

Toward robust locomotion subject to variations in robot scale, mass, payload, and environmental conditions

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GHOSTROBOTICS

Legged robotics in the field



GHOSTROBOTICS

Minitaur (6kg, 8dof direct drive)



Kodlab X-RHex



GHOSTROBOTICS

Vision-60 (25kg, 12dof)



Research

Scientific

Commercial

What do we want from our control algorithms? (long-term view)

Robust against

- State perturbations
 - Feedback control, MPC, ...
- Parameter perturbations
- Modeling errors
 - “robust” control, model reduction

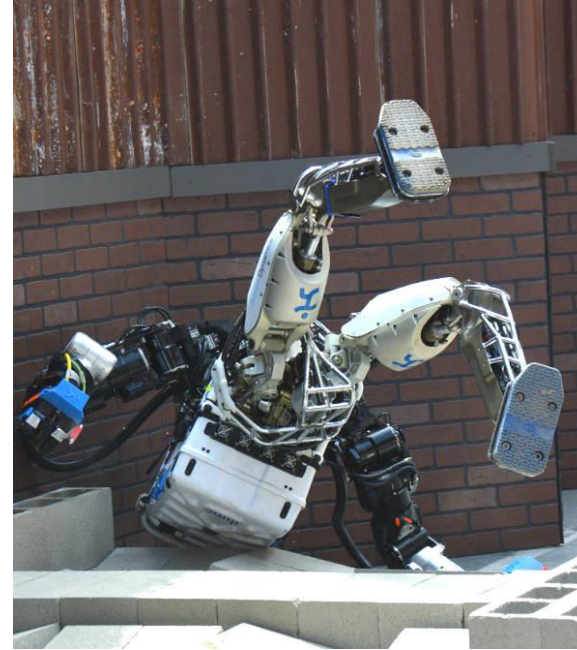
Verifiable

- Repeatability, accountability
 - Convergence
 - Local/global stability

Generalizable solns

- Across tasks
- Across platforms
 - “online” solution, ...

...Modularity

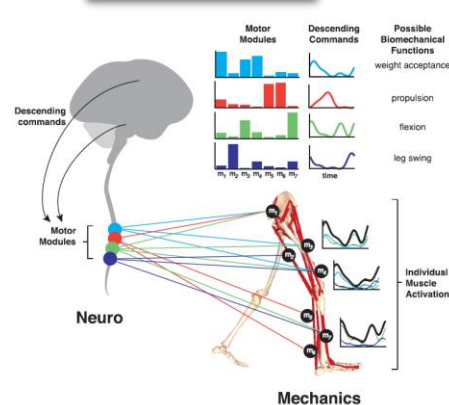


[DRC (2017)]

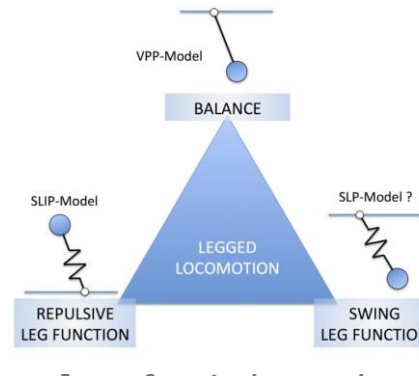


[Raibert (1986)]

In biology

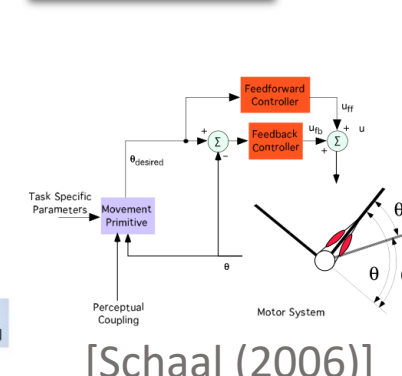


[Ting et. al. *Neuron* (2015)]

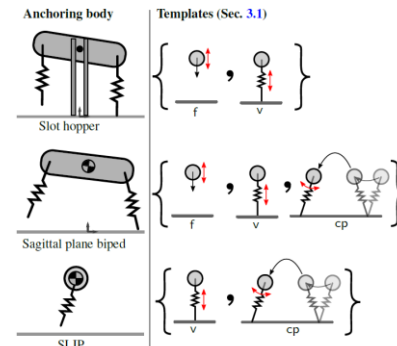


[Seyfarth (2015)]

In robotics



[Schaal (2006)]

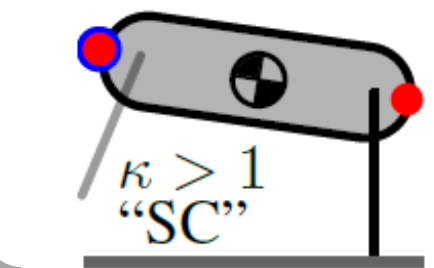
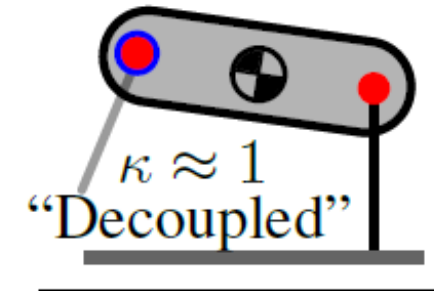
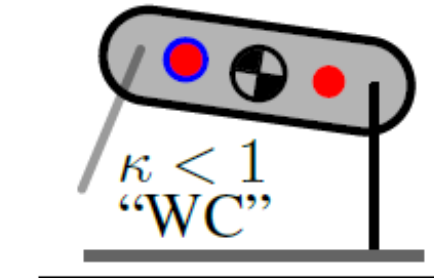
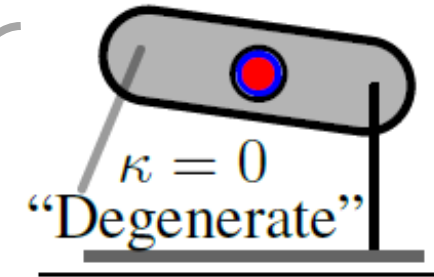
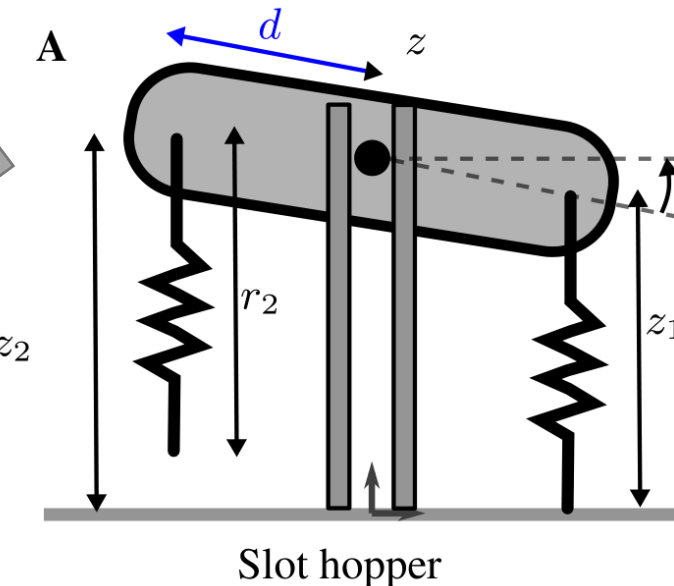
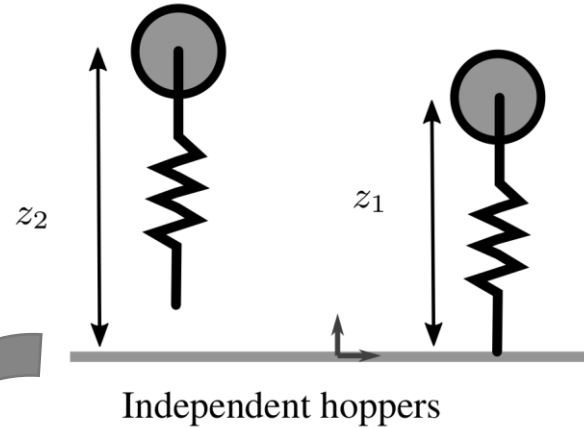


[De (2017)]

Virtual bipedal gaits: coordinate two hoppers



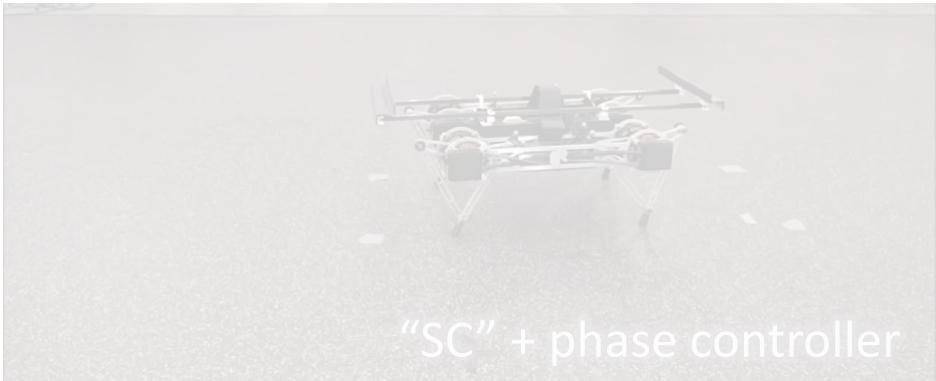
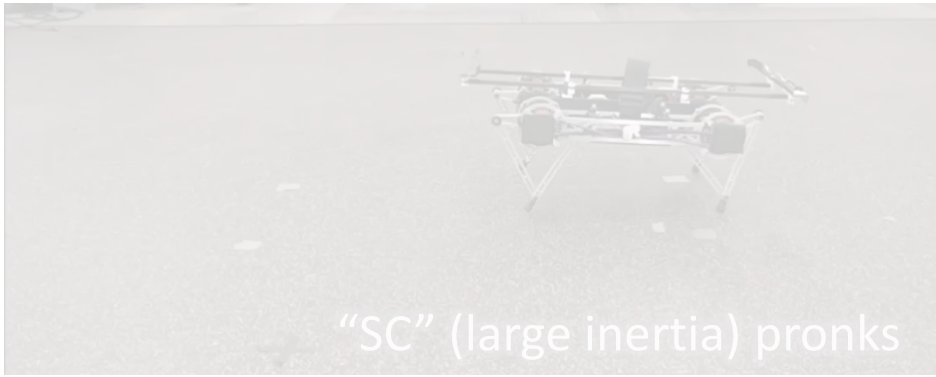
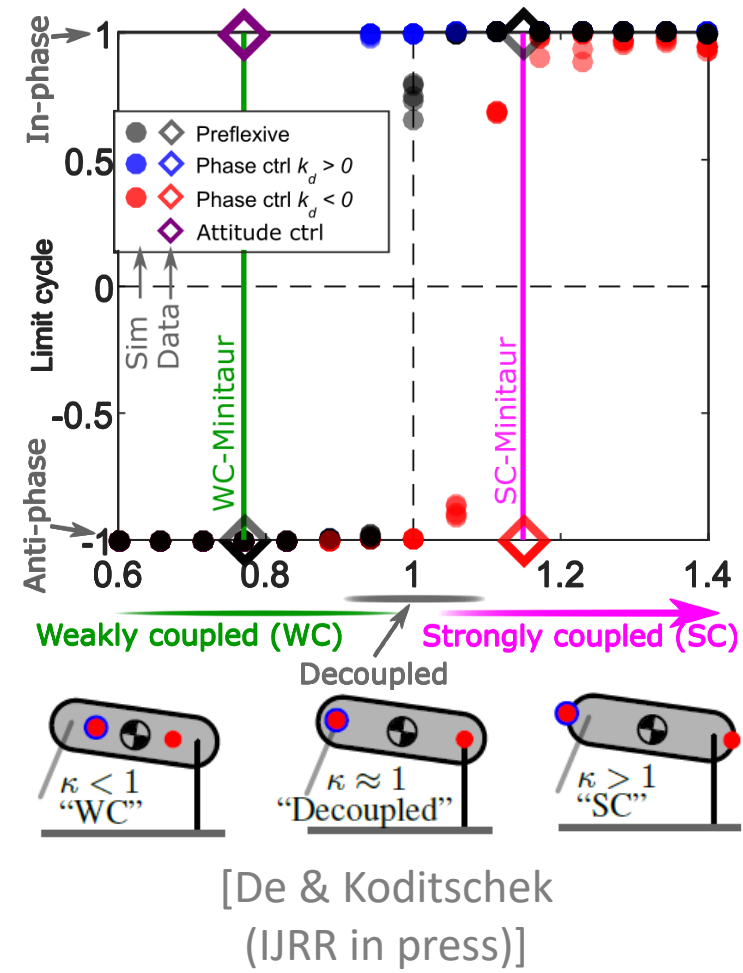
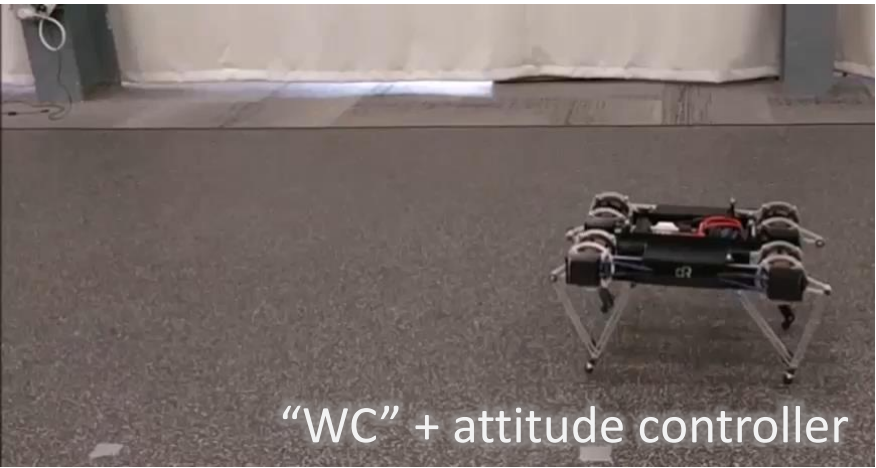
[De & Koditschek
(IJRR in press)]



Mass concentration distance to CoM

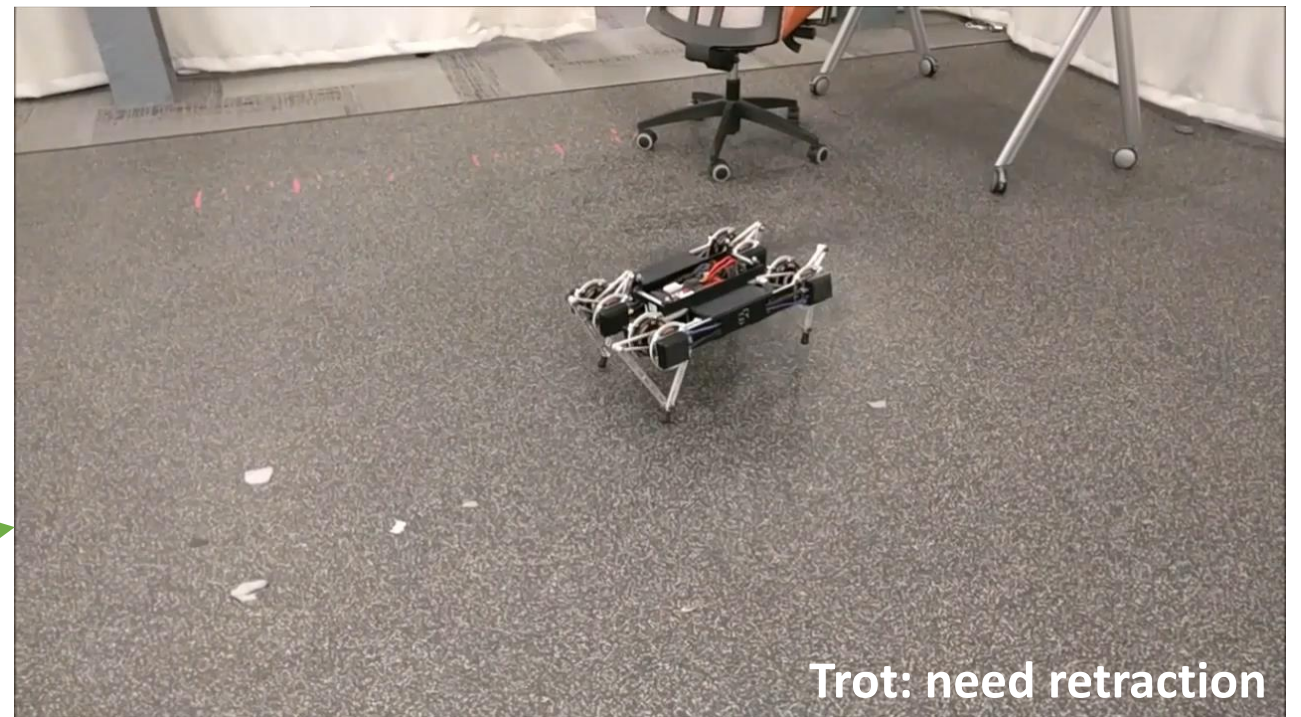
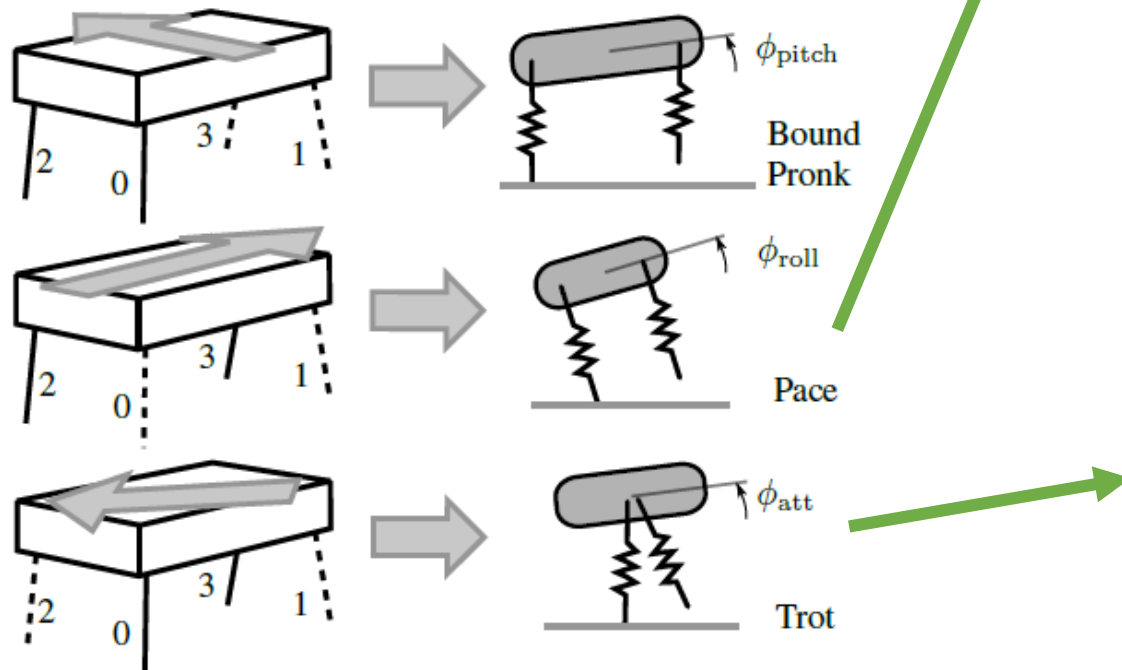
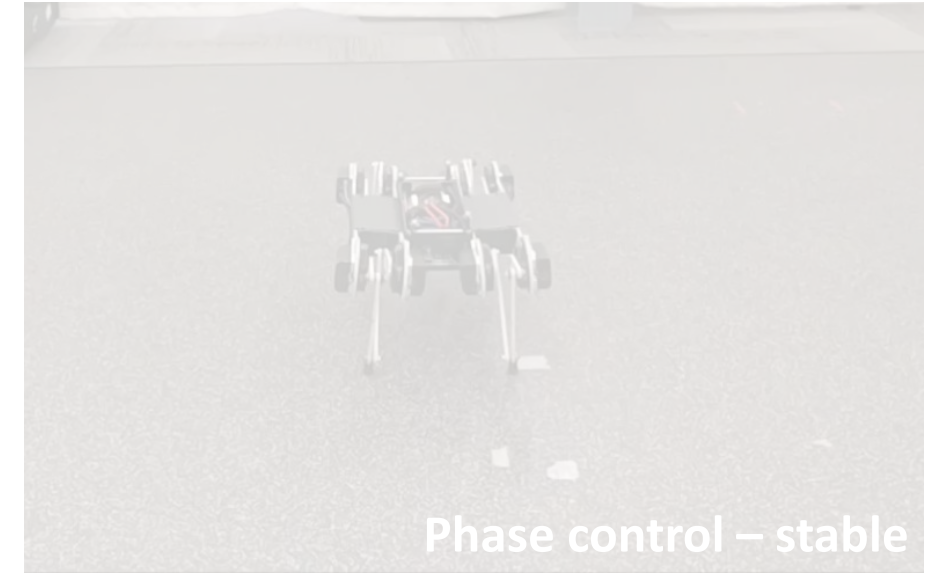
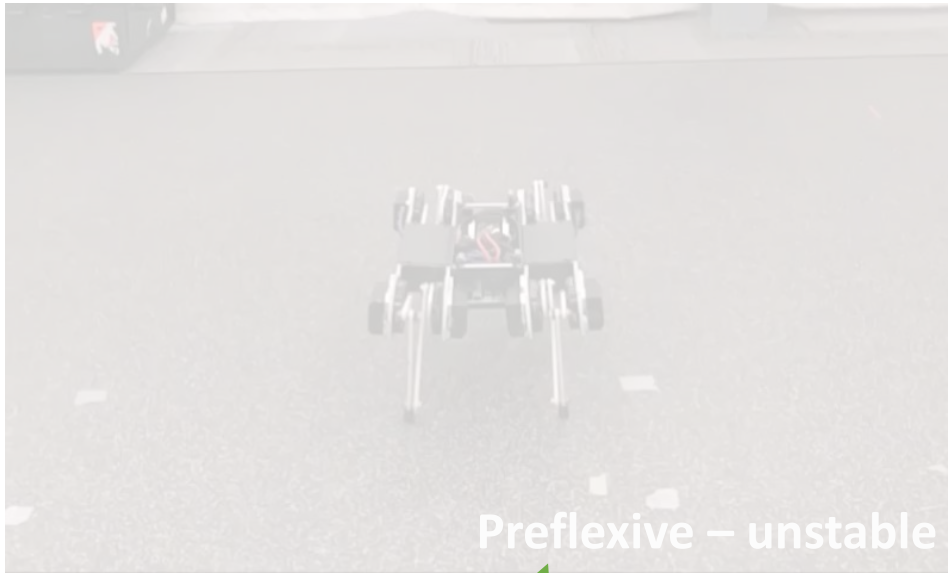
Controller with virtual spring,
 $u_i(x) := \omega^2(\rho - z_i) + \varepsilon v_i(x)$
 tunable and natural damping,
 $v_i(x) := -\beta \dot{z} - k_a \cos \psi_i + w_i(x)$
 and (optional) phase control
 $w_i(x) := (-1)^{i-1} k_d (\dot{z}_1 - \dot{z}_2) \sin \psi_i$

Slot hopper phase locking



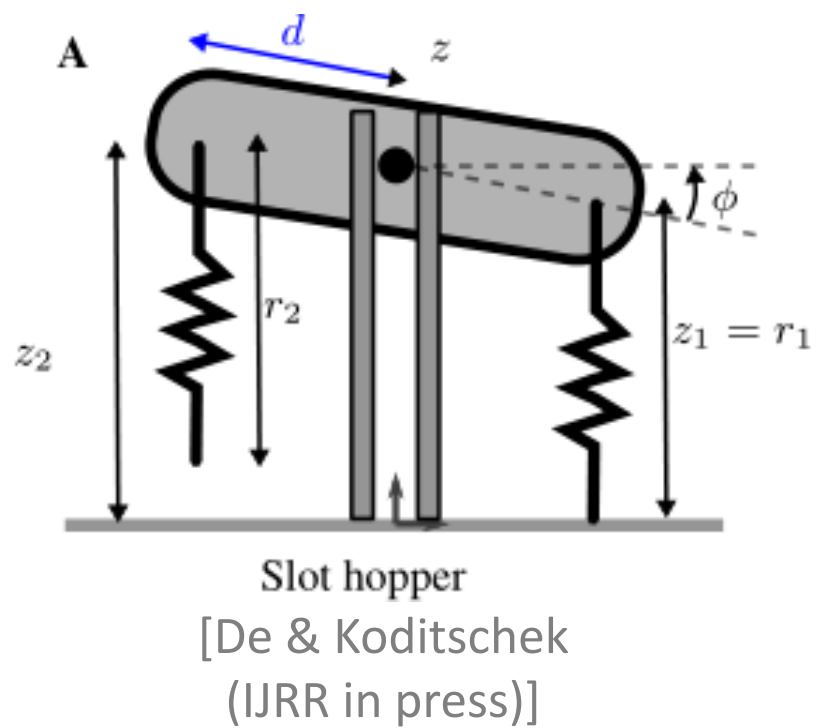
Other “virtual leg” assignments

[De & Koditschek
(IJRR in press)]

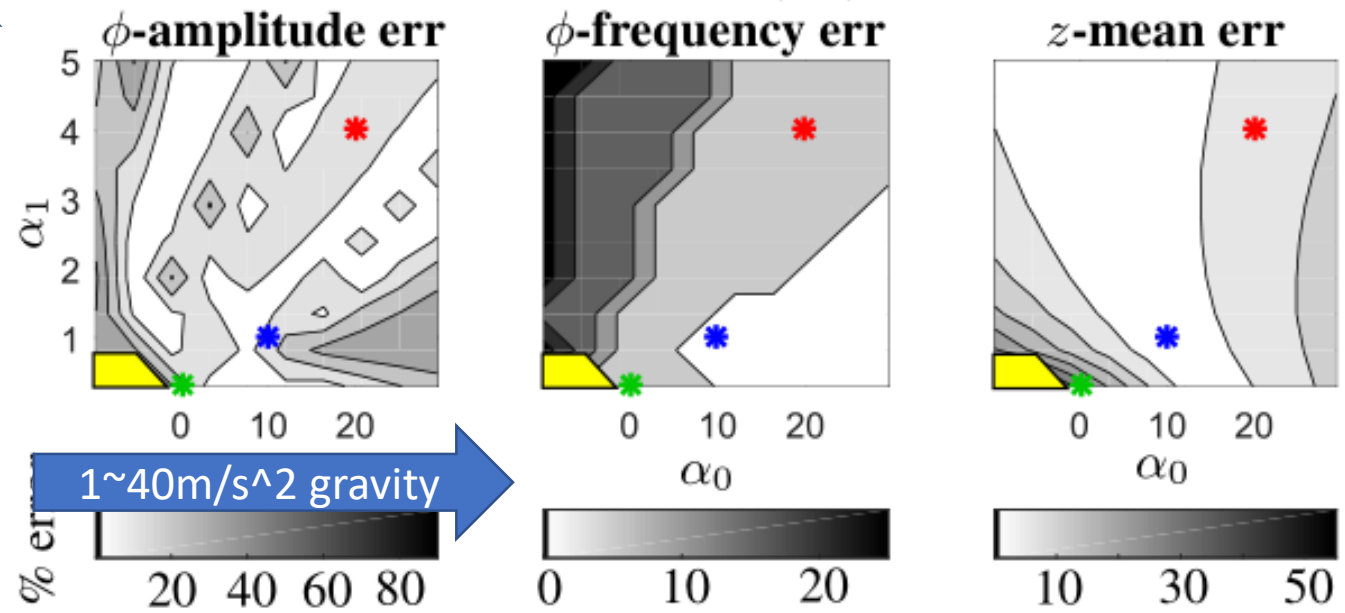
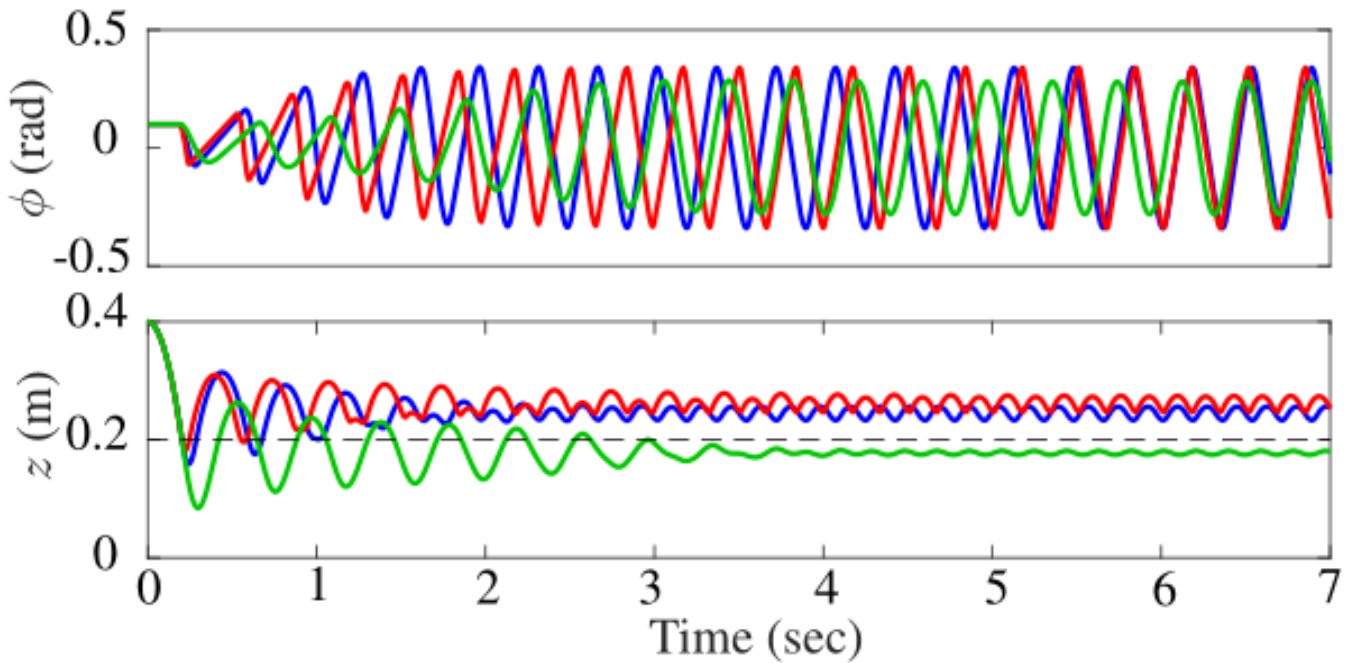


Simplicity \Rightarrow robustness to parametric uncertainty, initial conditions

...despite small perturbation theory



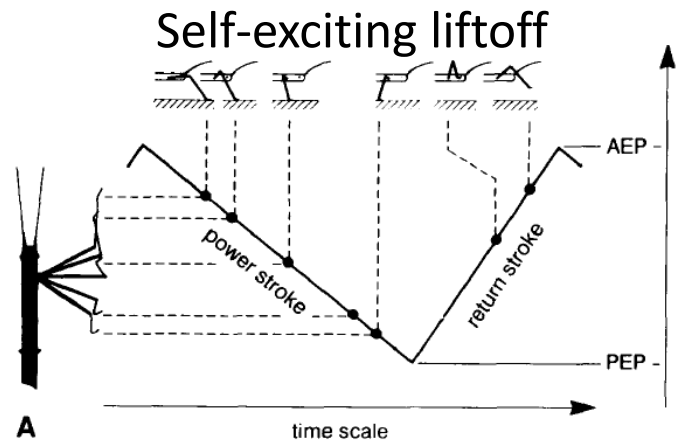
5x mass variation



1~40m/s² gravity

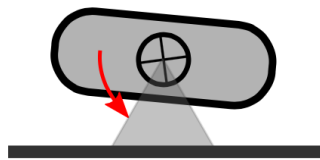


Feedback-driven walking

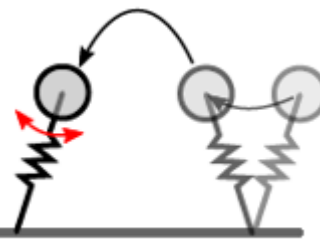


What mechanisms coordinate leg movement in walking arthropods?

Holk Cruse



Attitude control



Stepping control

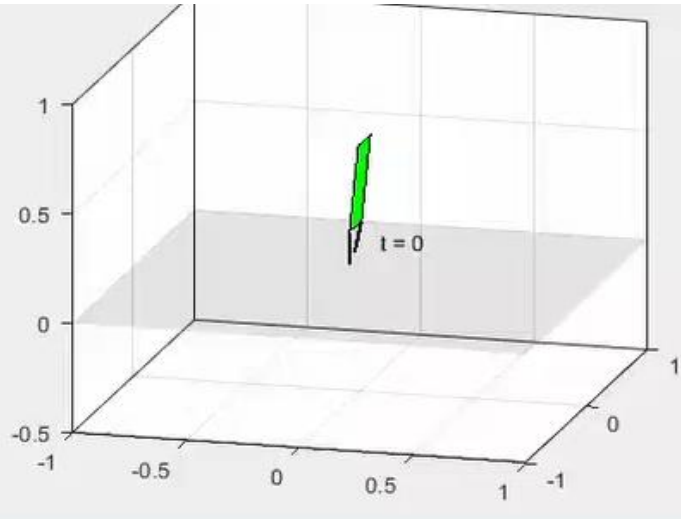
cp



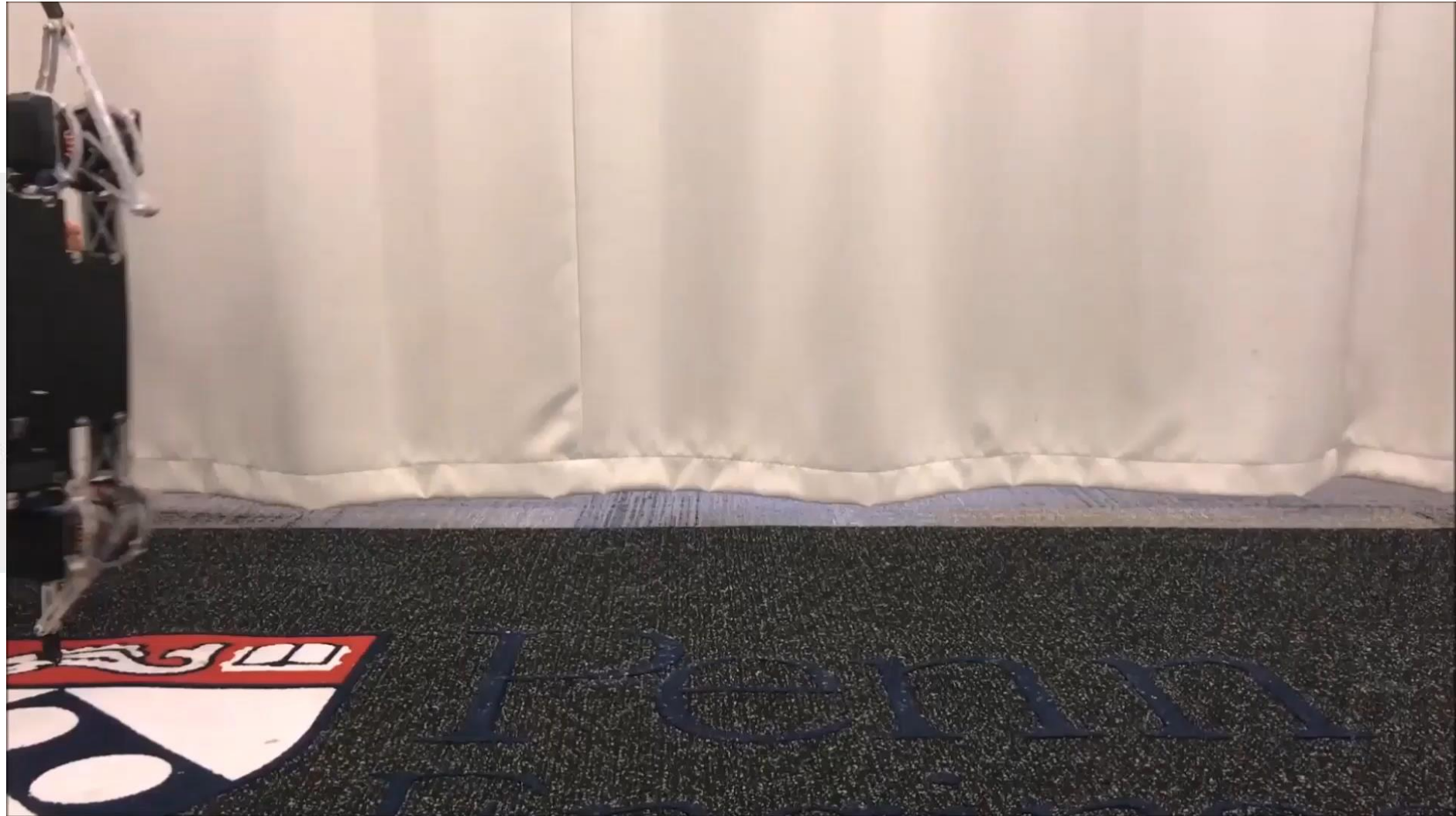


Preliminary bipedal walking

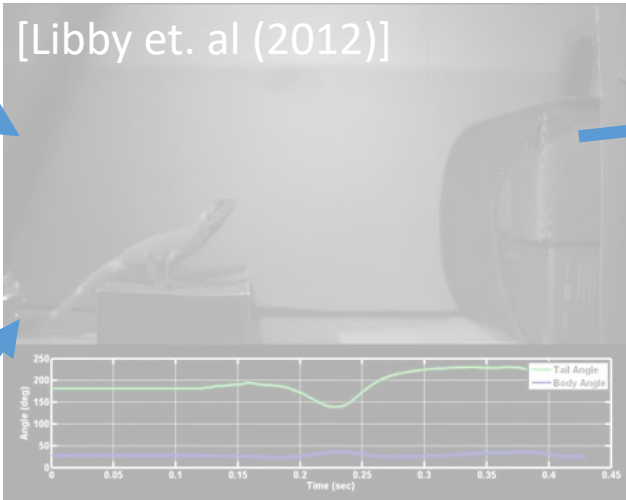
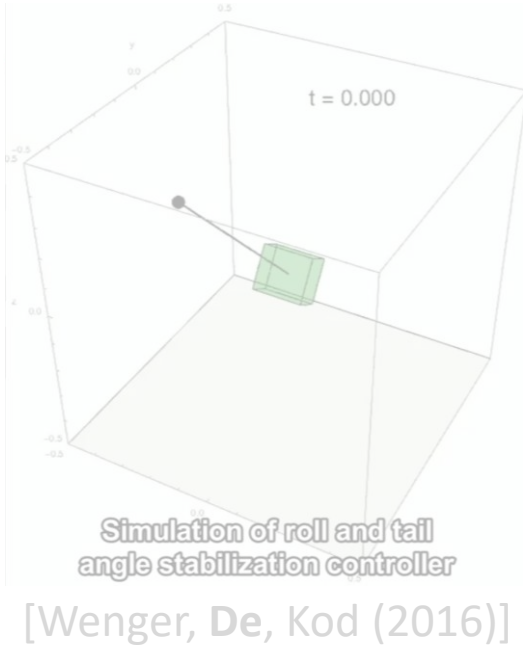
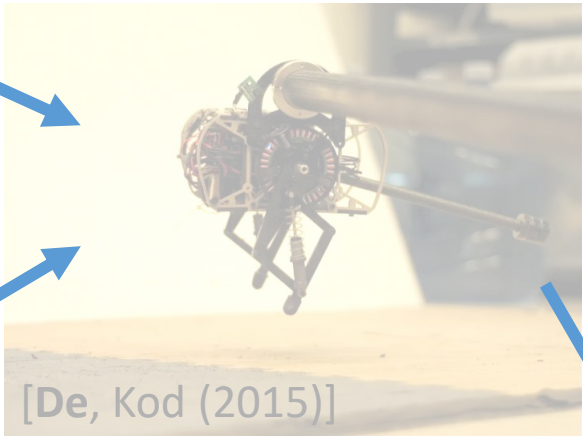
Self-exciting liftoff \rightarrow
asymptotically stable
minimal sets?



With V. Vasilopoulos



Compositions in action: tailed robotic hopping





1/2x

Ghost Robotics is hiring!