

Modeling Humans & Animals

But first, final projects

- Final Project (50%)
 - Paper presentation & project proposal (20%)
 - Final report & presentation (30%)
 - Progress Report Presentation, next class (10%)
 - Final Report (20%) due latest on May 9
 - 1-2 page write-up, final video demonstration



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Barry Goyette / CC-BY-2.0



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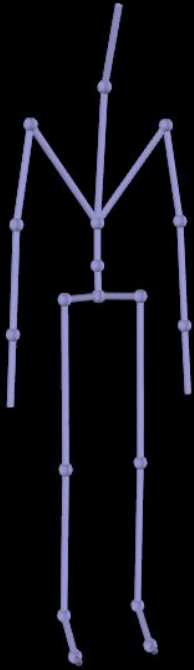


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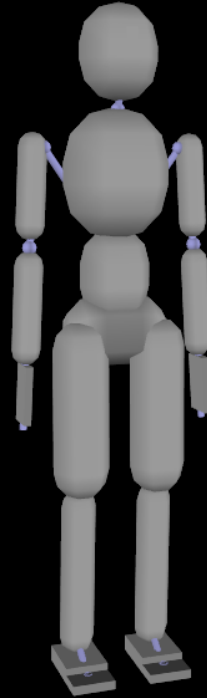
Simulation Model



Joint Hierarchy



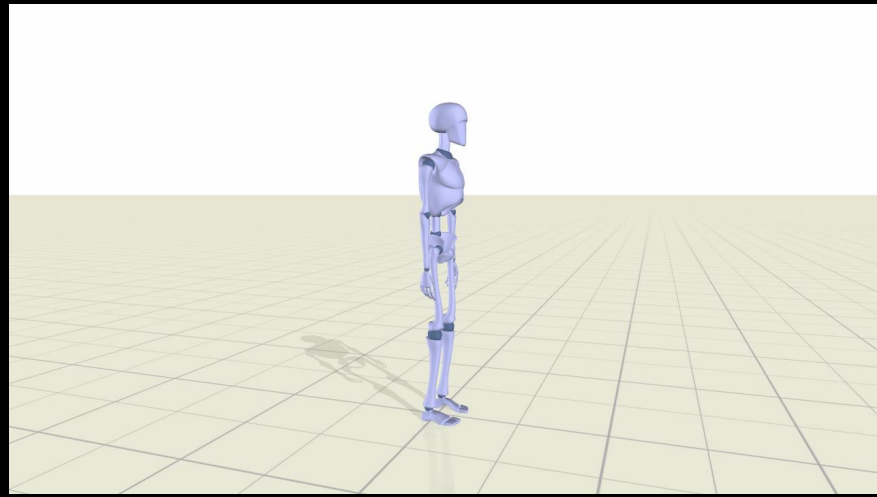
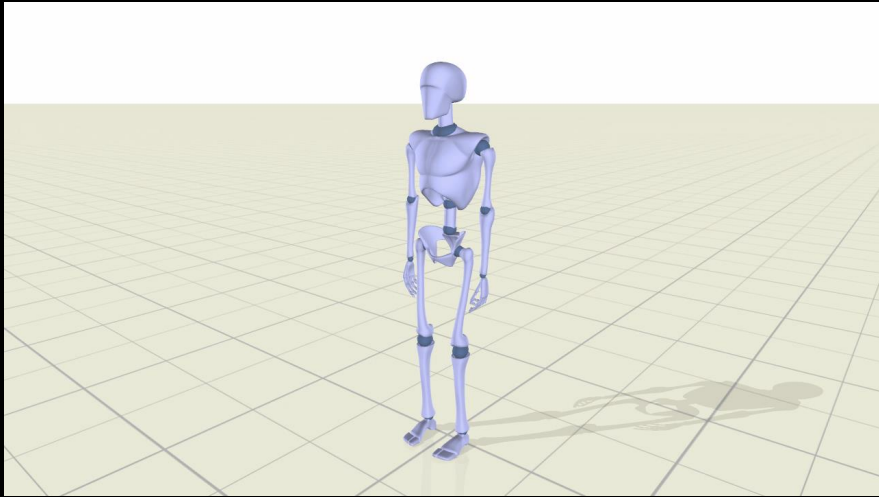
Virtual Actuators

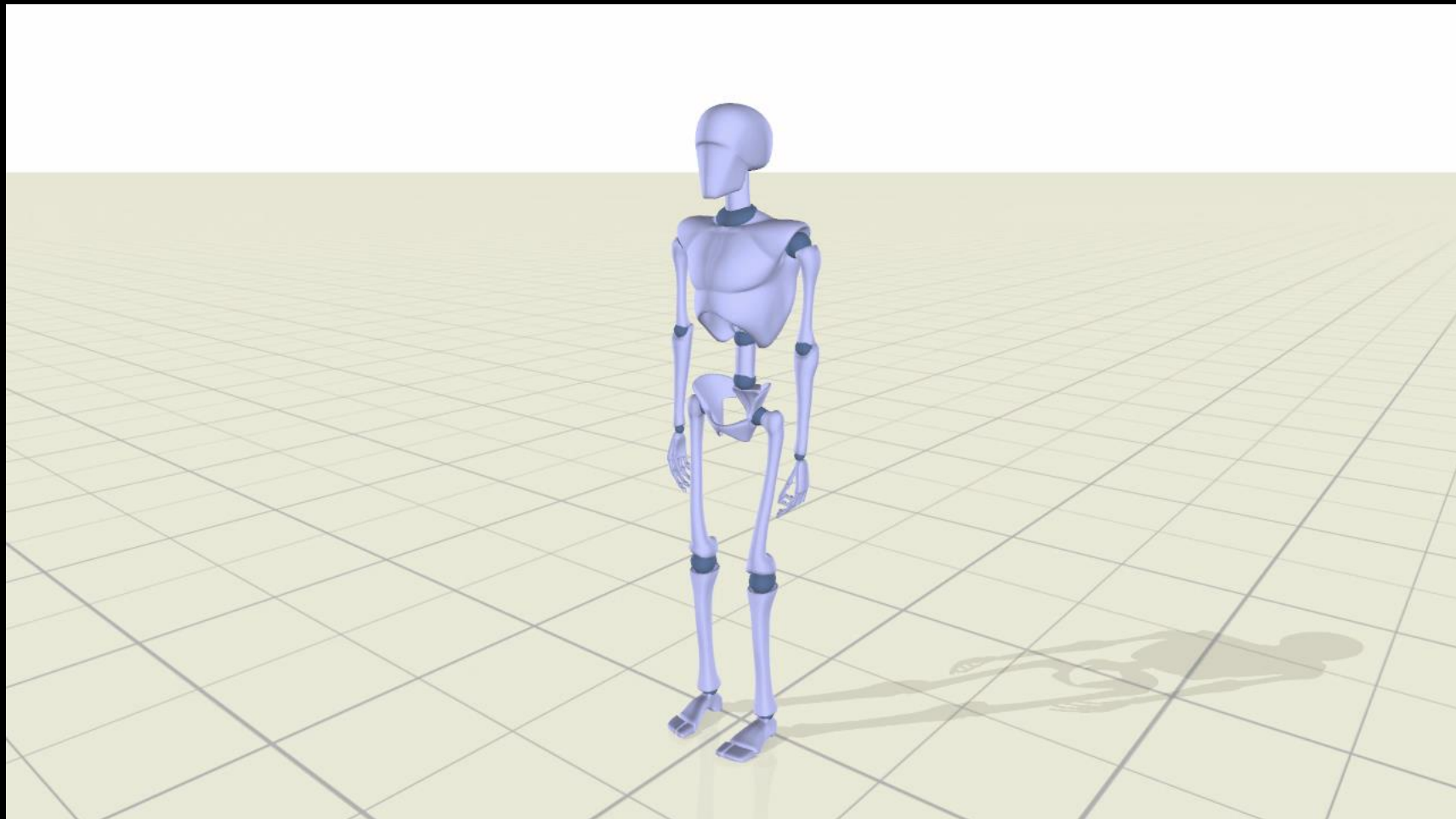


Proxy Geometry

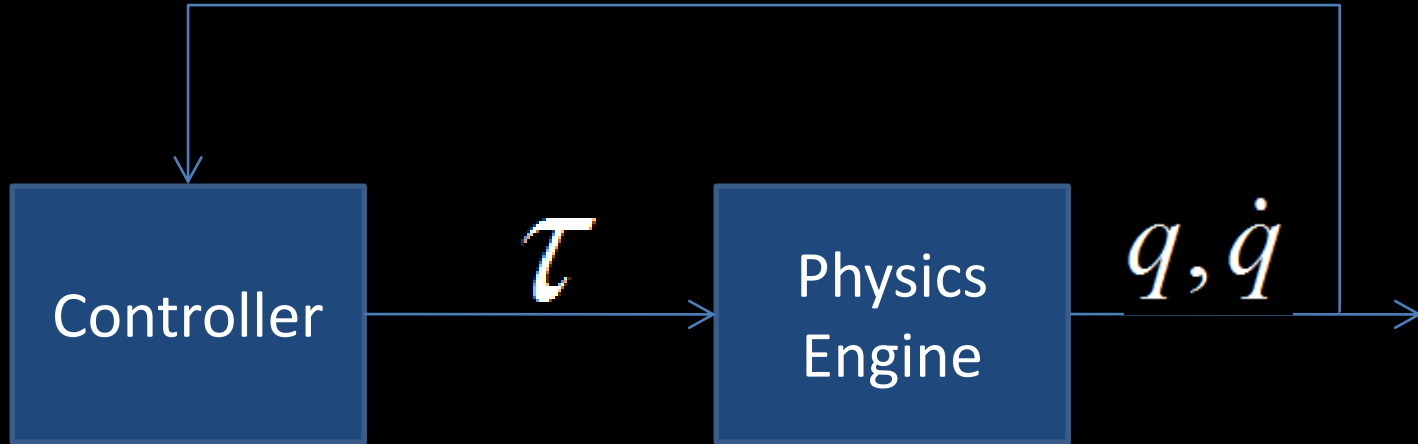


Visualization Mesh

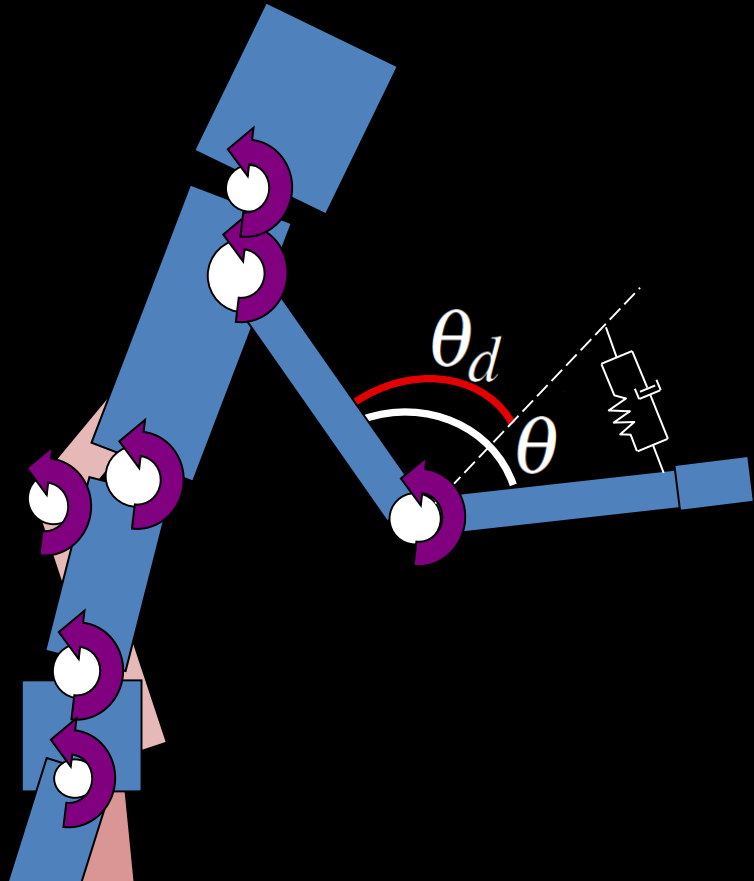




Physics-based Animation

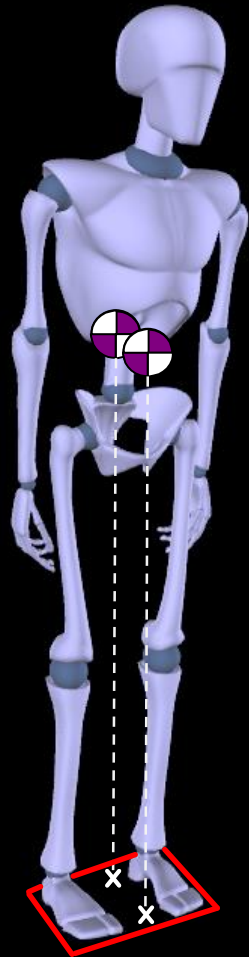


Posture Control

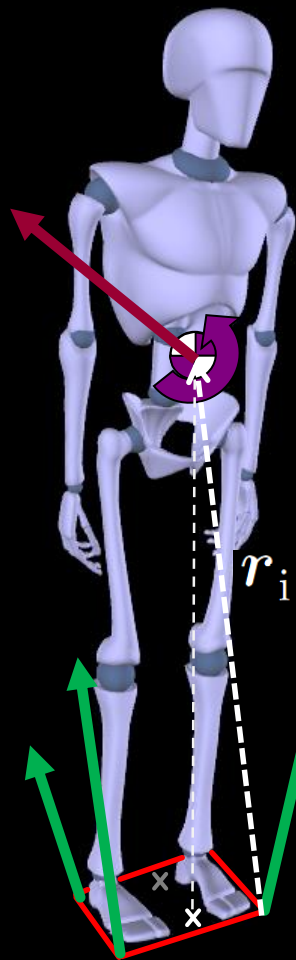


Under actuated
Inherently unstable





$$\underbrace{\begin{bmatrix} \mathbf{F}^d \\ \mathbf{T}^d \end{bmatrix}}_{\mathbf{b}} = \mathbf{k}_p(\mathbf{q}_b^d - \mathbf{q}_b) + \mathbf{k}_d(\dot{\mathbf{q}}_b^d - \dot{\mathbf{q}}_b) + \mathbf{k}_{ff}$$

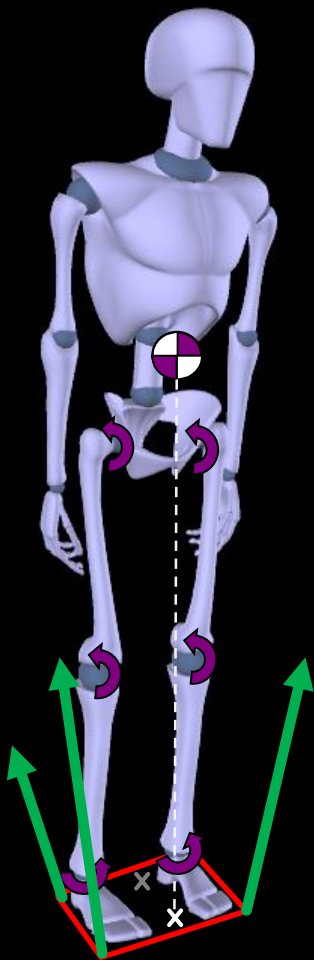


$$\underbrace{\begin{bmatrix} \mathbf{I} & \mathbf{I} & \cdots & \mathbf{I} \\ r_{0 \times} & r_{1 \times} & \cdots & r_{m \times} \end{bmatrix}}_{\mathbf{A}} \underbrace{\begin{pmatrix} \mathbf{F}_0 \\ \mathbf{F}_1 \\ \vdots \\ \mathbf{F}_m \end{pmatrix}}_{\mathbf{x}} = \begin{pmatrix} \mathbf{F}_B \\ \mathbf{T}_B \end{pmatrix}$$

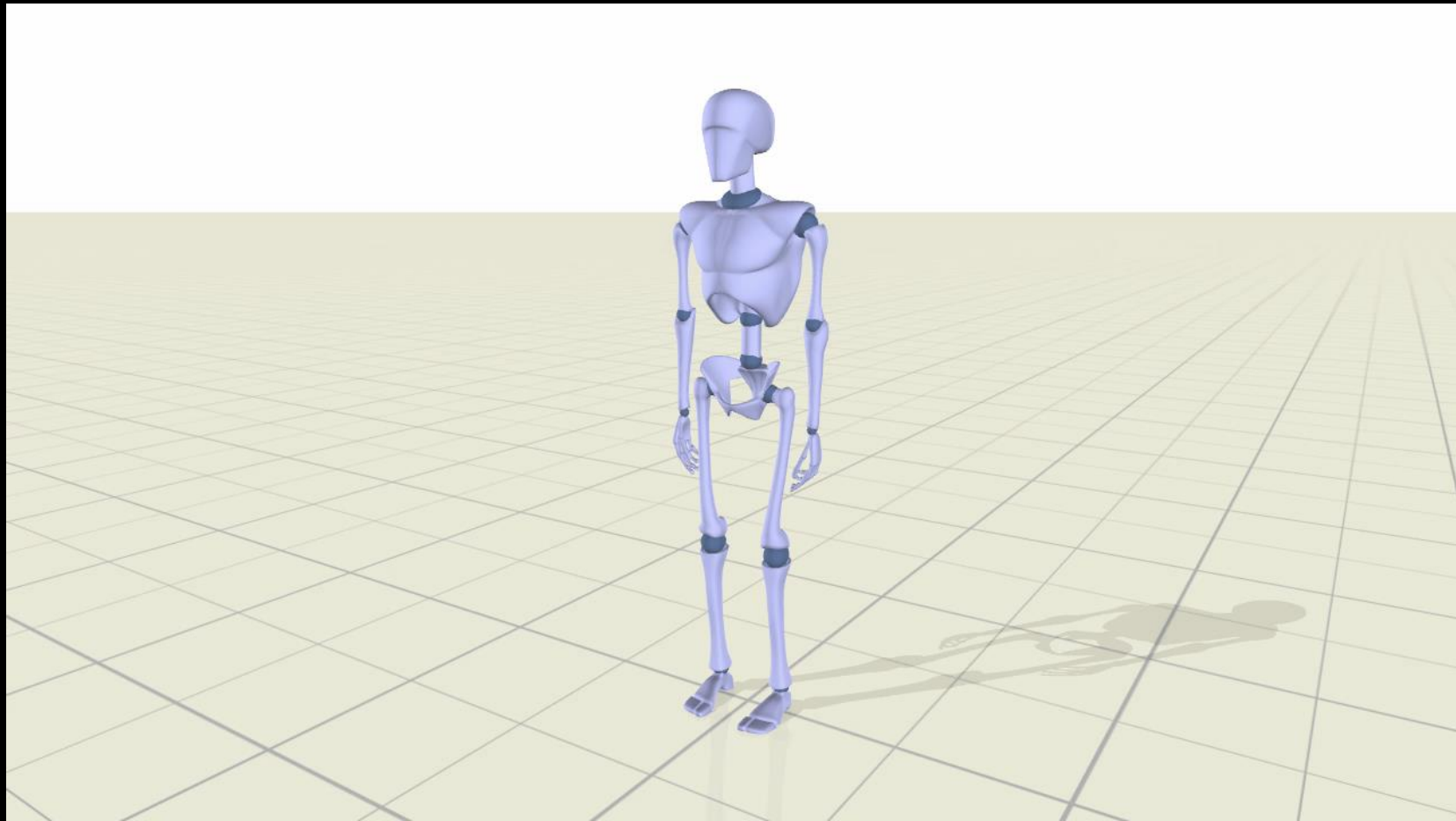
$$\min (\mathbf{A}\mathbf{x} - \mathbf{b})^T (\mathbf{A}\mathbf{x} - \mathbf{b})$$

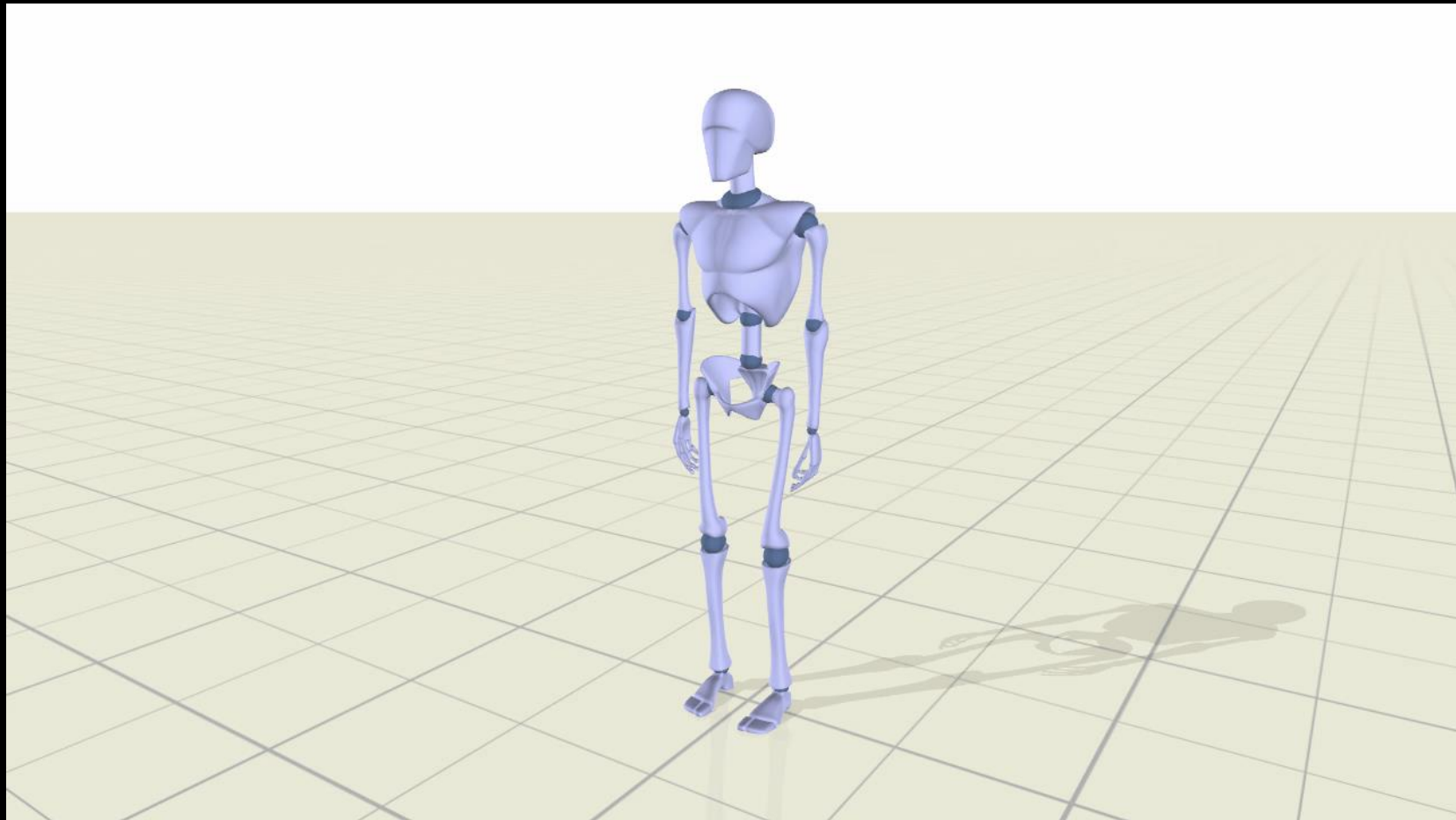
$$\text{subject to } F_i^n \geq F_{\min}^n$$

$$- \mu F_i^n \leq F_i^t \leq \mu F_i^n$$



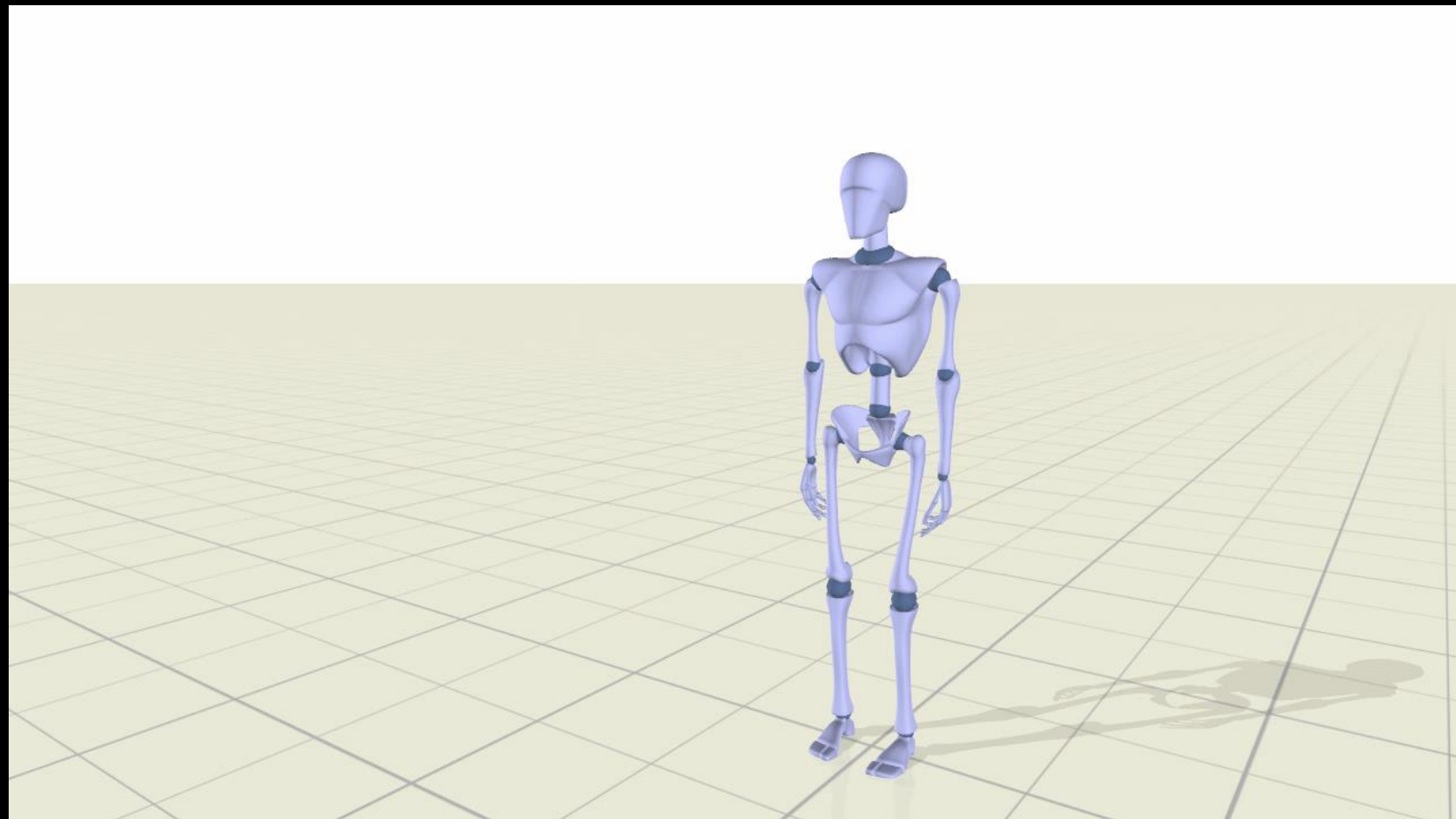
$$\boldsymbol{\tau} = \mathbf{J}^T \mathbf{F}$$





Walking

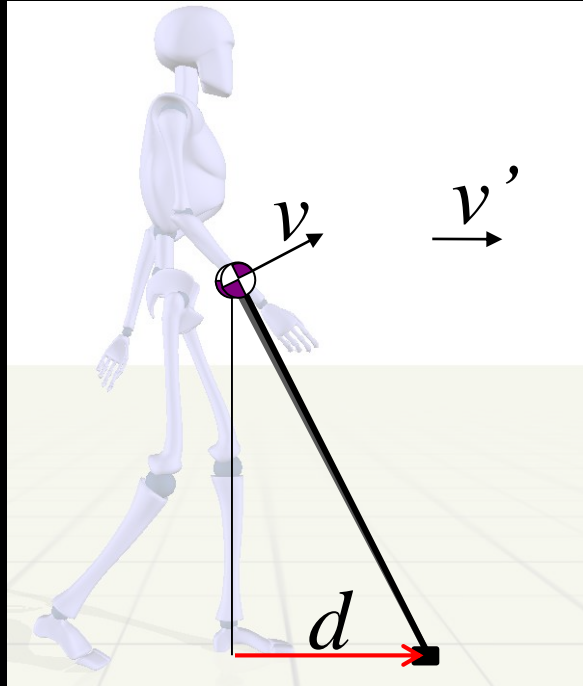
- Described **temporally** in terms of stride duration and its two components per leg, swing time and stance time



Walking

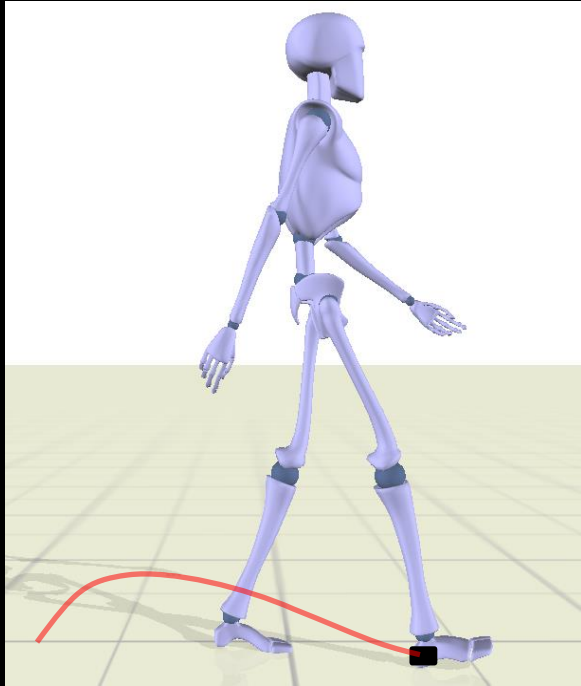
- Described **temporally** in terms of stride duration and its two components per leg, swing time and stance time, and **spatially** in terms of foot placement locations

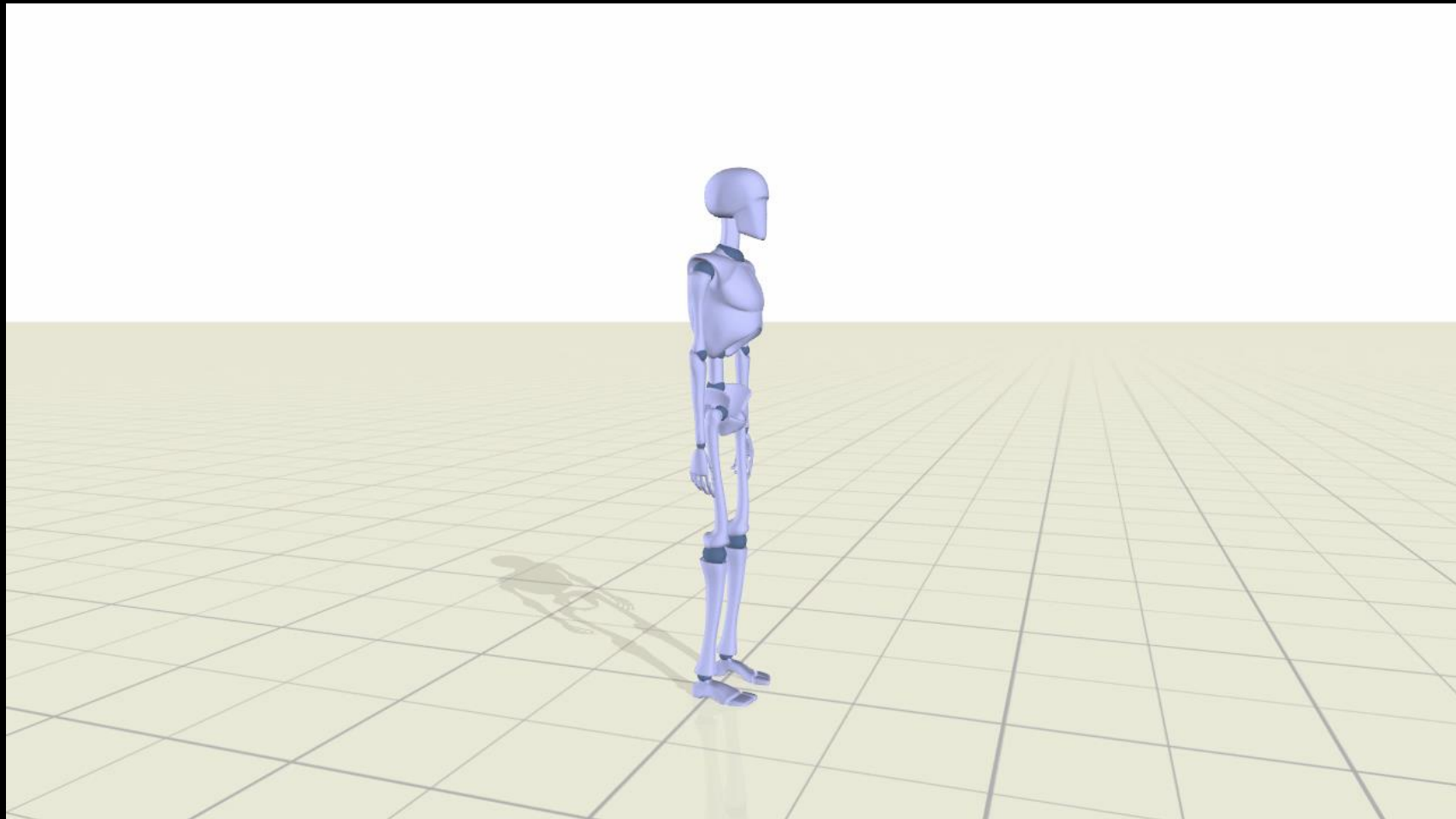
Foot Placement Control



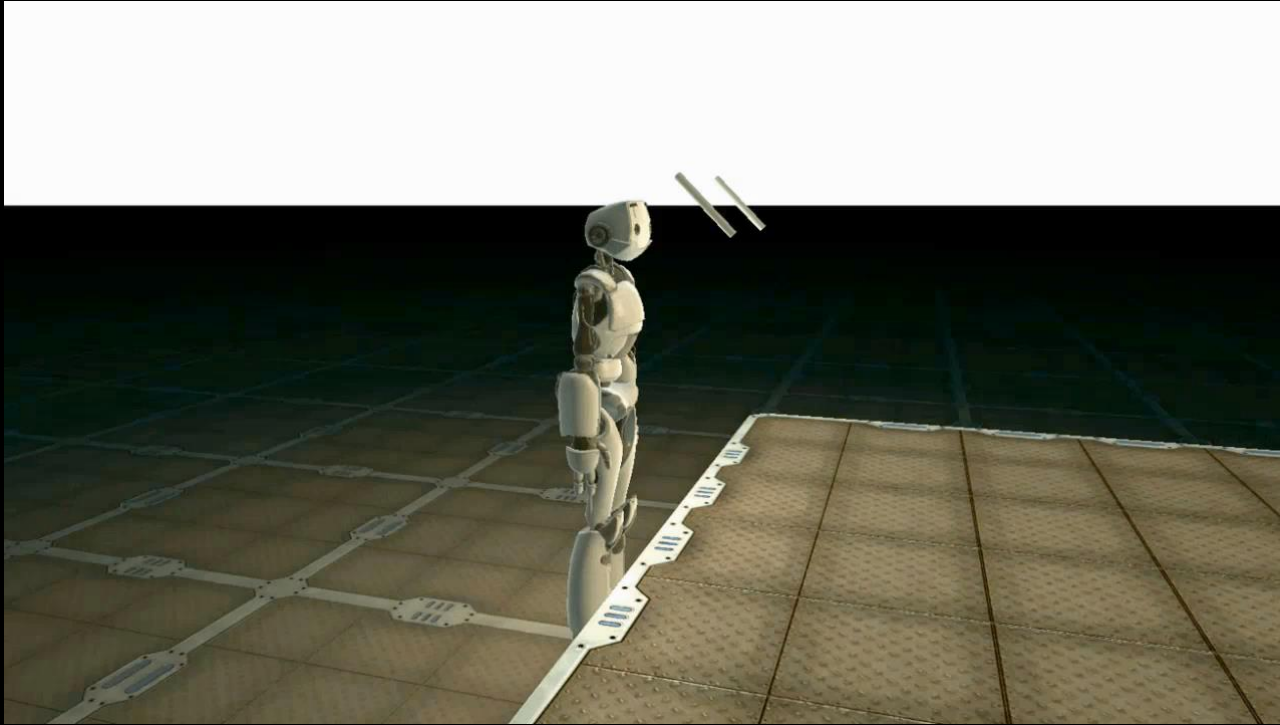
$$d = d_f(v_d) + (v - v_d) \sqrt{\frac{h}{g}}$$

Foot Placement Control



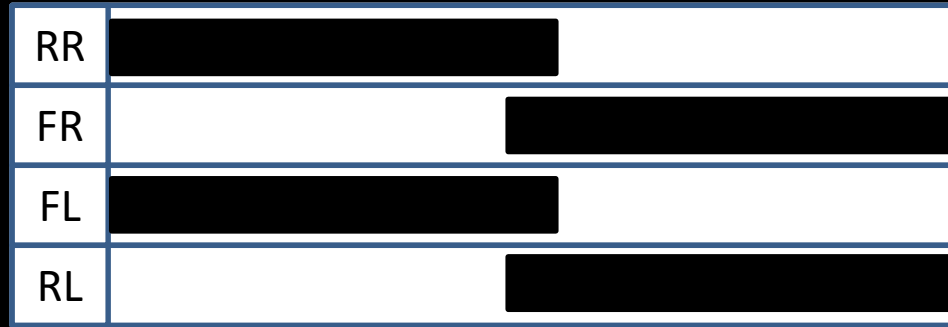


Towards Increasingly Complex Motor Skills

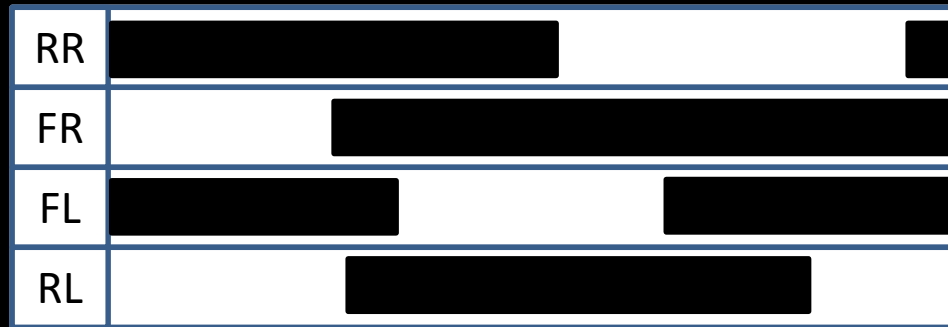


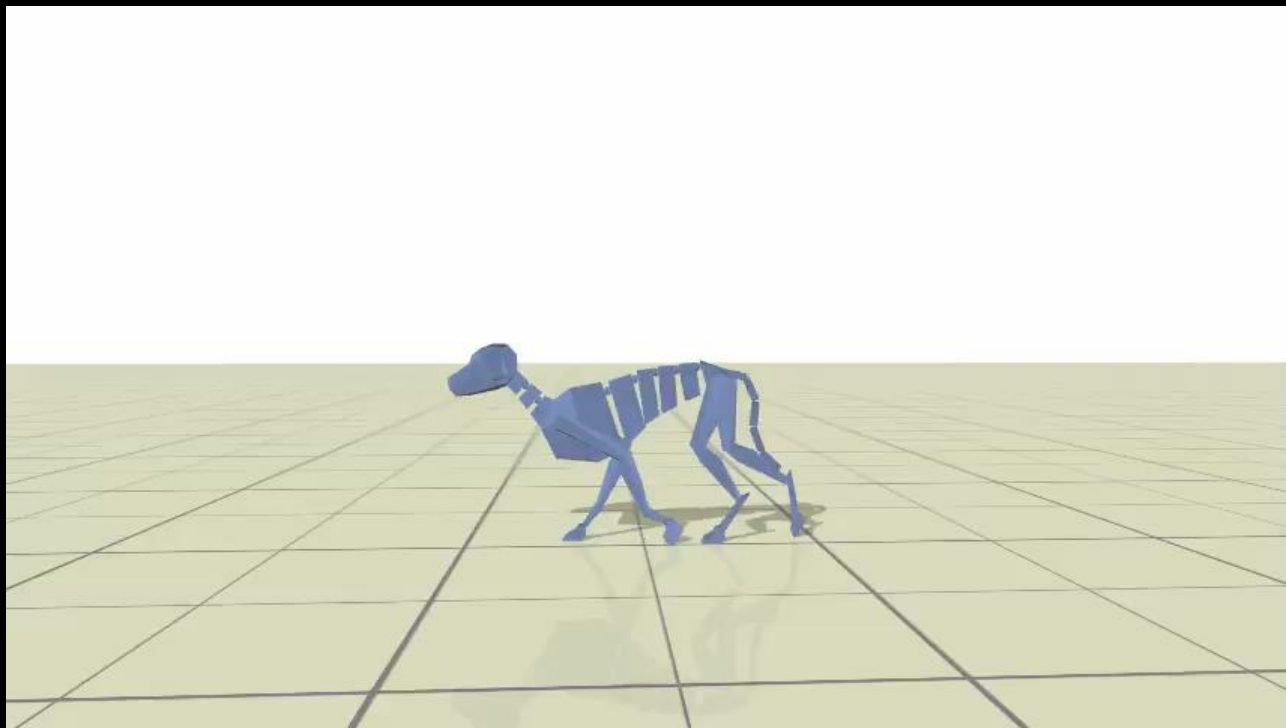
Quadrupedal Gaits

Trot

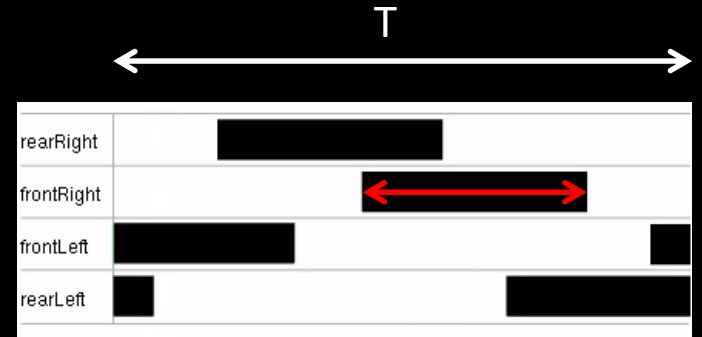
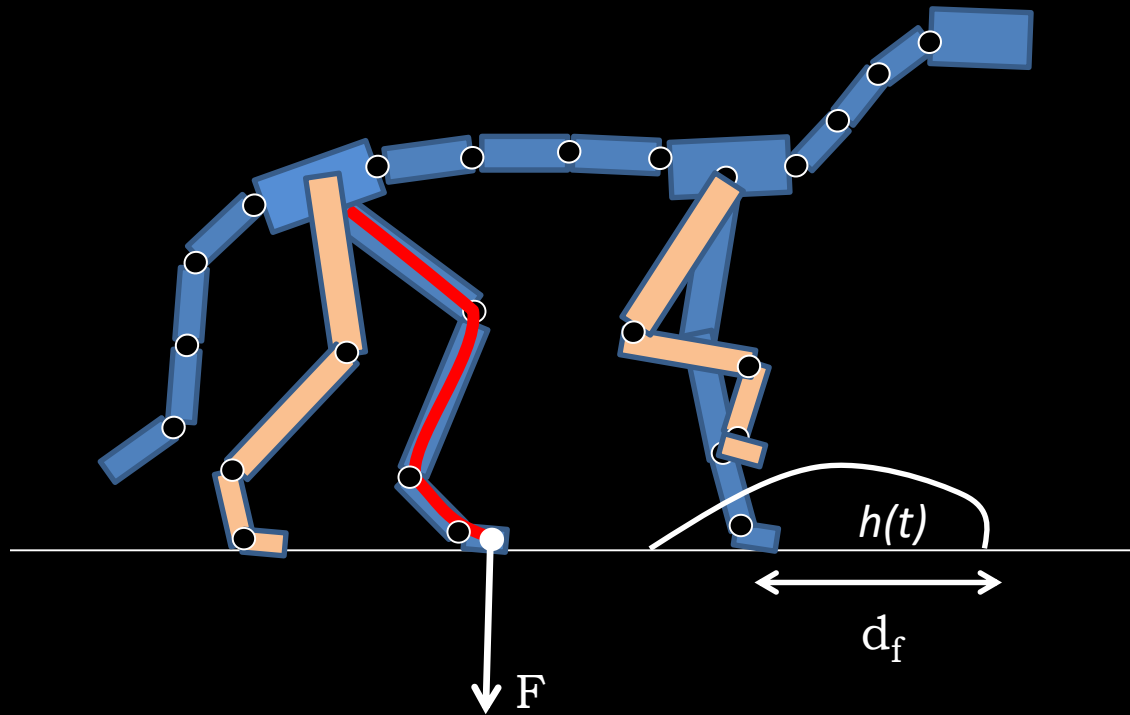


Canter

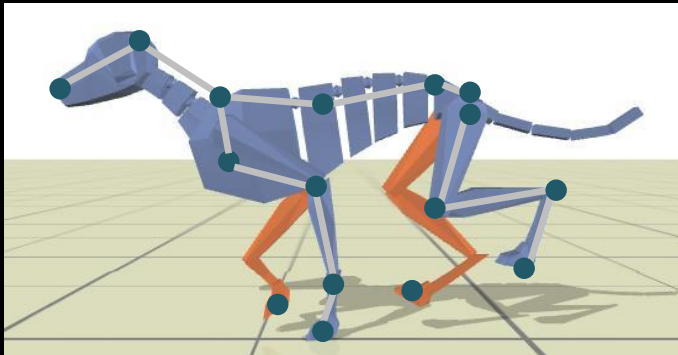
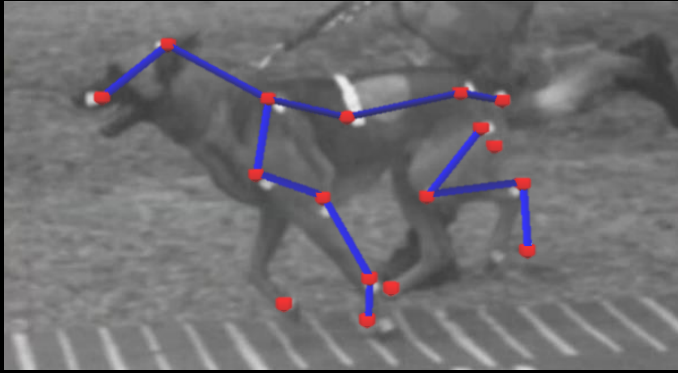




Controller Parameterization

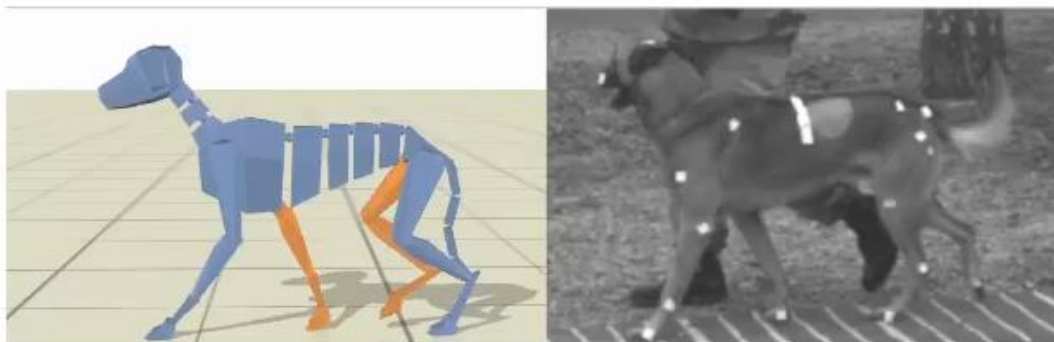


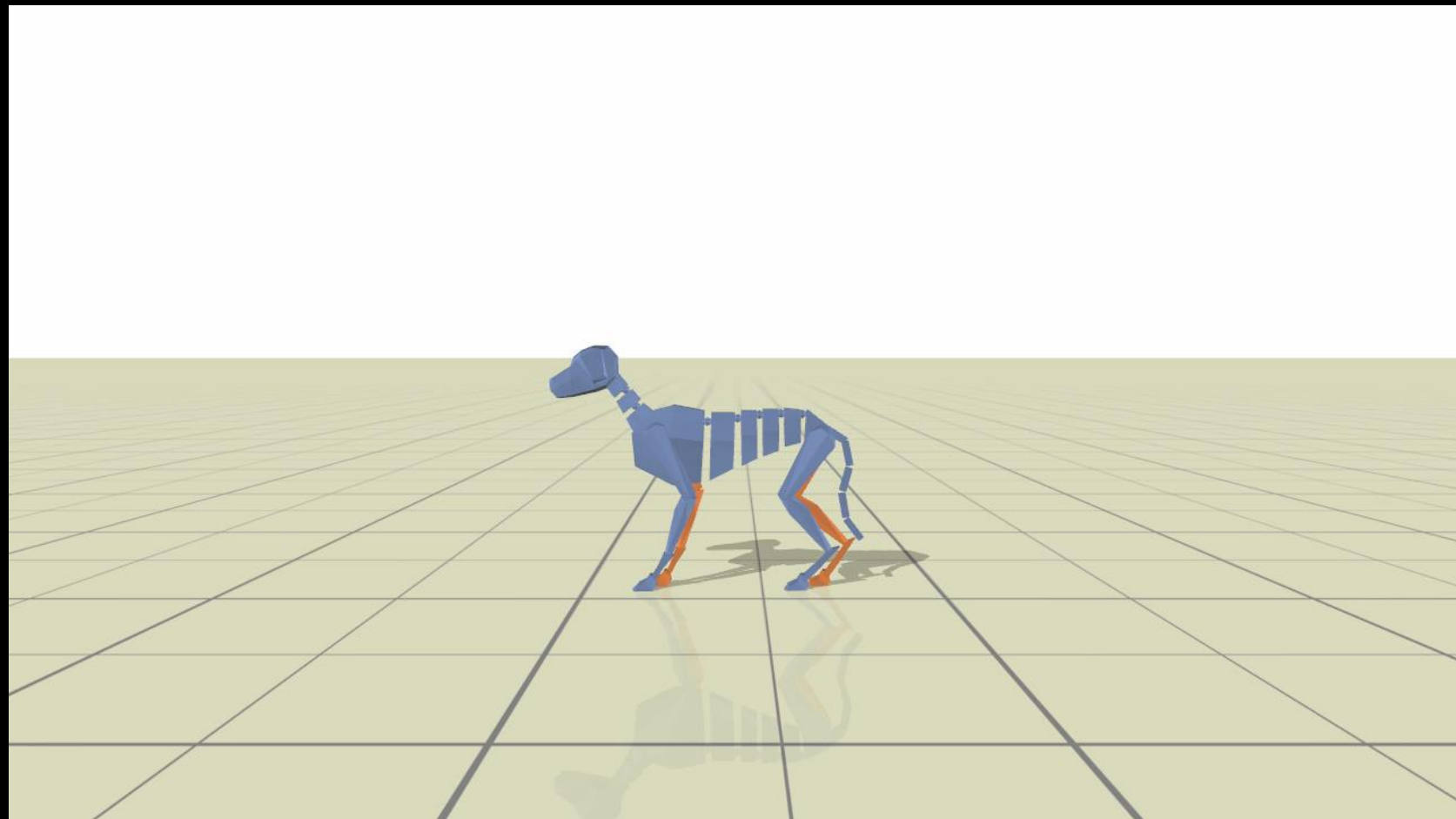
Motion Data



After Learning

walk





Locomotion Control for Legged Robots



Locomotion Control for Legged Robots



Towards increasingly accurate biomechanical models

Flexible Muscle-Based Locomotion for Bipedal Creatures

SIGGRAPH ASIA 2013

**Thomas Geijtenbeek
Michiel van de Panne
Frank van der Stappen**

Towards increasingly accurate biomechanical models

Realistic Biomechanical Simulation and Control of Human Swimming

Weiguang Si* Sung-Hee Lee[†] Eftychios Sifakis[‡] Demetri Terzopoulos*

*University of California, Los Angeles

[†]Korea Advanced Institute of Science and Technology

[‡]University of Wisconsin, Madison

Questions?