Human Motion

source: http://scaq.blogspot.com/2006_11_01_archive.html

Adrien Treuille

Overview

- Data-Driven Motion
- Physics Based Motion
- Motion of other Animals
- Questions

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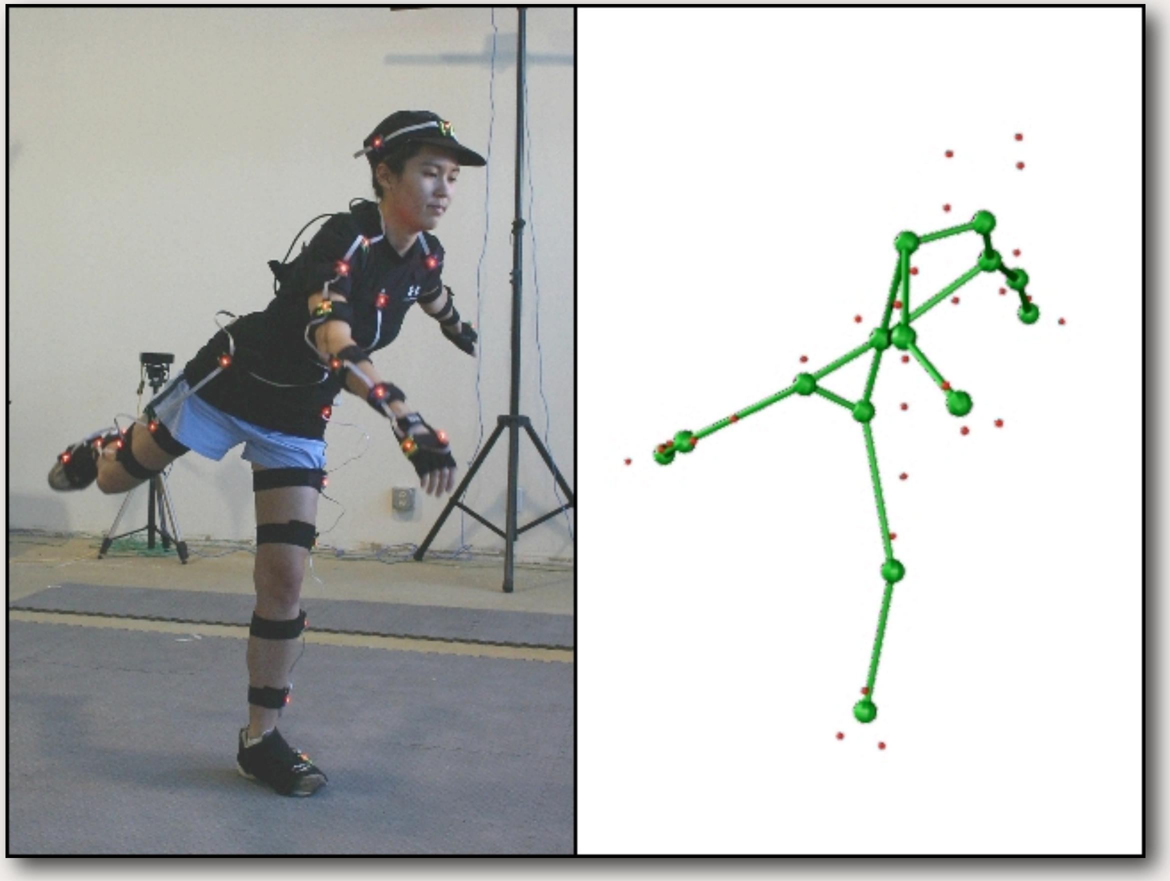
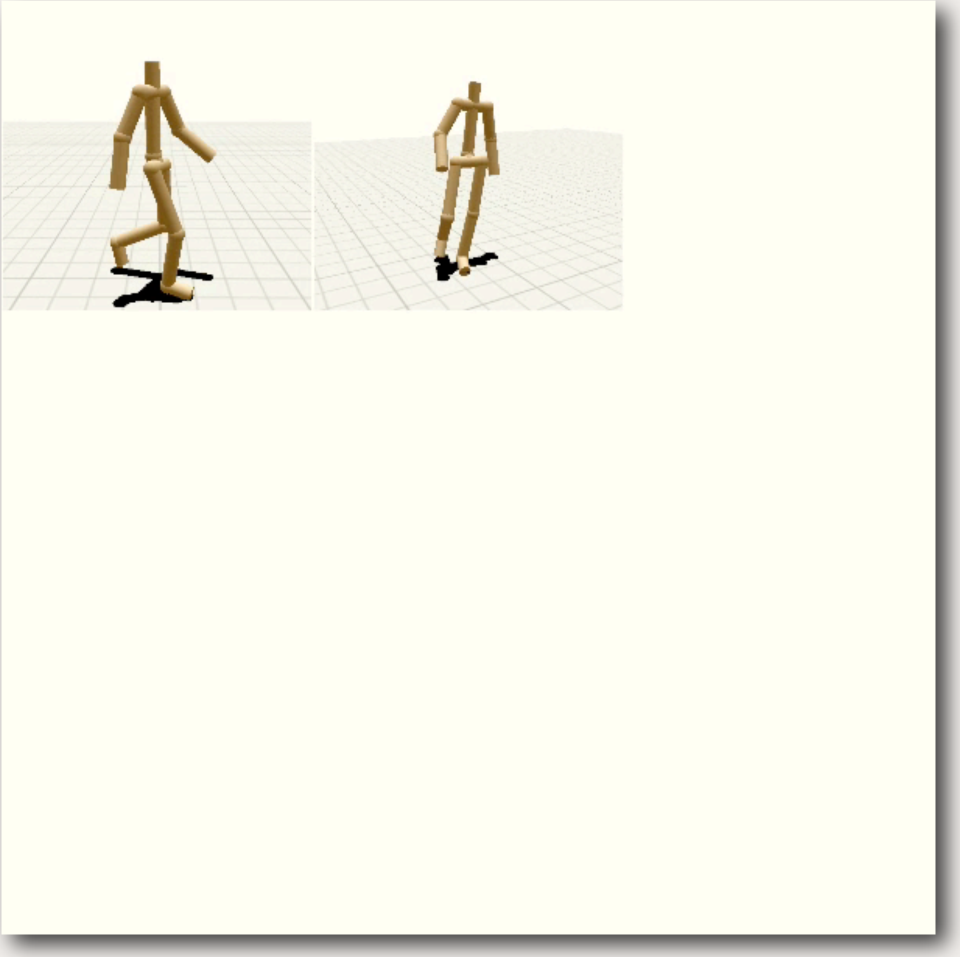
Motion Capture

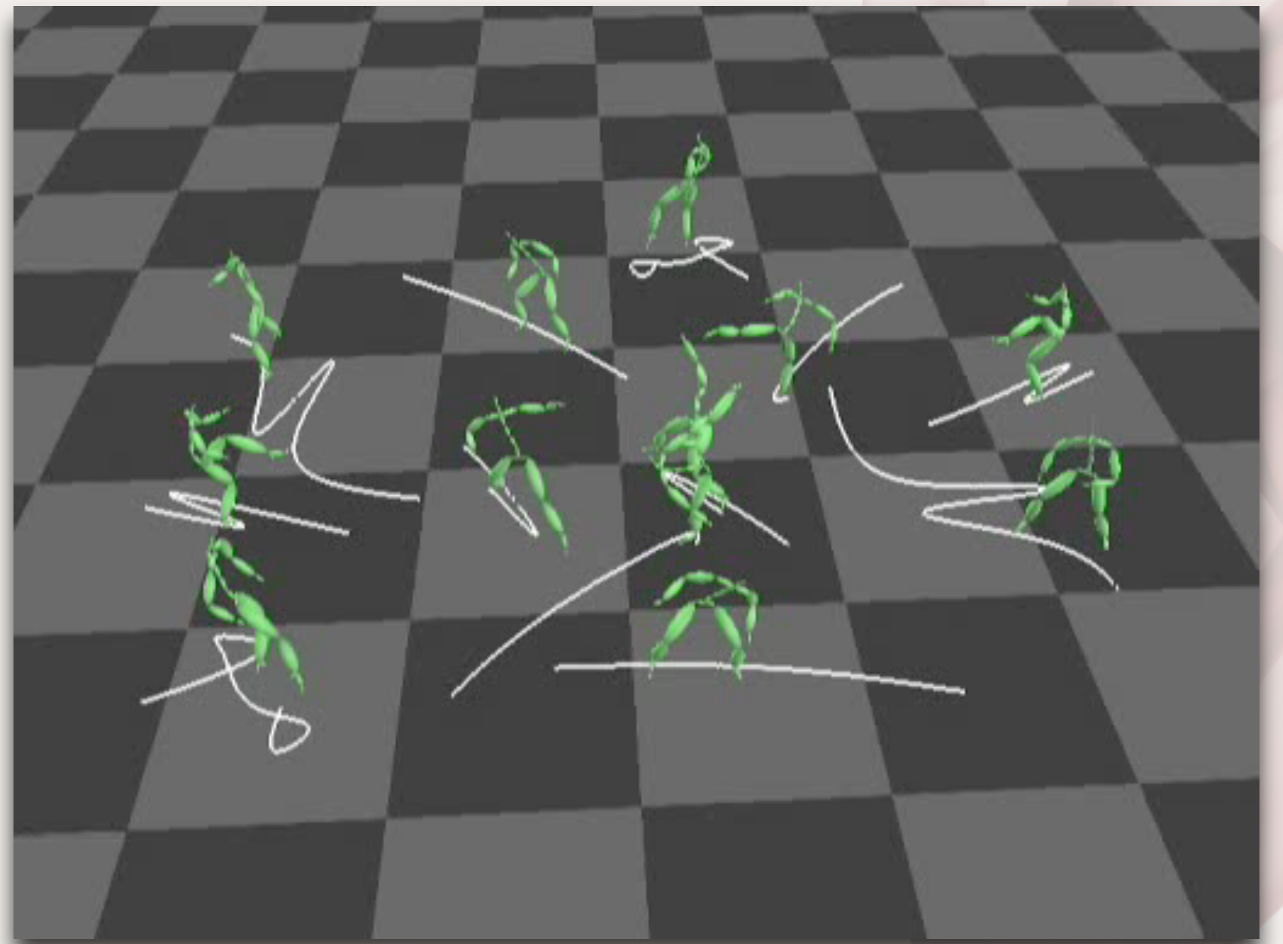


- **Telescoping composition of functions from root.**
- **Compute derivatives in the *opposite* direction!**

Clips

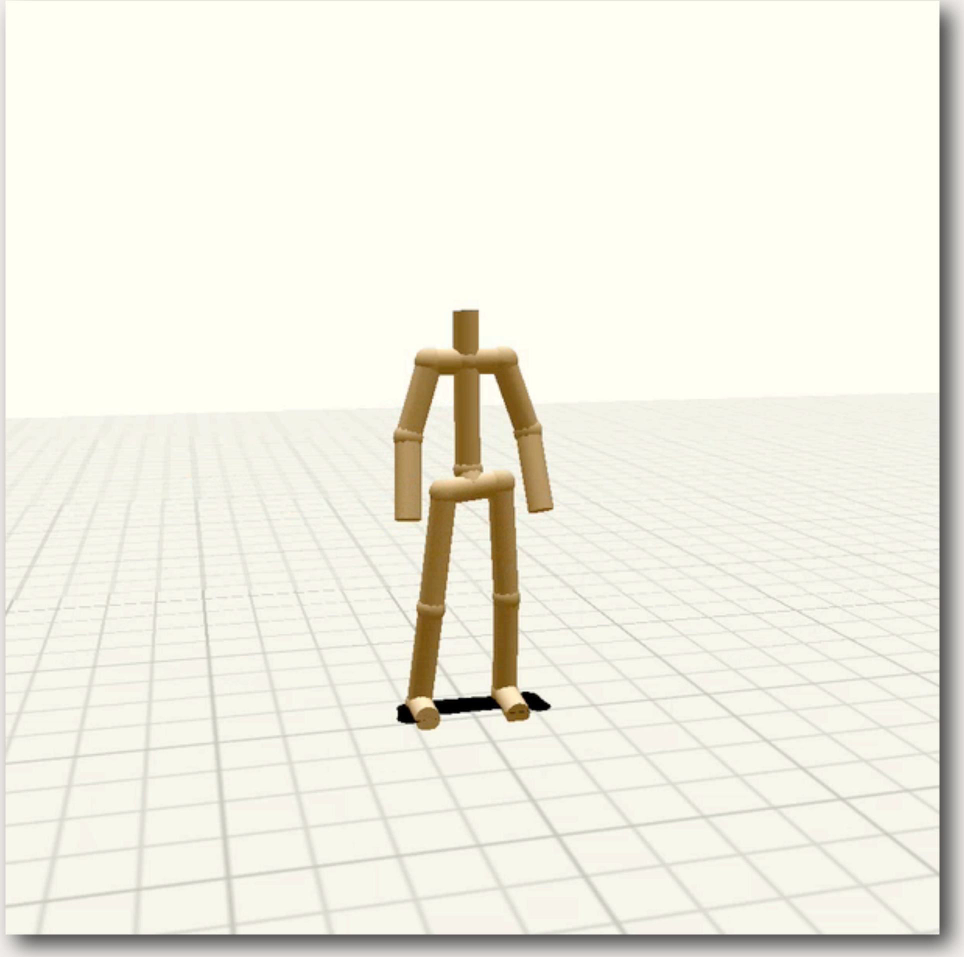


source: Treuille et al. [2002]

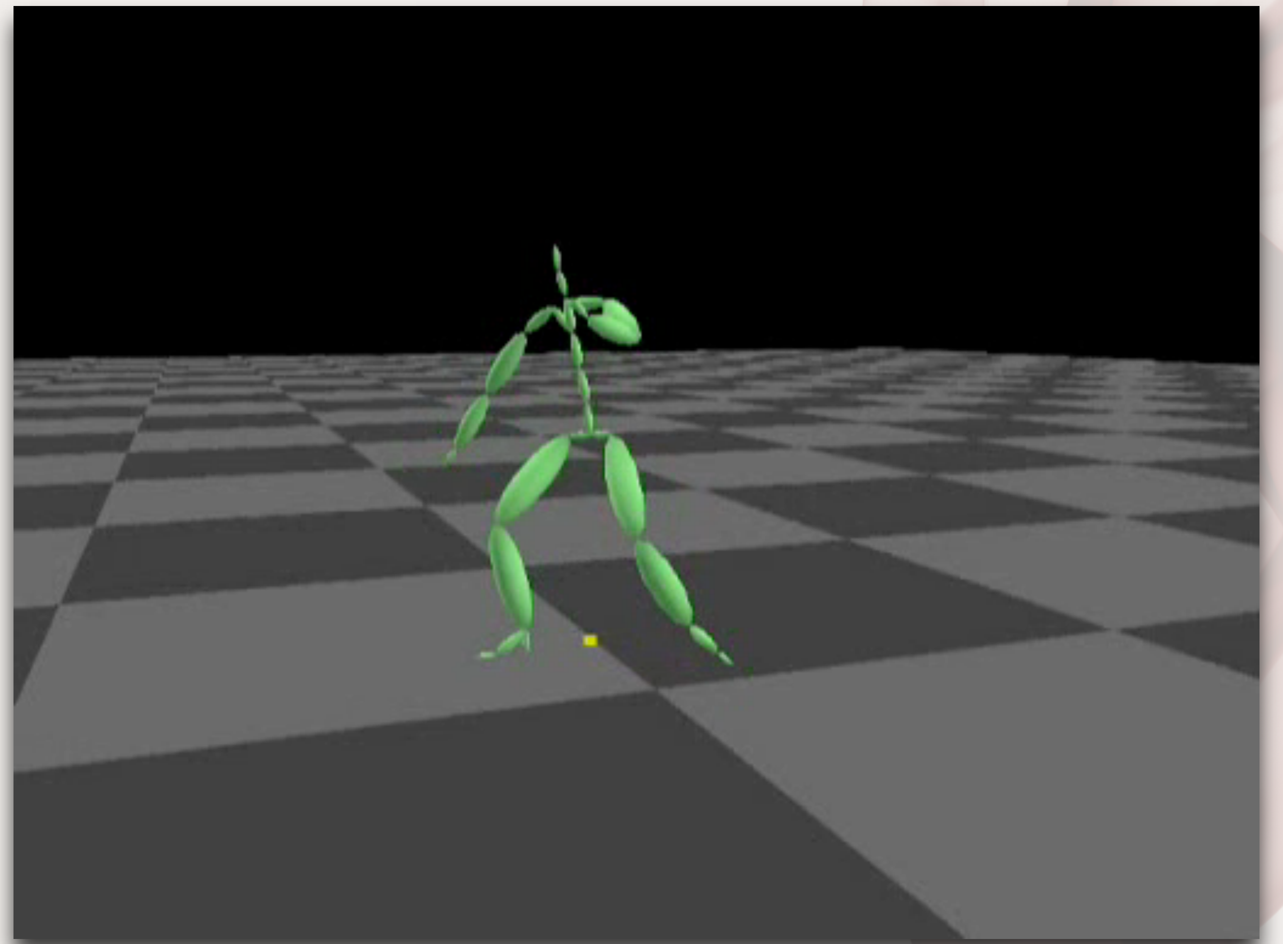


source: Kovar et al. [2002]

Sequences



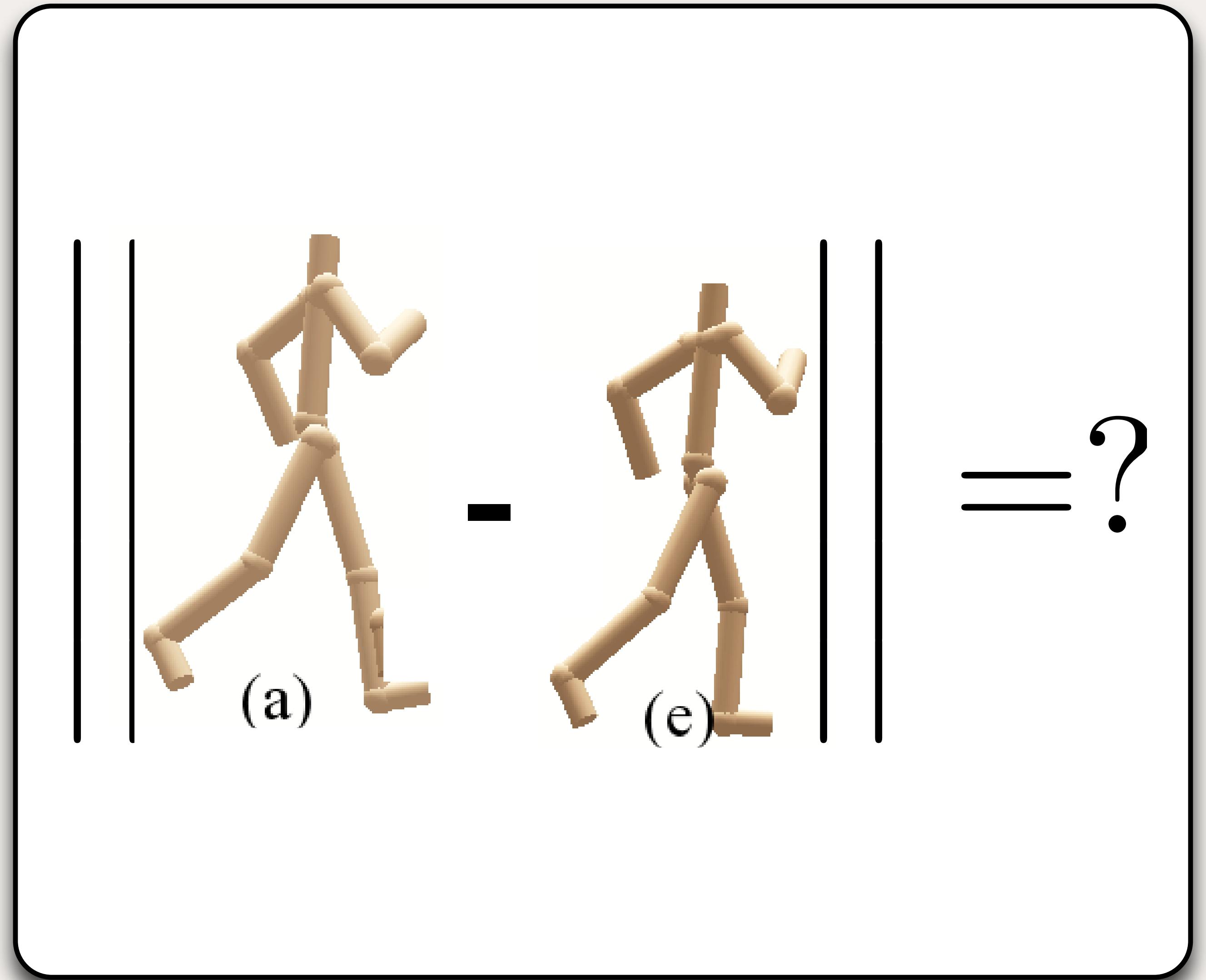
source: Treuille et al. [2002]

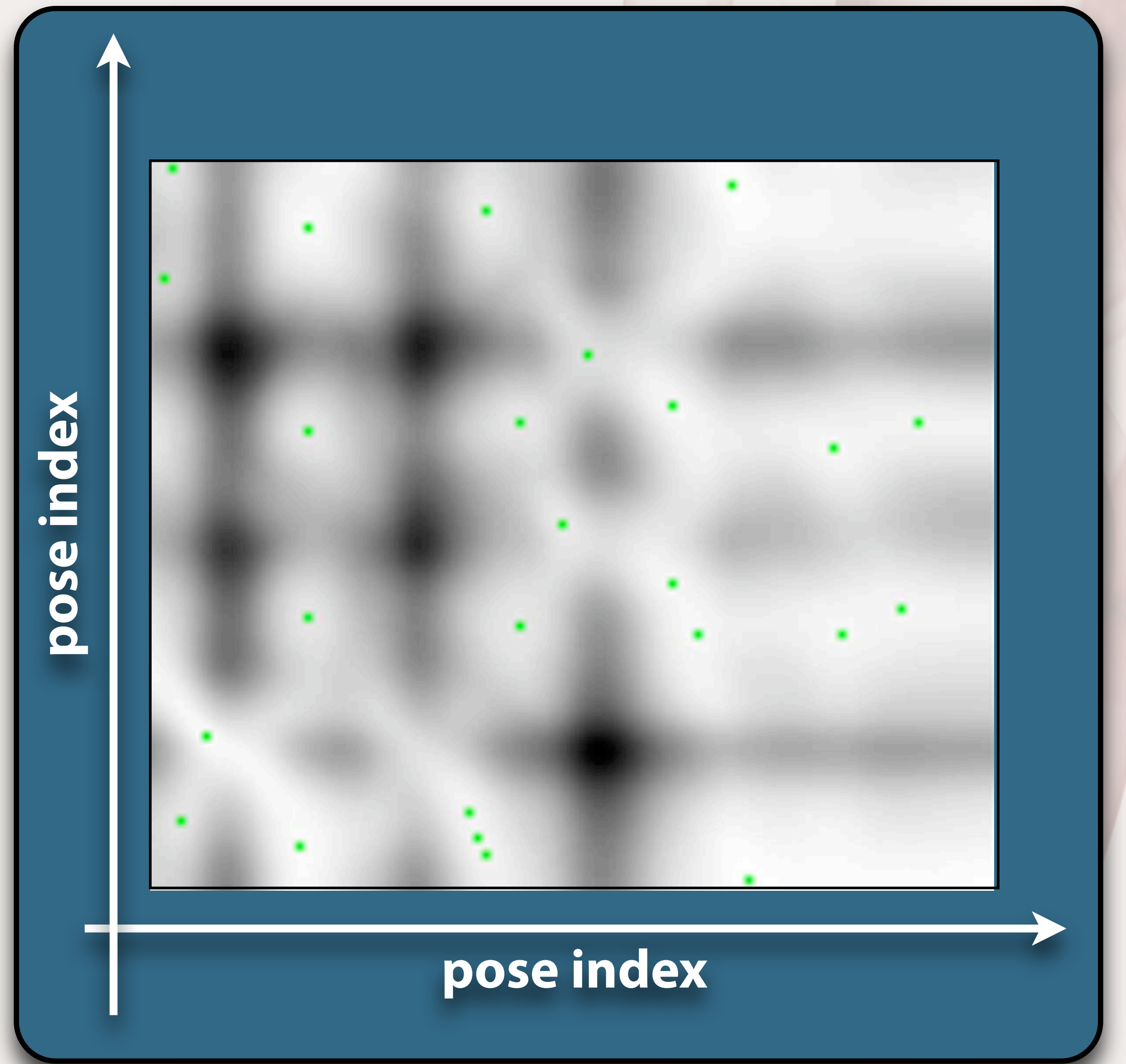


source: Kovar et al. [2002]

How?

Pose Metrics

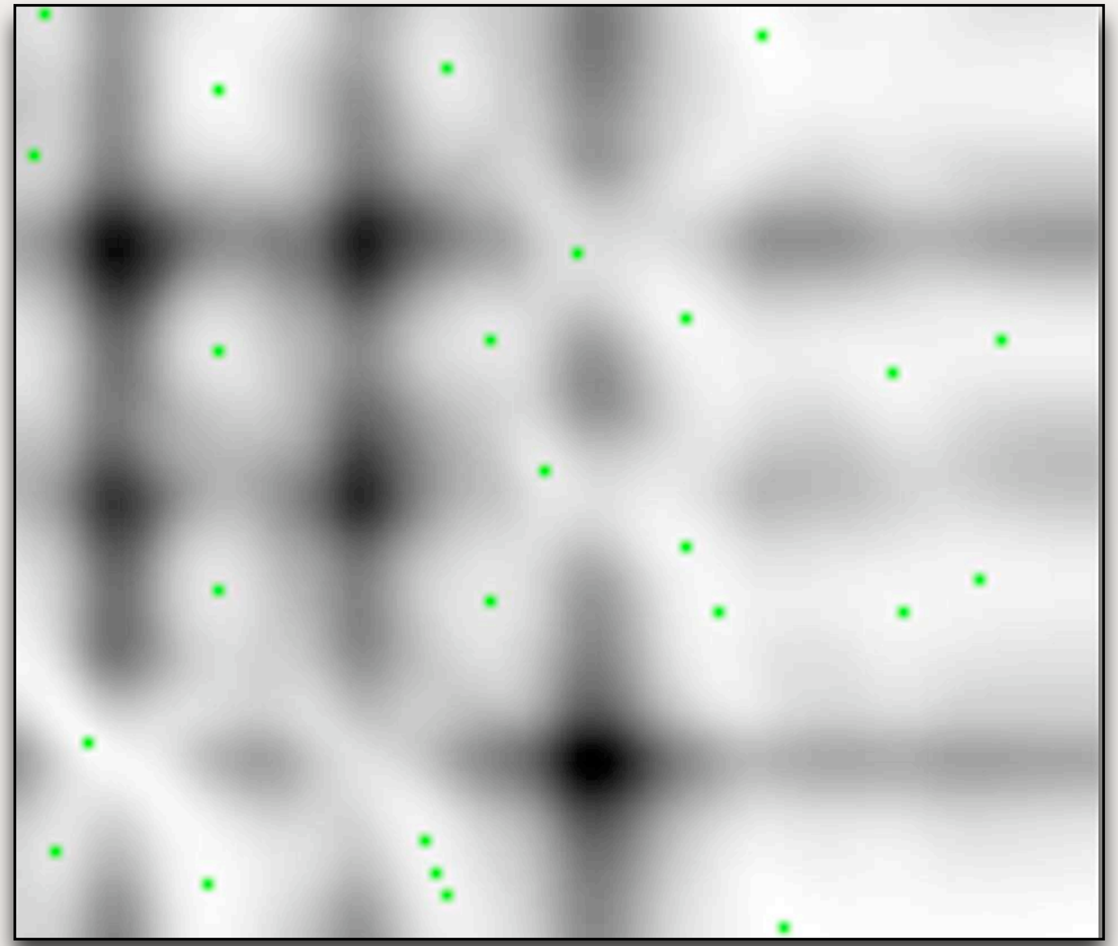




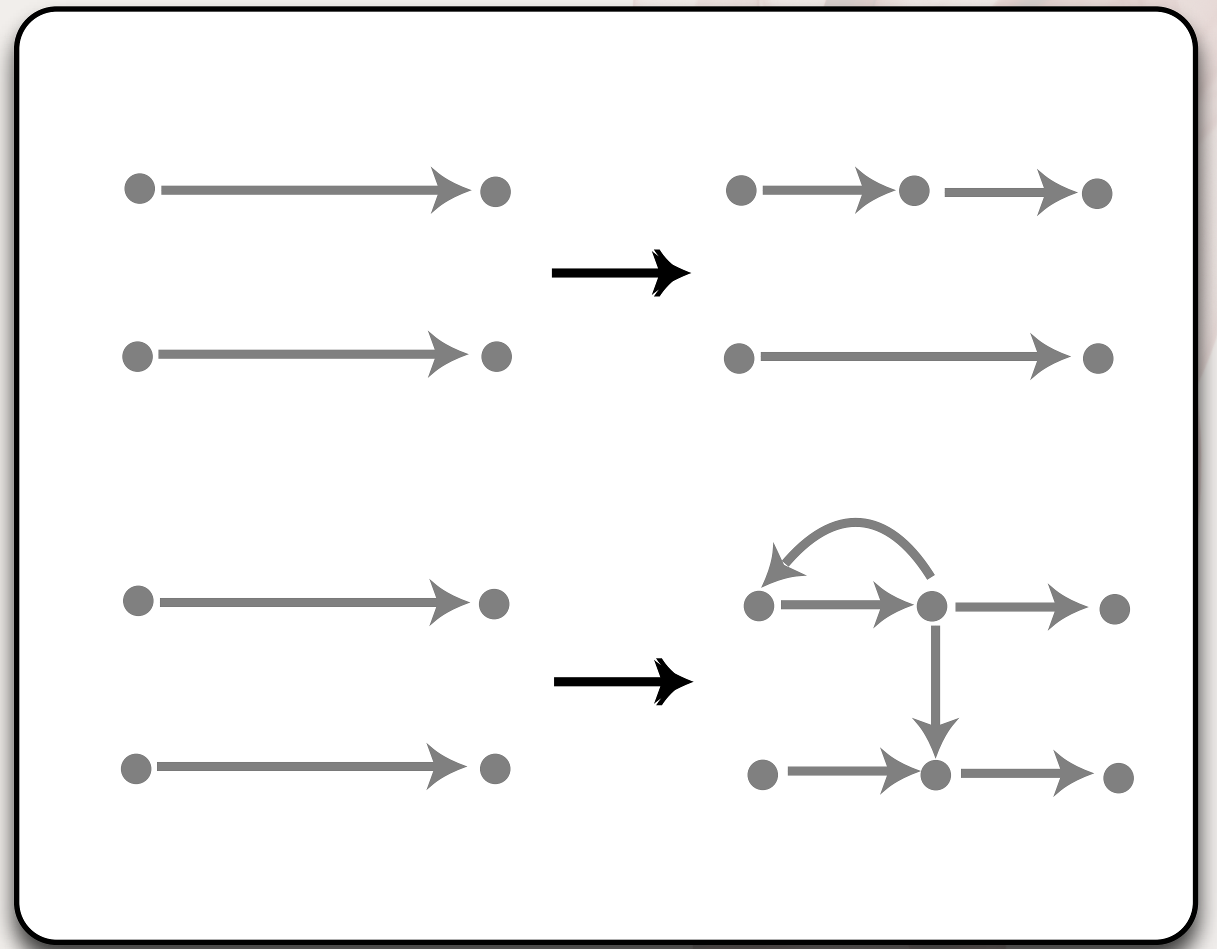
How can we define a metric on poses?

Pairwise pose differences.

Pose Metrics

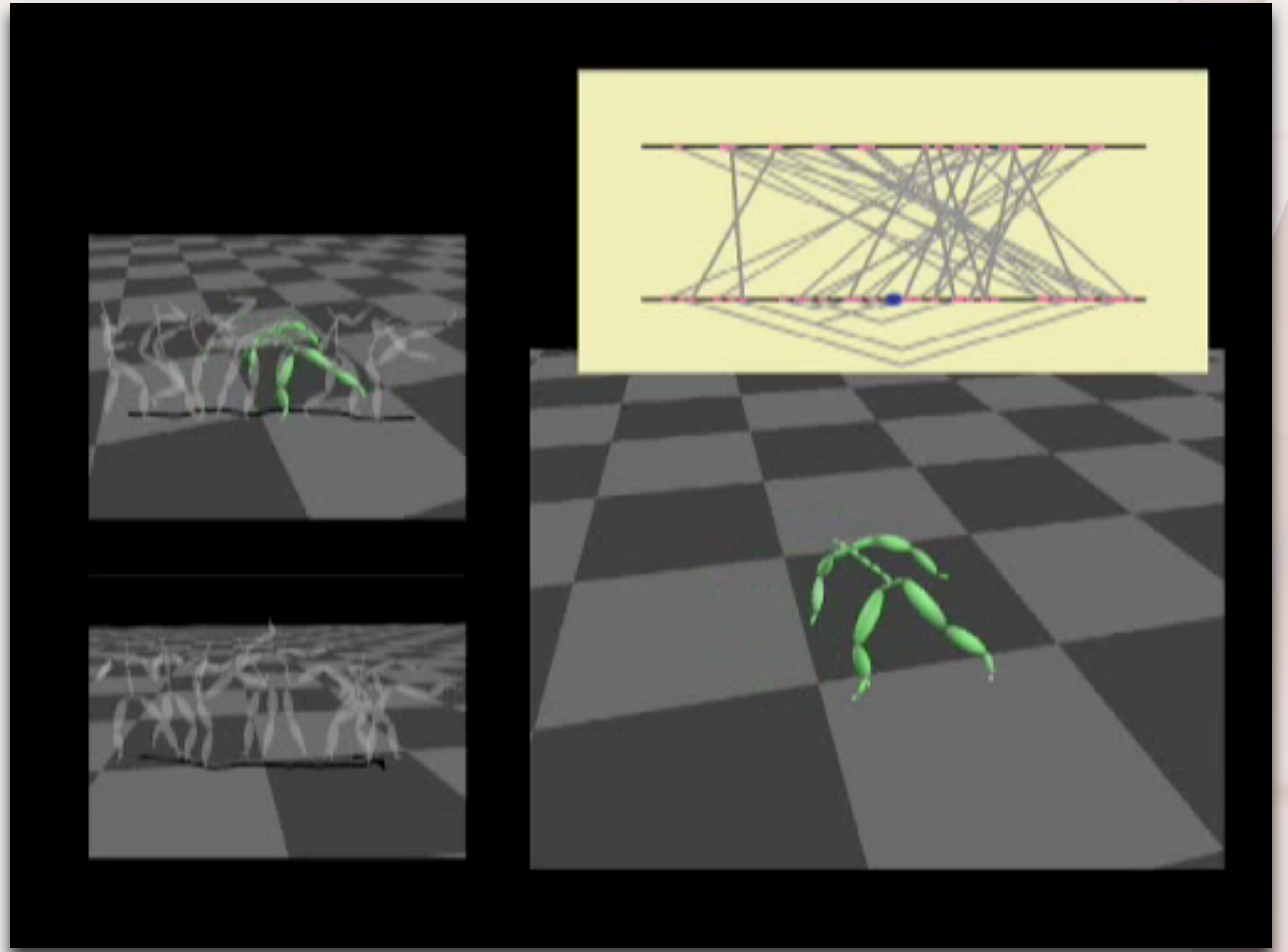


Pairwise Pose Differences



Motion Graph Schematic

Results

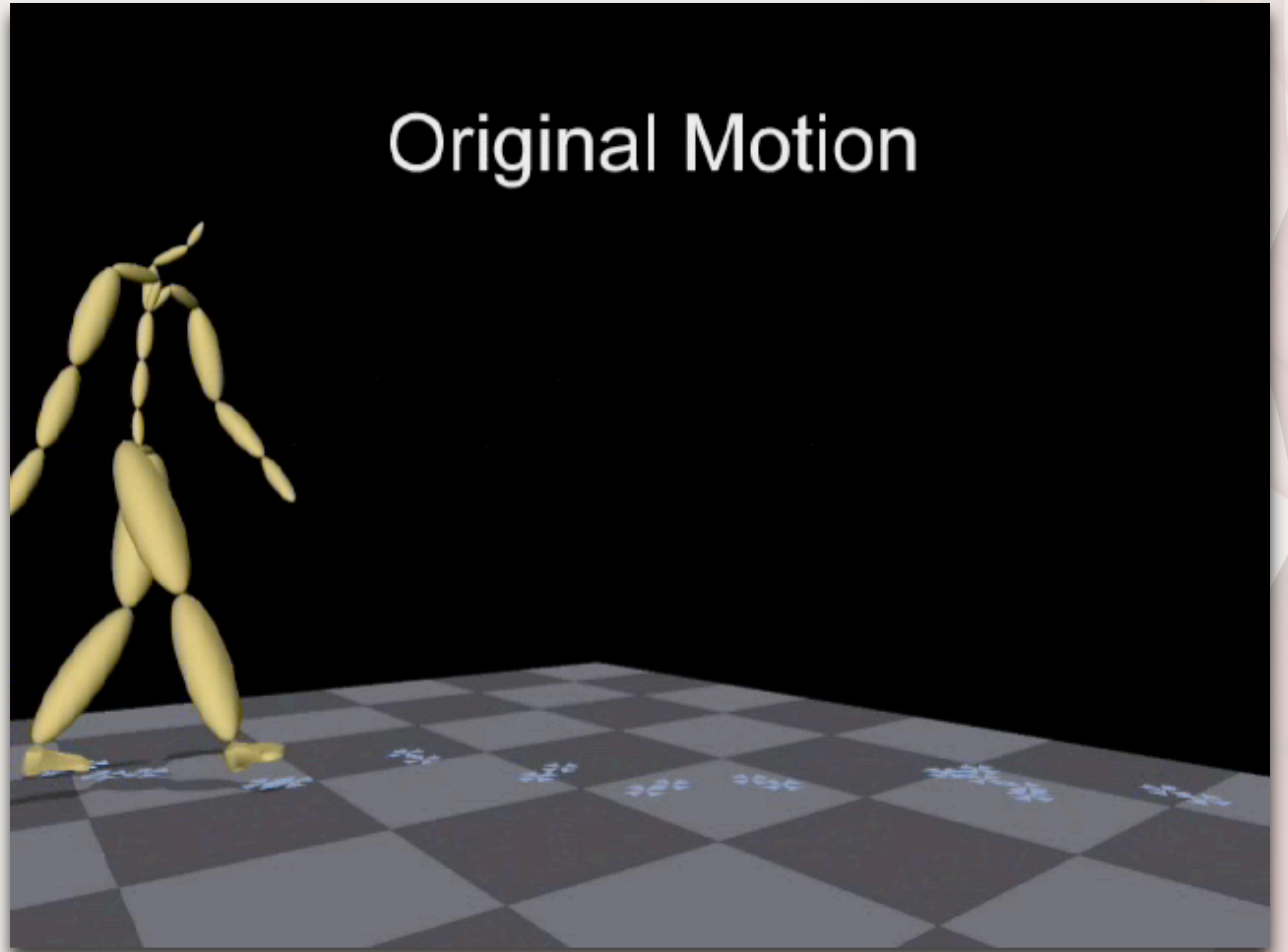


source: Kovar et al. [2002]

Constraints

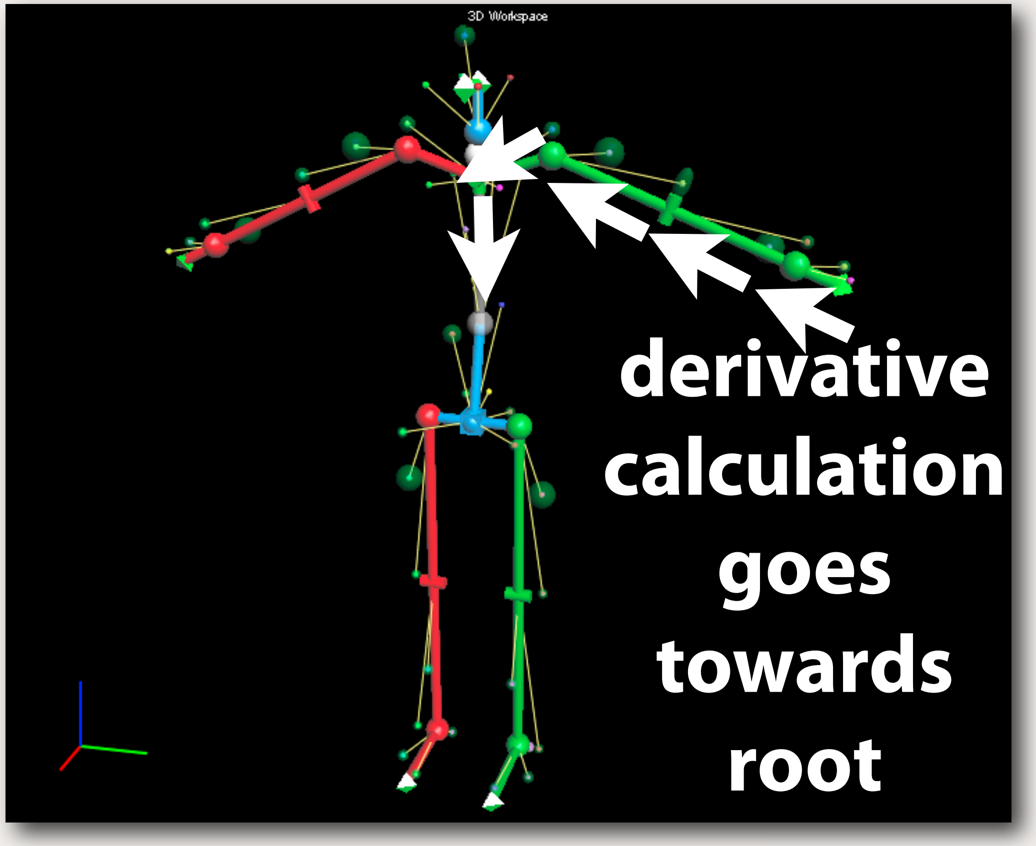
- **Pose blending may violate physical constriants**
  - **Linear Momentum Conservation**
  - **Angular Momentum Conservation**
  - **Frictional Constraints ("Foot Skate")**

“Foot Skate” Poblem



source: http://www.cs.wisc.edu/graphics/Gallery/kovar.vol/Cleanup/

Inverse Kinematic Solution

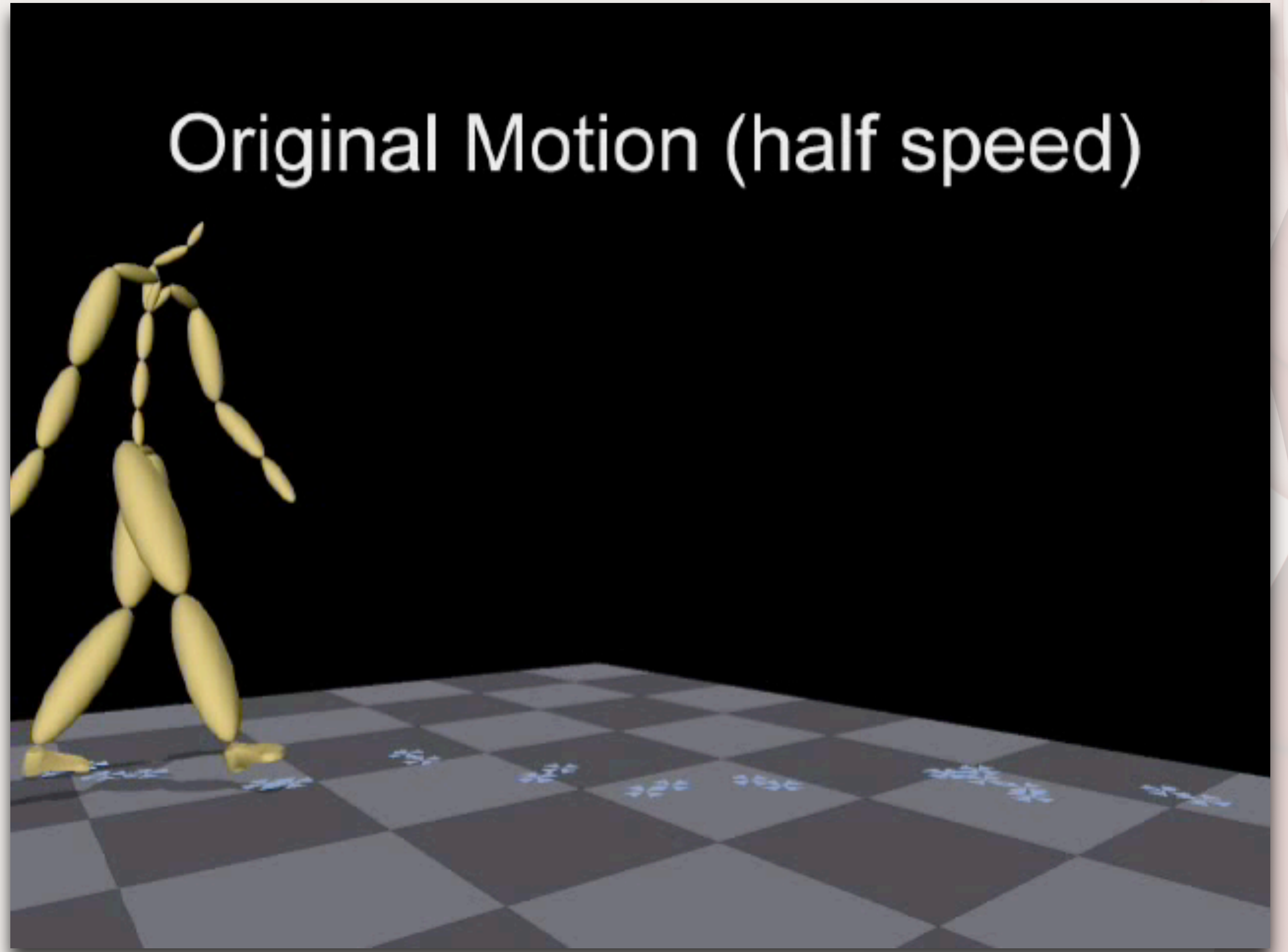


$$\omega_i = f_{i,\Omega}(\omega_{i-1})$$

$$\frac{dE}{d\Omega} = 2\sum_j (\hat{\mathbf{m}}_j^\star - \hat{\mathbf{m}}_j)^T \frac{d\hat{\mathbf{m}}_j}{d\Omega}$$

$$\frac{d\hat{\mathbf{m}}_j}{d\Omega} = \frac{\partial \hat{\mathbf{m}}_j}{\partial \omega_i}\left(\frac{\partial \omega_i}{\partial \Omega} + \frac{\partial \omega_i}{\partial \omega_{i-1}}\frac{\partial \omega_{i-1}}{\partial \Omega} + \frac{\partial \omega_i}{\partial \omega_{i-1}}\frac{\partial \omega_{i-1}}{\partial \omega_{i-2}}\frac{\partial \omega_{i-2}}{\partial \Omega} + \cdots\right)$$

IK Results



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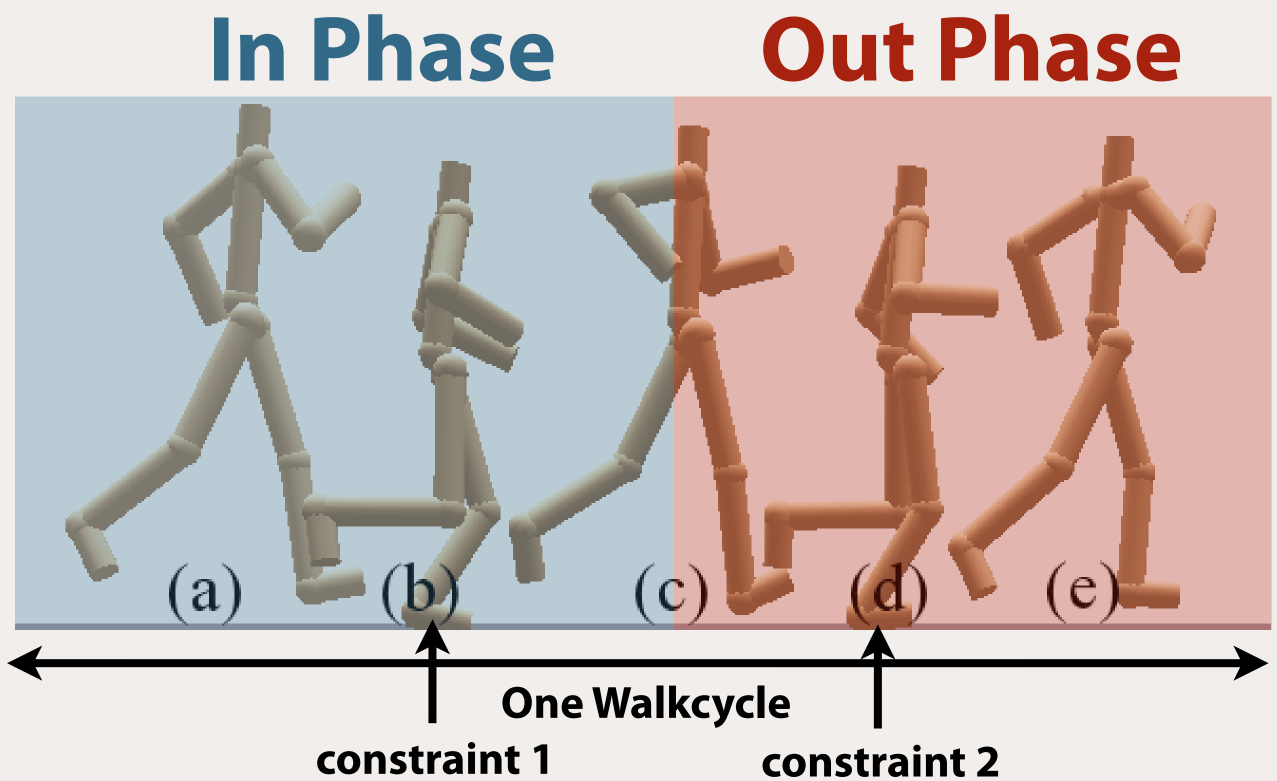
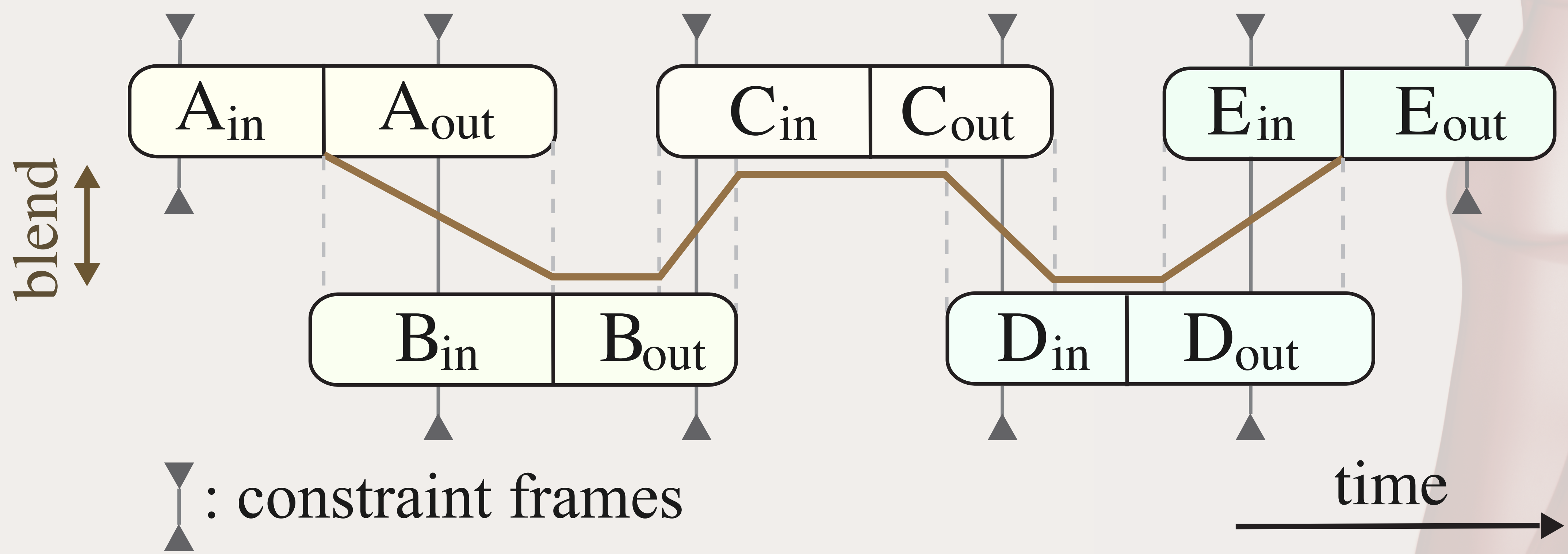
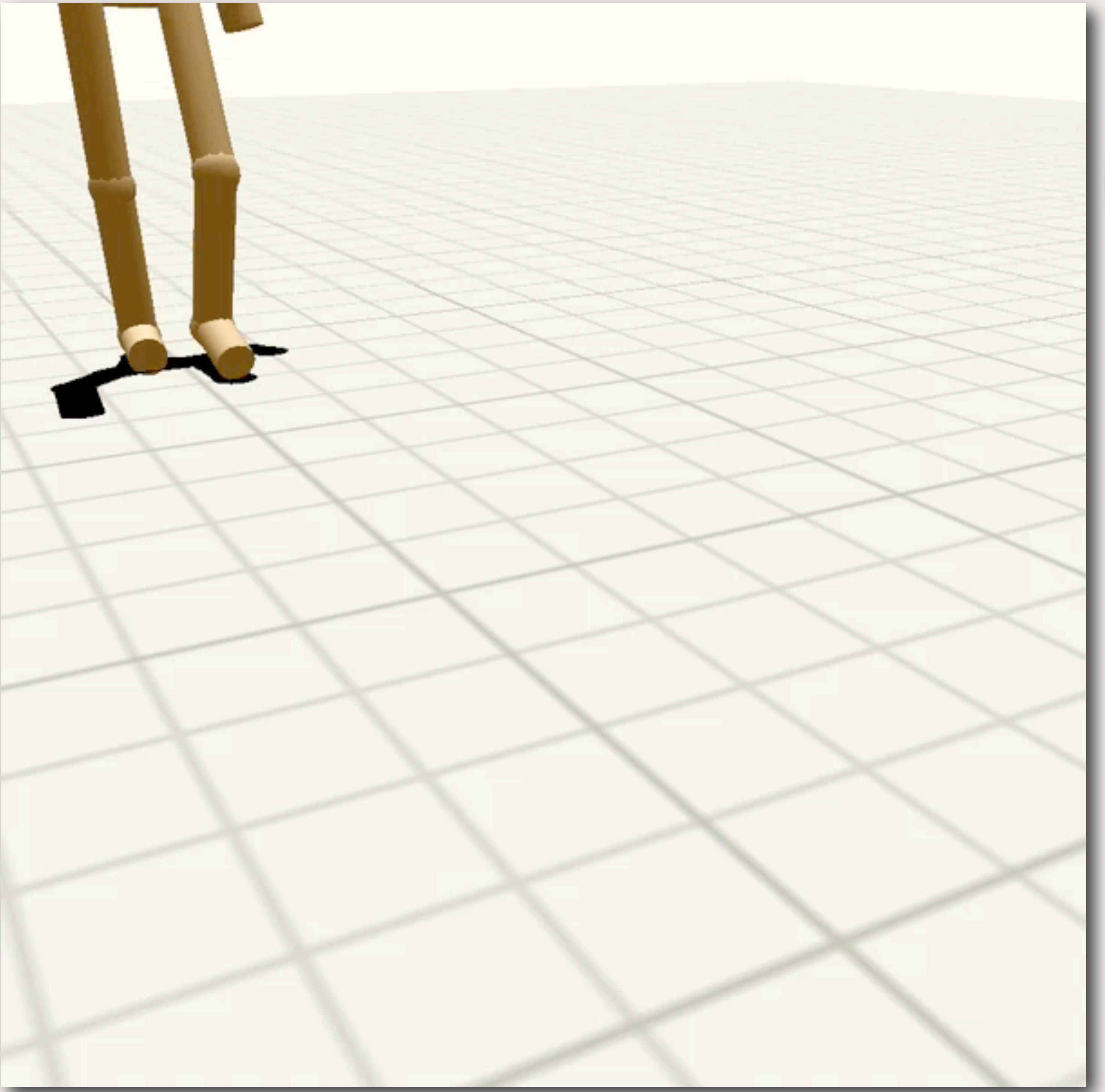
Smart Blending





Smart Blending Example



source: Treuille et al. [2002]

Open Problems

- How to pick to which clip to transition?
- How to enforce temporal contraints?
- How to generalize beyond the given clips?

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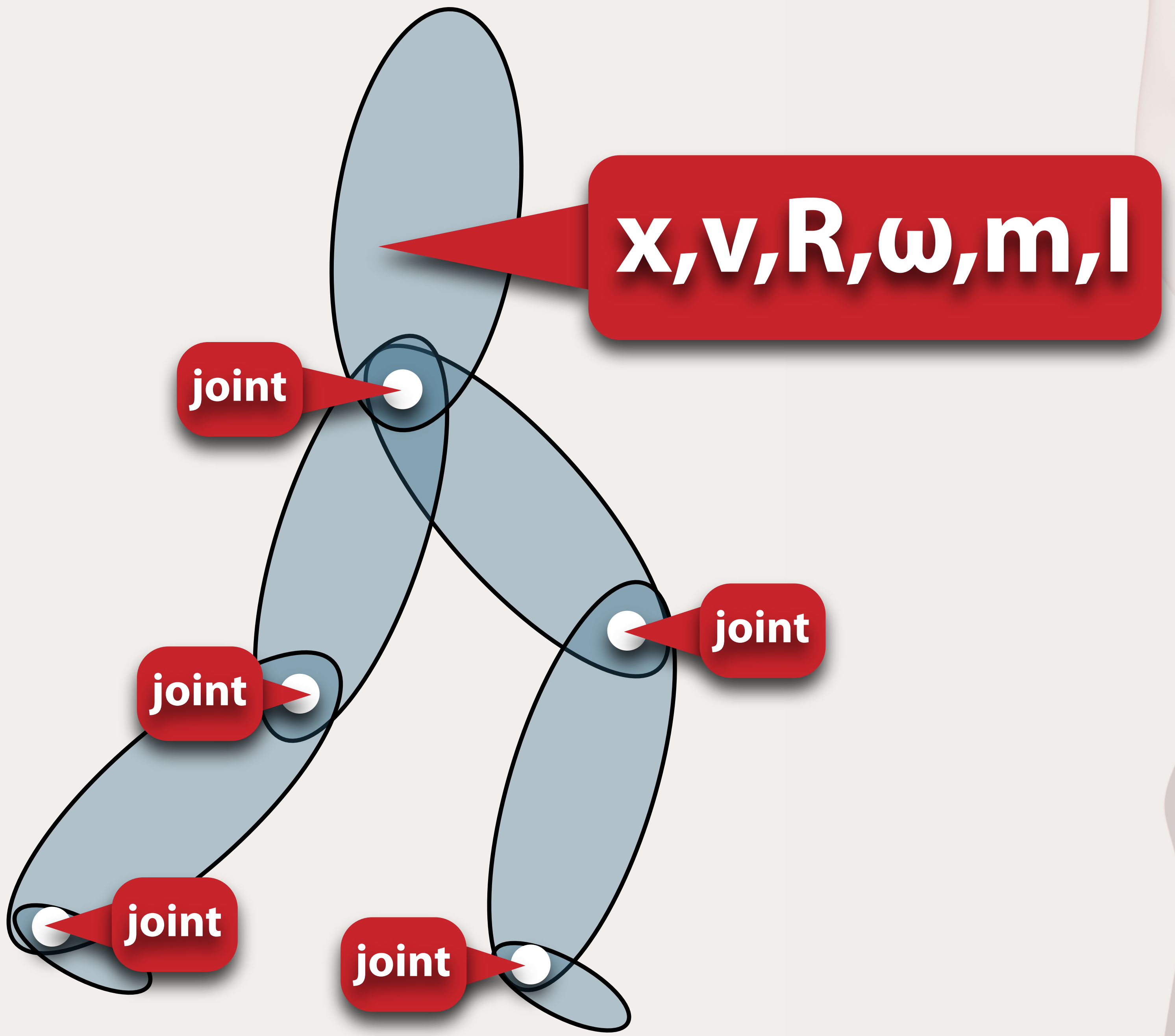
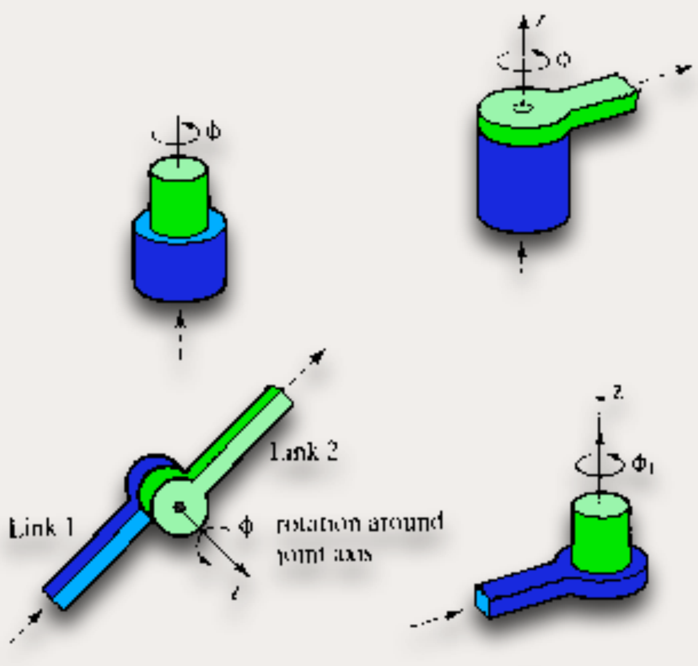
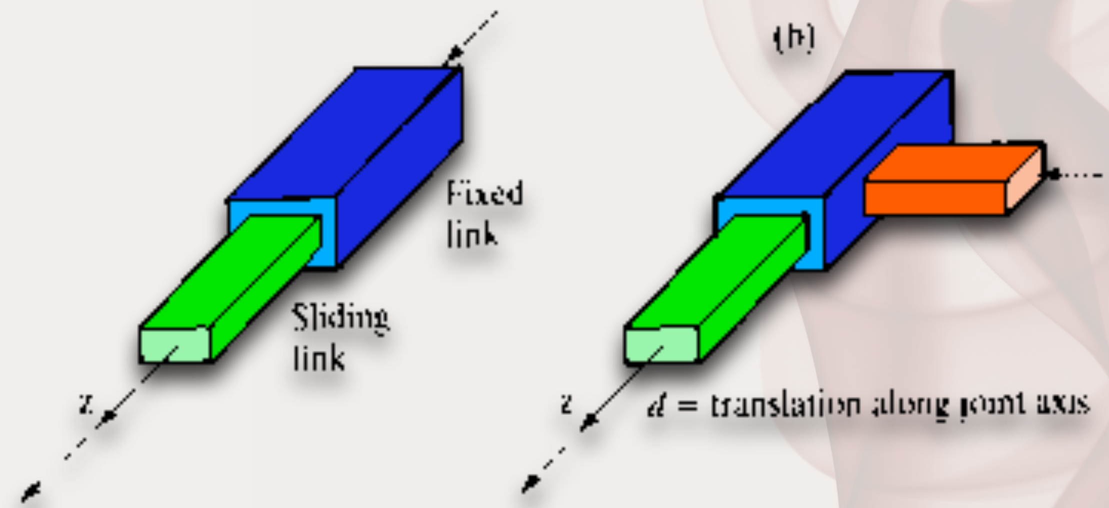
Physical Model



Joint Types

All joints can be written as the composition of...





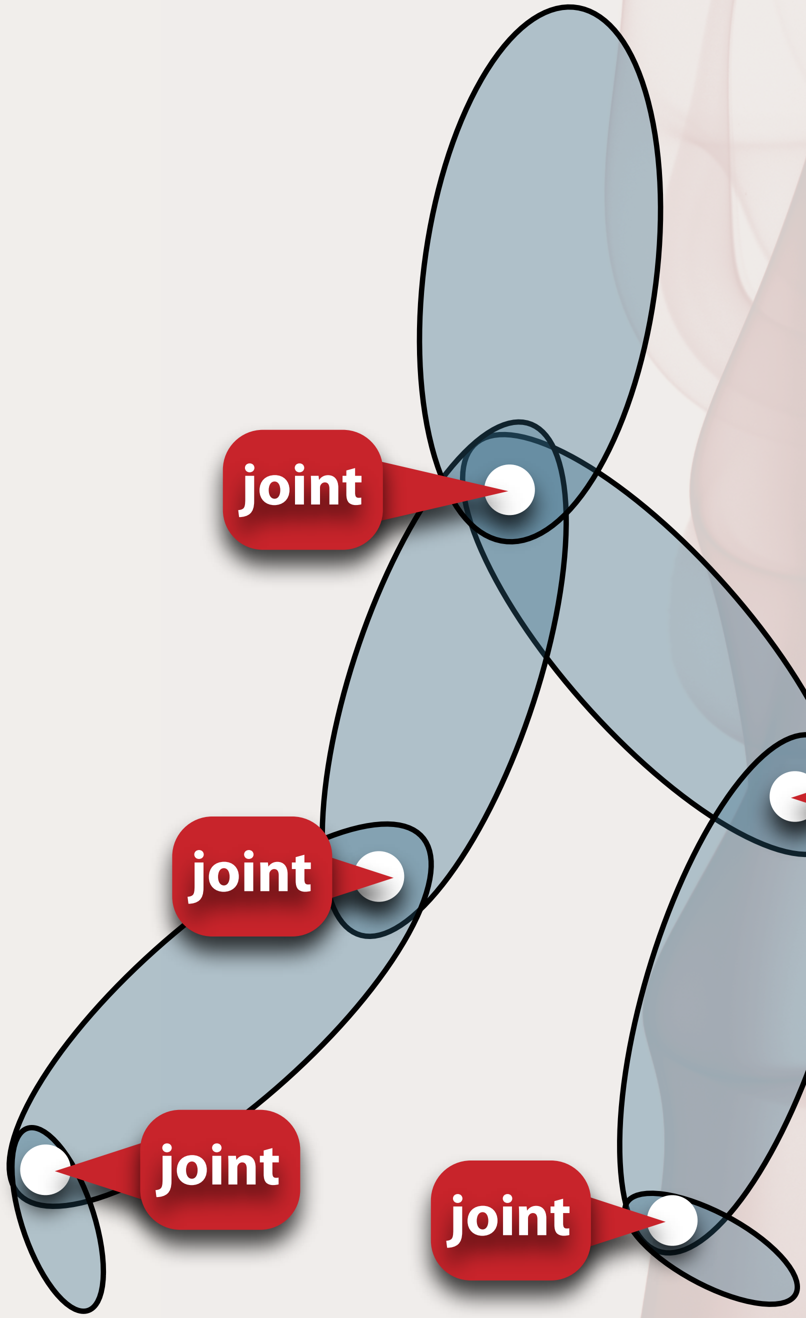
Rotary | **Prismatic**

...and have two forms:

1. Constraint Form
2. Functional Form

Joint Enforcement

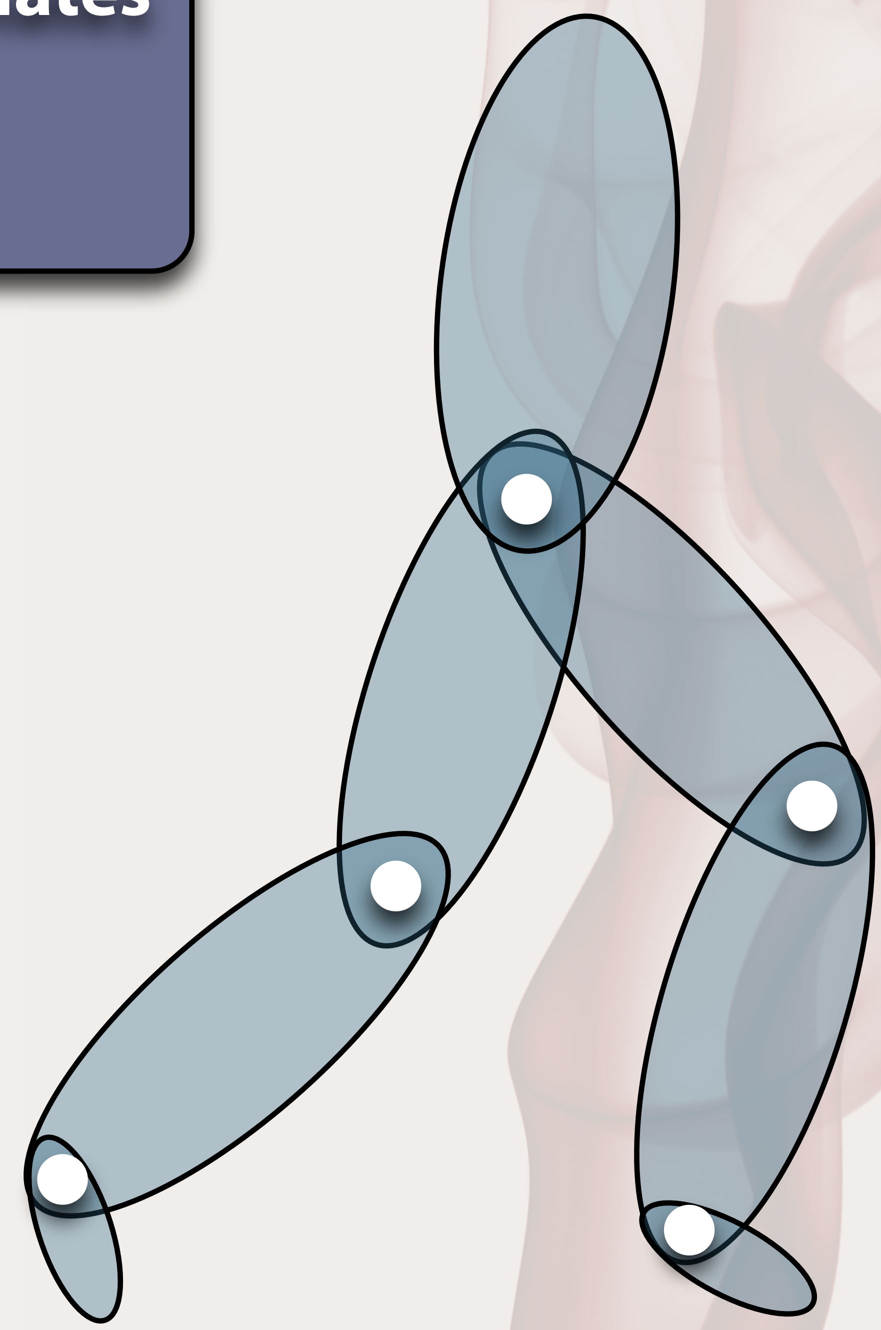
- Penalty Methods
- Contraint Methods
  - aka Maximal Coordinate
- Minimal Coordinates



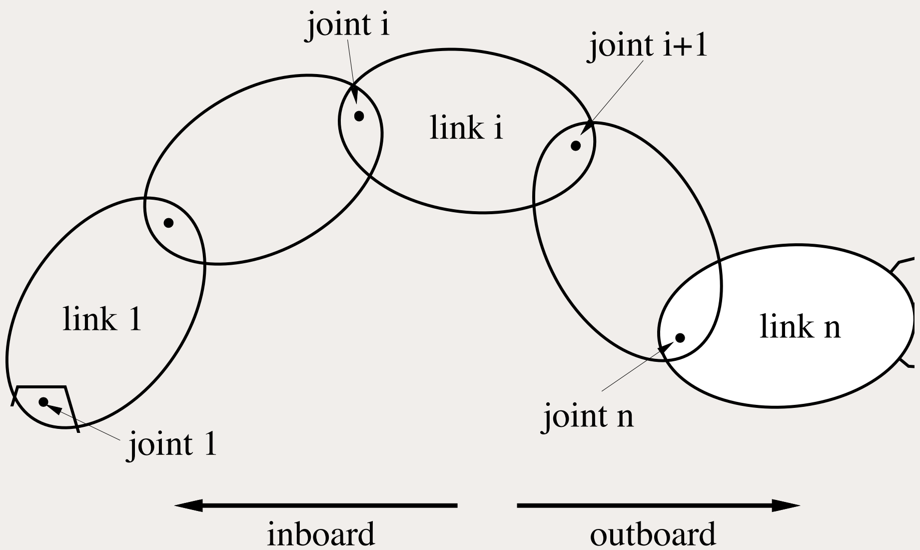
Internal Coordinates

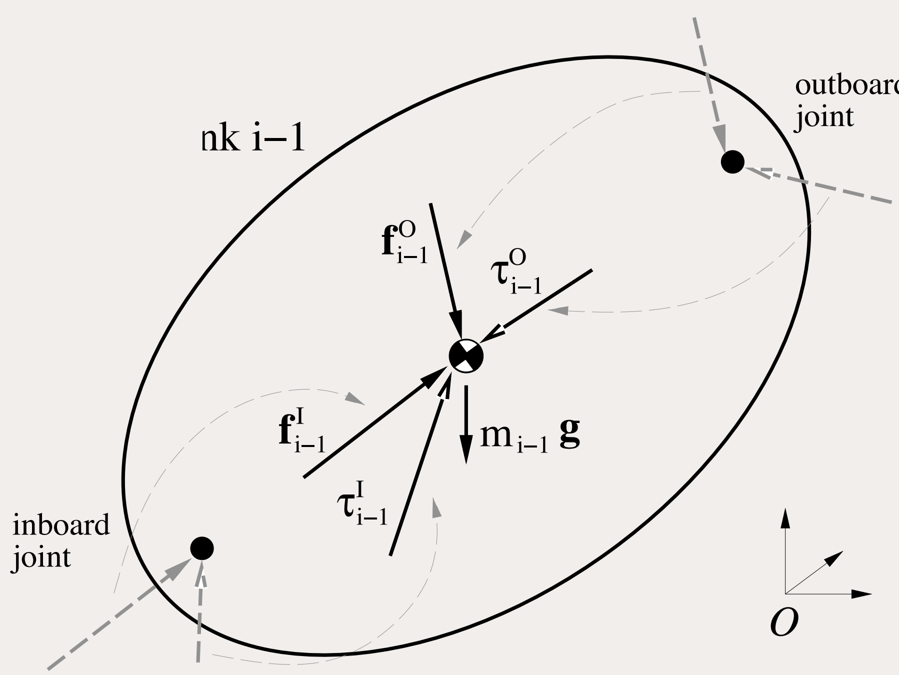
- q: the skeletal coordinates
- $\dot{q}$: joint velocities
- $\ddot{q}$: joint accelerations

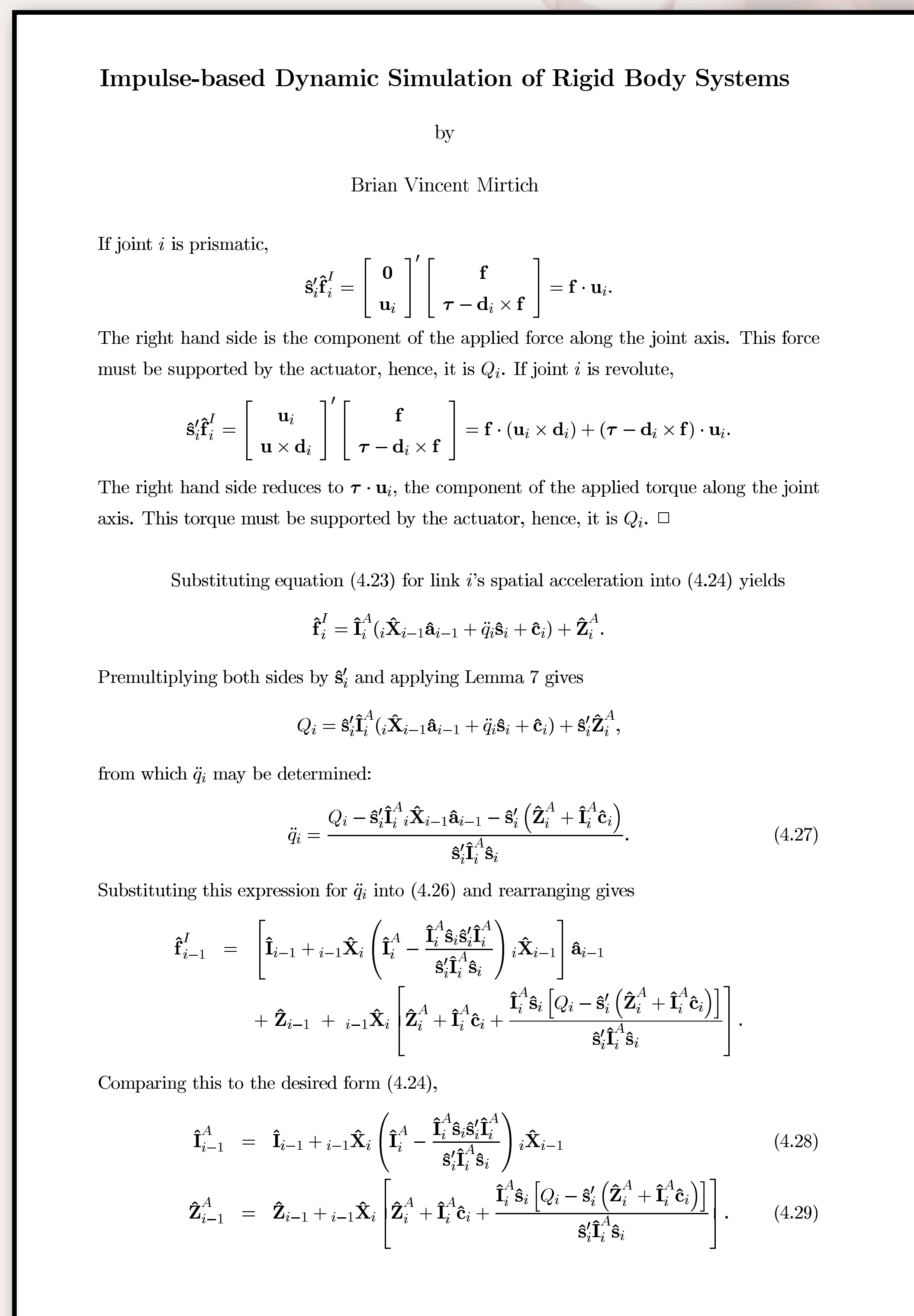
- ***Forward Dynamics Problem***
  - **Compute $\ddot{q} = F(q, \dot{q}, f, \tau)$**
    - **f: external forces**
    - **τ: internal torques**
  - **Then use ODE solver.**
- ***Inverse Dynamics Problem***
  - **Compute $\tau = G(q, \dot{q}, \ddot{q}, f)$**



Featherstone Algorithm







Impulse-based Dynamic Simulation of Rigid Body Systems

by

Brian Vincent Mirtich

If joint i is prismatic,

$$\hat{\mathbf{s}}_i'\hat{\mathbf{f}}_i^I = \begin{bmatrix} \mathbf{0} \\ \mathbf{u}_i \end{bmatrix}' \begin{bmatrix} \mathbf{f} \\ \boldsymbol{\tau} - \mathbf{d}_i \times \mathbf{f} \end{bmatrix} = \mathbf{f} \cdot \mathbf{u}_i.$$

The right hand side is the component of the applied force along the joint axis. This force must be supported by the actuator, hence, it is Q_i. If joint i is revolute,

$$\hat{\mathbf{s}}_i'\hat{\mathbf{f}}_i^I = \begin{bmatrix} \mathbf{u}_i \\ \mathbf{u} \times \mathbf{d}_i \end{bmatrix}' \begin{bmatrix} \mathbf{f} \\ \boldsymbol{\tau} - \mathbf{d}_i \times \mathbf{f} \end{bmatrix} = \mathbf{f} \cdot (\mathbf{u}_i \times \mathbf{d}_i) + (\boldsymbol{\tau} - \mathbf{d}_i \times \mathbf{f}) \cdot \mathbf{u}_i.$$

The right hand side reduces to $\boldsymbol{\tau} \cdot \mathbf{u}_i$, the component of the applied torque along the joint axis. This torque must be supported by the actuator, hence, it is Q_i. □

Substituting equation (4.23) for link i's spatial acceleration into (4.24) yields

$$\hat{\mathbf{f}}_i^I = \hat{\mathbf{I}}_i^A ({}_i\hat{\mathbf{X}}_{i-1}\hat{\mathbf{a}}_{i-1} + \ddot{q}_i\hat{\mathbf{s}}_i + \hat{\mathbf{c}}_i) + \hat{\mathbf{Z}}_i^A.$$

Premultiplying both sides by $\hat{\mathbf{s}}_i'$ and applying Lemma 7 gives

$$Q_i = \hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A ({}_i\hat{\mathbf{X}}_{i-1}\hat{\mathbf{a}}_{i-1} + \ddot{q}_i\hat{\mathbf{s}}_i + \hat{\mathbf{c}}_i) + \hat{\mathbf{s}}_i'\hat{\mathbf{Z}}_i^A,$$

from which $\ddot{q}_i$ may be determined:

$$\ddot{q}_i = \frac{Q_i - \hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\,{}_i\hat{\mathbf{X}}_{i-1}\hat{\mathbf{a}}_{i-1} - \hat{\mathbf{s}}_i'\left(\hat{\mathbf{Z}}_i^A + \hat{\mathbf{I}}_i^A\hat{\mathbf{c}}_i\right)}{\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i}. \tag{4.27}$$

Substituting this expression for $\ddot{q}_i$ into (4.26) and rearranging gives

$$\begin{aligned} \hat{\mathbf{f}}_{i-1}^I \;=\; & \left[\hat{\mathbf{I}}_{i-1} + {}_{i-1}\hat{\mathbf{X}}_i \left(\hat{\mathbf{I}}_i^A - \frac{\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A}{\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i}\right) {}_i\hat{\mathbf{X}}_{i-1}\right]\hat{\mathbf{a}}_{i-1} \\ & + \hat{\mathbf{Z}}_{i-1} + {}_{i-1}\hat{\mathbf{X}}_i \left[\hat{\mathbf{Z}}_i^A + \hat{\mathbf{I}}_i^A\hat{\mathbf{c}}_i + \frac{\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i\left[Q_i - \hat{\mathbf{s}}_i'\left(\hat{\mathbf{Z}}_i^A + \hat{\mathbf{I}}_i^A\hat{\mathbf{c}}_i\right)\right]}{\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i}\right]. \end{aligned}$$

Comparing this to the desired form (4.24),

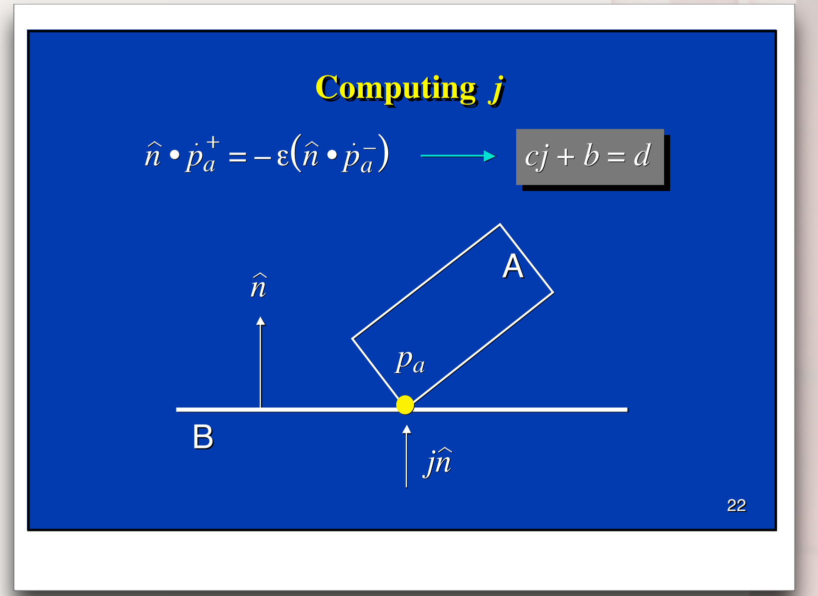
$$\hat{\mathbf{I}}_{i-1}^A = \hat{\mathbf{I}}_{i-1} + {}_{i-1}\hat{\mathbf{X}}_i \left(\hat{\mathbf{I}}_i^A - \frac{\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A}{\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i}\right) {}_i\hat{\mathbf{X}}_{i-1} \tag{4.28}$$

$$\hat{\mathbf{Z}}_{i-1}^A = \hat{\mathbf{Z}}_{i-1} + {}_{i-1}\hat{\mathbf{X}}_i \left[\hat{\mathbf{Z}}_i^A + \hat{\mathbf{I}}_i^A\hat{\mathbf{c}}_i + \frac{\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i\left[Q_i - \hat{\mathbf{s}}_i'\left(\hat{\mathbf{Z}}_i^A + \hat{\mathbf{I}}_i^A\hat{\mathbf{c}}_i\right)\right]}{\hat{\mathbf{s}}_i'\hat{\mathbf{I}}_i^A\hat{\mathbf{s}}_i}\right]. \tag{4.29}$$

Constraints

- **Accelerations are *linear* in applied torques and forces.**

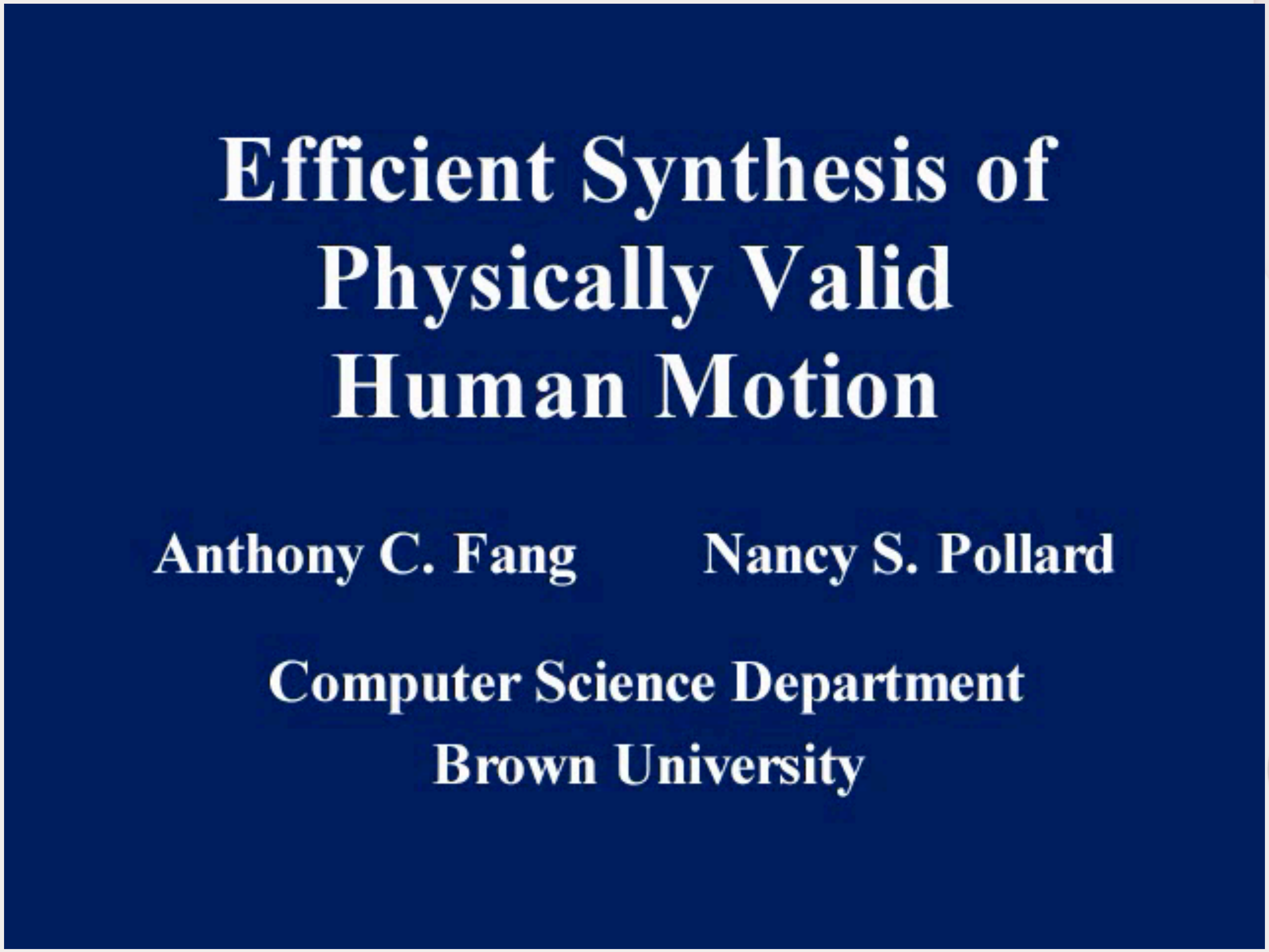
$$a_f = kf + a_0$$



- **Use of "test forces"**
- **Multiple test forces**

$$\mathbf{a}_f = K\mathbf{f} + \mathbf{a}_0$$

Examples


Efficient Synthesis of
Physically Valid
Human Motion
Anthony C. Fang
Nancy S. Pollard
Computer Science Department
Brown University

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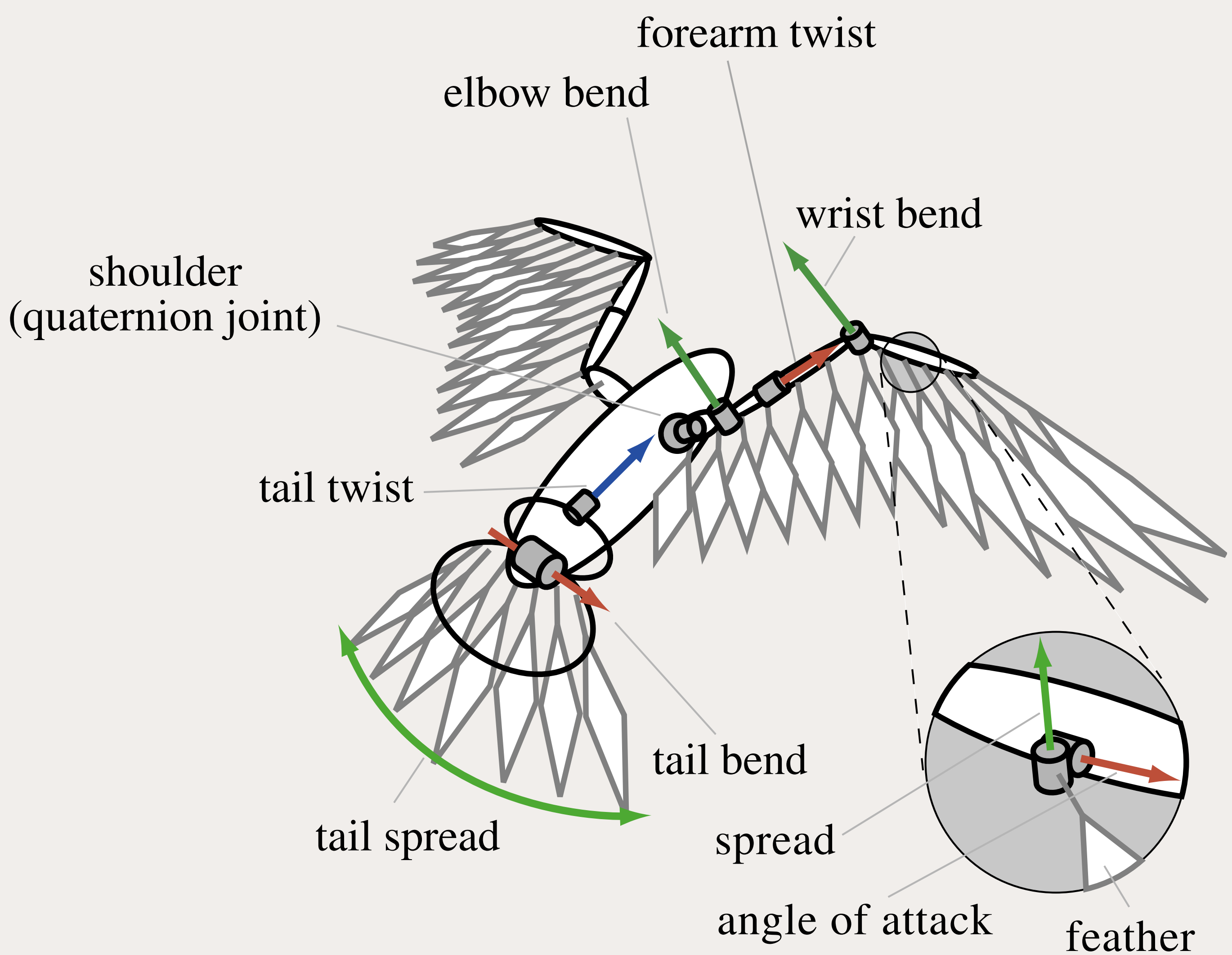
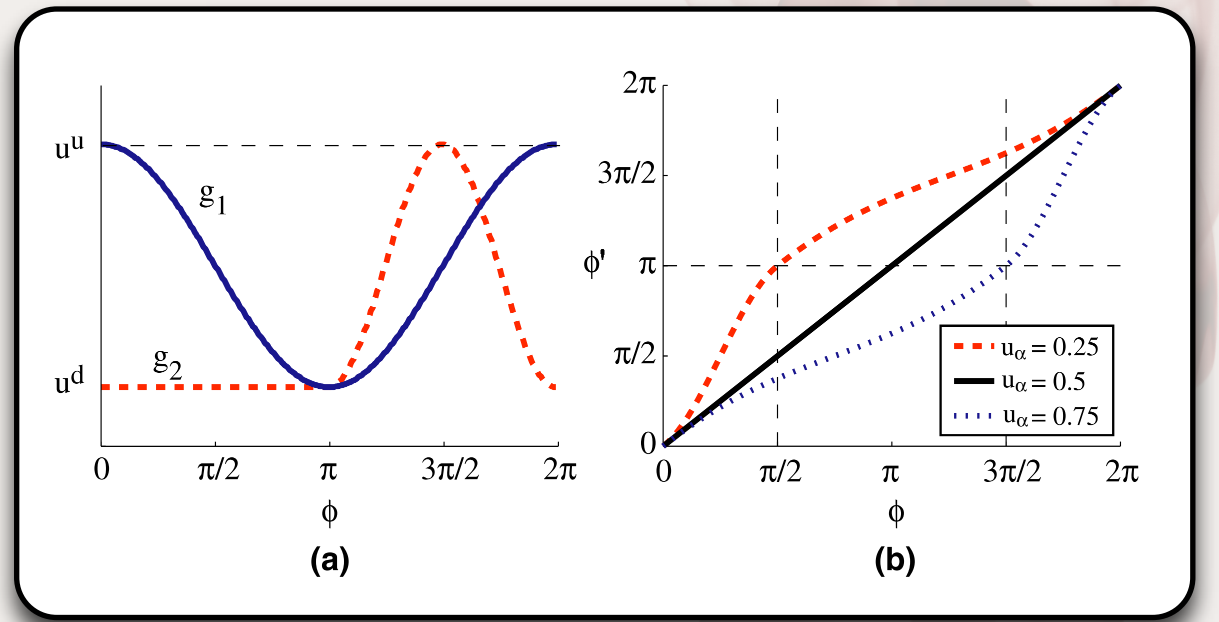
Bird Flight

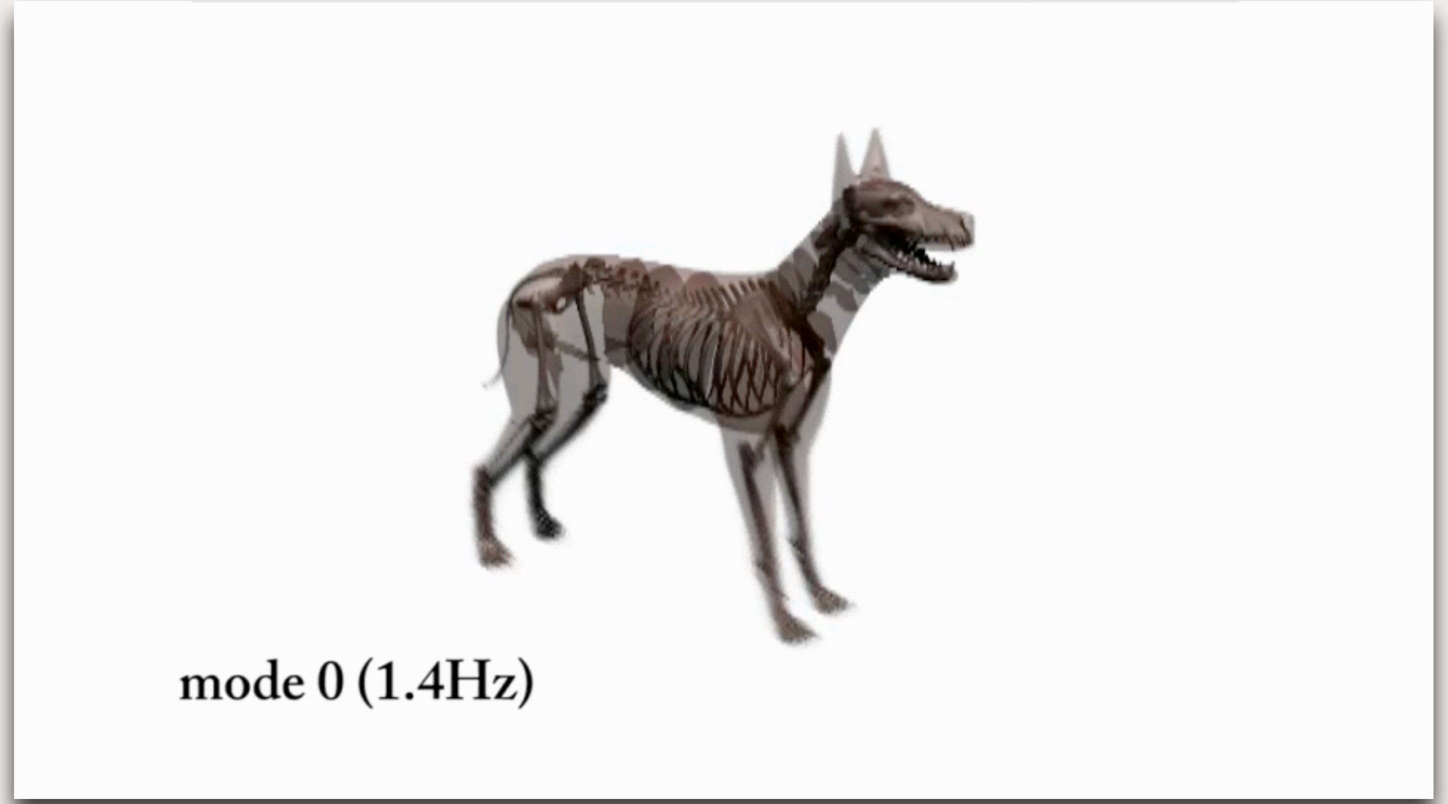




source: Wu and Popović [2003]

Bird Flight Examples

Dogs



source: Kry et al [2007]

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Questions

- What might be the best physics control paradigm from the animator's perspective?
- How can we control physics (in general)?
- What about linear dynamics (like springs), vs. nonlinear dynamics (like fluids)?
- What about constraints? (e.g. joints)