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

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TC Poster Session and Netorking Event

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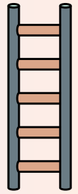
Motivation

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



Contributions

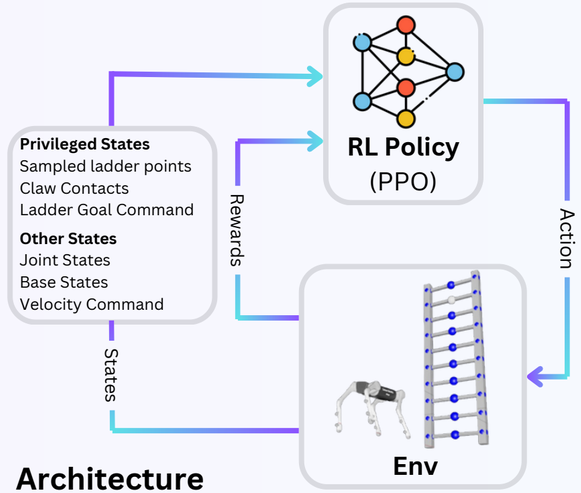
Simplified Carpal Claw **Design** [1]

Privileged **RL Control Policy** for Climbing

Partially Dense **Reward Formulation**

Approach

Simplified Claw Design



Architecture

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

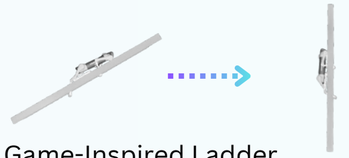
$$r_{claw} = \mathbb{1}_{claw} \cdot r_{tracking} \cdot (\theta_{pitch} > -0.05)$$

Goal Reached Sparse Reward

Standard Locomotion **Regularization** Rewards

Rewards

Ladder Curriculum



Game-Inspired Ladder Inclination Curriculum (2 deg)

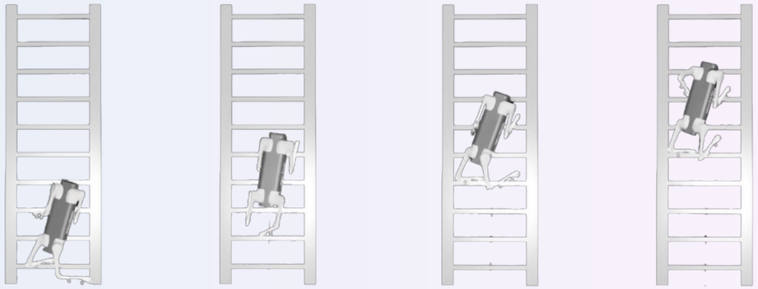
Reward Curriculum
High claw incentivisation reward initially to facilitate exploration and gradually decayed

Curriculums

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)

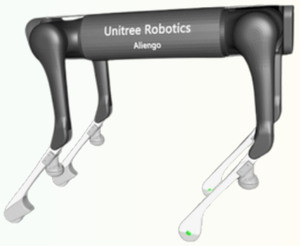
Future Directions

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.