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

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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, ...

In biology
- Modularity

In robotics
- [DRC (2017)]
- [Raibert (1986)]
- [Schaal (2006)]
- [De (2017)]
- [Ting et. al. Neuron (2015)]
Virtual bipedal gaits: coordinate two hoppers

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

Mass concentration distance to CoM

[De & Koditschek (IJRR in press)]
Slot hopper phase locking

“WC” + attitude controller

“WC” (small inertia) bounds

“SC” (large inertia) pronks

“SC” + phase controller

[De & Koditschek (IJRR in press)]
Other “virtual leg” assignments

[De & Koditschek (IJRR in press)]

Preflexive – unstable

Phase control – stable

Trot: need retraction
Simplicity $\Rightarrow$ robustness to parametric uncertainty, initial conditions

...despite small perturbation theory

[De & Koditschek (IJRR in press)]
Feedback-driven walking

Self-exciting liftoff

What mechanisms coordinate leg movement in walking arthropods?

Hakl Cane

Attitude control

Stepping control
Preliminary bipedal walking

Self-exciting liftoff → asymptotically stable minimal sets?
Compositions in action: tailed robotic hopping

[De, Kod (2015)]

[Libby et. al (2012)]

[Wenger, De, Kod (2016)]

[Shamsah, De, Kod (submitted)]
Ghost Robotics is hiring!