CAREER: Morphological Computation for Resilient Dynamic Locomotion of Compliant Legged Robots with Application to Precision Agriculture

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Motivation

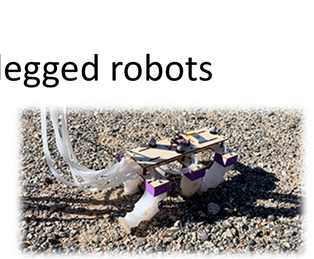
- Unprecedented challenges to meet the growing global demand for food (e.g., climate change, global population growth, aging and shrinking agricultural workforce, etc.)
- Agrobotics can improve input utilization through proximal sensing and physical sampling
- Legged robots' mobility and adaptability may create new ways to interact physically with crops

Goal

- Investigate how compliance embedded in legged robots can facilitate control and computation for efficient and resilient navigation

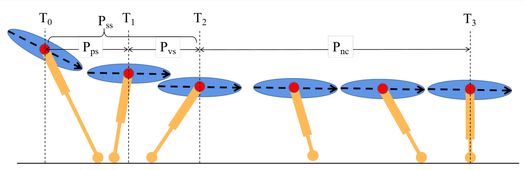
Objectives

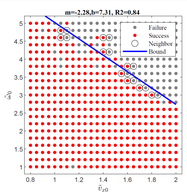
- Investigation of effect of various forms of compliance on center of mass motion and gait stabilization for some classes of legged robots
- Introduction of new hardware designs that can harness compliance and enable principles of morphological computation
- Development of compliance-aware legged locomotion whole-body and central-pattern-generator-based controllers
- Development of non-holonomic motion planners based on robot body morphology and embedded compliance

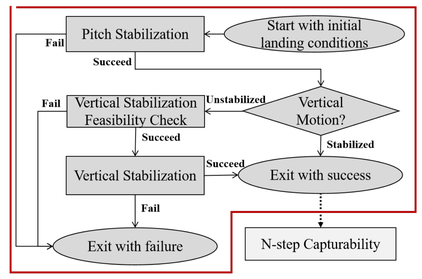


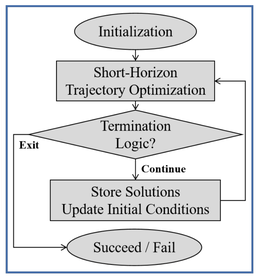
Significant Results

- Evaluation of the capability of aggressive legged robot landing under significant touchdown linear and angular velocities upon impact
  - Approach: nonlinear iterative constrained trajectory optimization to stabilize the first stance step prior to N-step Capturability analysis via the Planar Inverted Pendulum with Flywheel (PIPF) model
  - Analysis: performance maps across many different initial conditions reveal approximately linear boundaries as well as the effect of inertia, body incidence angle and leg attacking angle on the boundary shape.
  - Engineering insight: body inertia affects performance map the most and should be optimized first when the target is to improve robot landing efficacy
- Additional results: 1) development of a full-stack autonomous navigation pipeline; 2) hardware design and system integration for a new built-in-house medium-scale quadrupedal robot with spinal compliance









Educational Activities

- University-wide robotics makerspace
- Robotics summer camp for middle school students

Broader Impacts

- Theory and practice of harnessing compliance to improve efficiency
- Hardware design and dynamic modeling, locomotion control, and non-holonomic motion planning and autonomous navigation
- Supporting legged robots' use in precision agriculture

Products

- K. Ye and K. Karydis, "Evaluation of Legged Robot Landing Capability Under Aggressive Linear and Angular Velocities," IEEE ICRA 2023 (to appear)
- K. Ye, K. Chung and K. Karydis, "A Novel Lockable Spring-loaded Prismatic Spine to Support Agile Quadrupedal Locomotion," Submitted to IEEE/RSJ IROS 2023 (under review)

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