Quadruped Robots Walk Bipedally Using Reward-Based Methods
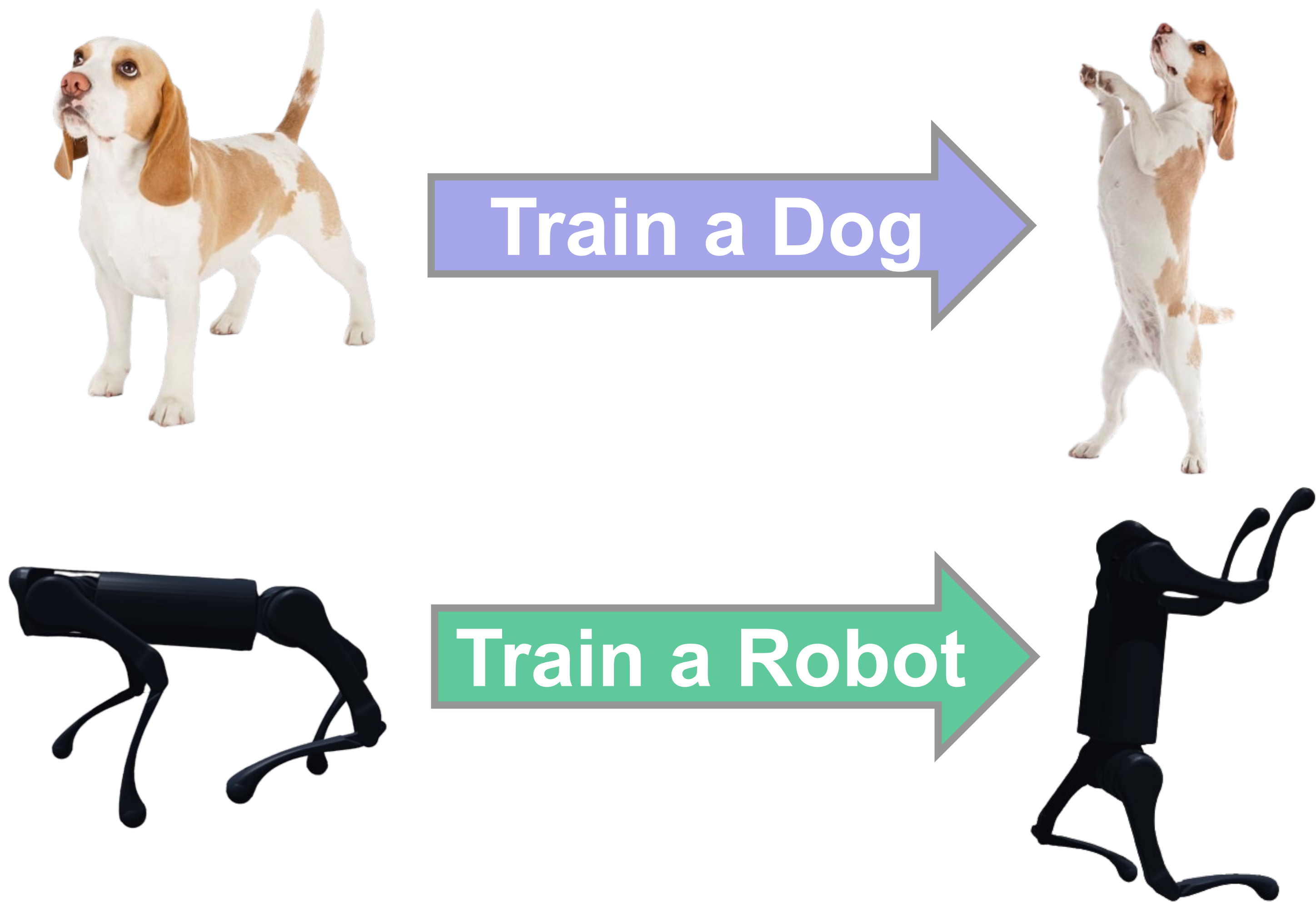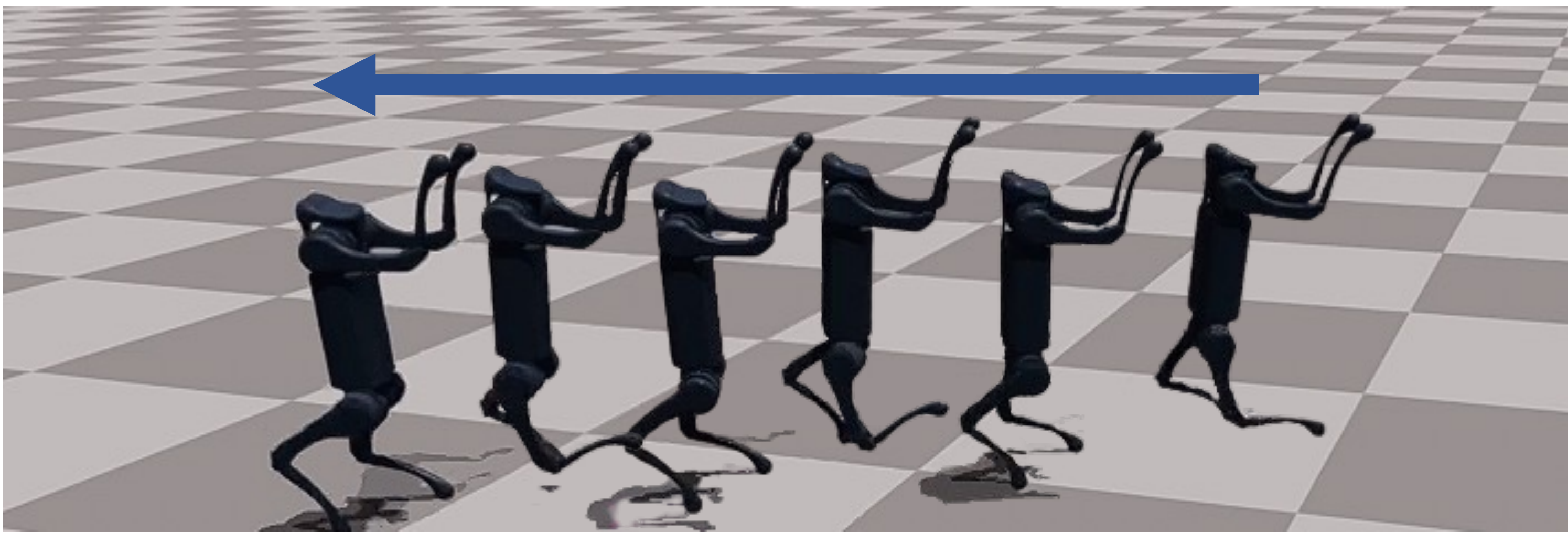
Liangsheng Yin (liangsheng.yin@outlook.com)
Shanghai Jiao Tong University

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Background

Quadruped Robots Walk Bipedally

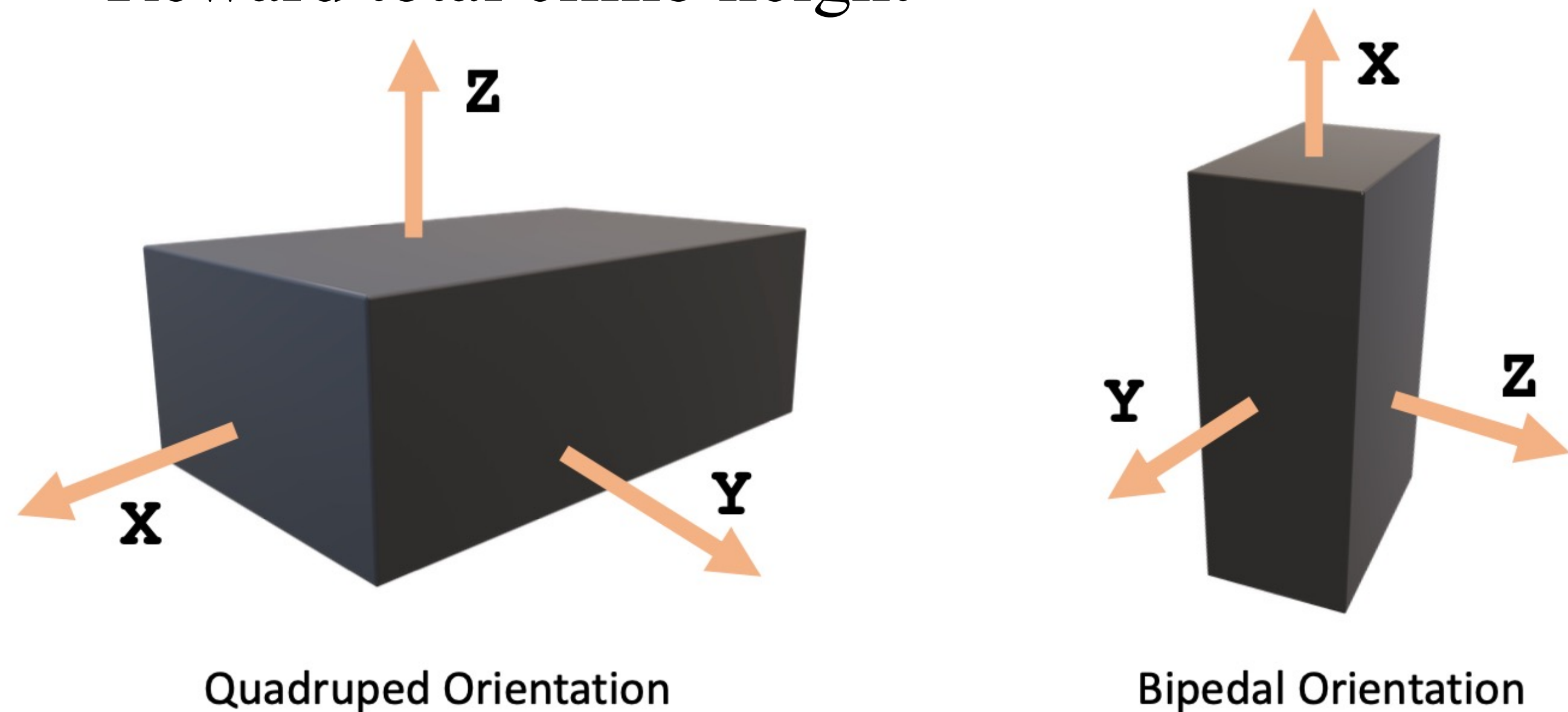Train a Dog

Train a Robot

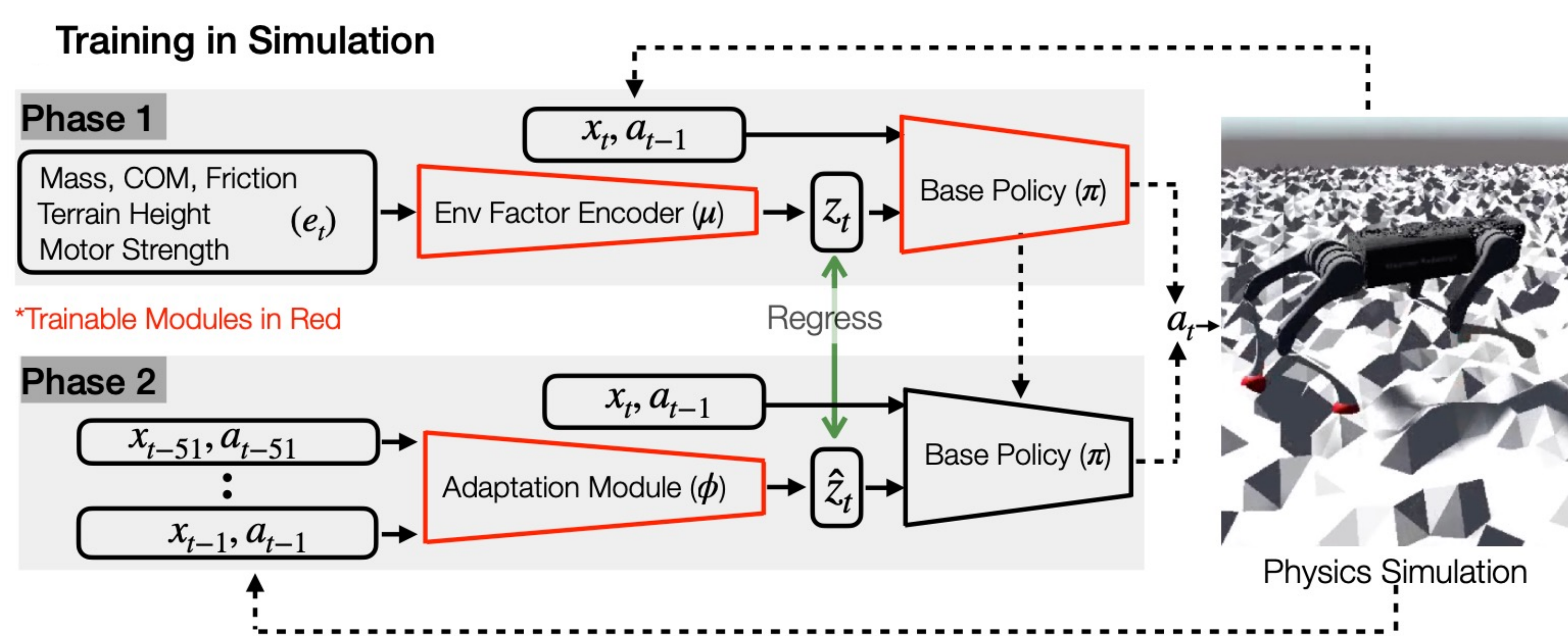## Bipedal Walking Postures

Challenges

- Keep Balance when walking bipedally
- Reward moving forward
- Penalize linear deviation
- Penalize angular deviation
- Penalize falling down
- Reward total climb height

Quadruped Orientation

Bipedal Orientation

Adjust Joints' Parameters

Joint Name	Default Parameter (rad)	Bipedal Walking Parameter (rad)
FL Hip	0.1	0.2
RL Hip	0.1	0.7
FR Hip	-0.1	0.2
RR Hip	-0.1	0.7
FL Thigh	0.8	-1.0
RL Thigh	1.0	1.5
FR Thigh	0.8	-1.0
RR Thigh	1.0	1.5
FL Calf	-1.5	-2.2
RL Calf	-1.5	-0.8
FR Calf	-1.5	-2.2
RR Calf	-1.5	-0.8

Based Framework

Training in Simulation

Phase 1
Mass, COM, Friction Terrain Height Motor Strength (e_t) — Env Factor Encoder (μ) — z_t — Base Policy (π) — x_t, a_{t-1}

*Trainable Modules in Red

Regress

Phase 2
x_{t-51}, a_{t-51} ... x_{t-1}, a_{t-1} — Adaptation Module (ϕ) — $\hat{z}_t$ — Base Policy (π) — x_t, a_{t-1}

Physics Simulation

Reward Scales

Reward Name	Plain Terrain	Stairs Terrain
torques	-0.0002	-0.0002
action rate	-0.05	-0.05
z linear velocity	1.0	1.5
x linear velocity	0.5	2.0
y linear velocity	1.0	1.0
x angular velocity	5.0	5.0
z angular velocity	1.0	1.0
bipedal orientation	-5.0	-5.0
bipedal fall down	-10.0	-10.0
total climb height	0	10.0
collision	-1.0	0

Climb Out of A Pit Bipedally
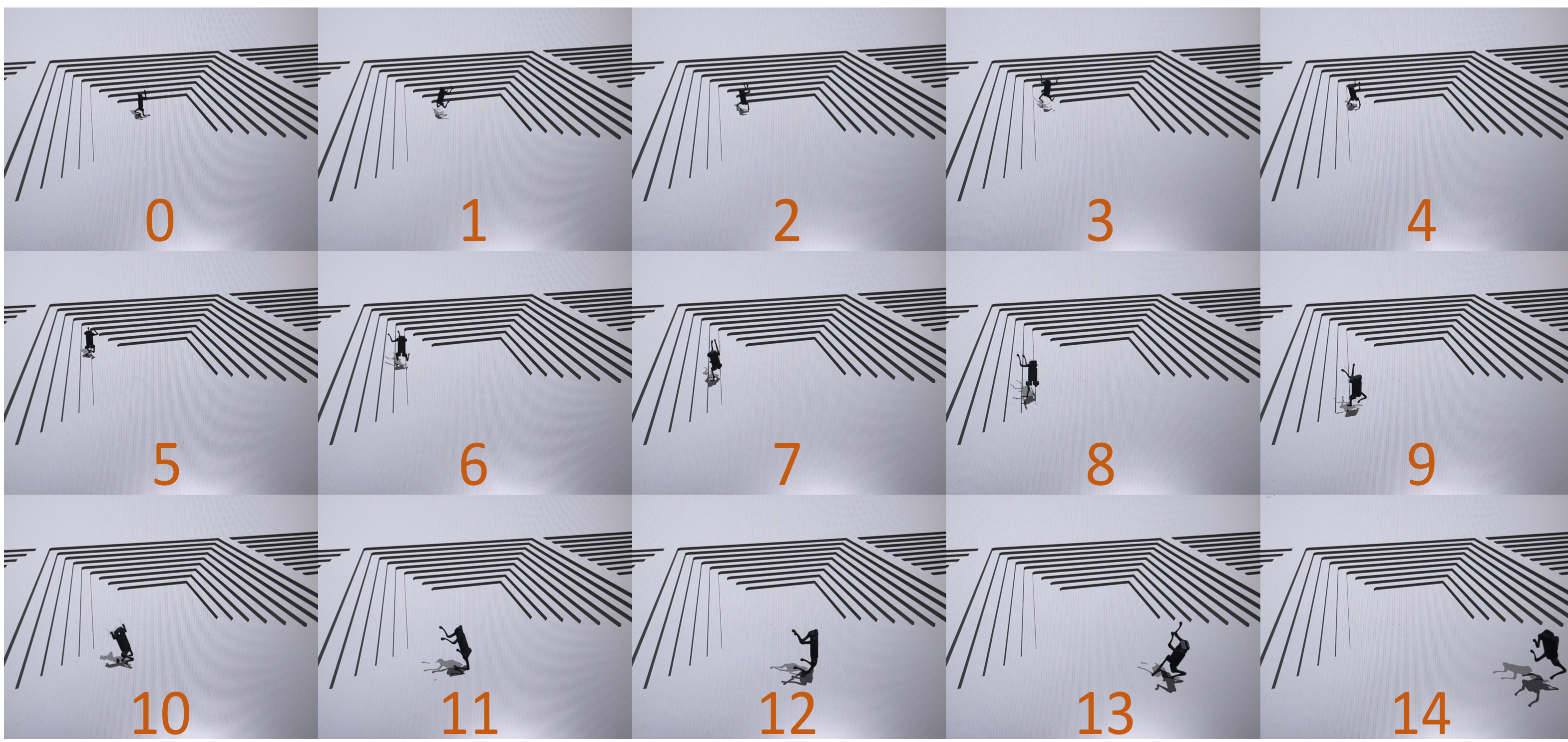
Results

- The teacher and student models perform similarly on flat surfaces, achieving speeds of up to 3m/s with a fall risk below 2%.
- When climbing stairs, the teacher model stands out, reliably reaching the 4th level in a 10-level staircase with steps measuring 0.15m, surpassing the student model, which maxes out at the 3rd level.
- Moreover, the teacher model demonstrates superior balance, featuring a lower probability of falling compared to the student model's 10% risk.