Learning to Climb Vertical Ladders with Quadruped using Carpal-Claw Design

Authors: Shafeef Omar[1,2], Majid Khadiv[1], Victor Barasuol[2], Giulio Turrisi[2], Claudio Semini[2]
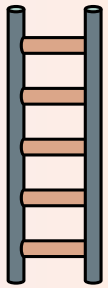**Corresponding email:** shafeef.omar@tum.de

[1]Technische Universität München [2]Istituto Italiano di Tecnologia

TC Poster Session and Netorking Event
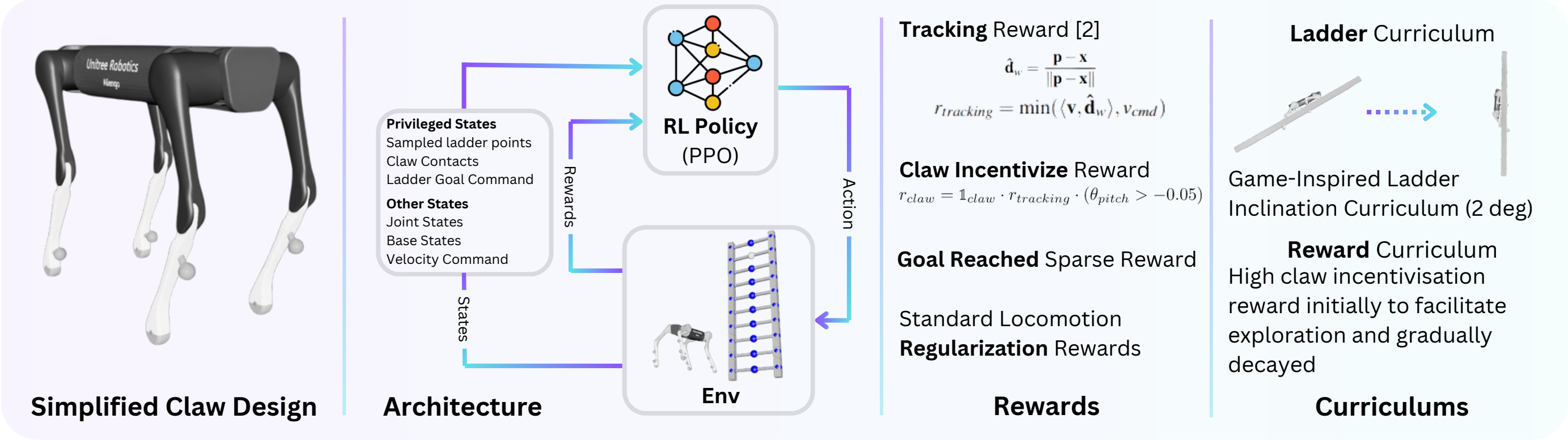
Motivation

Navigating highly inclined surfaces/structures with sparse and disconnected support regions such as **ladders**

Contributions

Simplified Carpal Claw **Design** [1]

Privileged **RL Control Policy** for Climbing

Partially Dense **Reward Formulation**

Approach

Simplified Claw Design

Architecture

Privileged States
Sampled ladder points
Claw Contacts
Ladder Goal Command
Other States
Joint States
Base States
Velocity Command

States → RL Policy (PPO)
Rewards →
Action → Env

Env

Rewards

Tracking Reward [2]

$$\hat{\mathbf{d}}_w = \frac{\mathbf{p}-\mathbf{x}}{\|\mathbf{p}-\mathbf{x}\|}$$

$$r_{tracking} = \min(\langle\mathbf{v},\hat{\mathbf{d}}_w\rangle, v_{cmd})$$

Claw Incentivize Reward
$$r_{claw} = \mathbb{1}_{claw} \cdot r_{tracking} \cdot (\theta_{pitch} > -0.05)$$

Goal Reached Sparse Reward

Standard Locomotion
Regularization Rewards

Curriculums

Ladder Curriculum

Game-Inspired Ladder Inclination Curriculum (2 deg)

Reward Curriculum
High claw incentivisation reward initially to facilitate exploration and gradually decayed

Simulation Results

IsaacLab

Training Time: **16 hrs**
GPU: **Nvidia RTX 4090**

Emergence of new behaviours to support climbing
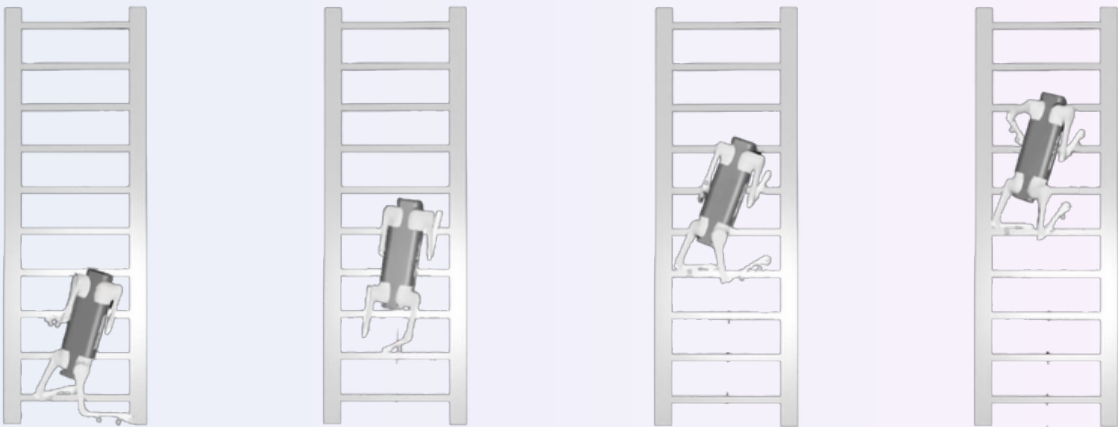
Discussions

Exploration with claw reward is **difficult but sufficient**

Reward Curriculum is **difficult**

Unsafe transition between walking and vertical climbing

Sparse Goal Reaching **Reward** (Value Bootstrap)

Future Directions

Hook-shaped Front Claws

Teacher-Student Distillation using **Depth Cameras**

Enforcing **Gait Patterns** using Claw on Ladder

Hierachical Structure
- Higher level Contact Planning Policy
- Lower level RL Controller

References

[1] Barasuol, V., Emre, S., Suzano Medeiros, V., Bratta, A., & Semini, C. (2024). Introducing the Carpal-Claw: a Mechanism to Enhance High-Obstacle Negotiation for Quadruped Robots. IEEE International Conference on Robotics and Automation (ICRA).

[2] Cheng, X., Shi, K., Agarwal, A., & Pathak, D. (2023). Extreme Parkour with Legged Robots. ArXiv Preprint ArXiv:2309.14341.