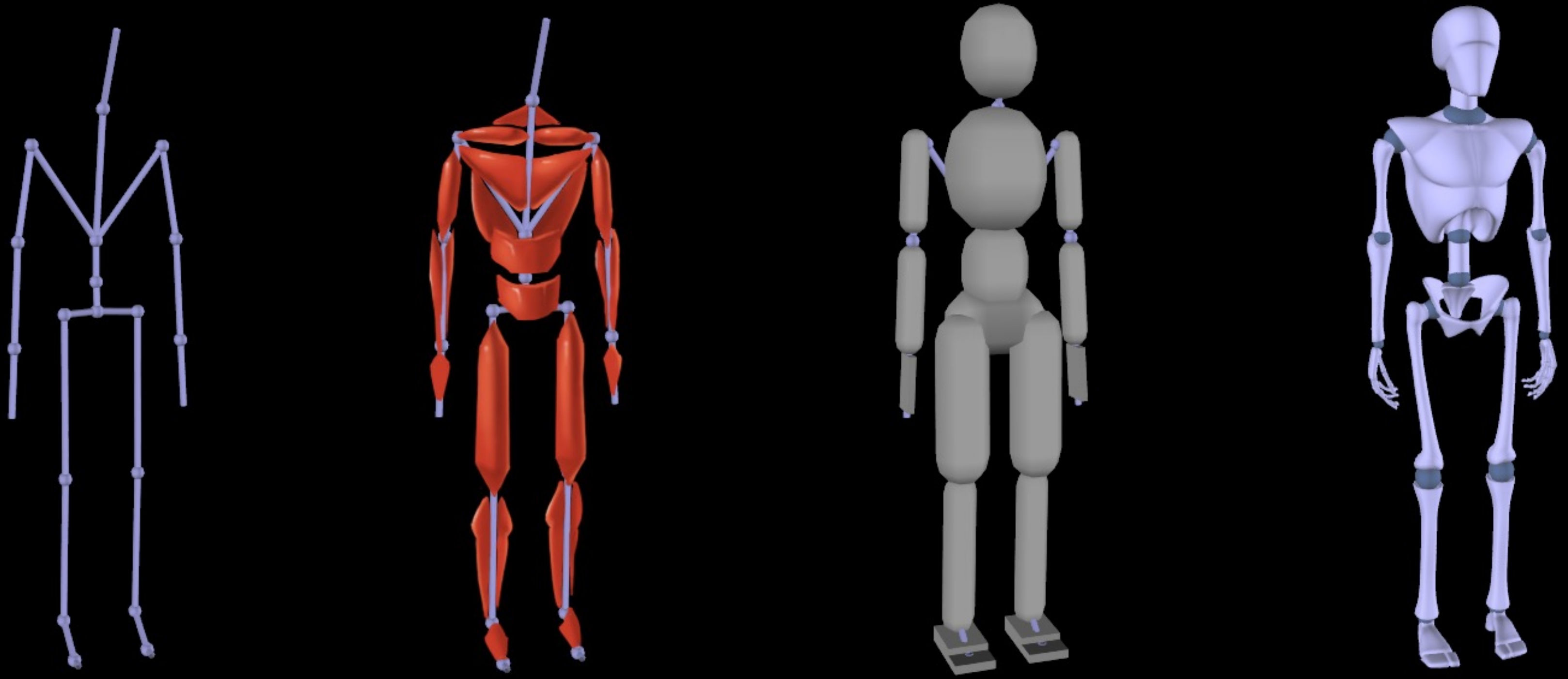
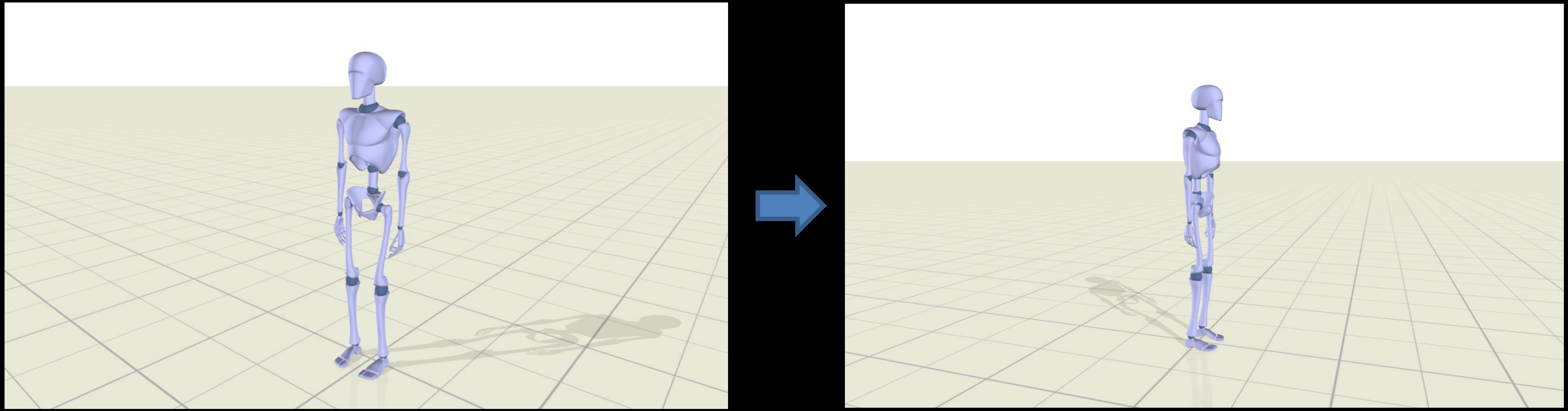
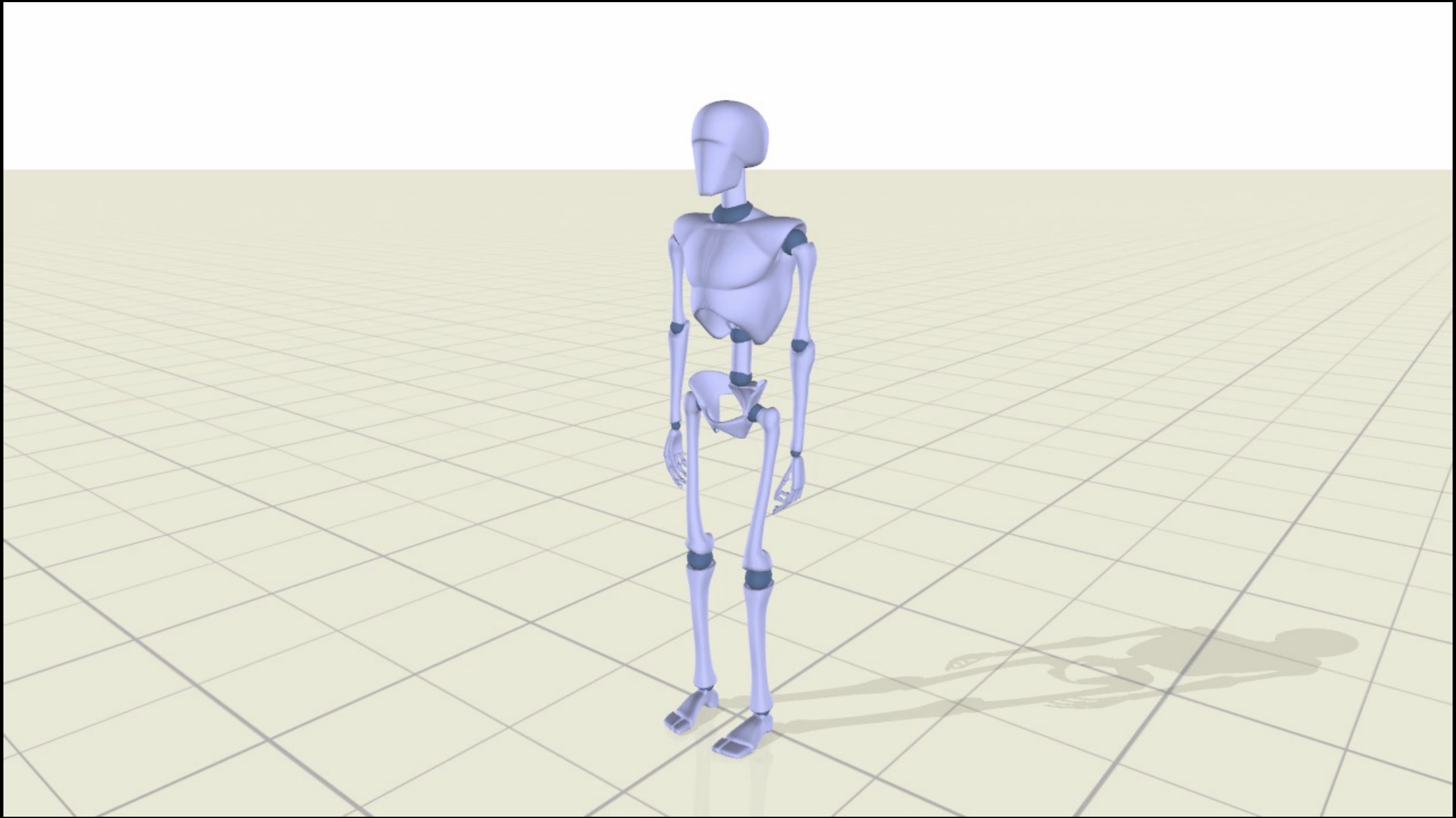
Modeling Humans & Animals

Simulation Model

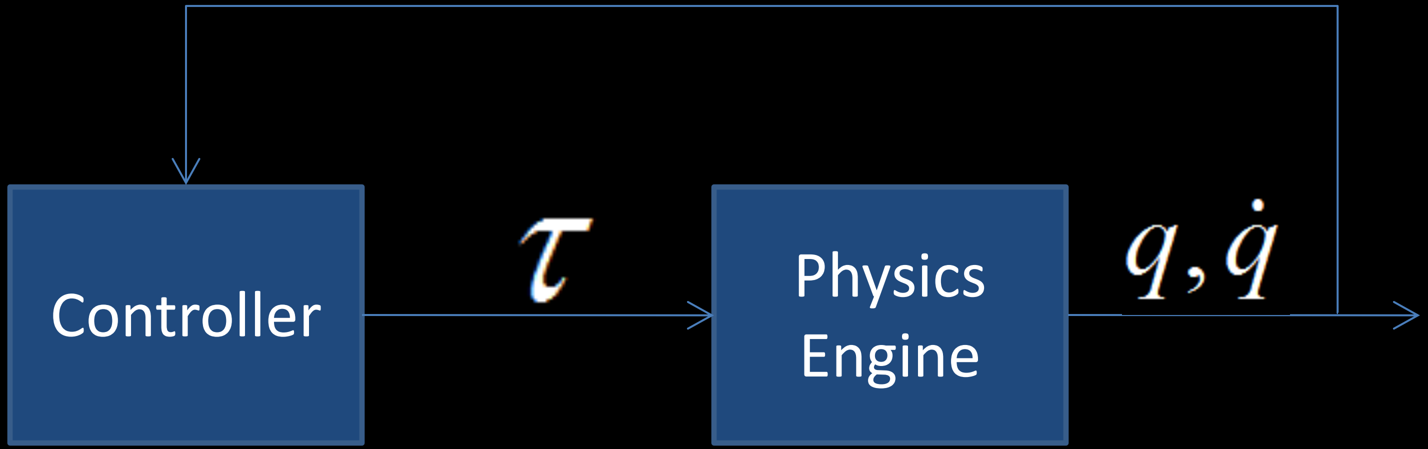


Joint Hierarchy | Virtual Actuators | Proxy Geometry | Visualization Mesh

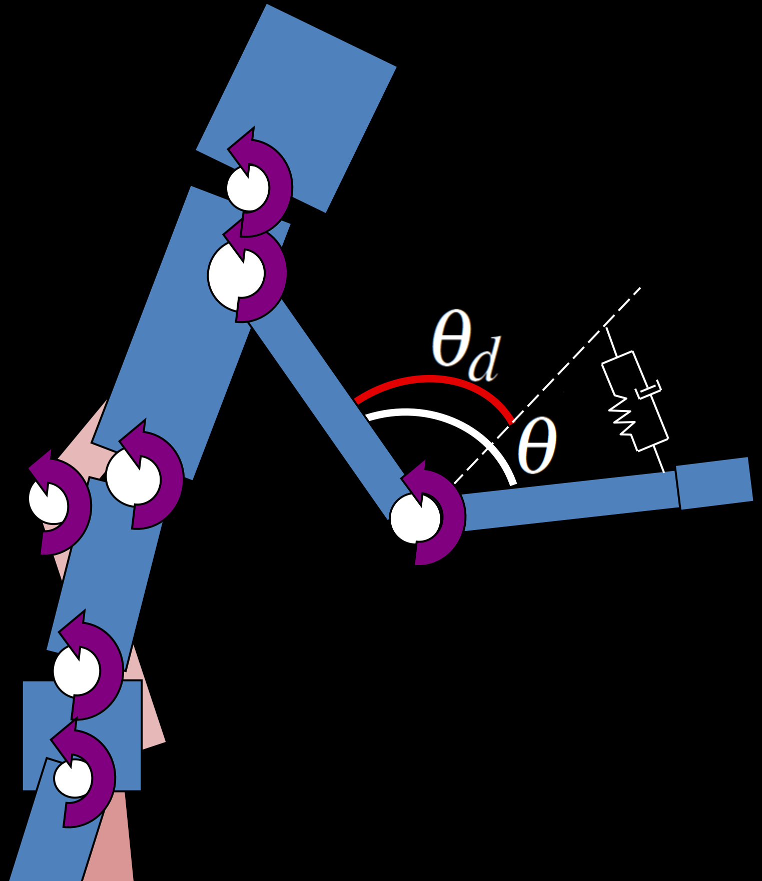




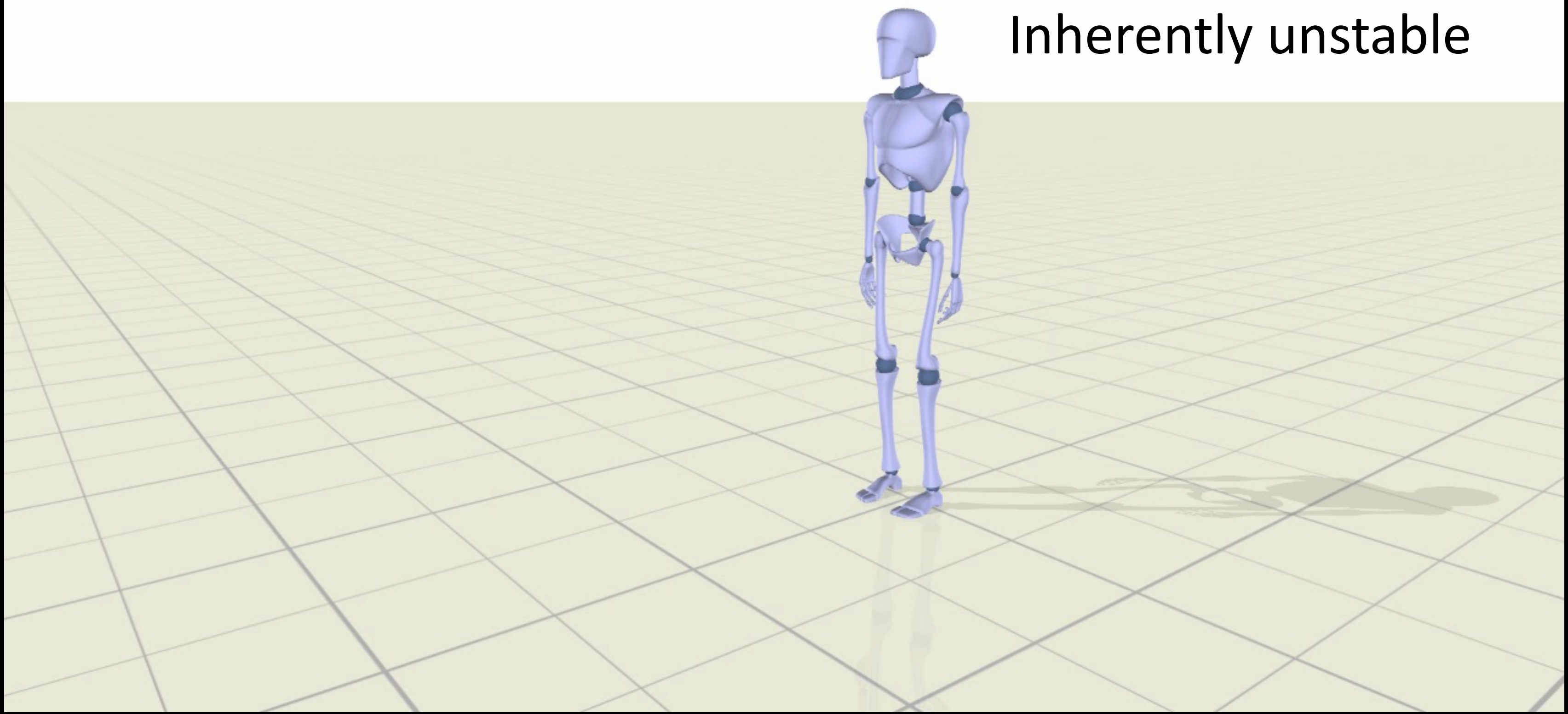
Physics-based Animation

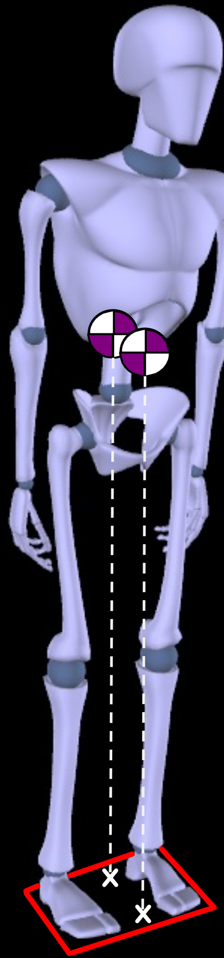


Posture Control

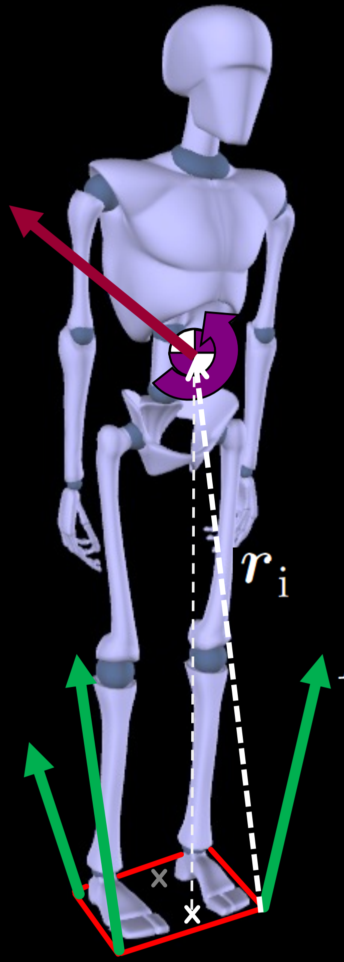


Under actuated
Inherently unstable





$$\underbrace{\begin{bmatrix} \boldsymbol{F}^d \\ \boldsymbol{T}^d \end{bmatrix}}_{\boldsymbol{b}} = \boldsymbol{k_p}(\boldsymbol{q}_b^d - \boldsymbol{q}_b) + \boldsymbol{k_d}(\dot{\boldsymbol{q}}_b^d - \dot{\boldsymbol{q}}_b) + \boldsymbol{k_{ff}}$$

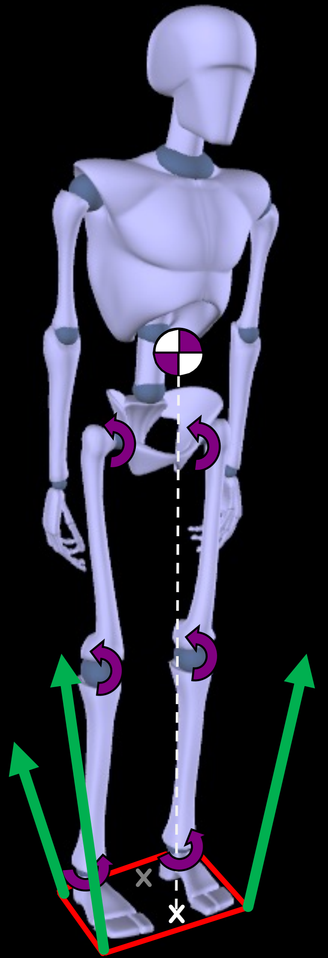


$$\underbrace{\begin{bmatrix} \boldsymbol{I} & \boldsymbol{I} & \cdots & \boldsymbol{I} \\ \boldsymbol{r_0}\times & \boldsymbol{r_1}\times & \cdots & \boldsymbol{r_m}\times \end{bmatrix}}_{A} \underbrace{\begin{pmatrix} \boldsymbol{F}_0 \\ \boldsymbol{F}_1 \\ \vdots \\ \boldsymbol{F}_{\mathrm{m}} \end{pmatrix}}_{\boldsymbol{x}} = \begin{pmatrix} \boldsymbol{F}_{\mathrm{B}} \\ \boldsymbol{T}_{\mathrm{B}} \end{pmatrix}$$

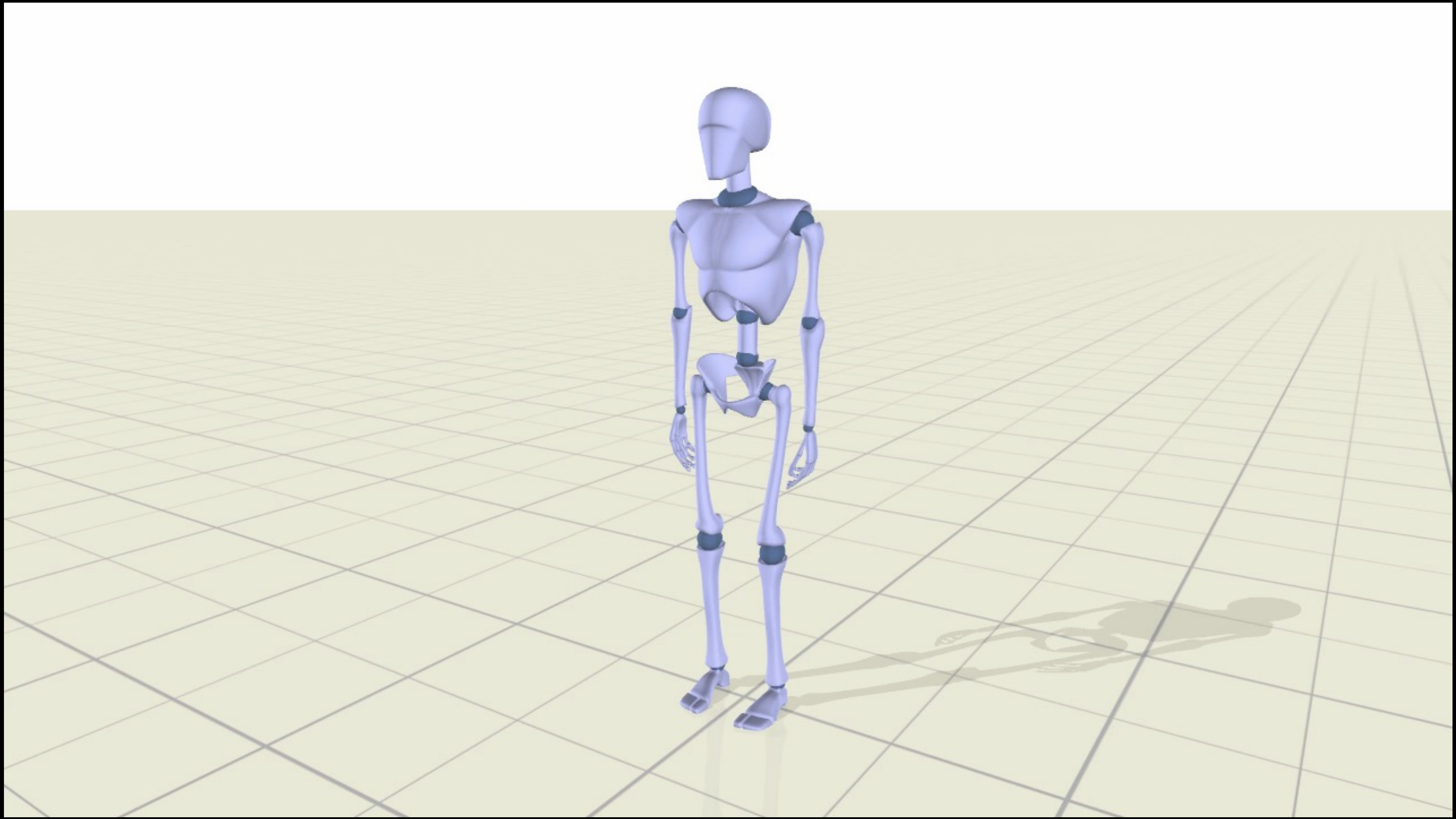
$$\min\,(A\boldsymbol{x} - \boldsymbol{b})^{\mathrm{T}}(A\boldsymbol{x} - \boldsymbol{b})$$

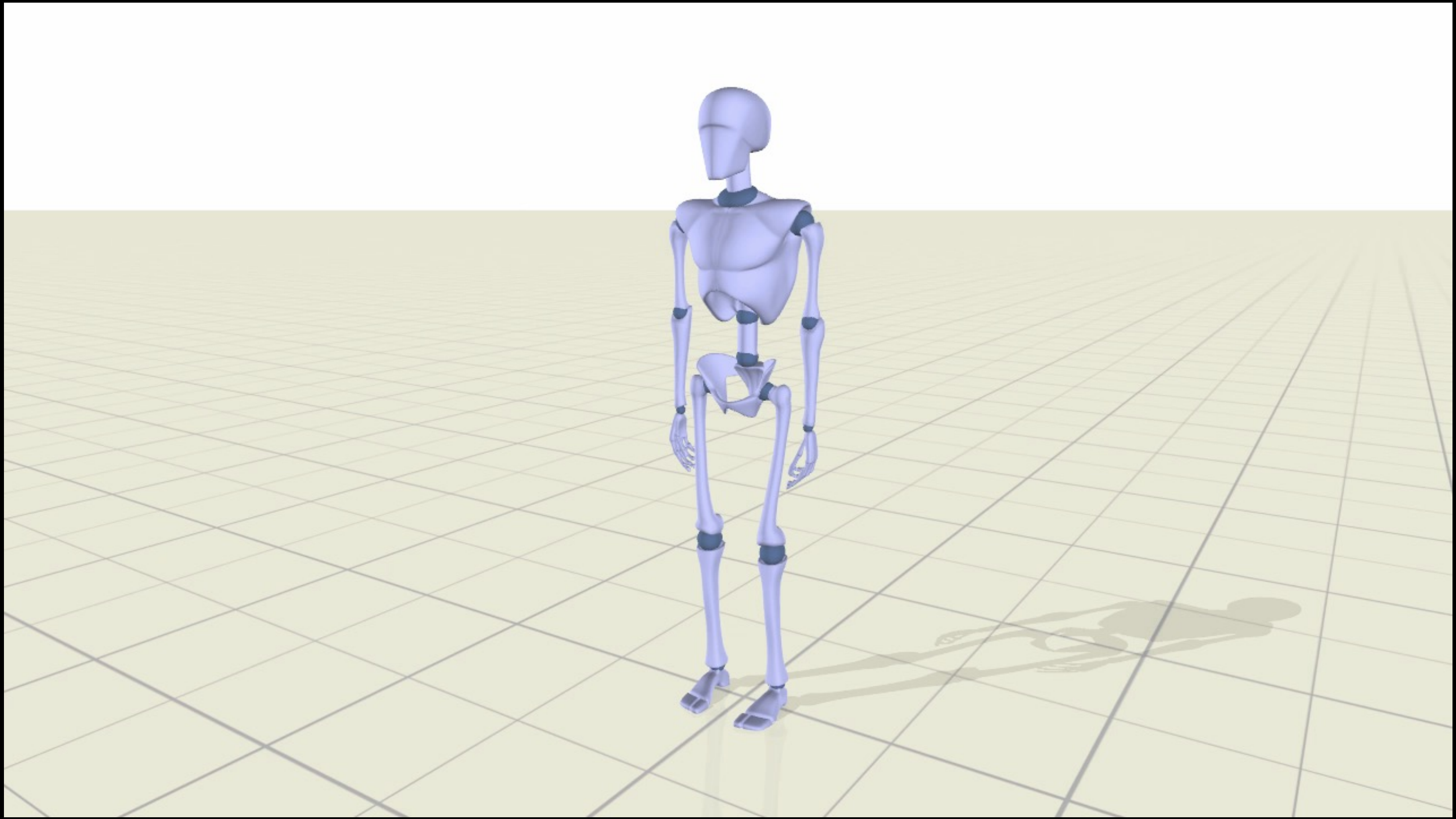
$$\text{subject to}\; F_{\mathrm{i}}^n \geq F_{\min}^n$$

$$-\mu F_{\mathrm{i}}^n \leq F_{\mathrm{i}}^t \leq \mu F_{\mathrm{i}}^n$$



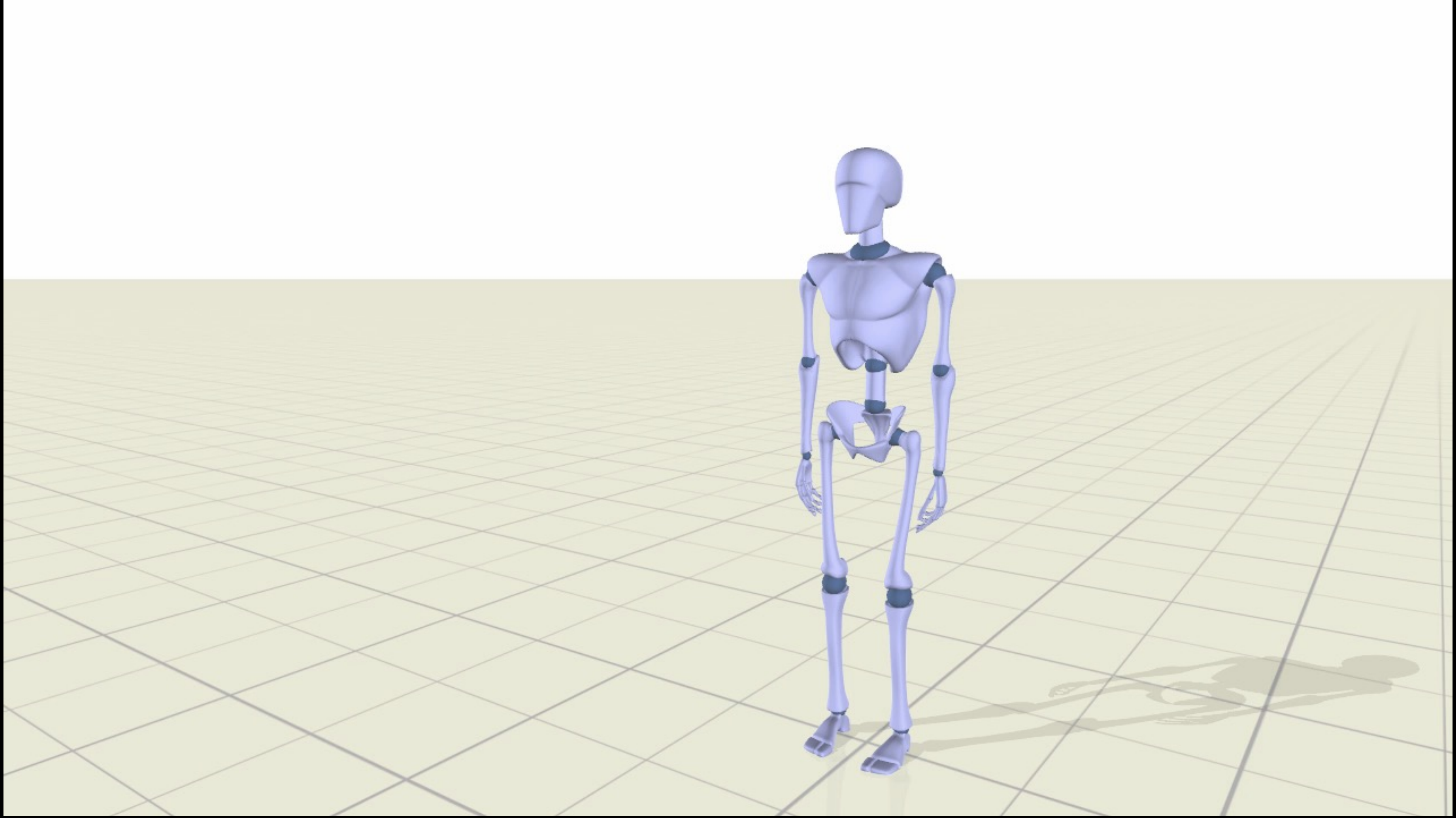
$$\boldsymbol{\tau} = J^T \boldsymbol{F}$$





Walking

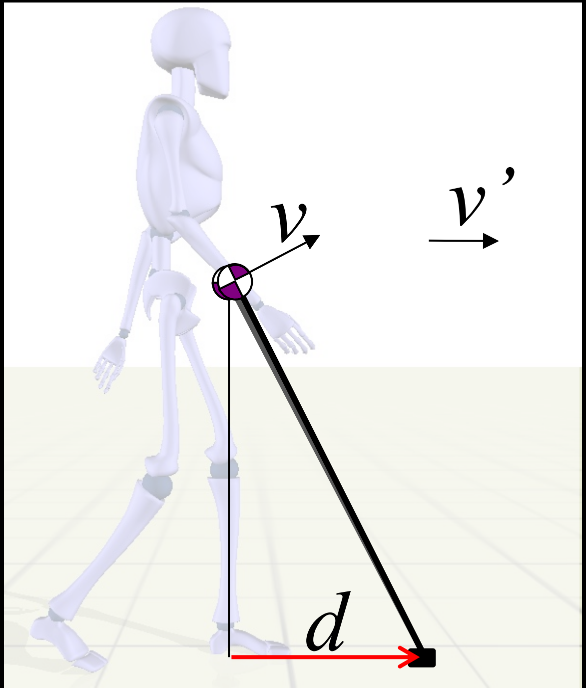
- Described temporally in terms of stride duration and its two components per leg, swing time and stance time



Walking

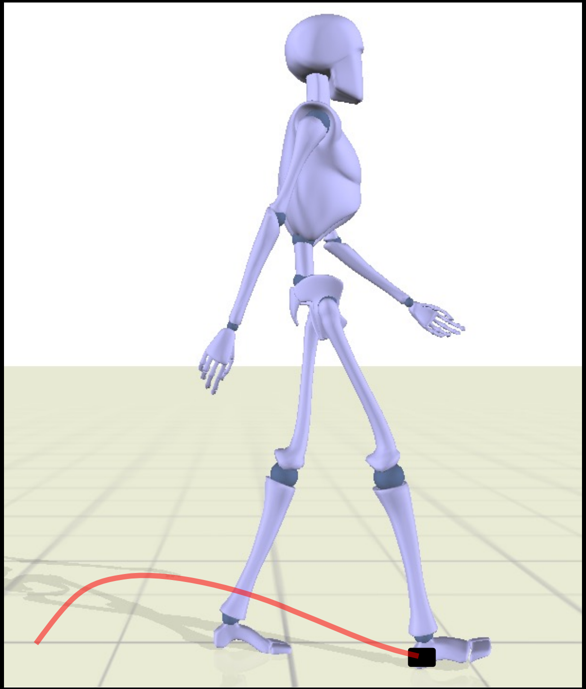
- Described temporally in terms of stride duration and its two components per leg, swing time and stance time, and spatially in terms of foot placement locations

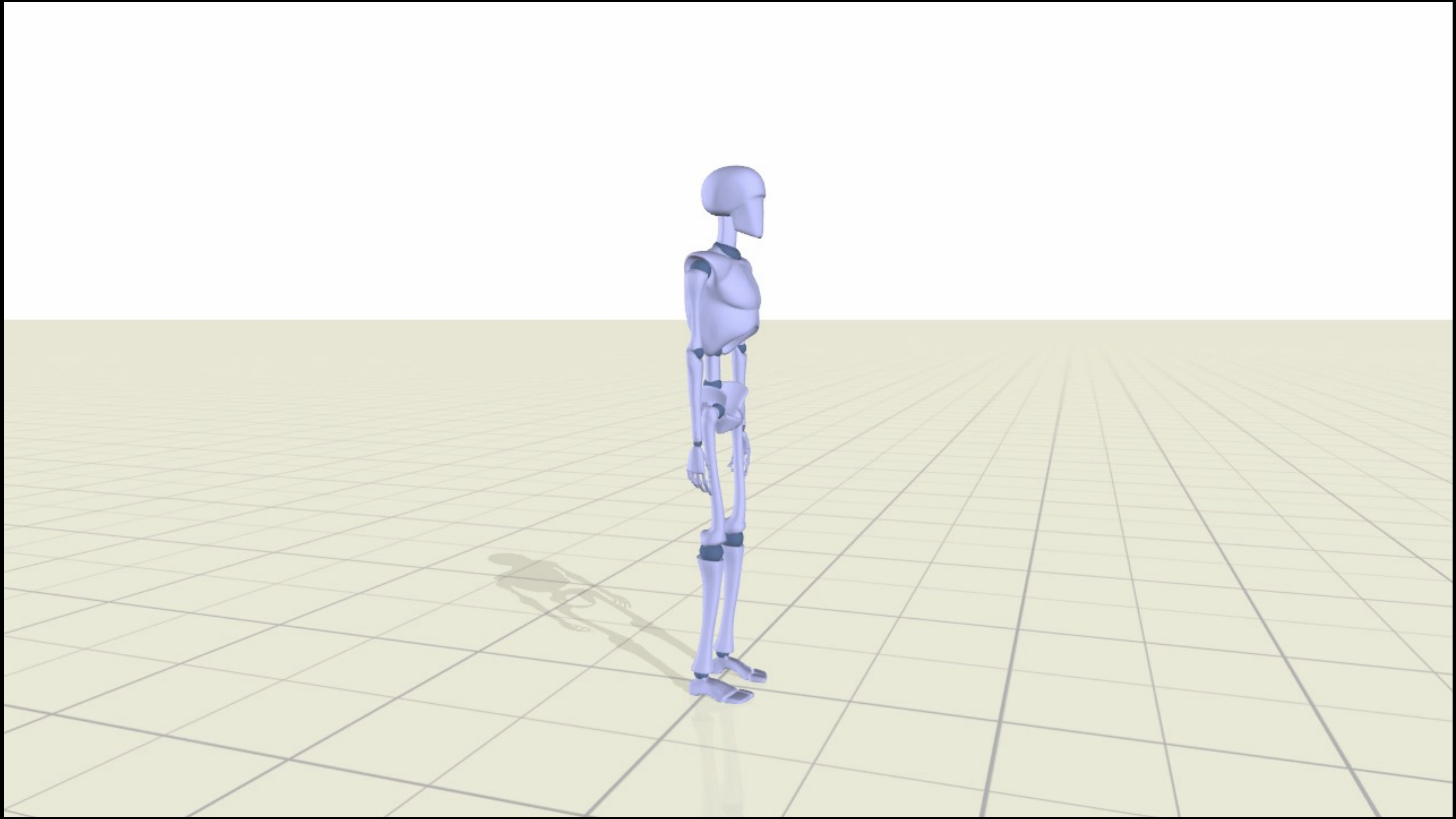
Foot Placement Control



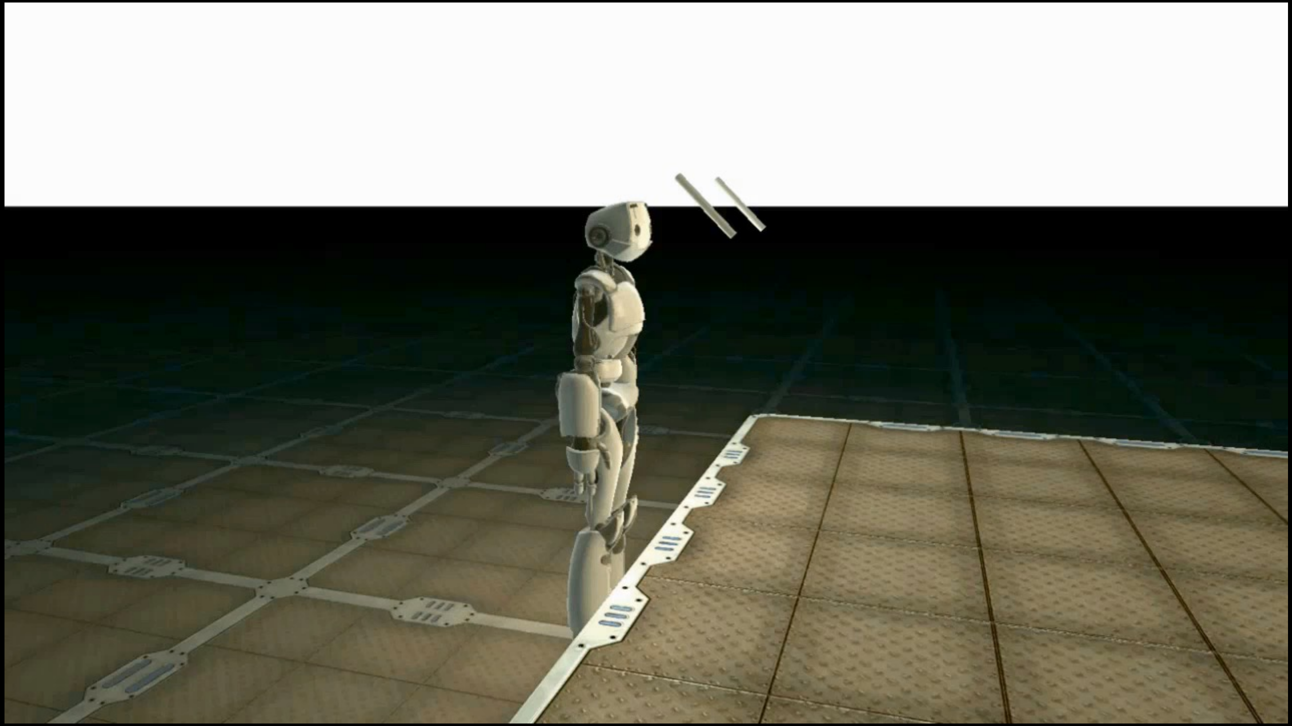
$$d = d_f(v_d) + (v - v_d)\sqrt{\frac{h}{g}}$$

Foot Placement Control





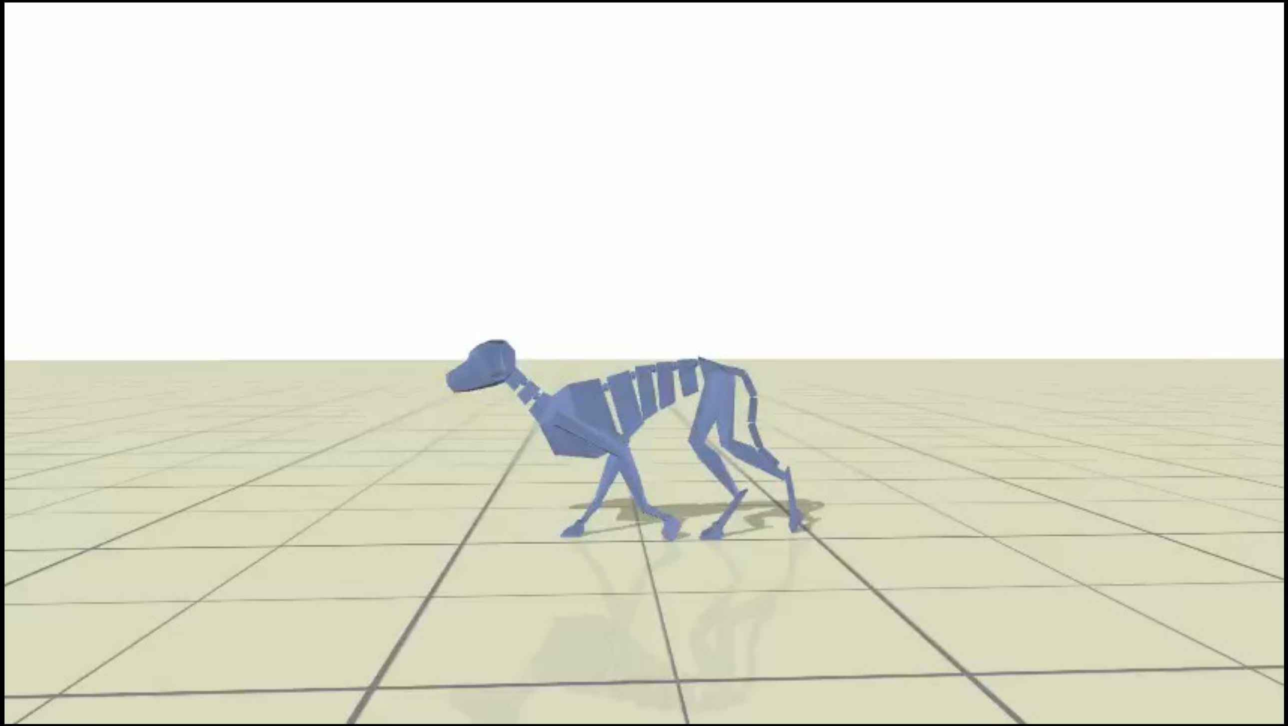
Towards Increasingly Complex Motor Skills



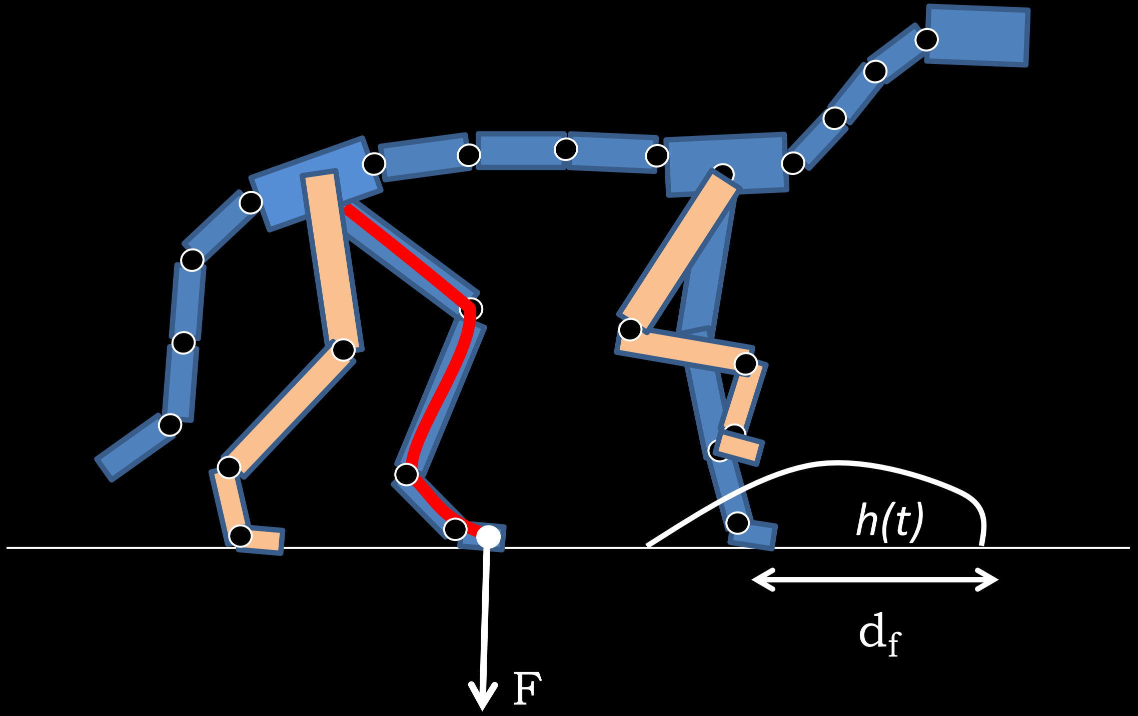
Quadrupedal Gaits

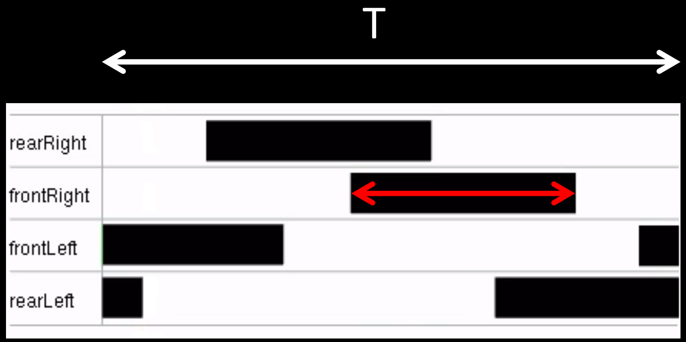
Trot

Canter

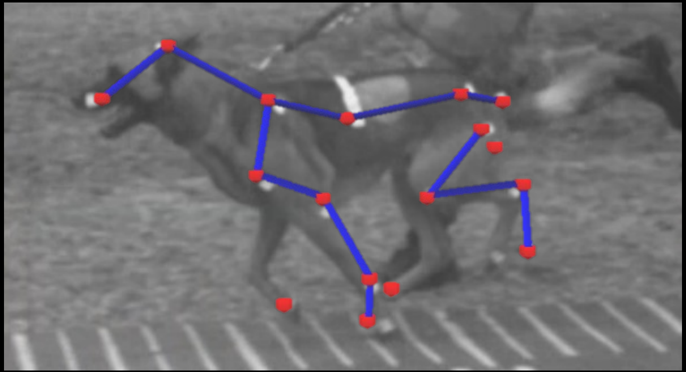


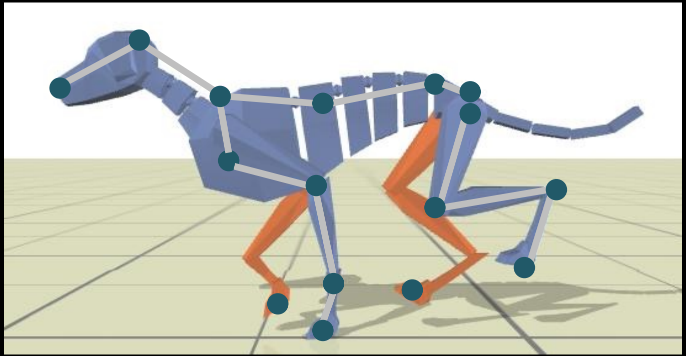
Controller Parameterization





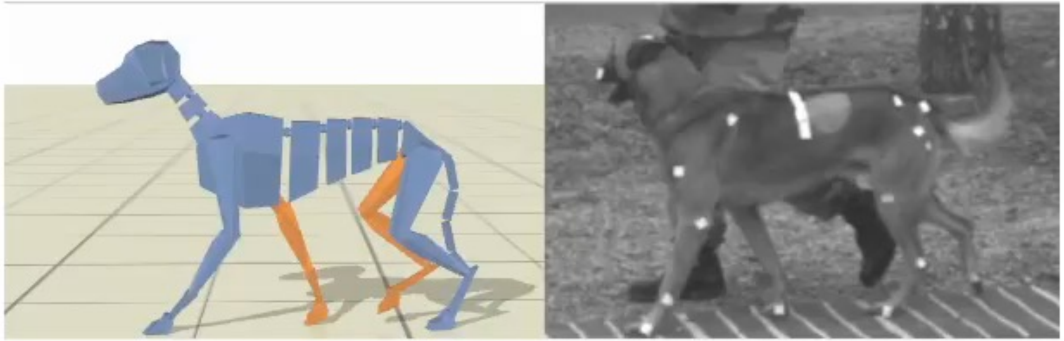
Motion Data

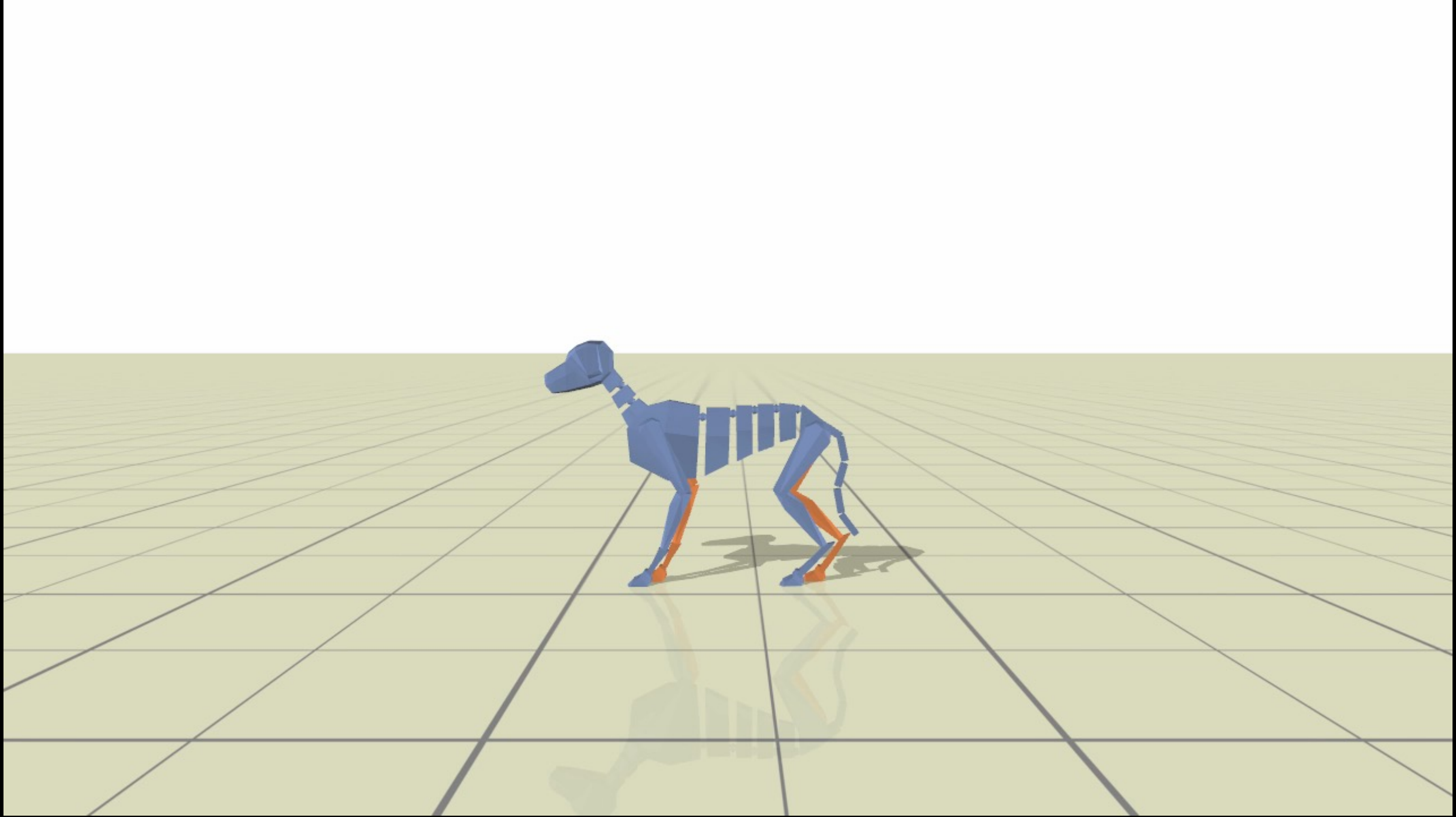


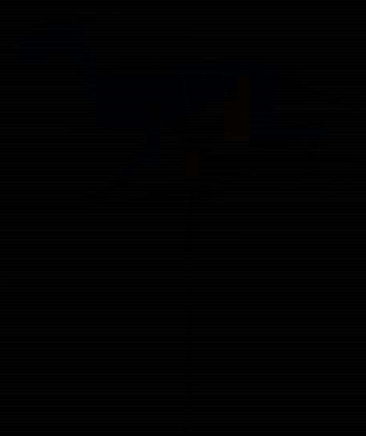


After Learning

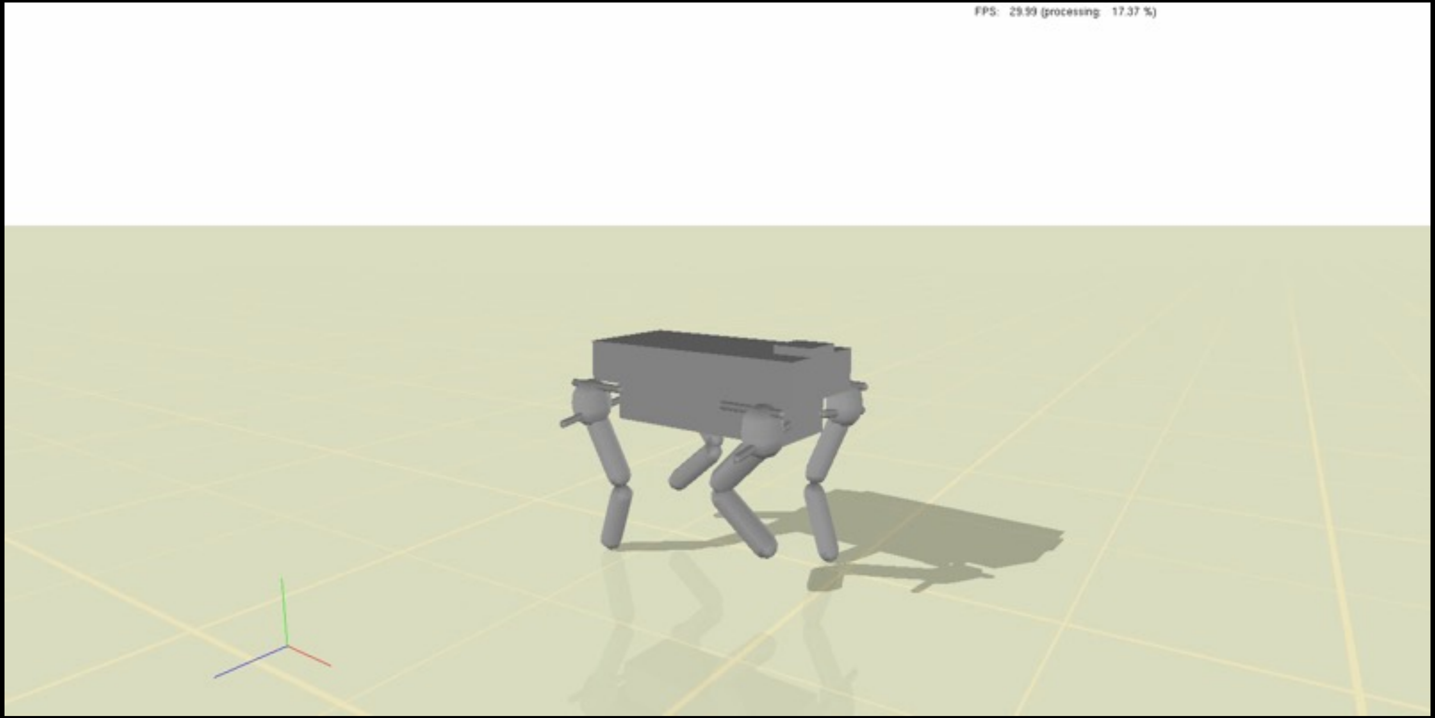
walk



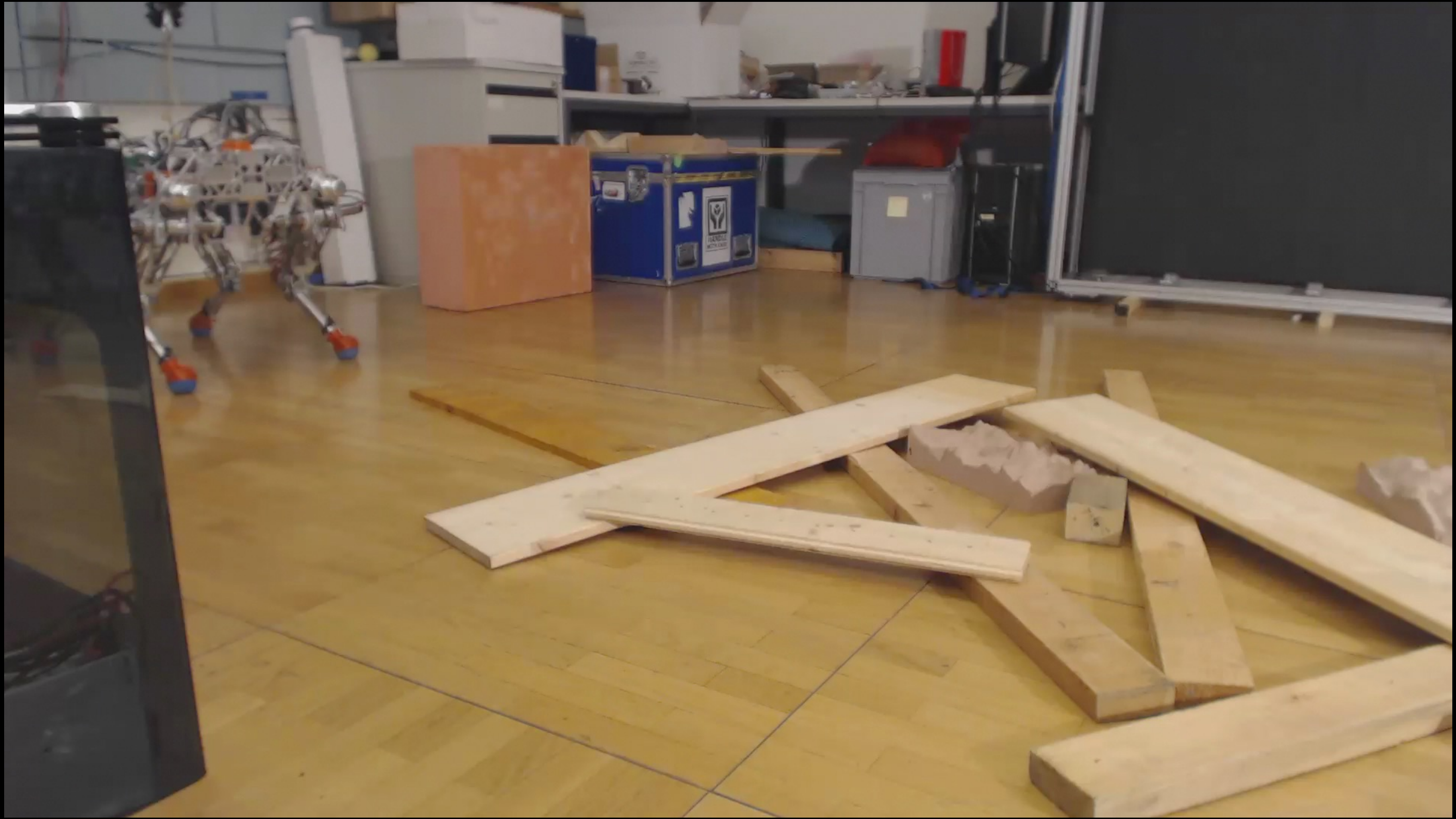




Locomotion Control for Legged Robots



Locomotion Control for Legged Robots



Physics simulation and sampling

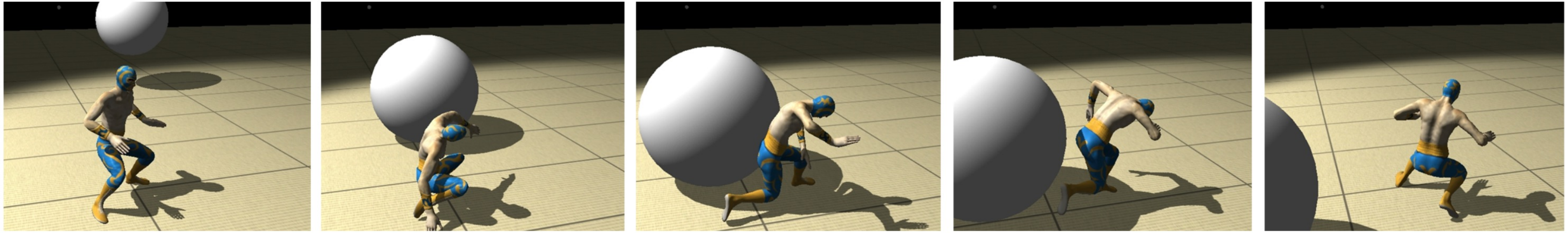
Online Motion Synthesis Using Sequential Monte Carlo

Perttu Hämäläinen[1] Sebastian Eriksson[1] Esa Tanskanen[1] Ville Kyrki[1] Jaakko Lehtinen[1,2]

[1]Aalto University [2]NVIDIA Research

To appear in Proc. SIGGRAPH 2014.

Part of the Future Game Animation project.



An example of emergent evasive behavior generated by our method.

https://mediatech.aalto.fi/publications/graphics/OnlineSMC/

Physics simulation and sampling

Online Control of Simulated Humanoids Using Particle Belief Propagation

Perttu Hämäläinen[1] Joose Rajamäki[1] C. Karen Liu[2]

[1]Aalto University [2]Georgia Tech

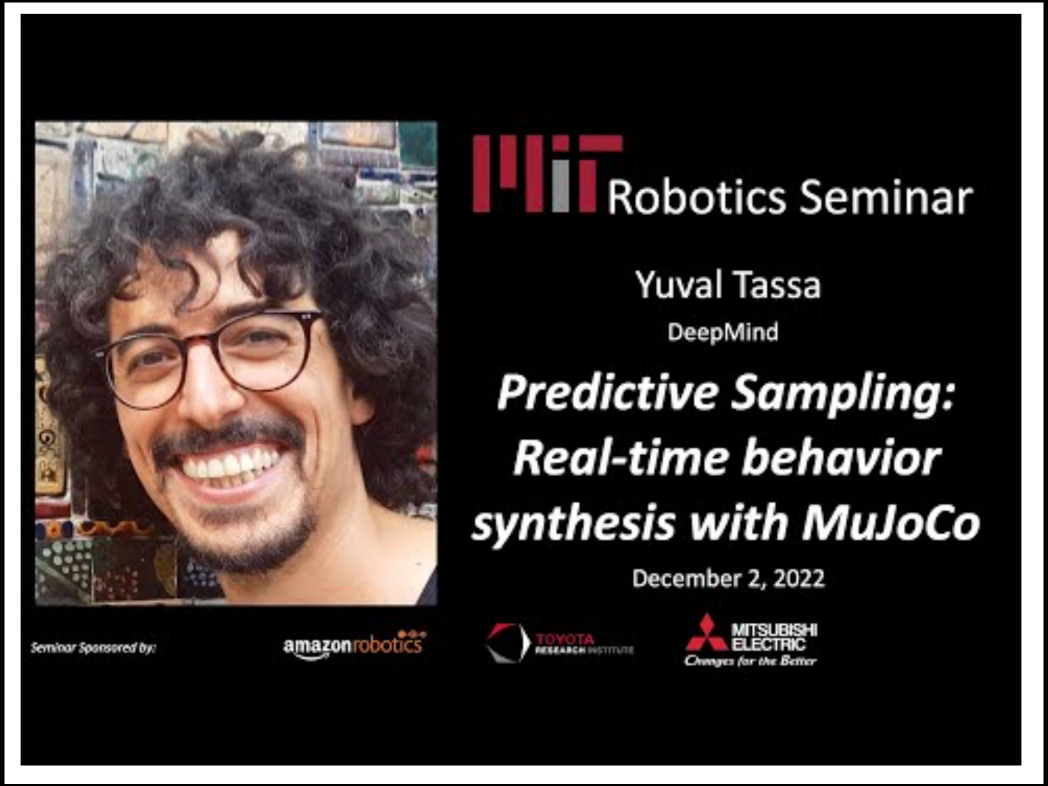
To appear in Proc. SIGGRAPH 2015.

Part of the Future Game Animation project.

Our algorithm can handle complex balancing and manipulation tasks while adapting to user interactions. All our demonstrated movements emerge from simple cost functions without animation data or offline precomputation.

https://mediatech.aalto.fi/publications/graphics/C-PBP/

Physics simulation and sampling



https://github.com/deepmind/mujoco_mpc

Improving the biomechanical model

Flexible Muscle-Based Locomotion for Bipedal Creatures

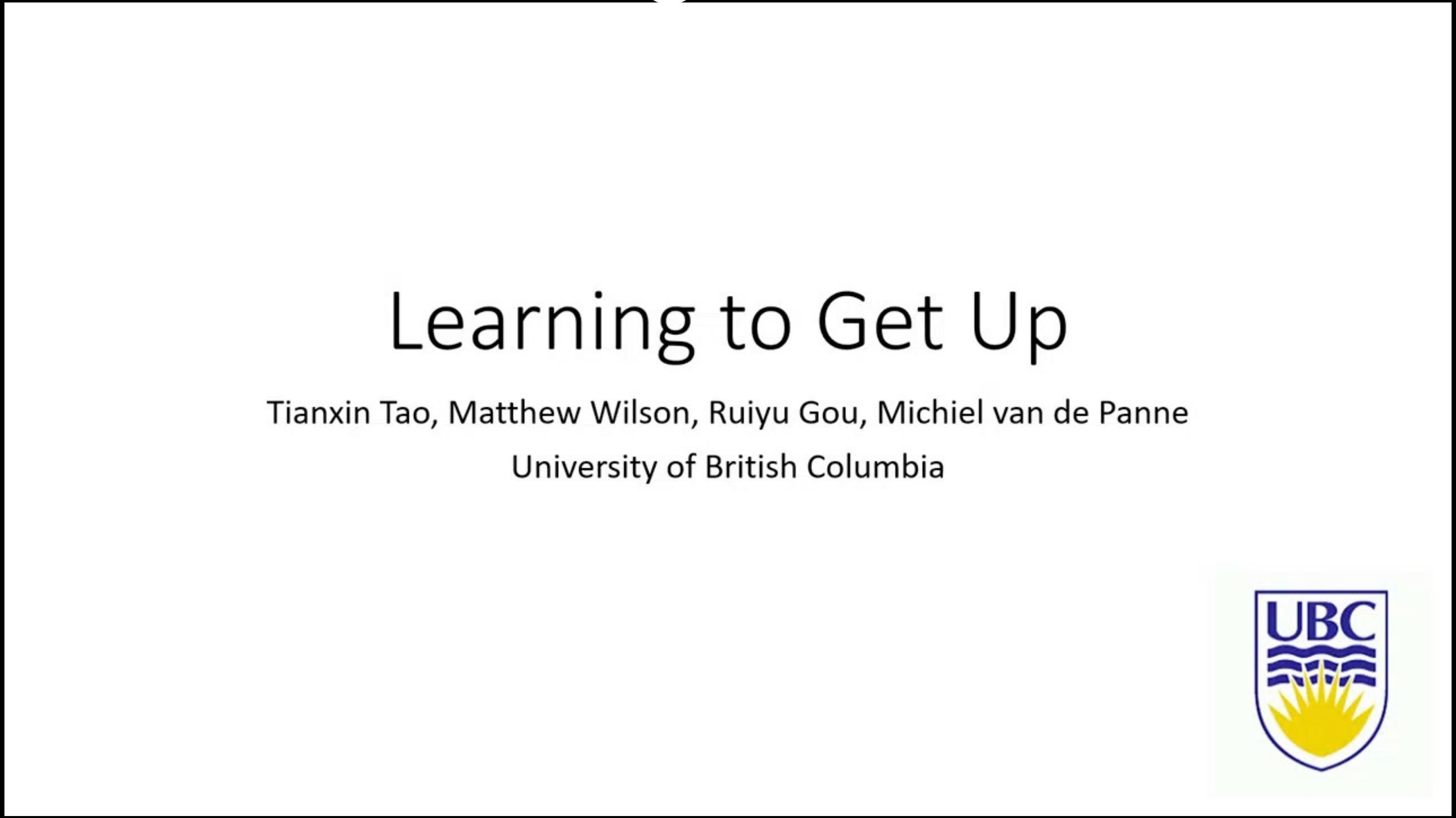
SIGGRAPH ASIA 2013

Thomas Geijtenbeek
Michiel van de Panne
Frank van der Stappen

Learning new skills

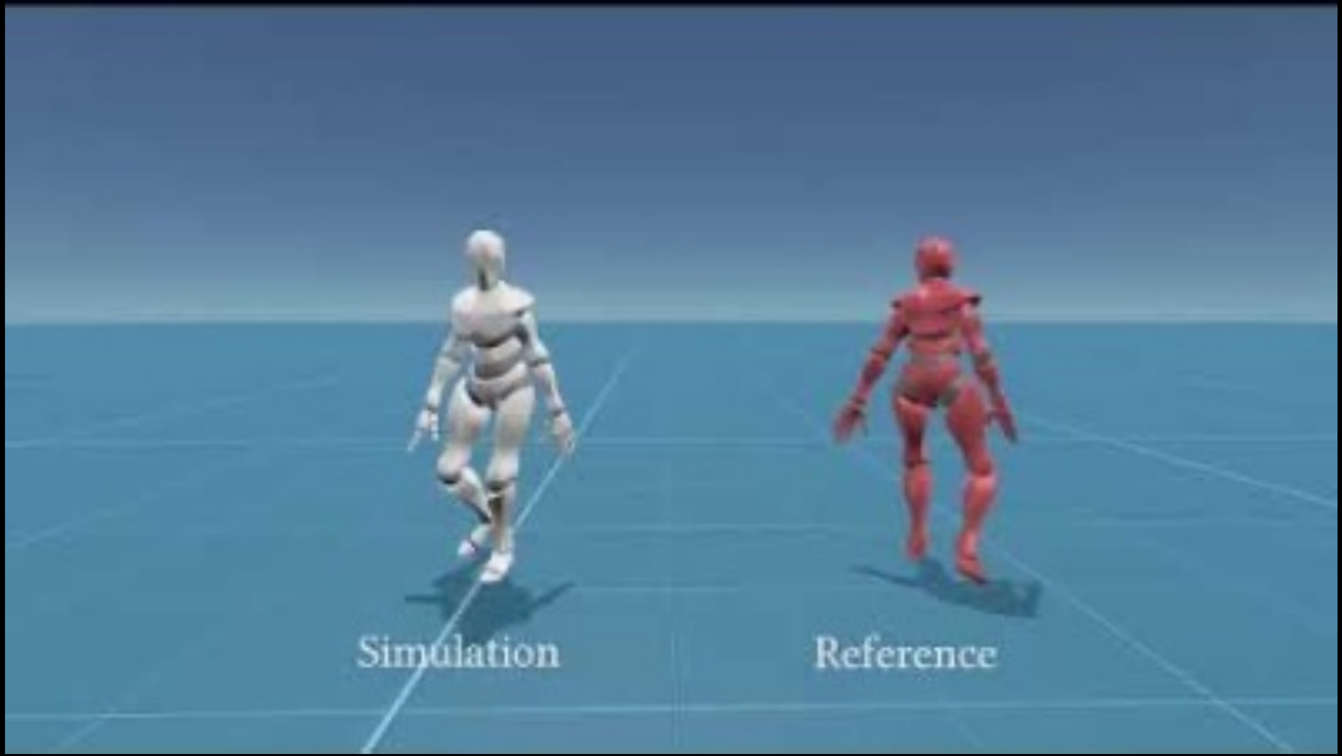
Tan, Jie, Yuting Gu, C. Karen Liu, and Greg Turk. "Learning bicycle stunts." *ACM Transactions on Graphics (TOG)* 33, no. 4 (2014): 1-12.

Learning new skills



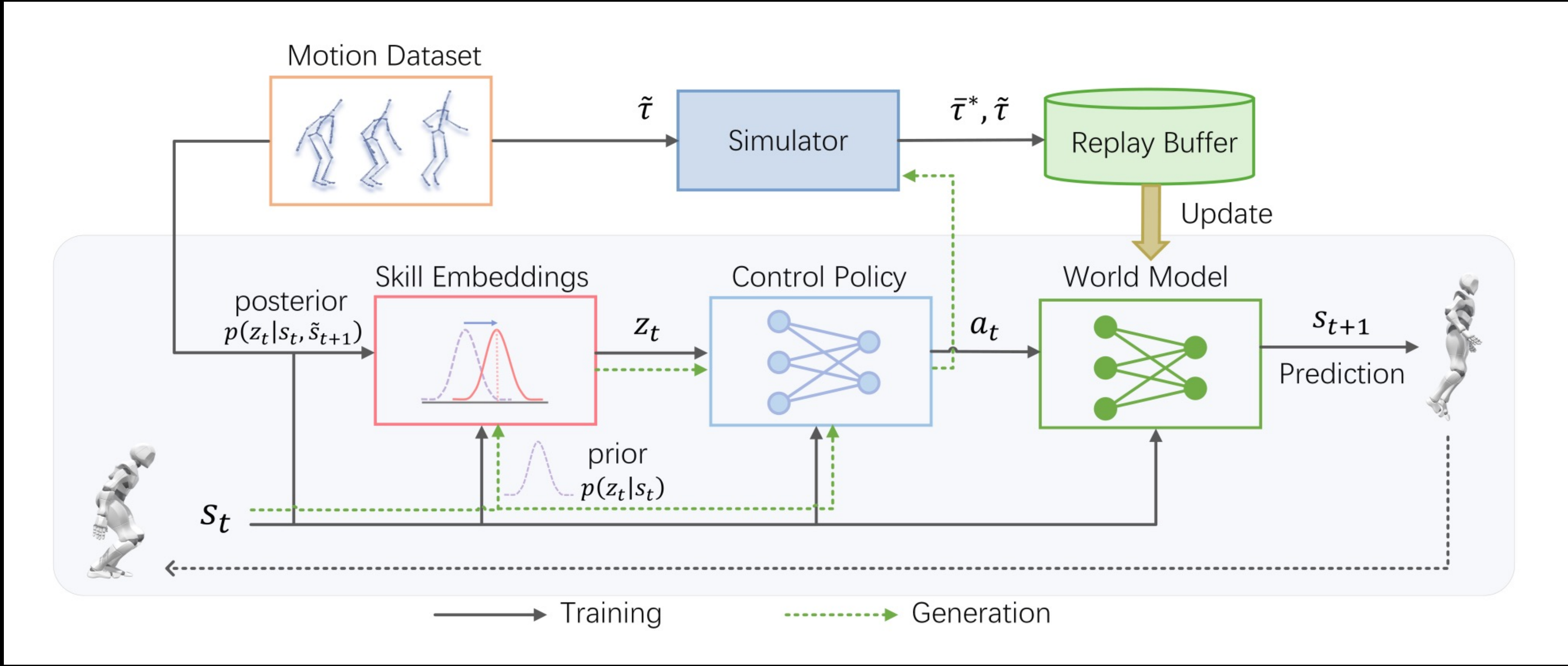
Tao, Tianxin, Matthew Wilson, Ruiyu Gou, and Michiel Van De Panne. "Learning to get up." In *ACM SIGGRAPH 2022 Conference Proceedings*, pp. 1-10. 2022.

Learning new skills



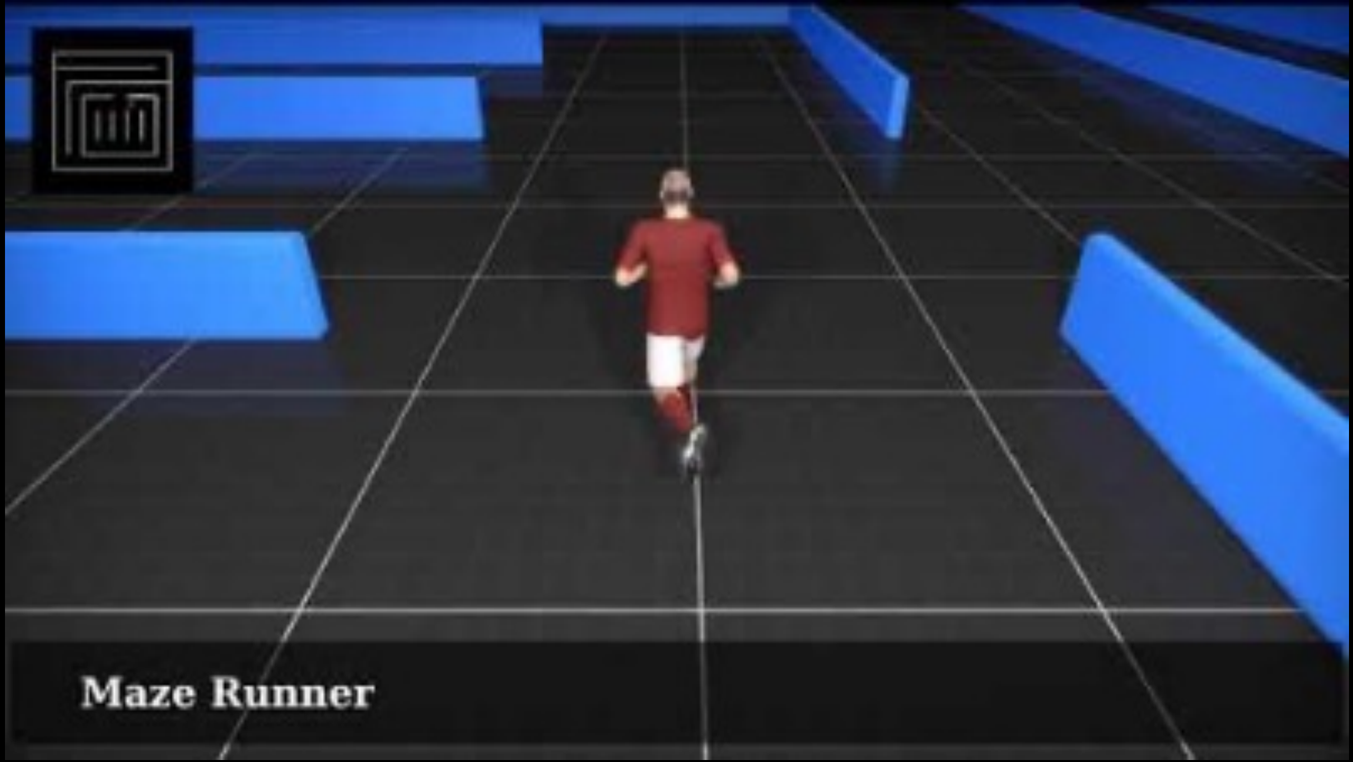
Yao, Heyuan, Zhenhua Song, Baoquan Chen, and Libin Liu. "ControlVAE: Model-Based Learning of Generative Controllers for Physics-Based Characters." *ACM Transactions on Graphics (TOG)* 41, no. 6 (2022): 1-16.

What is a VAE?



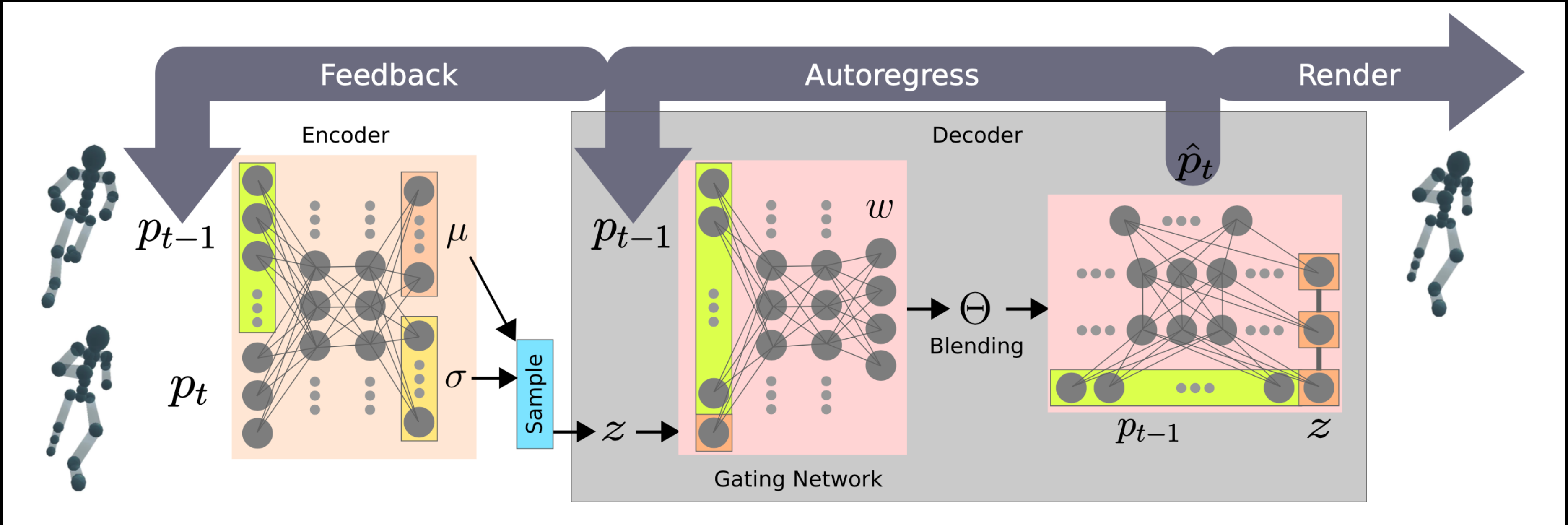
Yao, Heyuan, Zhenhua Song, Baoquan Chen, and Libin Liu. "ControlVAE: Model-Based Learning of Generative Controllers for Physics-Based Characters." *ACM Transactions on Graphics (TOG)* 41, no. 6 (2022): 1-16.

VAE without simulation



Ling, Hung Yu, Fabio Zinno, George Cheng, and Michiel Van De Panne. "Character controllers using motion vaes." *ACM Transactions on Graphics (TOG)* 39, no. 4 (2020): 40-1.

VAE without simulation



Ling, Hung Yu, Fabio Zinno, George Cheng, and Michiel Van De Panne. "Character controllers using motion vaes." *ACM Transactions on Graphics (TOG)* 39, no. 4 (2020): 40-1.

Creating variation from limited motion

Li, Peizhuo, Kfir Aberman, Zihan Zhang, Rana Hanocka, and Olga Sorkine-Hornung. "Ganimator: Neural motion synthesis from a single sequence." *ACM Transactions on Graphics (TOG)* 41, no. 4 (2022): 1-12.

What about performance?

Curtis, Cassidy, Sigurdur Orn Adalgeirsson, Horia Stefan Ciurdar, Peter McDermott, J. D. Velásquez, W. Bradley Knox, Alonso Martinez et al. "Toward Believable Acting for Autonomous Animated Characters." In *Proceedings of the 15th ACM SIGGRAPH Conference on Motion, Interaction and Games*, pp. 1-15. 2022.