomotion' 2015
- [7] https://www.teachersoncall.ca/what-is-stem-and-how-can-you-engage-your-child/