TECHNISCHE UNIVERSITÄT WIEN

**Autonomous Systems**

UNIV.-PROF. DR.-ING. DONGHEUI LEE

AUTONOMOUS SYSTEMS

MASTER'S THESIS

# Adaptive Locomotion: Task-agnostic Reinforcement Learning through Learnable Stiffness

Problem description:

Reinforcement learning has become a promising solution for locomotion tasks in robotics due to the massive parallelization of training [1]. Conventionally, RL for locomotion follows a position-based paradigm, where a high-level controller (i.e. RL agents) is followed by a low-level proportional-derivative (PD) controller. The RL agents output the target joint positions at a low frequency while the PD controller generates torques at a high frequency. In this pipeline, the PD controller requires constant stiffness and damping for each joint to be defined. On the contrary, humans/animals can adjust their stiffness and damping to handle diverse tasks, for instance, large stiffness to jump high or low stiffness to walk. Additionally, torque-based methods are researched in [2, 3], in which RL agents produce motor torques to actuate directly, thus they need to run at a high-speed rate on robots. In general, torque-based approaches are more difficult to train than position-based methods, and a high-speed rate for neural networks also requires a powerful CPU or GPU on board. In this thesis, the student will research an RL-based method for locomotion, in which the control is decoupled into two stages: position and torque. In the first stage, the agent performs as a position controller to produce target joint positions. In the second stage, the agent should output the stiffness (and damping) based on the robot's state and target joint positions. Finally, a PD controller runs with the learned stiffness (and damping) to reach target joint positions.

Tasks:

- Task1. Literature research
- Task2. Design and research on RL methods with learnable stiffness (and damping)
- Task3. Train your RL agents on Unitree GO2 for different tasks in simulation, for instance, walking/running at various speeds, jumping at diverse heights, etc.
- Task4. Compare your learnable stiffness method with position-based and torque-based methods.
- Task5. Implement your method on a Unitree GO2 robot (offered by our lab)

Bibliography:

[1] Nikita Rudin, David Hoeller, Philipp Reist, and Marco Hutter. Learning to walk in minutes using massively parallel deep reinforcement learning, 2022.

[2] Donghyeon Kim, Glen Berseth, Mathew Schwartz, and Jaeheung Park. Torque-based deep reinforcement learning for task-and-robot agnostic learning on bipedal robots using sim-to-real transfer. *IEEE Robotics and Automation Letters*, 8(10):6251–6258, October 2023.

[3] Shuxiao Chen, Bike Zhang, Mark W. Mueller, Akshara Rai, and Koushil Sreenath. Learning torque control for quadrupedal locomotion, 2023.

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