CAREER: Hierarchical Reinforcement Learning Framework for Safe Dynamic Bipedal Locomotion

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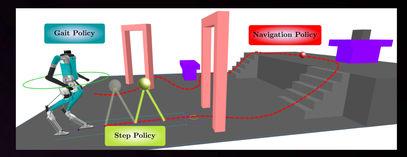
https://mae.osu.edu/cyberbotics



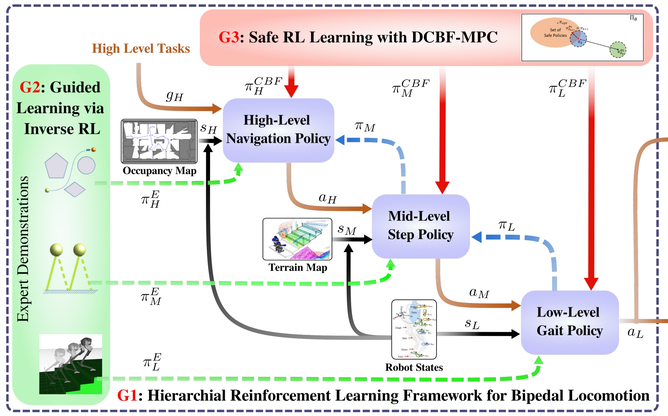
THE OHIO STATE UNIVERSITY
Cyberbotics Lab

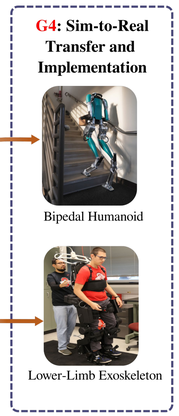
Research Objectives

- To address various challenges in bipedal locomotion control design due to:
  - **System dynamics** (*high-dimensional, underactuated, nonlinear, hybrid dynamics*)
  - **Motion control** (*task complexity, stability, robustness, uncertainties*)
  - **Interaction with environment** (*unstructured and dynamic settings, non-flat terrains*)
  - **Real-world deployment** (*sim-to real transfer, safety-critical implementation*)

Technical Approach

- Develop a novel hierarchical reinforcement learning framework for bipedal robot to efficiently explore the high-dimensional behavior space through the temporal abstraction of skill and tasks at different levels.



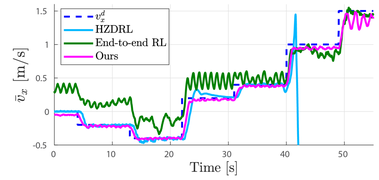


Key Highlights:

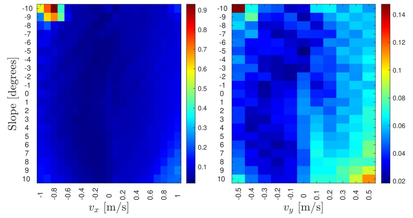
- Dimension reduction via layered learning and skill abstractions
- Safety-ensured learning by using CBF-MPC
- Expert guided imitation learning via Inverse RL
- Reliable sim-to-real transfer learning and implementation

Significant Progress (1st Year)

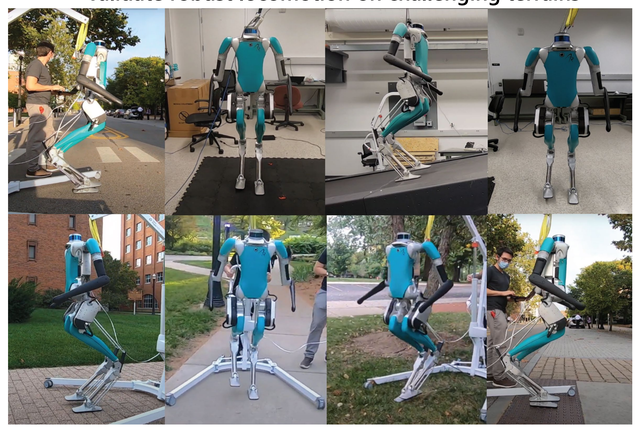
Comparison with other approaches



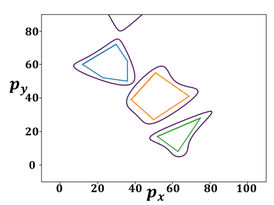
Robustness test in speed and slope



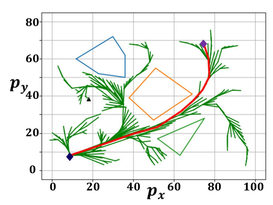
Validate robust locomotion on challenging terrains



[1] G. A. Castillo, B. Weng, W. Zhang, and A. Hereid, "**Reinforcement Learning-Based Cascade Motion Policy Design for Robust 3D Bipedal Locomotion**," *IEEE Access*, vol. 10, pp. 20135–20148, 2022.



Construct CBFs from the maps



Path planning via CBF-based RRT*

[2] C. Peng, O. Donca, and A. Hereid, "**Safe Path Planning for Polynomial Shape Obstacles via Control Barrier Functions and Logistic Regression**," in *IEEE International Conference on Robotics and Automation (ICRA)*, London, 2023.

Education and Outreach

- Improve robotics curriculum at the Ohio State University
  - *Developed "ME/ECE 5463: Introduction to Real-Time Robotics Systems" course*
- Engage underrepresented students in research activities
  - *Advised several underrepresented graduate/undergraduate/high-school students supported through this award and other university sponsored programs*
- Organize professional workshops to promote interdisciplinary collaborations
  - *Co-organized the 3rd Legged Robotics Workshop at 2022 American Control Conference*

Broader Impacts

- **Industry**: accelerate safe deployment of bipedal humanoid robots and lower-limb exoskeletons in complex and dynamic real-world settings
- **Health**: improve quality of life for SCI patients via crutch-free restored locomotion in daily activities using powered lower-limb exoskeletons.
- **Education**: promote education and public awareness in science and engineering through various educational and outreach activities that utilize the innate appeal of bipedal robots and lower-limb exoskeletons

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

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