Robotics and Embedded Systems

Master/Bachelor Thesis

Reinforcement Learning of Dynamic Locomotion Controller for a Quadruped Robot with Active Spine

Background

Many biological findings suggest that a quadruped's active spine plays a crucial role in its locomotion. Studies indicate that active spine joints can significantly enhance posture stabilization, dynamic gait performance, and energy efficiency. In addition to the underactuated body and dynamic constraints common to standard quadruped robots, introducing an active spine adds more degrees of freedom (DoFs) and time-varying inertia, making the control of highly dynamic quadrupeds particularly challenging.

Reinforcement learning (RL) methods have recently shown remarkable success in modeling complex behaviors for robotic control, offering a promising avenue for advancing the locomotion of quadruped robots with active spines. However, designing an appropriate reward function and accomplishing robust sim-to-real transfer remain major obstacles for RL-based control methods. The former demands careful calibration to shape desired behaviors, while the latter often requires significant resources and patience.

In this work, you will apply RL to train a policy network that enables a quadruped robot to achieve dynamic bounding gaits and demonstrate how actively controlling a multi-DoF spine can substantially improve advanced mobility in quadrupedal robotics.

Your Tasks

In this thesis, you will develop a locomotion controller for quadruped robot with an active spine using deep reinforcement learning that tries to improve robot's dynamic performance. To be specific:

1. You will learn knowledge about Robotic, RL, and traditional control methods.
2. You will work on the basis of our current algorithm and develop a novel algorithm.
3. You will have the opportunity to deploy the algorithms on an actual quadruped robot (in Fig.2, more details can be seen in video [4]).

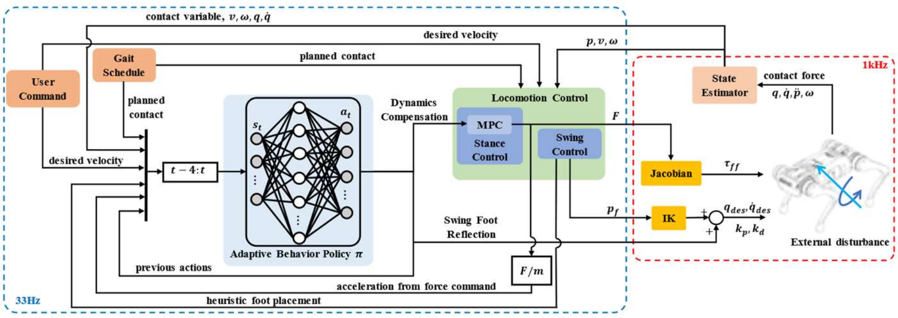

Fig.1 The framework of locomation control of quadruped robot with RL

Fig.2 The Unitree Go2 in our lab

Requirements

- High self-motivation and passion for research.
- Six months working time.
- Existing knowledge about robotic control, RL will be a bonus

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[1] J. D. Caporale, Z. Feng, S. Rozen-Levy, A. M. Carter and D. E. Koditschek, "Twisting Spine or Rigid Torso: Exploring Quadrupedal Morphology via Trajectory Optimization," *2023 IEEE International Conference on Robotics and Automation (ICRA)*, London, United Kingdom, 2023.

[2] J. Wang, J. Cheng, J. Hu, W. Gao and S. Zhang, "Spined Torso Renders Advanced Mobility for Quadrupedal Locomotion," *2024 IEEE International Conference on Robotics and Automation (ICRA)*, Yokohama, Japan, 2024.

[3] W. Li, Z. Zhou and H. Cheng, "Dynamic Locomotion of a Quadruped Robot with Active Spine via Model Predictive Control," *2023 IEEE International Conference on Robotics and Automation (ICRA)*, London, United Kingdom, 2023.

[4] https://www.youtube.com/watch?v=6zPvT0ig1VM