Robot Perception and Control

Legged Locomotion

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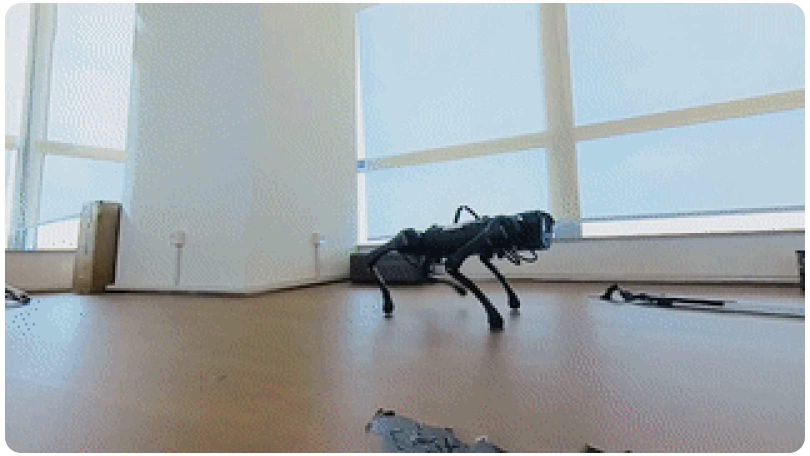
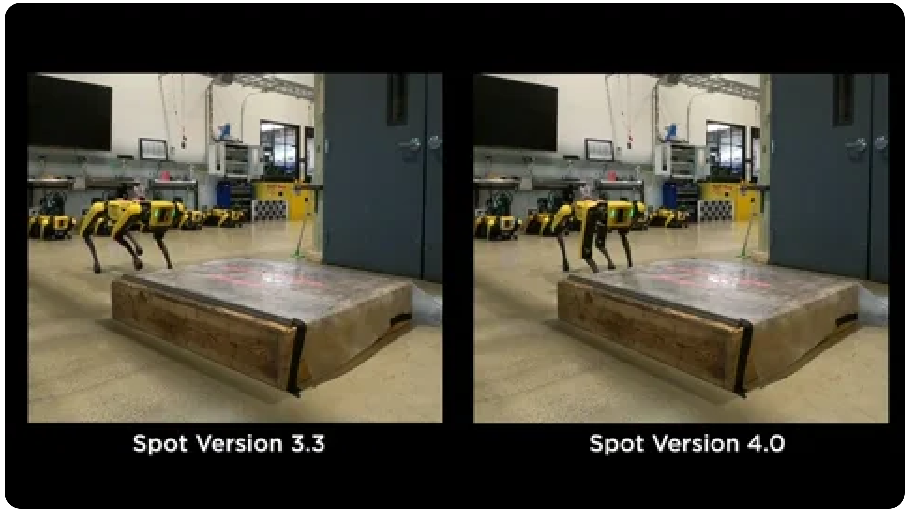
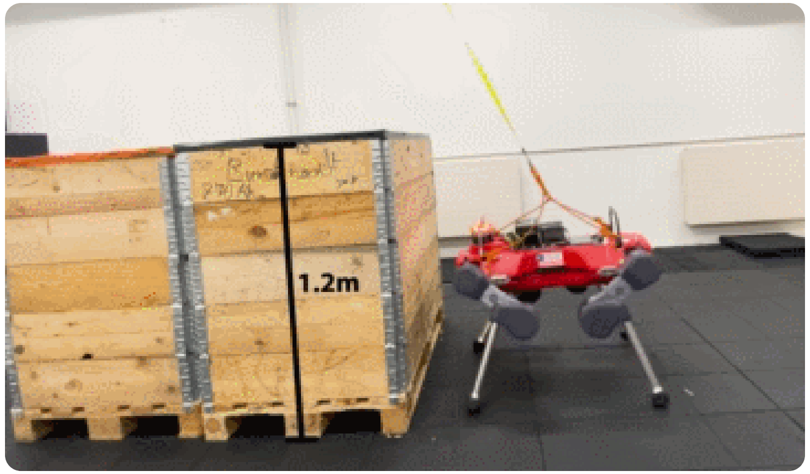
What can we do with RL × Legged Robots?







Actuator Networks arxiv ⮥

Actuators are extremely difficult to model accurately.

- *nonlinear* and *non-smooth* dissipation in dynamics.
- contains cascaded feedback loops and a number of internal states that are not even directly observable.

Actuator Networks is a **data driven** solution that can provide better simulation of an actuator via supervised learning.

- learns **action-to-torque** relationship that includes all software and hardware dynamics.
- actuator network estimated torque at the joints given a history of position errors and velocities.

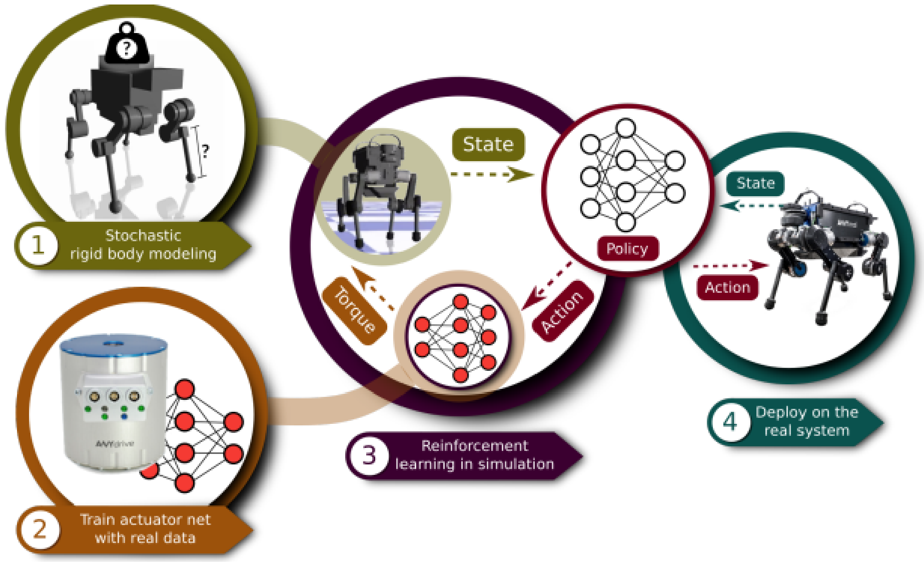
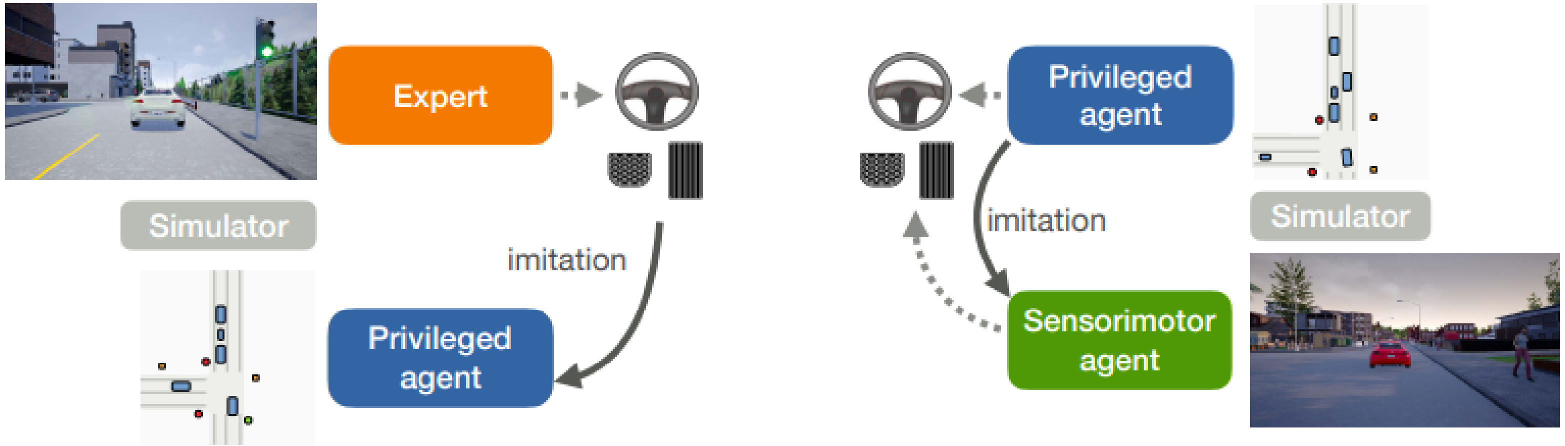


Fig. 1. Creating a control policy. In the first step, we identify the physical parameters of the robot and estimate uncertainties in the identification. In the second step, we train an actuator net that models complex actuator/software dynamics. In the third step, we train a control policy using the models produced in the first two steps. In the fourth step, we deploy the trained policy directly on the physical system.

> “ collect *joint position errors*, *velocities*, and *torque* using a controller for more than a million samples with varied amplitude and frequency and manual disturbances for diverse situation.

Learning by Cheating arxiv ↗ github ↗

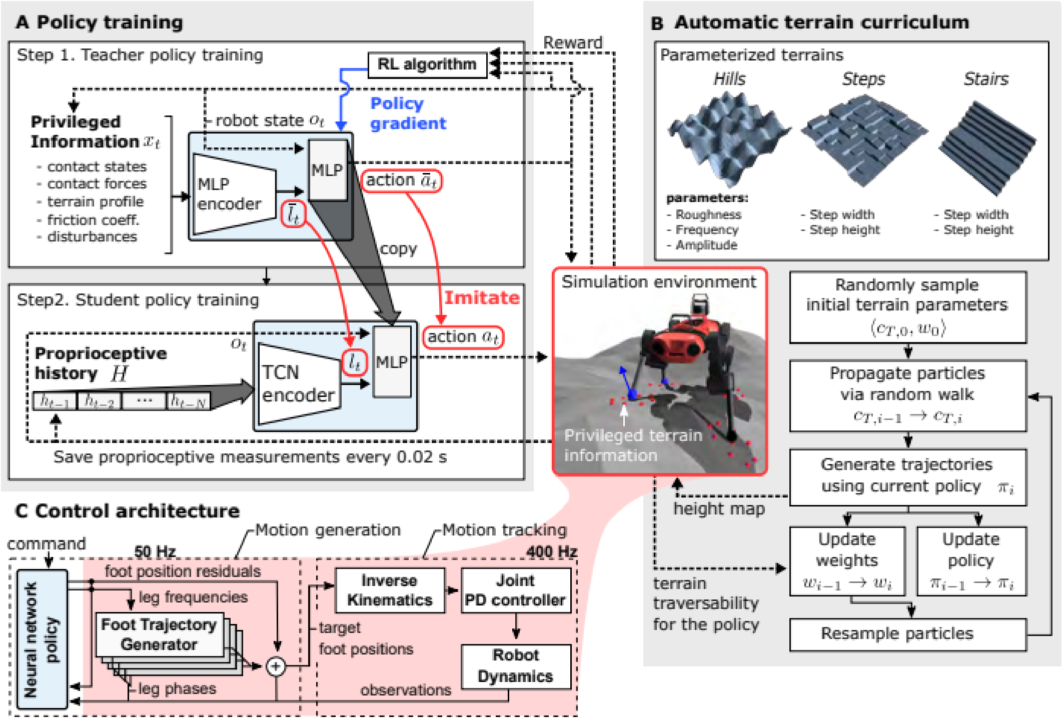
Proposed two-stage training procedure, which first train a privileged agent and then using the agent as a teacher to train a purely vision-based system, for effective imitation learning. This paradigm is the underlying concept in the legged RL.



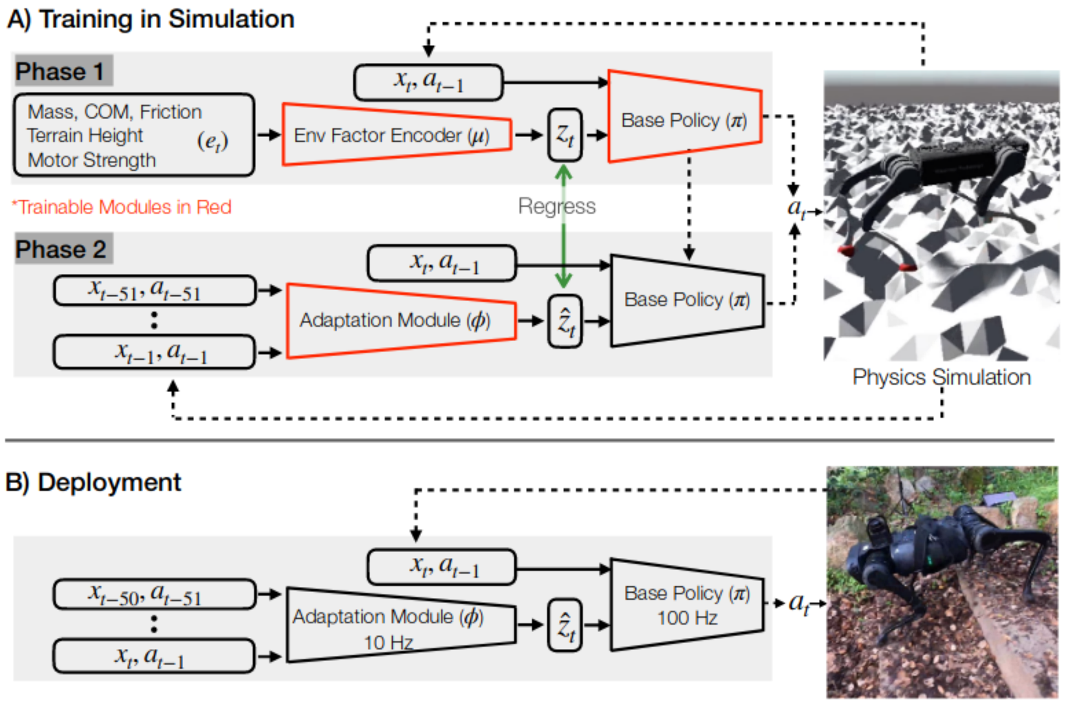
(a) Privileged agent imitates the expert (b) Sensorimotor agent imitates the privileged agent

Figure 1: Overview of our approach. **(a)** An agent with access to privileged information learns to imitate expert demonstrations. This agent learns a robust policy by cheating. It does not need to learn to see because it gets direct access to the environment's state. **(b)** A sensorimotor agent without access to privileged information then learns to imitate the privileged agent. The privileged agent is a "white box" and can provide high-capacity on-policy supervision. The resulting sensorimotor agent does not cheat.

Learning Locomotion over Challenging Terrain arxiv github



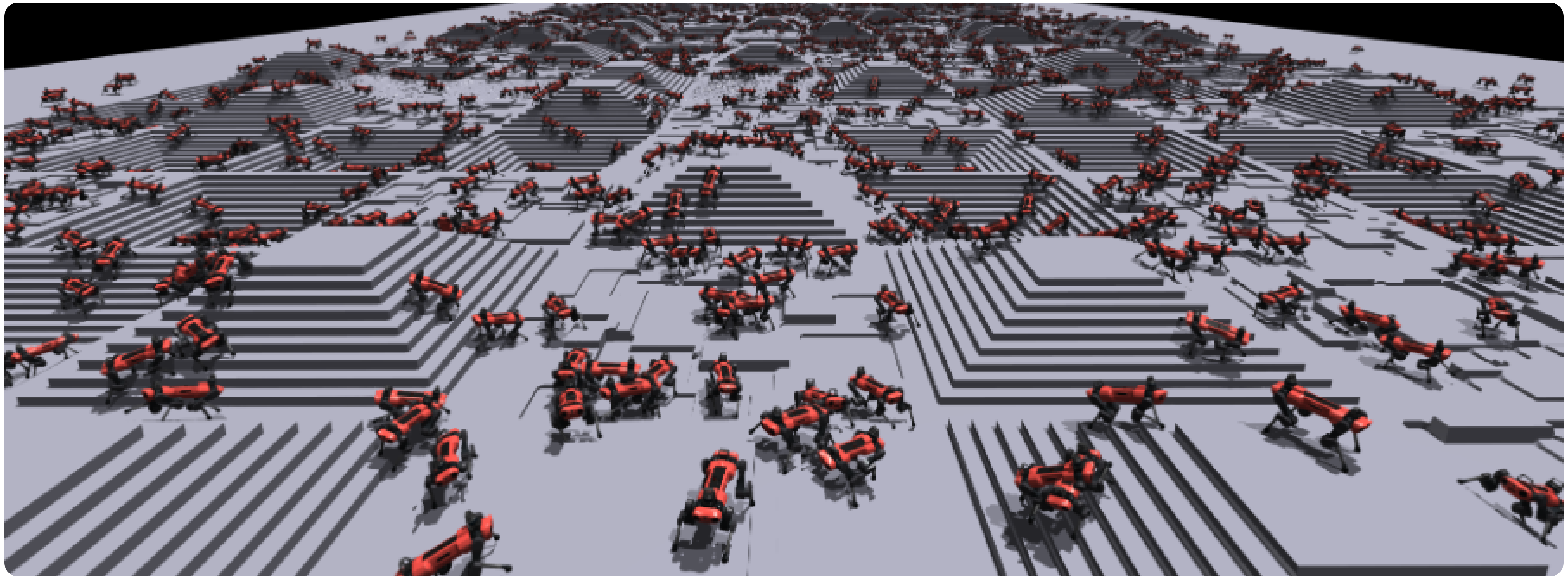
RMA: Rapid Motor Adaptation paper ⮥



Learning to Walk in Minutes arvix ⤴ github ⤴

Presents a training setup that achieves fast policy generation for real-world robotic tasks by using massive parallelism on a single workstation GPU (showcase of Isaac Gym).

- A codebase is widely used as baseline for developing legged locomotion system.



Walk These Ways arxiv

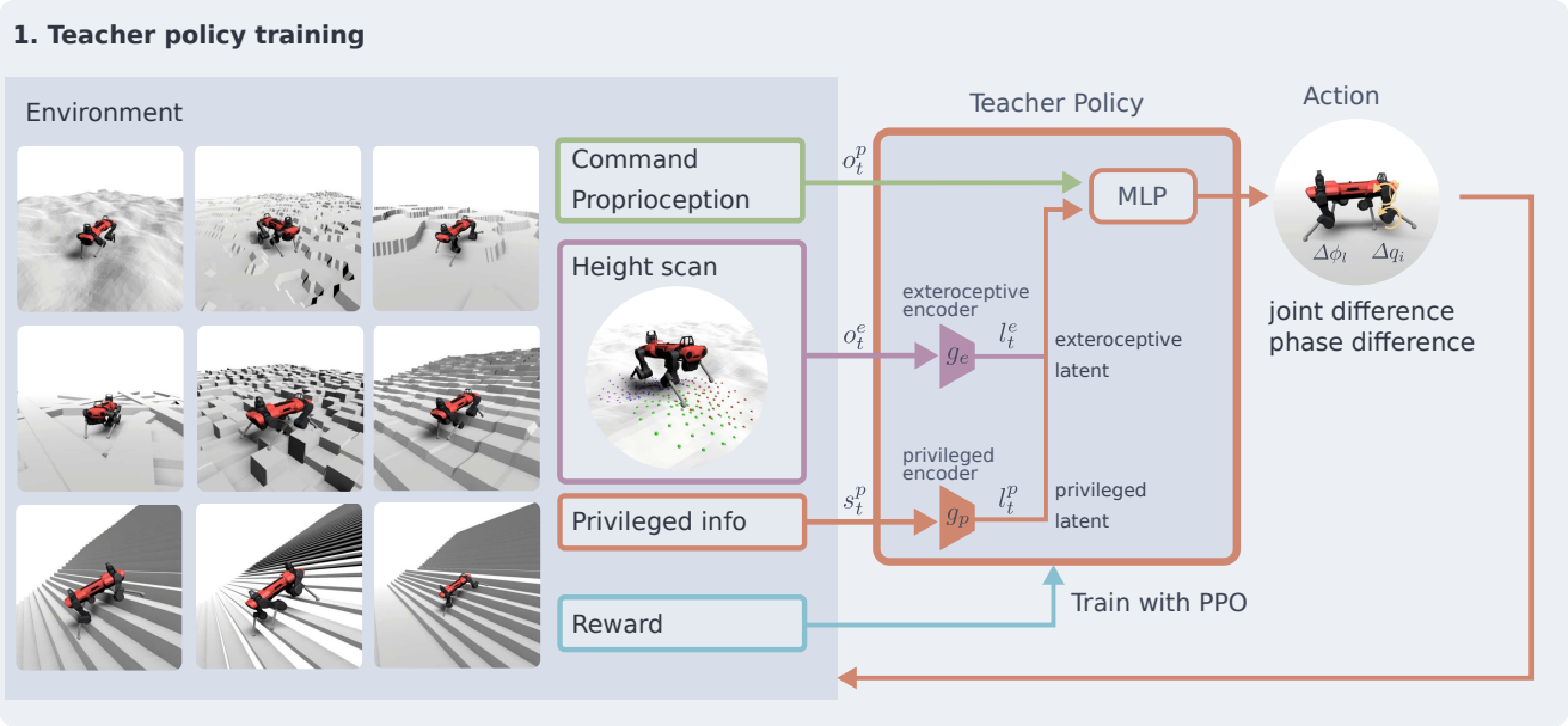
Perceptive locomotion

Perceptive locomotion for quadrupeds

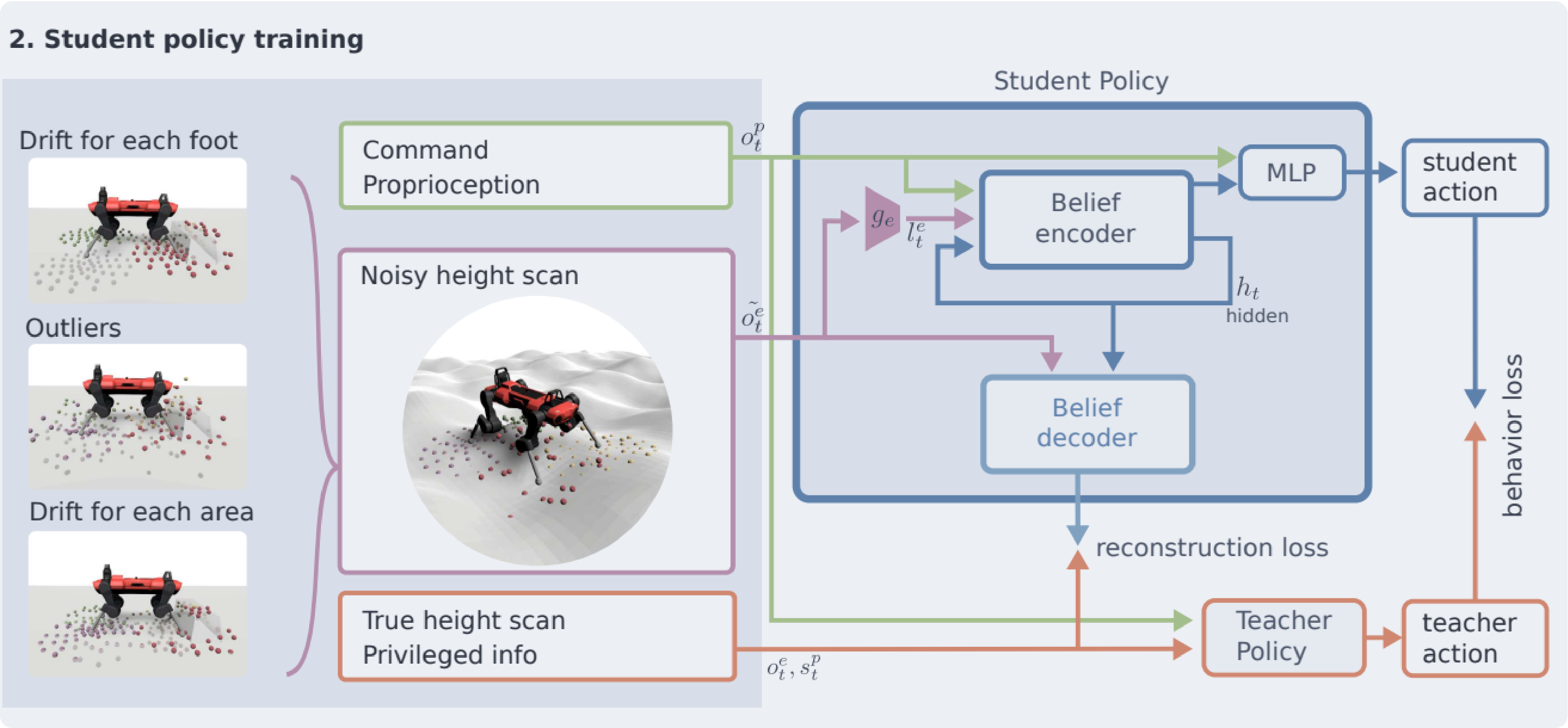
Presented a three stage training and deploy method to perform zero-shot sim-to-real transfer [1 ⮥].

1. a **teacher policy**, which has access to privileged information, is trained to follow a random target velocity over randomly generated terrain with random disturbances.
2. a **student policy** is trained to reproduce the teacher policy's actions without using this privileged information.
3. transfer the learned student policy to the physical robot and deploy it in the real world with onboard sensors.

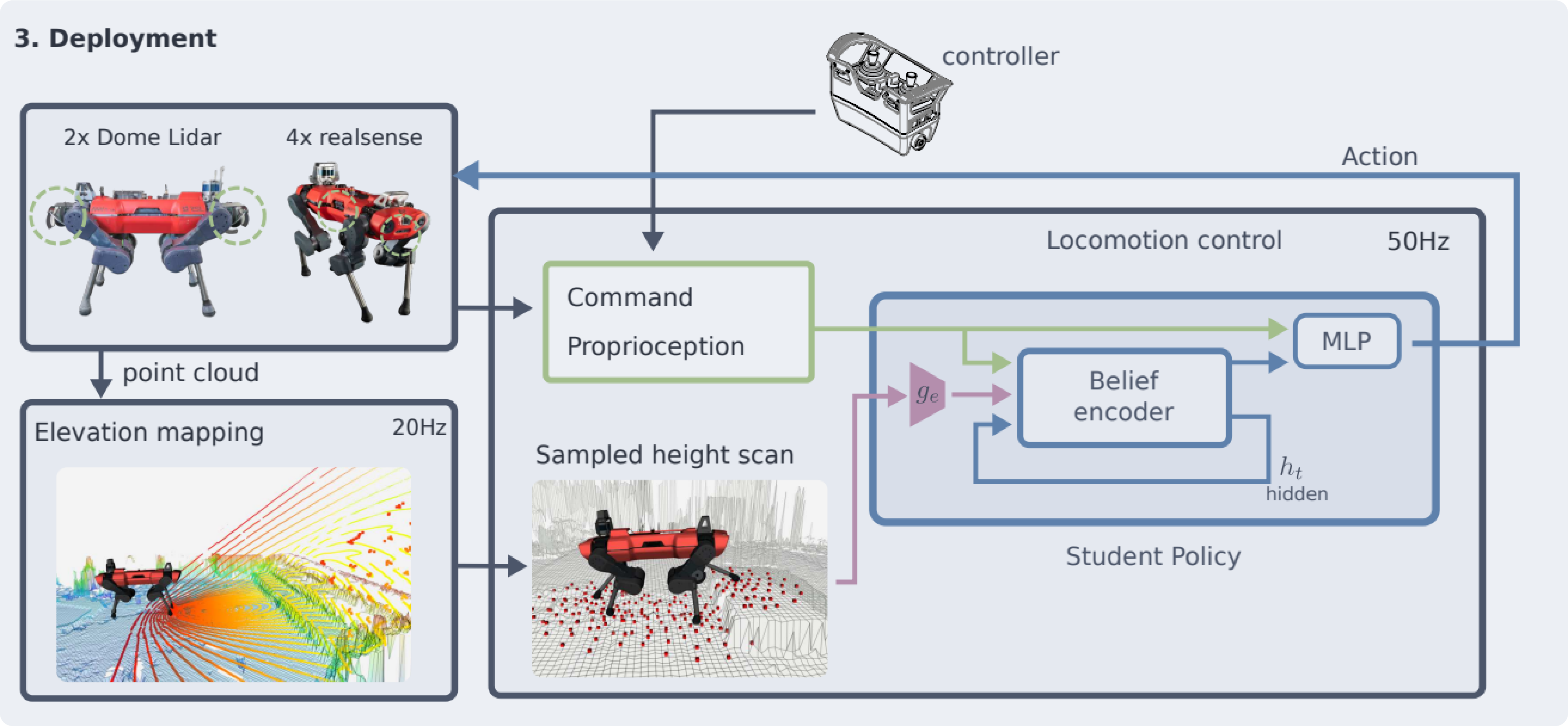
Training teacher policy



Training student policy



Deployment



3. Deployment
controller
Action
2x Dome Lidar
4x realsense
Locomotion control
50Hz
Command
Proprioception
MLP
Belief
encoder
g_e
h_t
hidden
point cloud
Elevation mapping
20Hz
Sampled height scan
Student Policy

Legged Locomotion using Egocentric Vision arxiv ⮥

Upstairs
17cm high, 30cm deep

	Success	#Stairs
Ours	100%	13
Blind	0%	2.2

Downstairs
17cm high, 30cm deep

	Success	#Stairs
Ours	100%	13
Blind	100%	13

Stepping Stones
30cm wide, 15cm apart

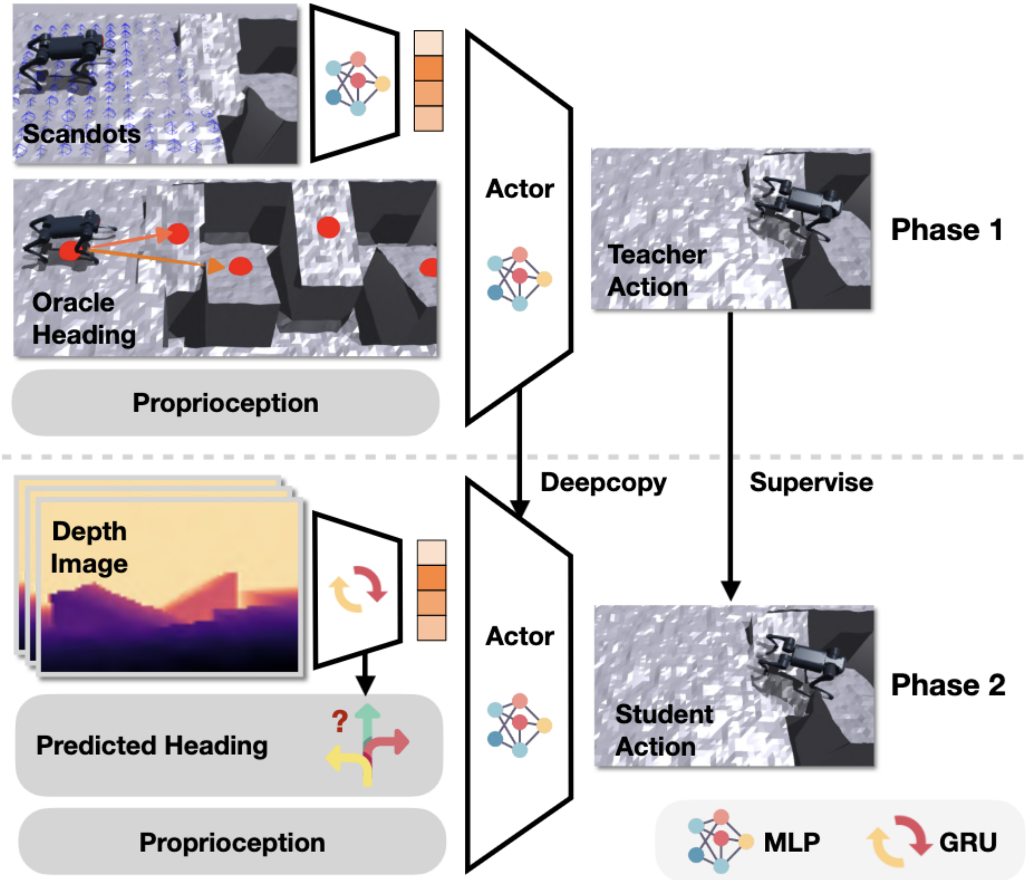
	Success	#Stones
Ours	94%	9.4
Blind	0%	0

Gaps
26cm apart

	Success
Ours	100%
Blind	0%

Parkour Learning arxiv ↗

Extreme Parkour arxiv ⮭



Humanoid Parkour Learning arxiv ↗