
The Role of Leg Differentiation in Hexapedal Running

Sam Burden

Dr. Daniel Koditschek,

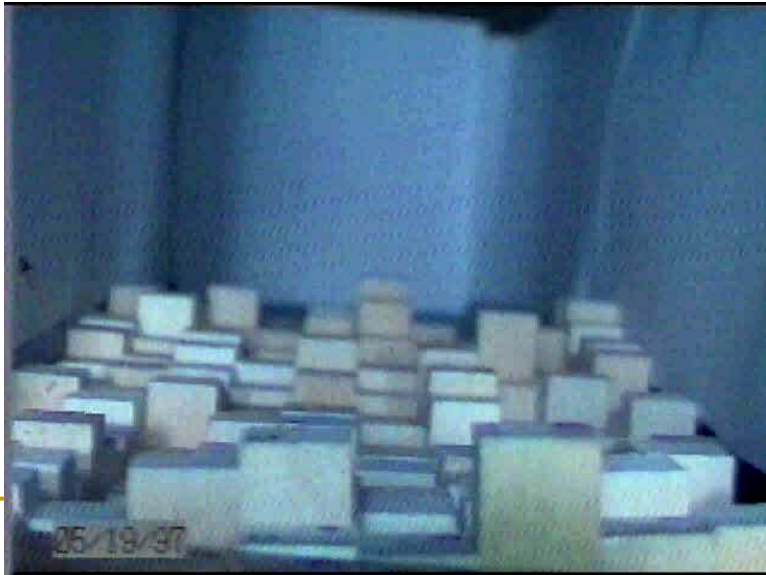
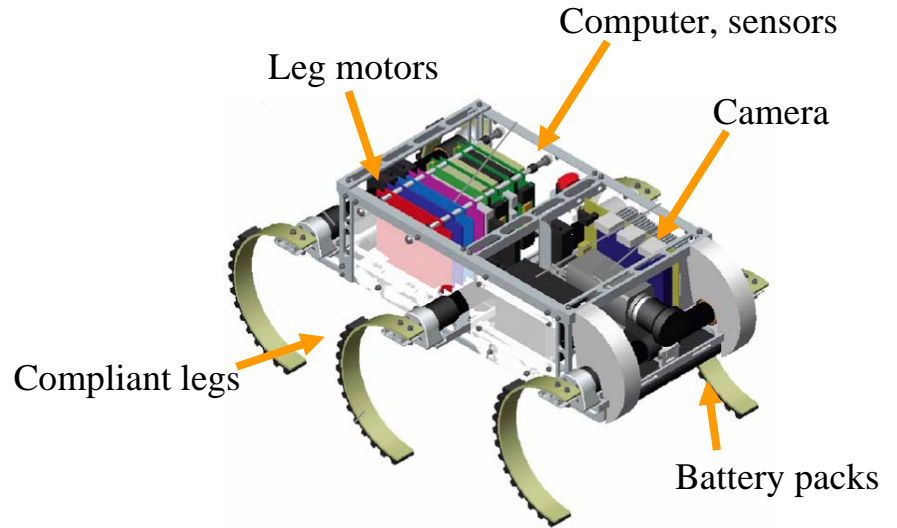
Dr. Jonathan Clark,

Joel Weingarten



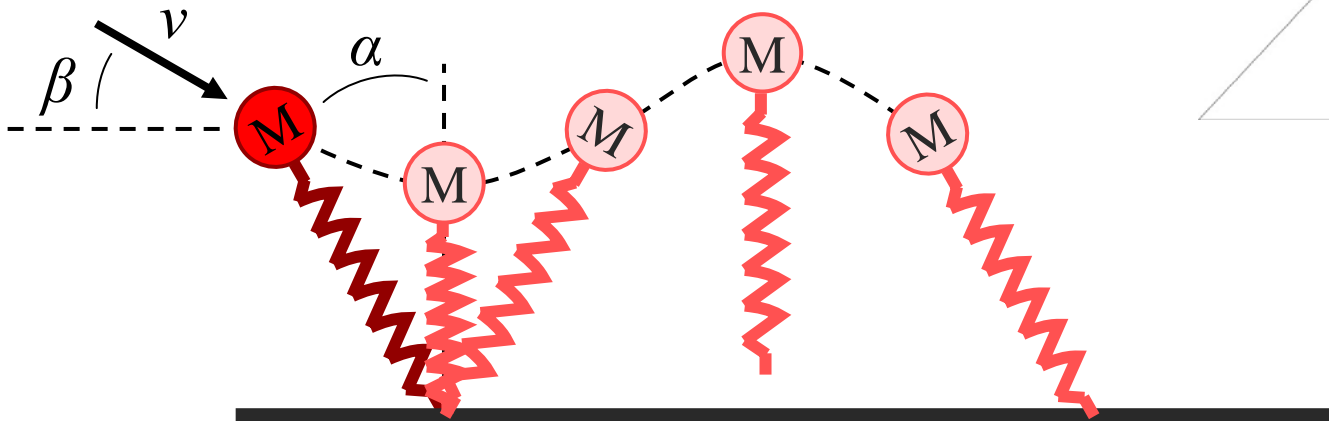
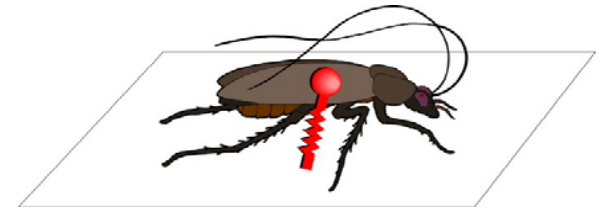
Legged Locomotion: RHex

- Fast (> 2 m/sec)
- Dynamically Stable



Spring-Loaded Inverted Pendulum

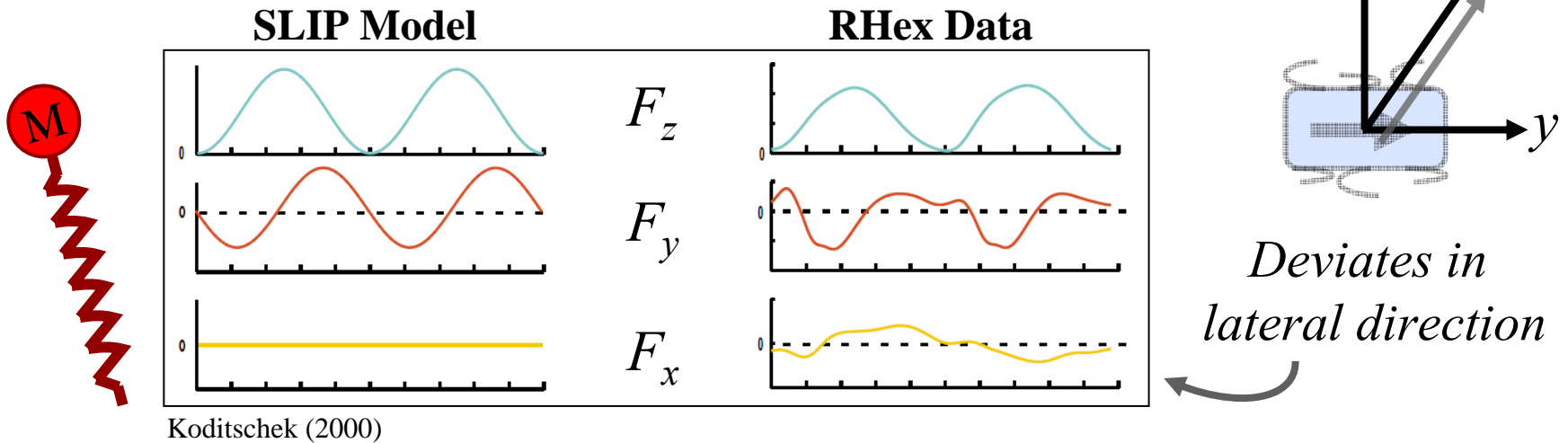
- Model for animal running
 - Wide applicability
 - Few parameters: M , v , β , α
- Hybrid dynamical model



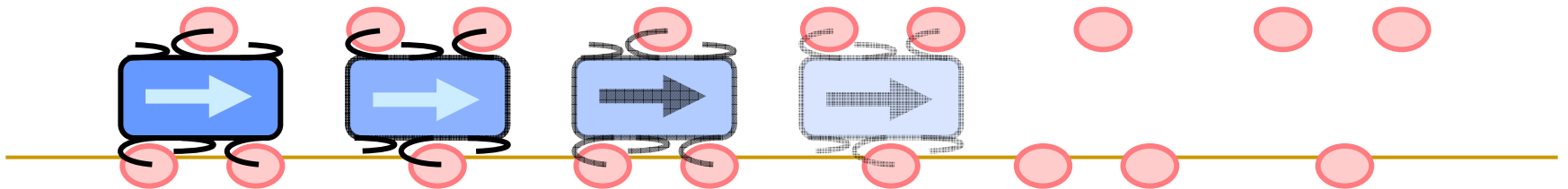
Blickhan (1989)

RHex's Gait

- Modeled well with SLIP

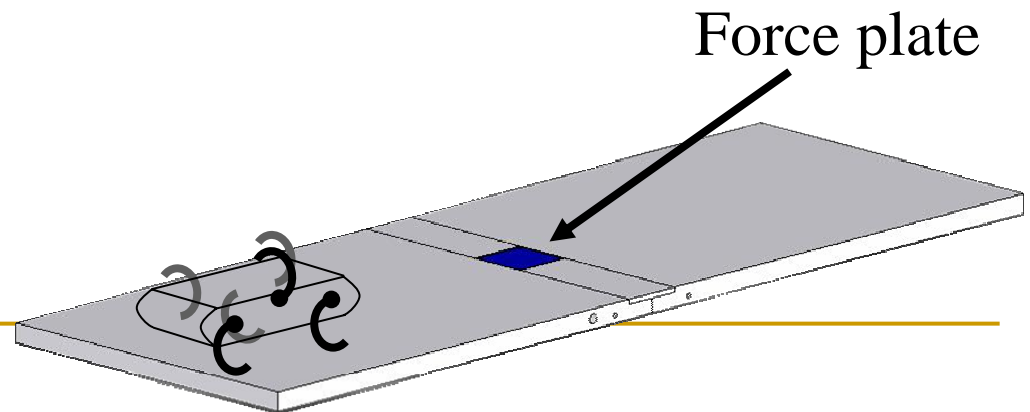
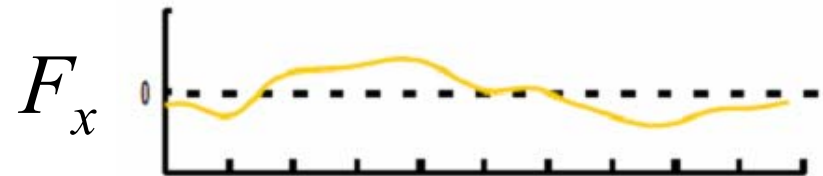
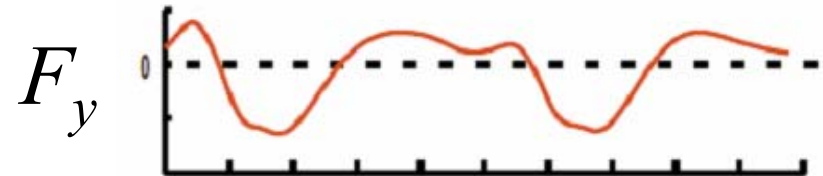
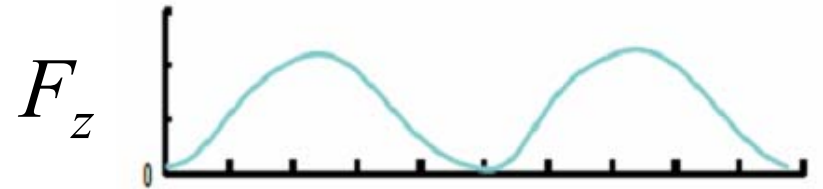


- Alternating-tripod gait



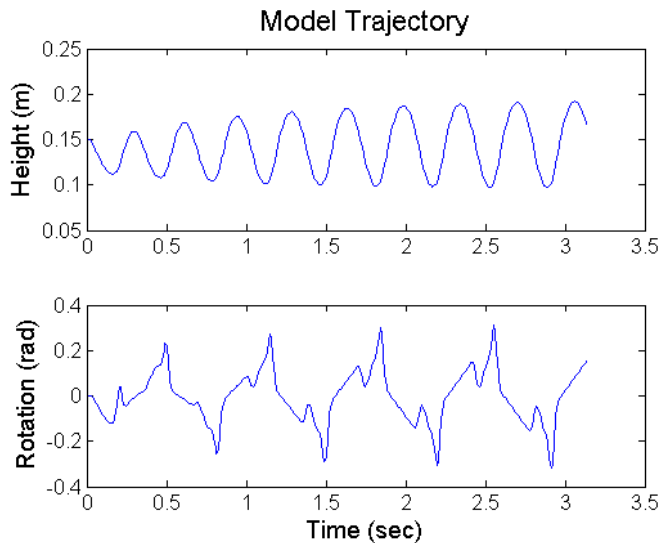
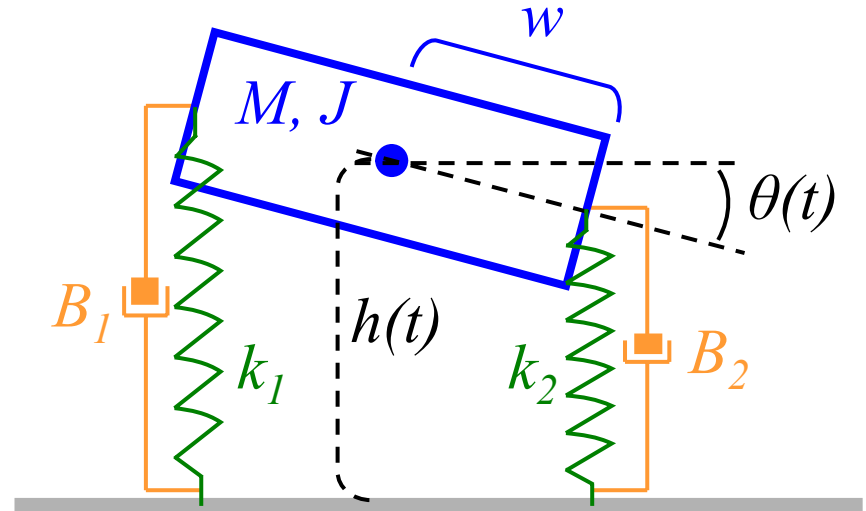
Lateral Rolling Motion

- Most animals roll
 - Efficiency?
 - Stability?
- Goal: stop rolling
 - Characterize roll
 - Ground reaction forces
 - Trajectory
 - Model roll
 - Modify hardware

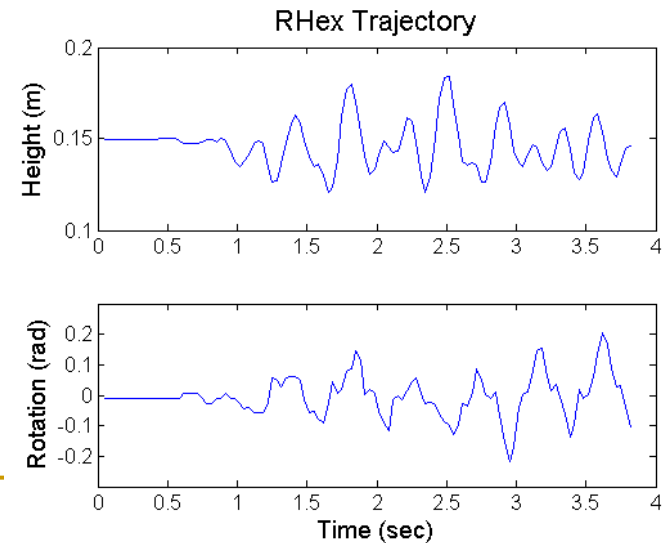
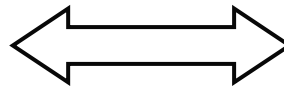


Model for Roll

- Conservative model sets $B_1 = B_2 = 0$
- Damped model sets $B_1 \neq B_2$
 - Energy added at maximum spring compression

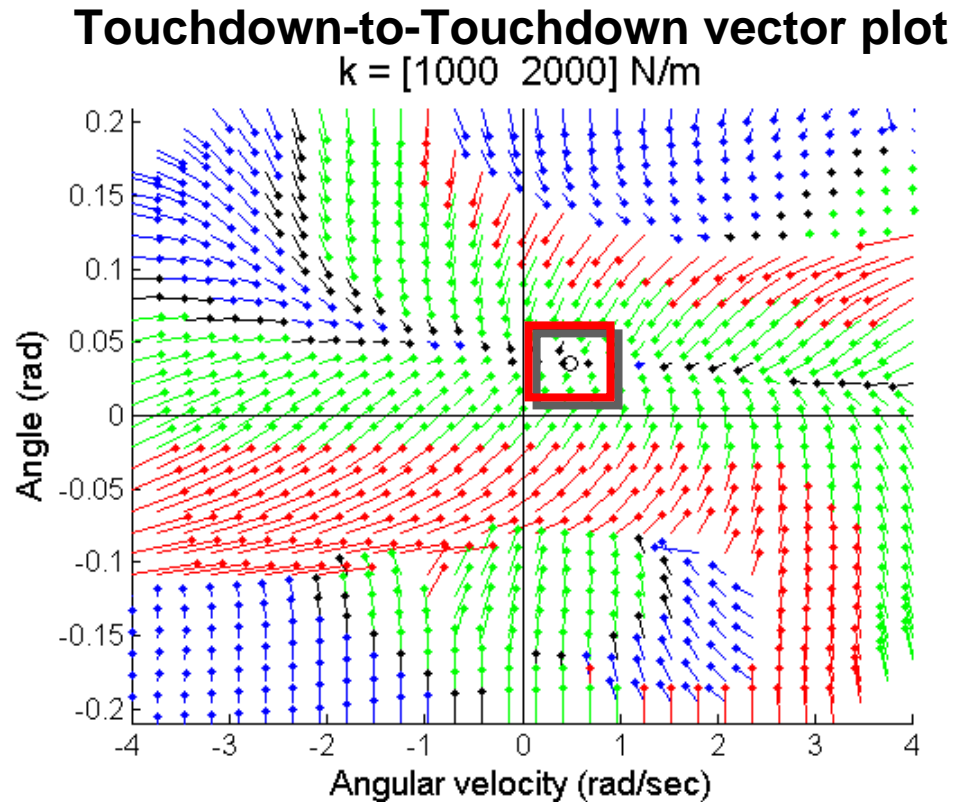
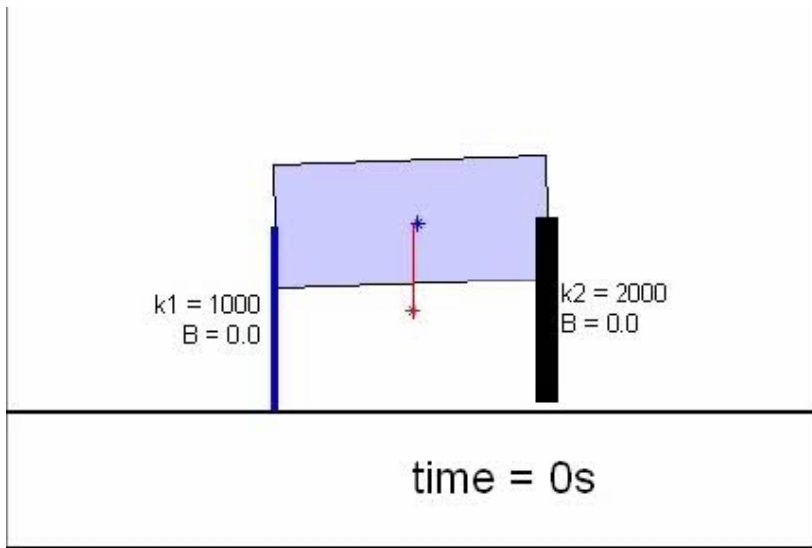


Qualitatively similar



Conservative Model ($B_1=B_2=0$)

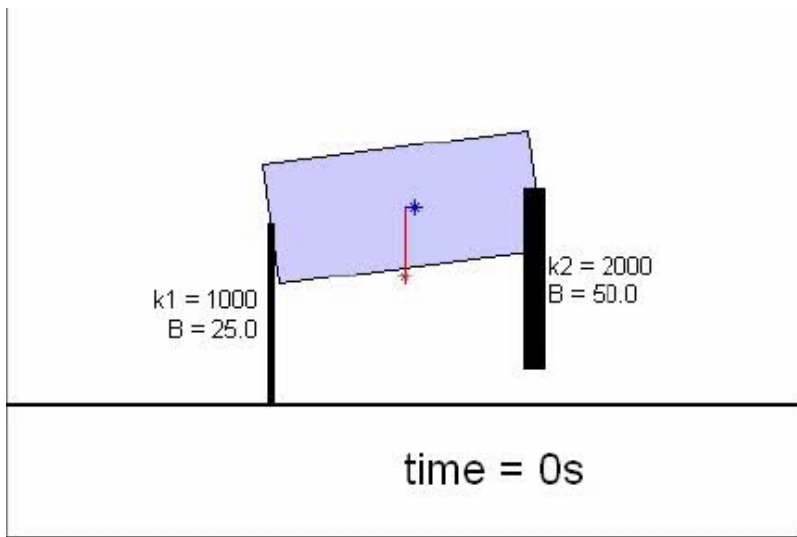
- Equilibrium gaits
 - “Small” vectors
 - Called *fixed points*
 - Appear *unstable*



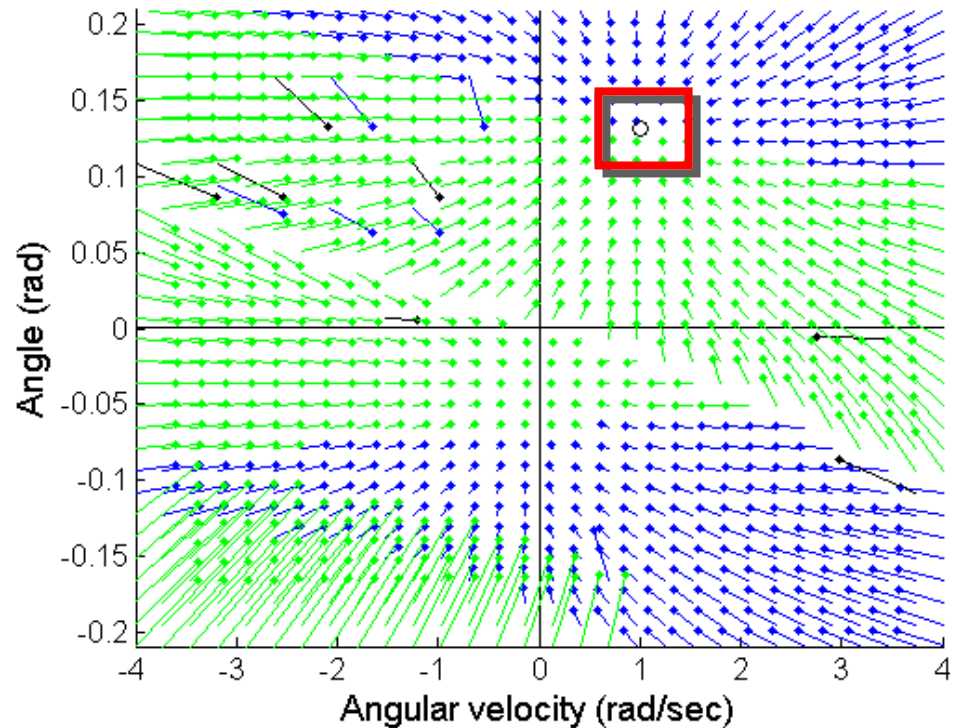
(Note: vectors scaled by 1/20)

Damped Model ($B \neq 0$)

- Equilibrium gaits
 - Appear *stable*



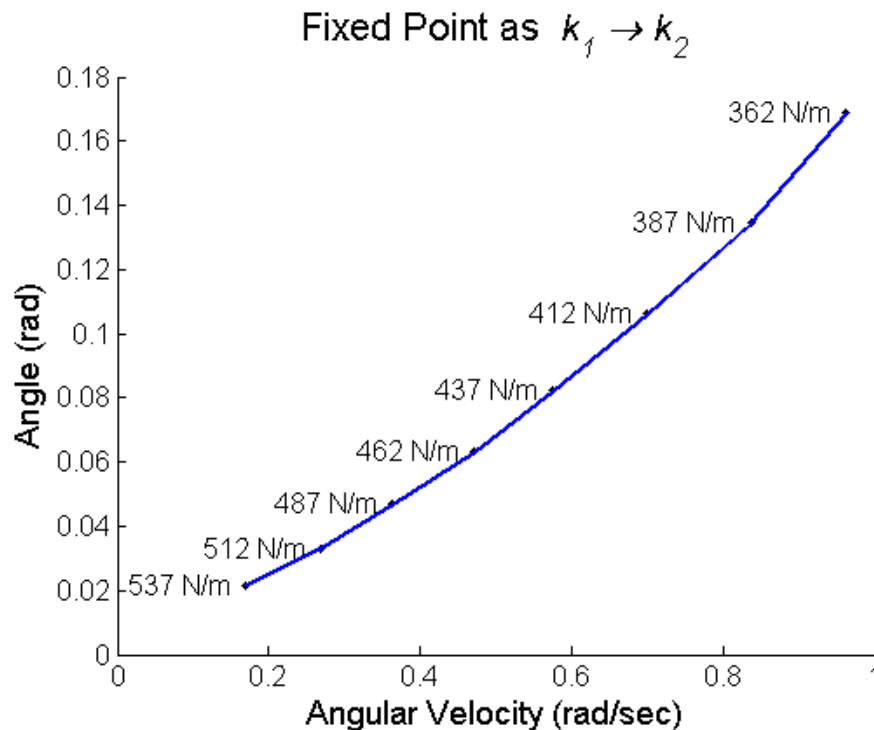
Touchdown-to-Touchdown vector plot
 $h' = -0.59$ m/s; $k = [1000 \ 2000]$ N/m; $B = [25 \ 50]$ N*sec/m



(Note: vectors scaled by 1/10)

Damped Model ($B \neq 0$)

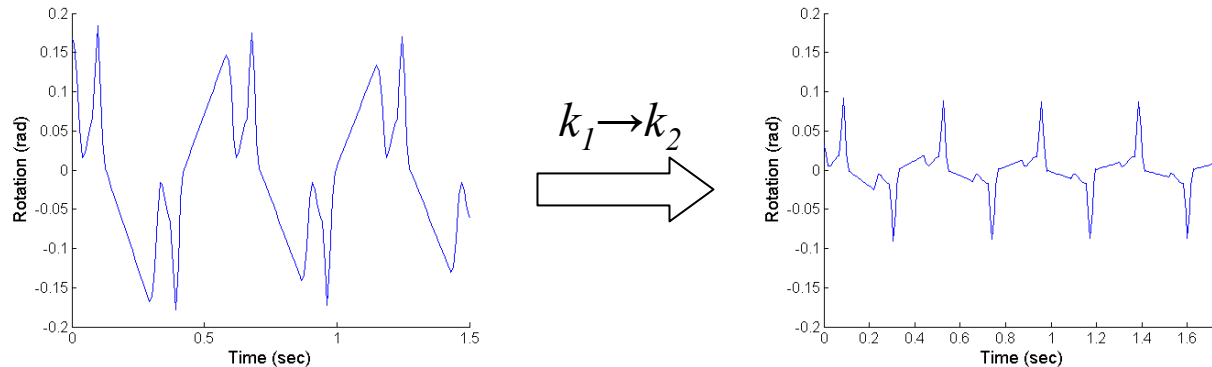
- Look at fixed point as $k_1 \rightarrow k_2$



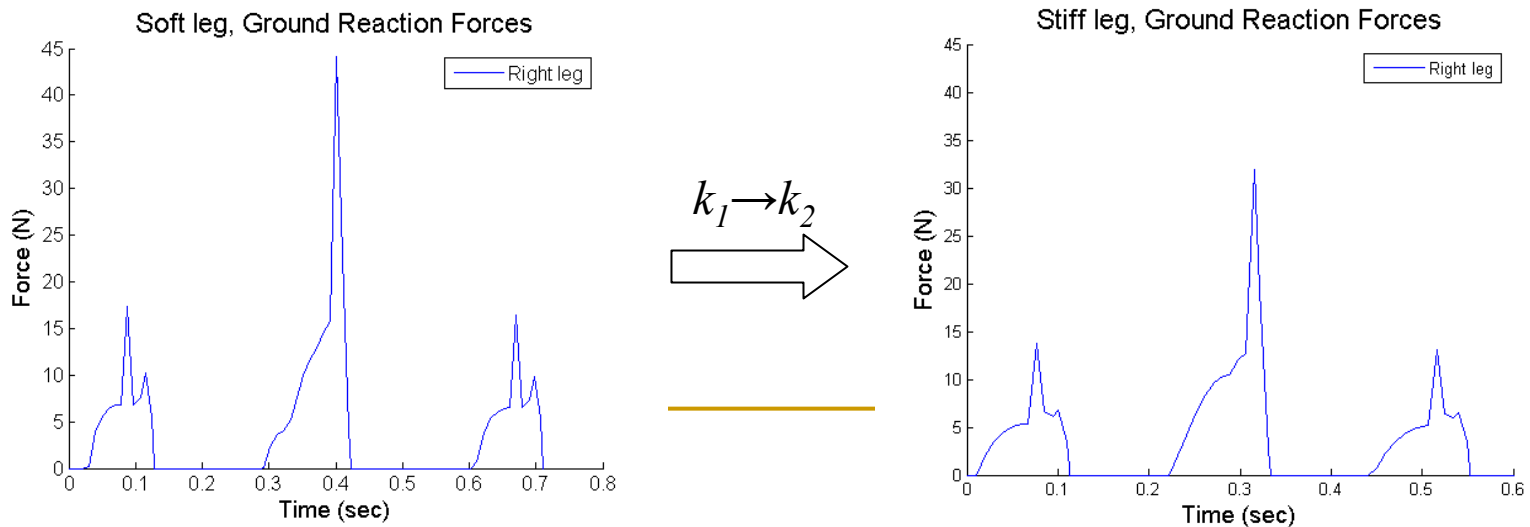
- Fixed point moves toward the origin

Model Prediction as $k_1 \rightarrow k_2$

- Maximum roll decreases

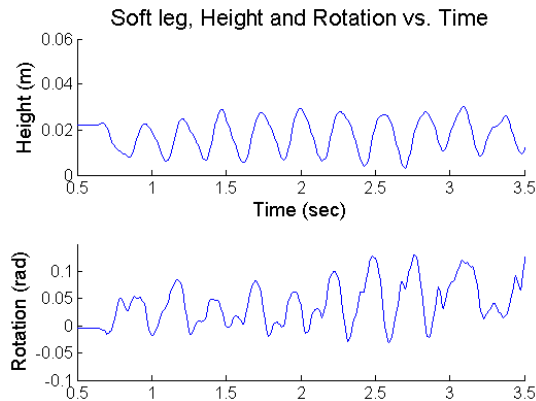


- Ground reaction forces equalize

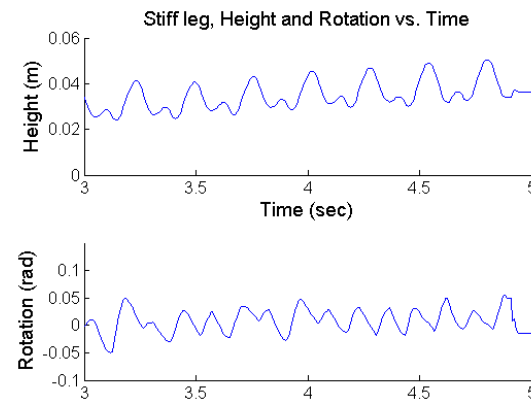


Preliminary Experimental Results

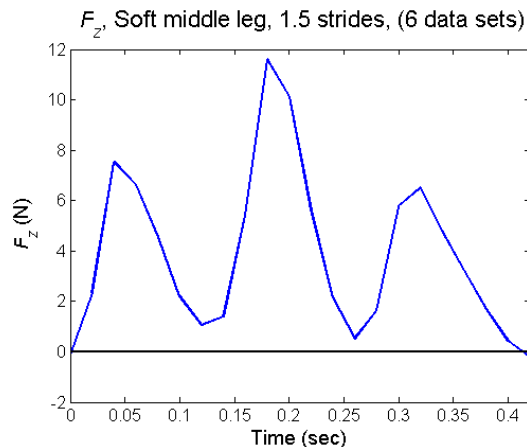
- As $k_1 \rightarrow k_2$, maximum roll decreases



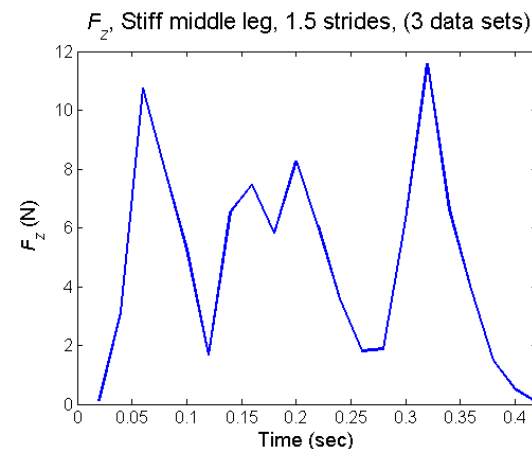
$k_1 \rightarrow k_2$



- As $k_1 \rightarrow k_2$, forces equalize



$k_1 \rightarrow k_2$



Results

- Model provides clear prediction
 - Roll decreases as $k_1 \rightarrow k_2$
 - Experiments are inconclusive
 - One more week . . .
 - Take-home message:
Dynamic legged locomotion
-

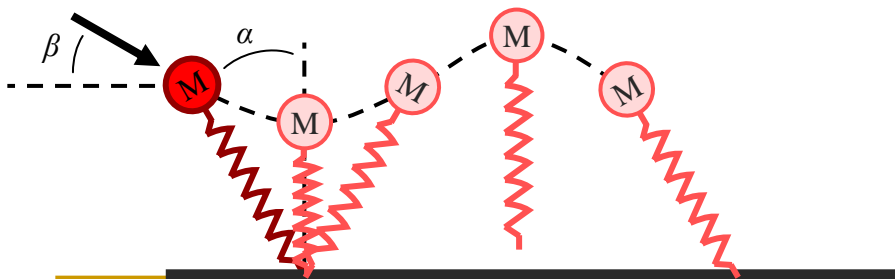
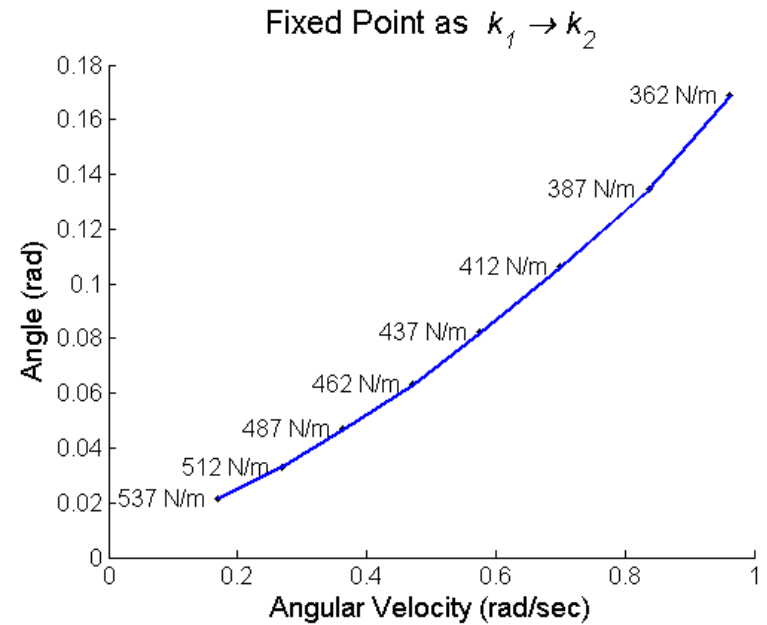
Acknowledgements

■ KodLab

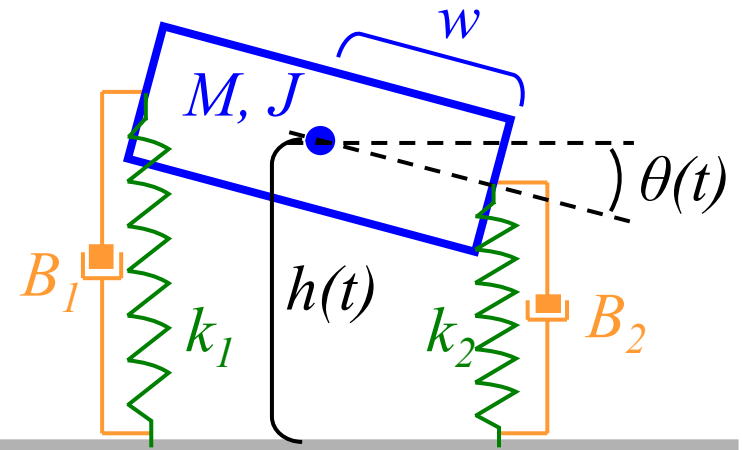
- Dr. Daniel Koditschek
- Dr. Jonathan Clark
- Joel Weingarten
- Goran Lynch
- Dr. Haldun Komsuoglu
- Aaron
- Sam Russem

■ SUNFEST

Discussion



Blickhan (1989)



Simple spring-mass model for roll