The Effect of Leg Design on Robotic Running Gaits

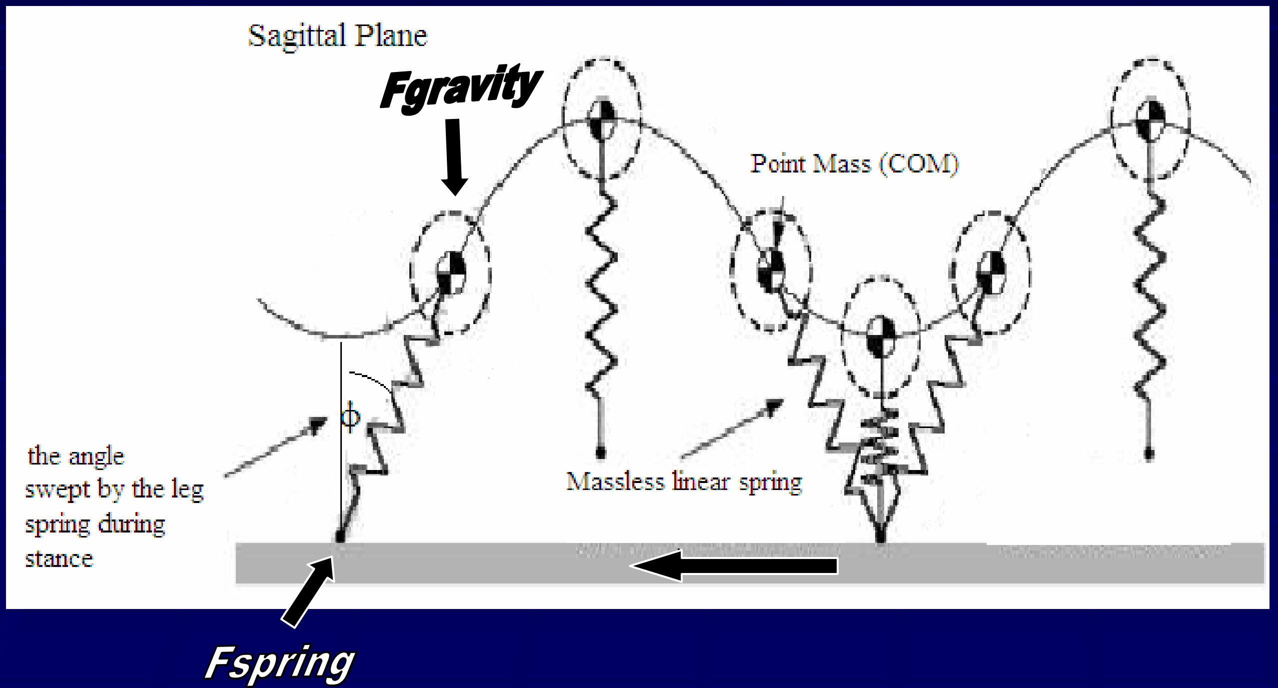
Nataliya Kilevskaya
University of Florida

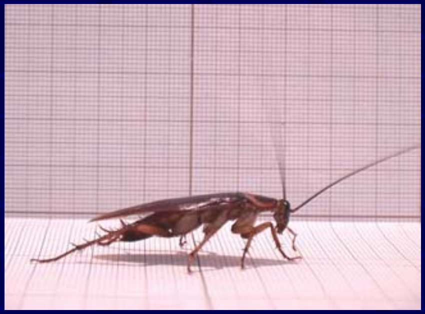
SUNFEST 2007

Mentors:
Jonathan Clark
Kevin Galloway

RHex: A Mobile Hexapod Robot

SLIP Model

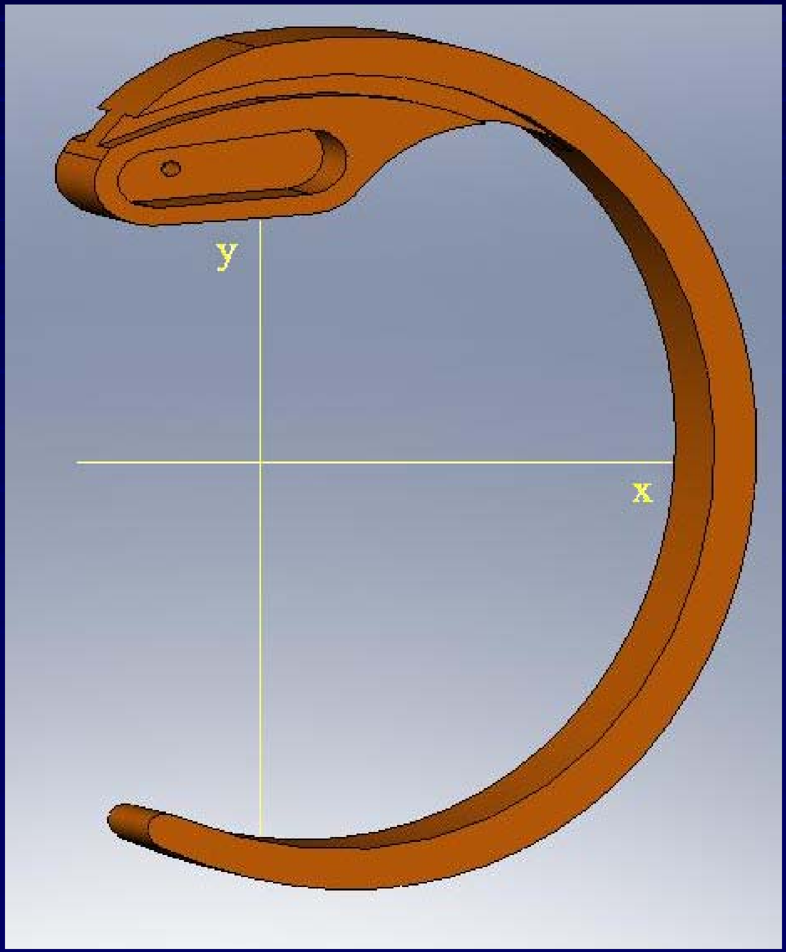




Spring Loaded Inverted Pendulum (SLIP) Model of animal running

Variable Stiffness C-leg

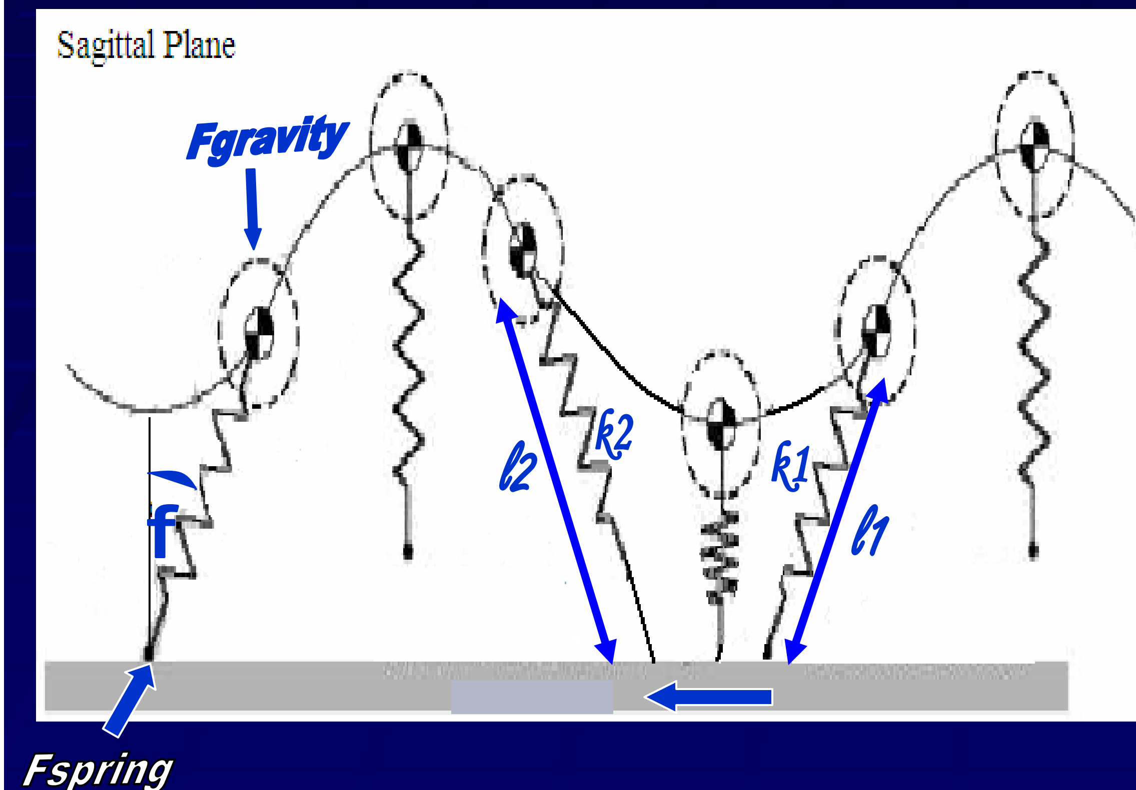
- Compliant C-shaped leg acts as a spring
- Why is the C-leg geometry so effective?
- Differences between C-leg and straight leg:
    1) Changing spring rest length
    2) Changing radial stiffness
    3) Coupled tangential deflection
- What characteristics are important for 'better' legs?



Project Goals

- Decouple characteristics of C-leg in a mathematical model
- Use model to discover performance effect of individual characteristics and predict behavior of different leg designs
- Build legs corresponding to models and run on robot to test model predictions

EduBot Running Model



- Modified SLIP model
  - Fixed angular velocity:

    $\dot{f} = \text{constant}$

  - Damper in parallel with spring
  - Increasing rest length during stance:

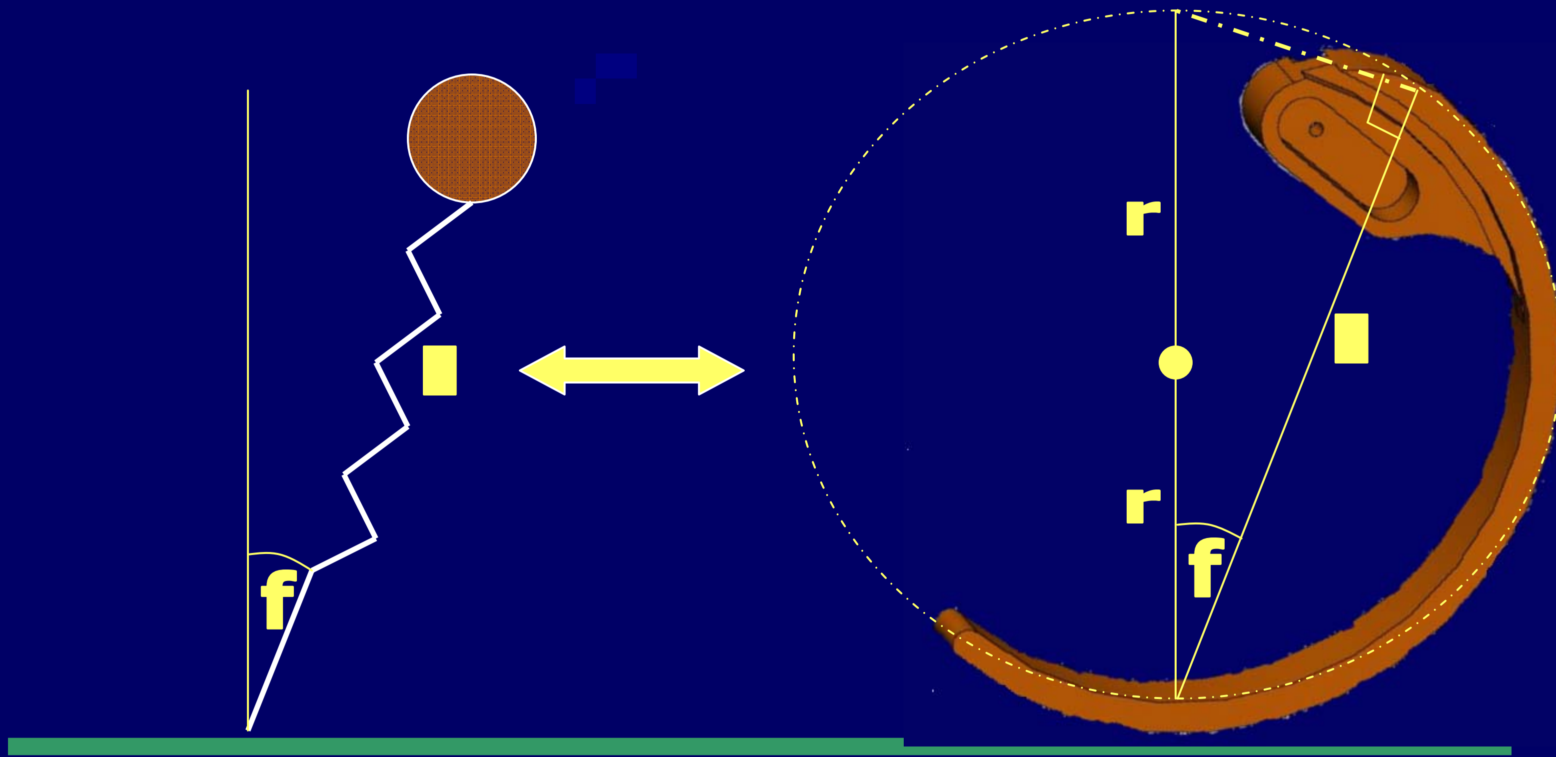
    l1 < l2

  - Decreasing stiffness during stance:

    k1>k2

  - Roll during stance

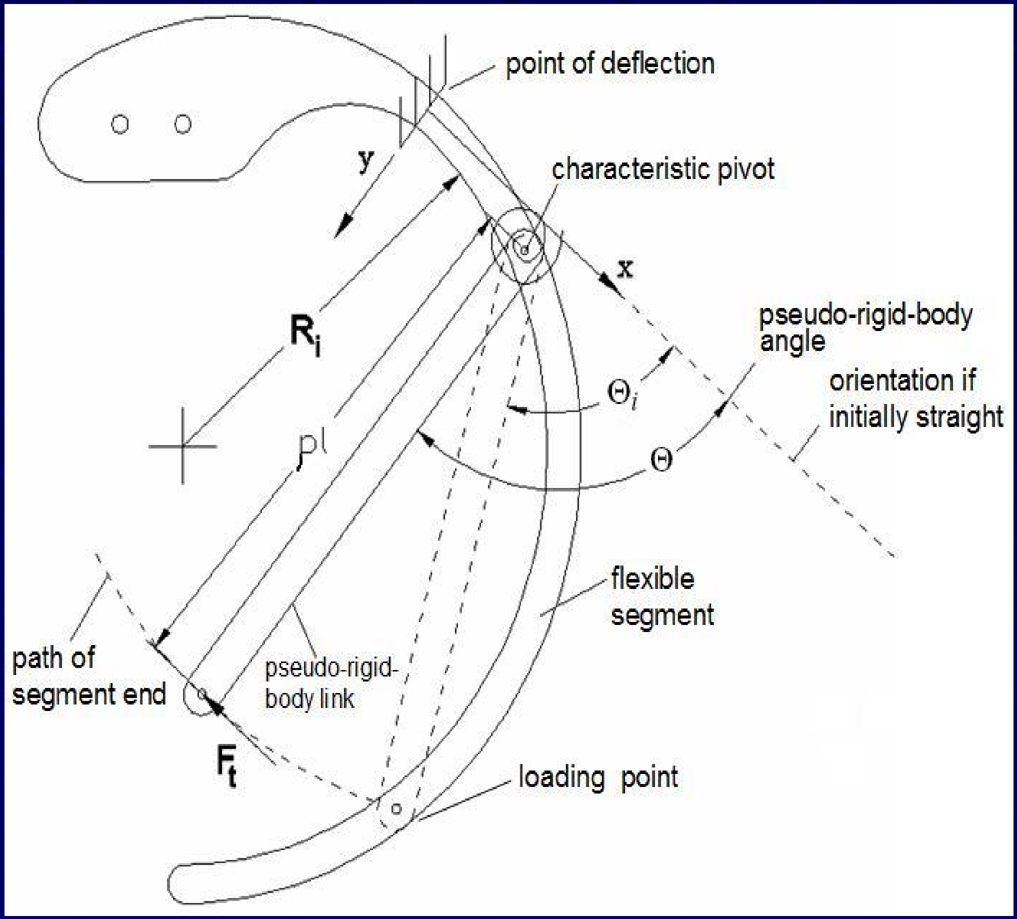
Spring Rest Length



$$l = 2r\cos f$$

C-leg Psuedo Rigid Body Model

- Deflection properties of C-leg can be modeled by two rigid links connected by a torsional spring
- Torsional Spring constant K_t is a function of the leg shape, material stiffness, and loading point

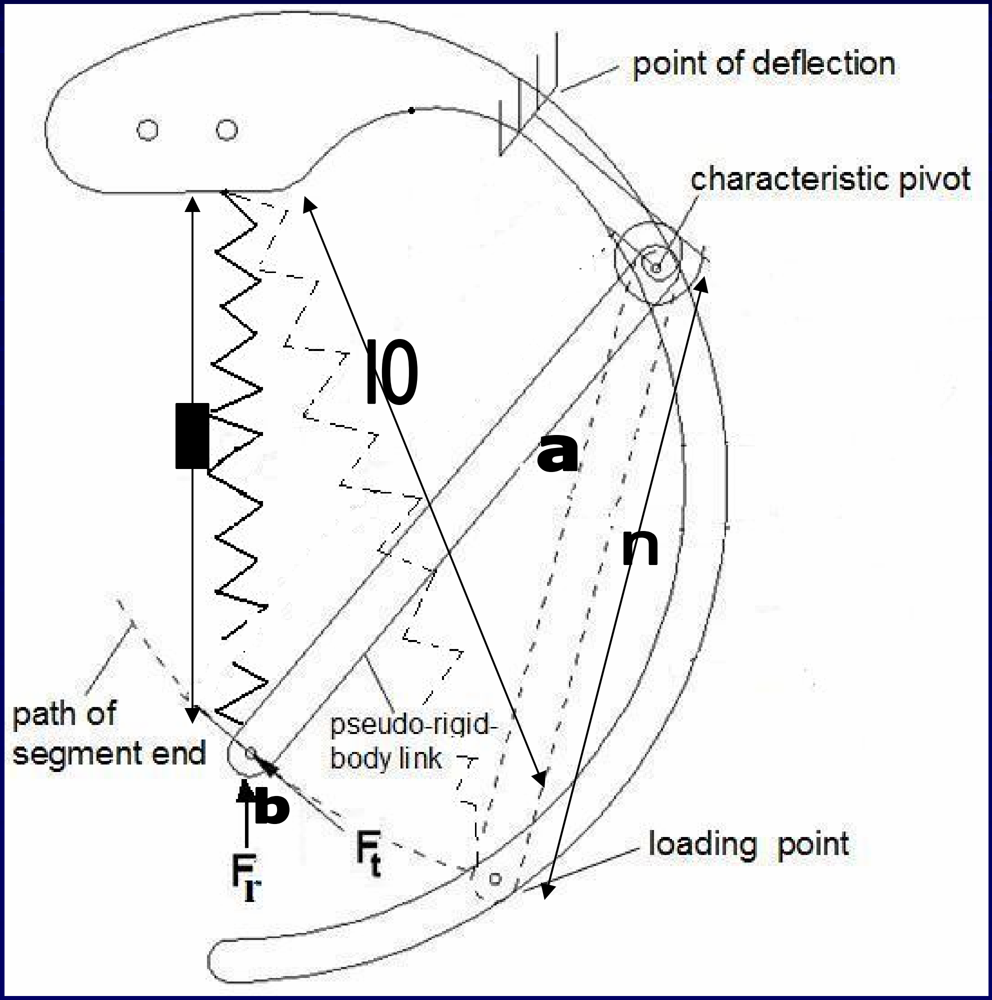


Radial Stiffness, K_r

- Based on PRB model
- $F_t n = K_t \mathbf{a}$
- $F_r = K_r(\mathbf{l_0} - \mathbf{l})$
- Source of error:

  Assumption:

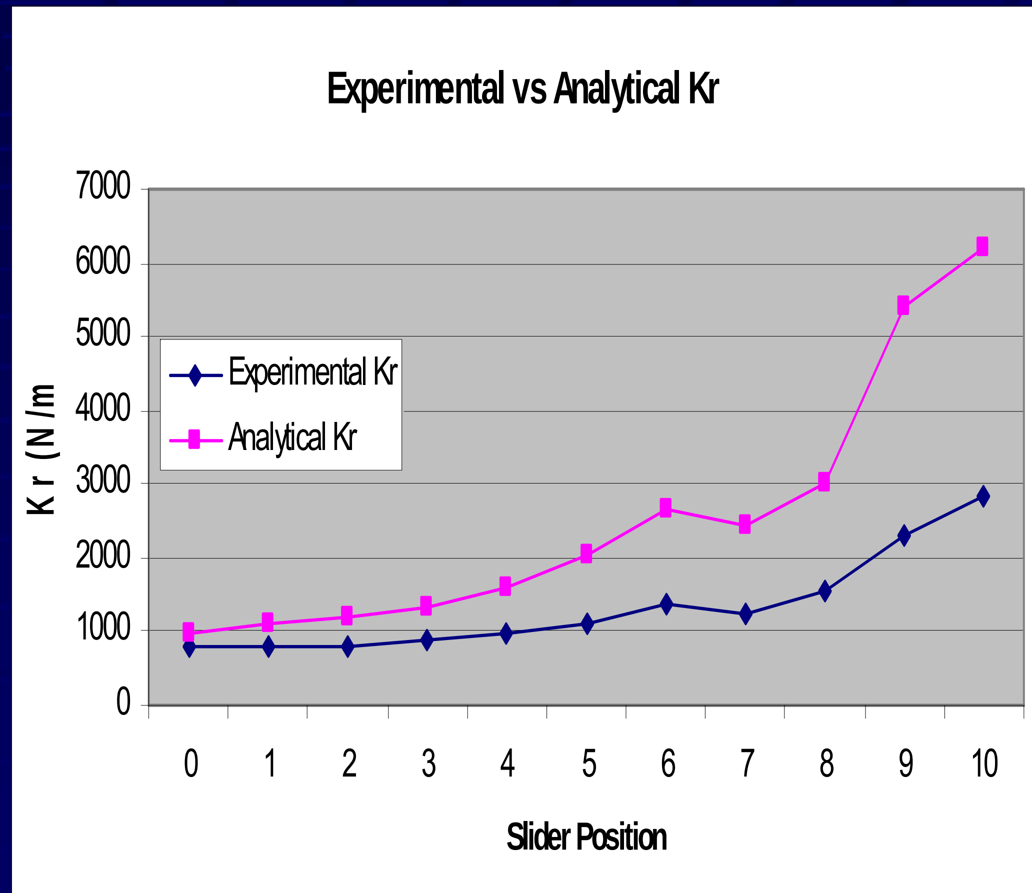
  $F_r \cos(\mathbf{b}) = F_t$



Experimental Testing of K_r

- Same general shape suggests K_r equation is promising
- Large buildup of error possibly due to assumption of cosine relationship between forces
- More data necessary to adjust K_r equation
- Temporary K_r equation:

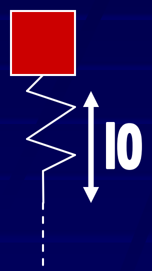
$$K_r=Kr_0\cos(\mathbf{f}_{TD}+\mathbf{f})$$



Modeling the Decoupled C-leg Characteristics

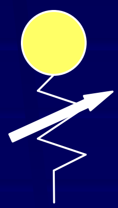
Cases modeled:

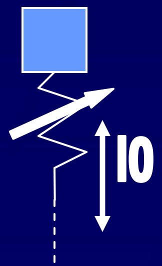
1) Straight leg: linear spring



2) Variable spring rest length

3) Variable stiffness

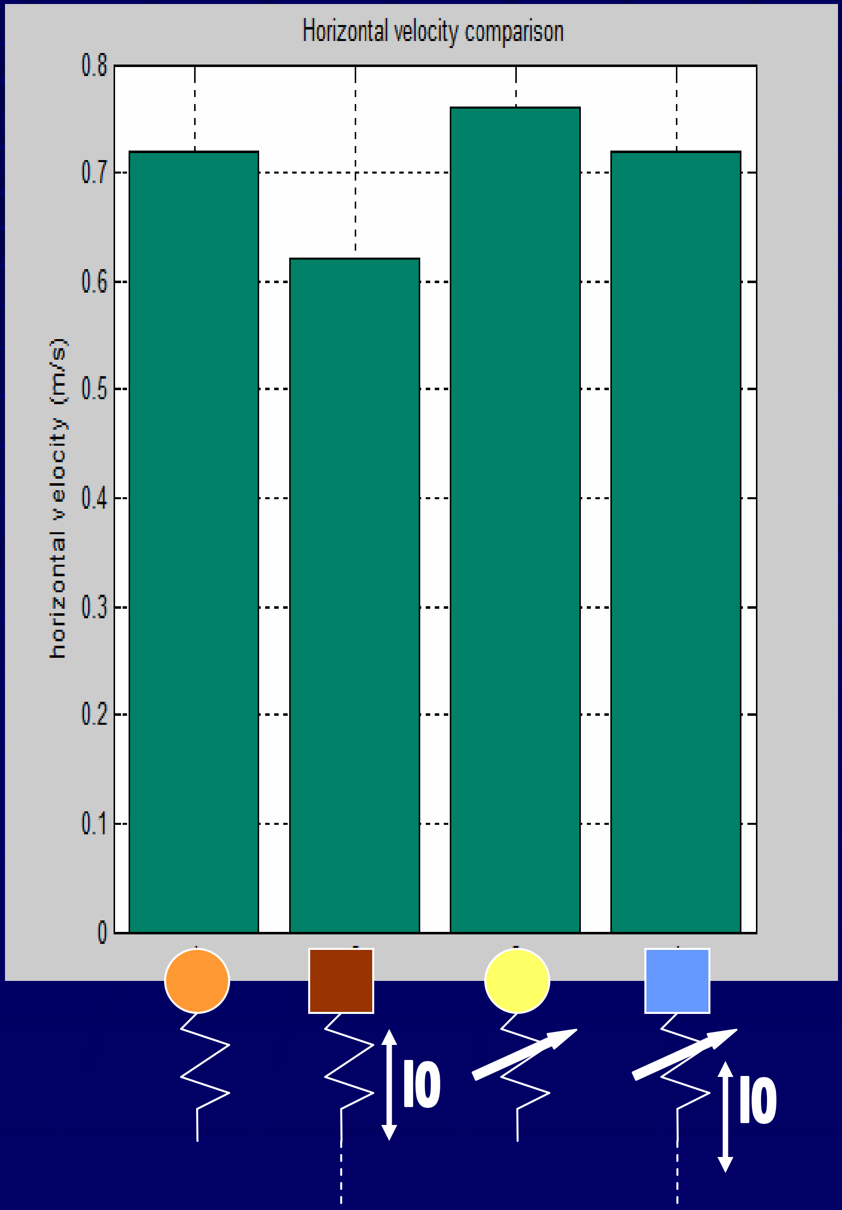


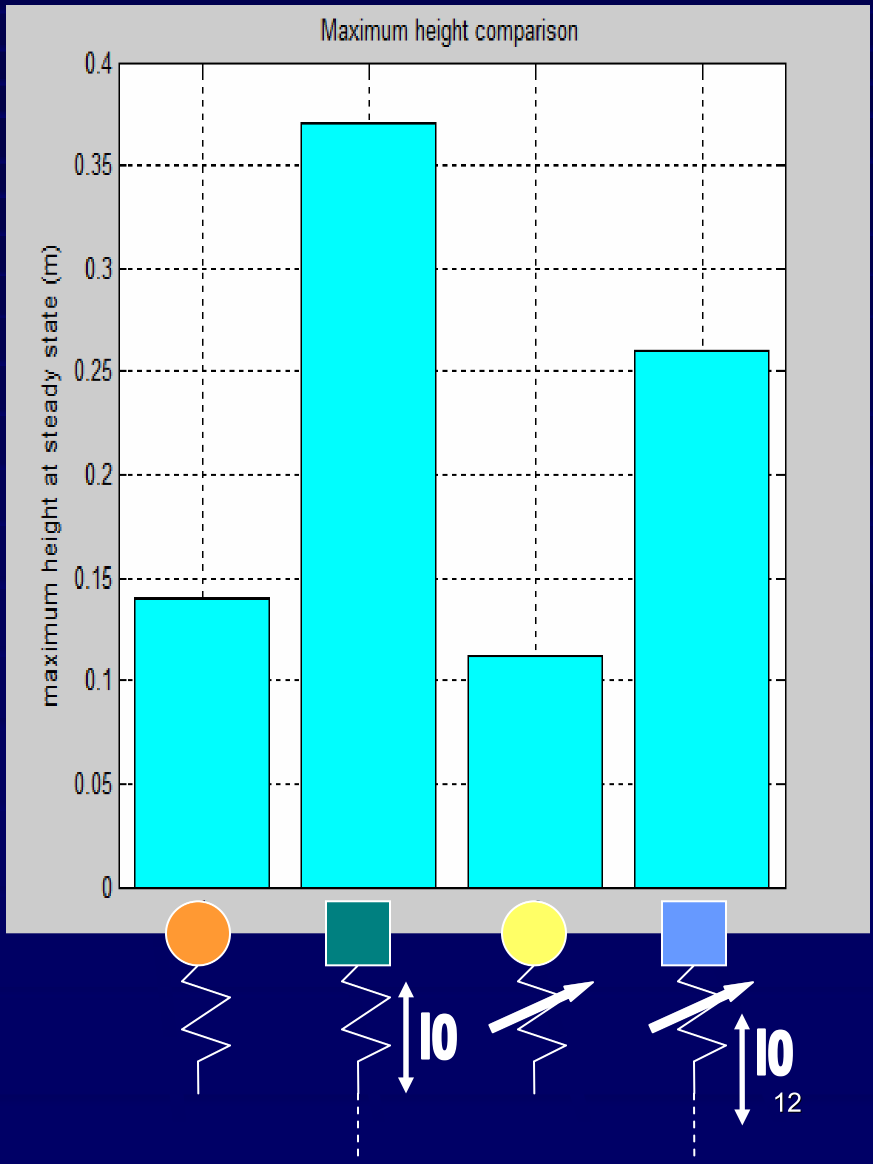


4) Variable stiffness and spring rest length

Tangential coupling not yet modeled

Simulation Results



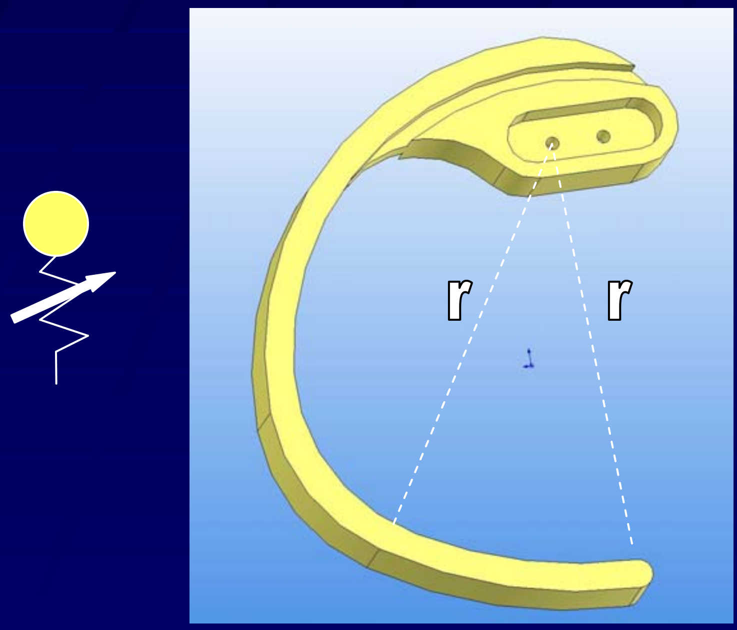


Discussion

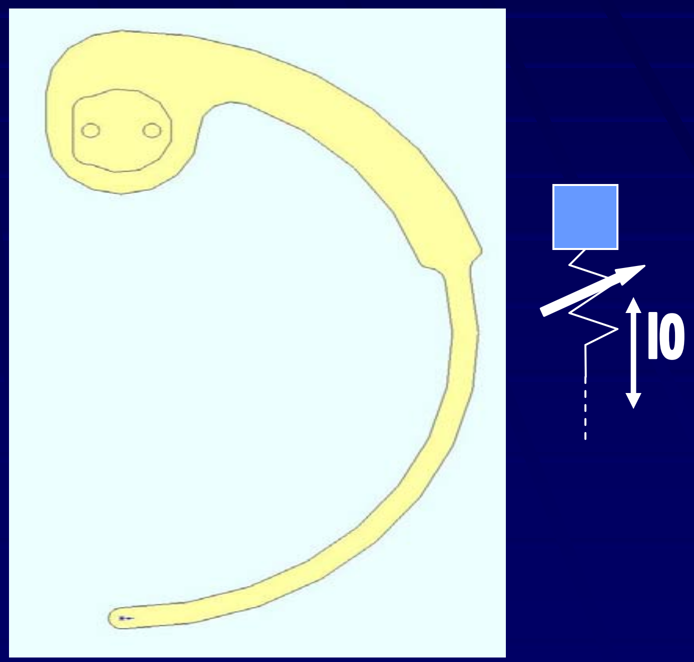
- Preliminary simulations suggest that both variable stiffness and increasing spring rest length are important for performance
- Decreasing stiffness increases horizontal velocity
- Increasing leg length adds energy

Continuing Work

- Add tangential deflection coupling to model
- Build legs and run on robot to test model's predictions



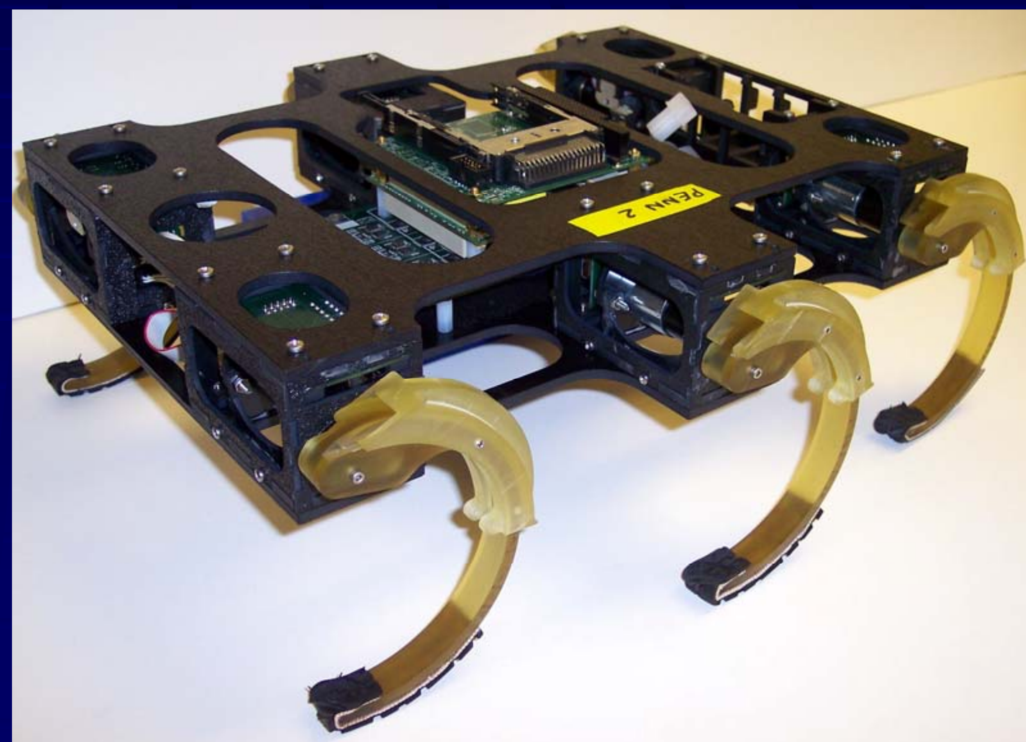
Variable-stiffness Leg



Variable-stiffness-and -spring-rest-length Leg

Acknowledgements

- Dr. Jonathan Clark
- Kevin Galloway
- Viktor Orekhov
- Goran Lynch
- SUNFEST
- NSF REU



?