NRI: Decision-making Foundations for Human-supervised Legged Robot Teams

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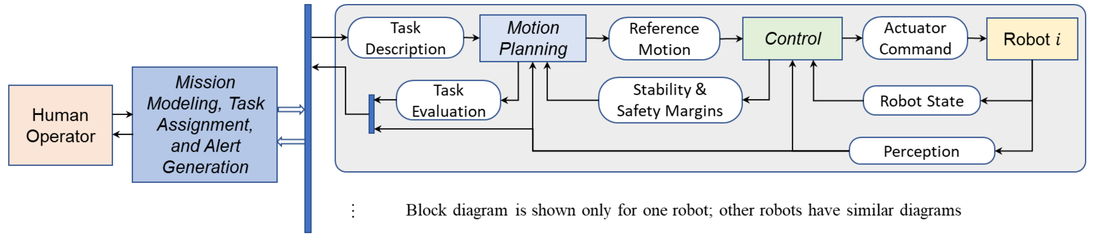
Goals and Motivation

- Semi-autonomous operation of legged robot teams
  - Collaborative legged robots can enhance exploration and task execution.
  - Human supervisors can make high-level decisions to ensure robots are taking the right actions based on the mission's needs.
- Legged robots can leverage whole-body motions to perform functional tasks while navigating uneven terrain.

System Overview

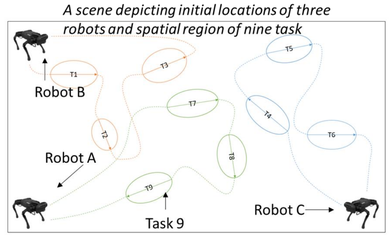


Block diagram is shown only for one robot; other robots have similar diagrams

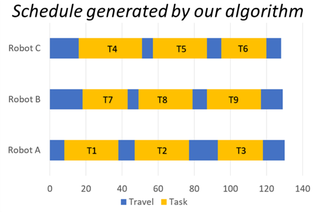
Topic 1: Task Assignment and Scheduling

- Mathematical formulation to convert task allocation problem into Mixed Integer Linear Programming (MILP) problem
  - ➢ Account for time to travel to task locations
  - ➢ Consider agent capabilities
  - ➢ Agent collaboration on complex tasks
- Event triggered replanning to handle delays and failures
- Allow human guidance and intervention
- Solving 10-agent 30-task problems in less than 1 minute

A scene depicting initial locations of three robots and spatial region of nine task

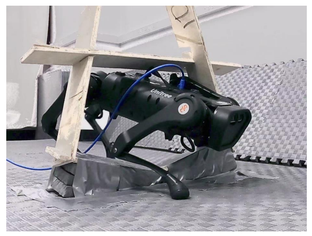


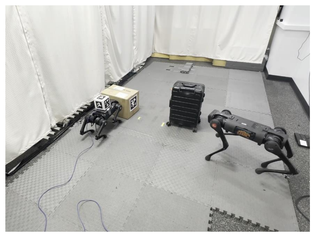
Schedule generated by our algorithm



Topic 2: Motion Planning

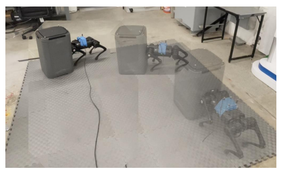
- Informed Sampling-Based Planning for Legged Robots Negotiating Permeable Obstacles
  - ➢ Simultaneous body and foothold planning
  - ➢ Informed biasing based on obstacle characterization
- Integrated Task and Motion Planning for Observation-Assisted Loco-Manipulation
  - ➢ Timestep-based heuristic search given coupled task constraints
  - ➢ Adaptive motion primitive to improve efficiency

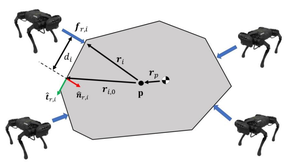




Topic 3: Loco-manipulation Control

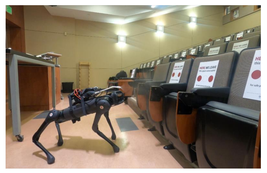
- Contact Optimization for Non-Prehensile Loco-manipulation via Hierarchical Model Predictive Control
  - ➢ Optimize for interaction force and contact location
  - ➢ Unified loco-manipulation MPC to effectively regulate the interaction force while keeping the robot balance
- Hierarchical Adaptive Loco-manipulation Control
  - ➢ Manipulate an unknown object over unknown terrain
  - ➢ Fast adaptation to time-varying load up 60% of the robot's weight
- Hierarchical Adaptive Control for Collaborative Manipulation
  - ➢ Collaborative manipulation of an unknown object (e.g., unknown mass, moment of inertia, and COM location)
  - ➢ QP-based control for optimizing force distribution and contact allocation of the robot team

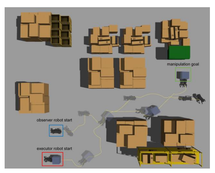




Applications

- Disinfection: spray-based disinfection via body manipulation in cluttered environments
- Logistics: warehouse management
- Disaster response: collaborative search & rescue over challenging terrain





Broader Impacts

- Integrated research results into a new graduate course (Robot Dynamics and Control)
- Engaged 1 high-school student, 2 undergraduate students (1 female student)
- Monthly lab tours and outreach activities
- Youtube videos for the general public

2023 FRR & NRI Principal Investigators' Meeting
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