Appendix A Nominal Morphology Generation Parameter Values

Parameter	Nominal Value
Hip Link Mass	0.696 kg
Upper Leg Link Mass	1.013 kg
Lower Leg Link Mass	0.166 kg
Toe Link Mass	0.06 kg
Mass (for joint PD gains scaling)	12.458 kg
Abduction P gain	100 Nm/rad
Abduction D gain	1.0 Nms/rad
Hip P gain	100 Nm/rad
Hip D gain	2.0 Nms/rad
Knee P gain	100 Nm/rad
Knee D gain	2.0 Nms/rad

Appendix B Reward Function

Similar to Peng et al. [7], we compute our reward function as follows:

$$r_t = w^{\text{p}} r_t^{\text{p}} + w^{\text{v}} r_t^{\text{v}} + w^{\text{bp}} r_t^{\text{bp}} + w^{\text{bv}} r_t^{\text{bv}}$$

$$w^{\text{p}} = 0.6, \quad w^{\text{v}} = 0.1, \quad w^{\text{bp}} = 0.15, \quad w^{\text{bv}} = 0.15$$

where the pose reward r_t^{p}, velocity reward r_t^{v}, base position reward r_t^{bp}, base velocity reward r_t^{bv} terms are defined according to:

$$r_t^{\text{p}} = \exp\left[-5 \sum_j \|\hat{q}_t^j - q_t^j\|^2\right]$$

$$r_t^{\text{v}} = \exp\left[-0.01 \sum_j \|\hat{\dot{q}}_t^j - \dot{q}_t^j\|^2\right]$$

$$r_t^{\text{bp}} = \exp\left[-20\|\hat{\mathbf{x}}_t^{\text{base}} - \mathbf{x}_t^{\text{base}}\|^2 - 10\|\hat{\mathbf{q}}_t^{\text{base}} - \mathbf{q}_t^{\text{base}}\|^2\right]$$

$$r_t^{\text{bv}} = \exp\left[-2\|\hat{\dot{\mathbf{x}}}_t^{\text{base}} - \dot{\mathbf{x}}_t^{\text{base}}\|^2 - 0.2\|\hat{\dot{\mathbf{q}}}_t^{\text{base}} - \dot{\mathbf{q}}_t^{\text{base}}\|^2\right]$$

where at timestep t,

- q_t^j represents the local joint rotation of joint j of the robot
- $\dot{q}_t^j$ represents the local joint angular velocity of joint j of the robot
- $\mathbf{x}_t^{\text{base}}$ represents the global position of the robot
- $\dot{\mathbf{x}}_t^{\text{base}}$ represents the linear velocity of the robot
- $\mathbf{q}_t^{\text{base}}$ represents the 3D base rotation of the robot
- $\dot{\mathbf{q}}_t^{\text{base}}$ represents the angular velocity of the robot
- $\hat{q}_t^j$ represents the local joint rotation of joint j from the reference motion
- $\hat{\dot{q}}_t^j$ represents the local joint angular velocity of joint j from the reference motion
- $\hat{\mathbf{x}}_t^{\text{base}}$ represents the global position from the reference motion
- $\hat{\dot{\mathbf{x}}}_t^{\text{base}}$ represents the linear velocity from the reference motion
- $\hat{\mathbf{q}}_t^{\text{base}}$ represents the 3D base rotation from the reference motion
- $\hat{\dot{\mathbf{q}}}_t^{\text{base}}$ represents the angular velocity from the reference motion

The pose reward encourages the robot to match its local joint rotations $\mathbf{q}_t$ with those specified by the reference motion. The velocity reward r_t^{v} encourages the robot to match the joint velocities of the reference motion. The base position reward r_t^{bp} encourages the robot to track the base position and rotation of the reference motion. The base velocity reward r_t^{bv} encourages the robot to move at the same speed as the reference motion.

Appendix C Policy Network Structure and State Initialization

We represent the actor policy network using a MLP with hidden layers $[1024, 512]$ and ReLU nonlinearity. The network for the value function uses the same structure for the hidden layers and linear activation for the final output layer. During the initialization of each episode, the robot uniformly samples a pose from the reference motion as its initial pose with probability 0.9, and is initialized from a nominal standing pose with probability 0.1.

Appendix D Dynamics Randomization Ranges

Table 3: Ranges of Randomization Parameters used in Simulation

Parameter	**Randomization Range**
Link mass	$[0.8, 1.2] \times$ default value
Link inertia	$[0.5, 1.5] \times$ default value
Ground friction	$[0.5, 1.25]$
Motor strength	$[0.8, 1.2] \times$ default value
Joint-level PD gains	$[0.7, 1.3] \times$ default value
Motor damping ratio	$[0, 0.05]$ Nms/rad
Latency	$[0.0, 0.04]$ s

The default values used in the table refer to the values (mass, inertia, etc.) from the underlying morphology—note that during training, these values were themselves produced by randomization within the morphology generation procedure.

Appendix E Existing Robot Specifications

Parameter	**A1**	**Go1**	**Laikago**	**Sirius**	**Aliengo**
Total weight (kg)	12	13	24	23	21
Base length (m)	0.27	0.38	0.56	0.44	0.65
Base width (m)	0.19	0.09	0.17	0.14	0.15
Base height (m)	0.11	0.11	0.19	0.22	0.11
Height, fully standing (m)	0.4	0.4	0.54	0.54	0.6
Thigh Length (m)	0.20	0.22	0.26	0.27	0.26
Calf Length (m)	0.20	0.22	0.26	0.27	0.26
	Mini Cheetah	**Spot**	**ANYmal-B**	**ANYmal-C**	**SpotMicro**
Total weight (kg)	9	32	30	50	4.8
Base length (m)	0.3	0.90	0.53	0.58	0.14
Base width (m)	0.2	0.26	0.27	0.14	0.11
Base height (m)	0.09	0.22	0.24	0.18	0.07
Height, fully standing (m)	0.4	0.7	0.5	0.65	0.26
Thigh Length (m)	0.20	0.43	0.27	0.3	0.12
Calf Length (m)	0.19	0.44	0.27	0.3	0.12

The robot parameters reported in this table were measured using the open-source design files of each robot.