Humans:
The Final Frontier

source: http://www.gimartex.es/myfiles/Ballet-dancer_01.jpg

Adrien Treuille

Overview

- State of the art.
- Body models.
- Animation
- Vote.
- Questions

source: 3dscience.com

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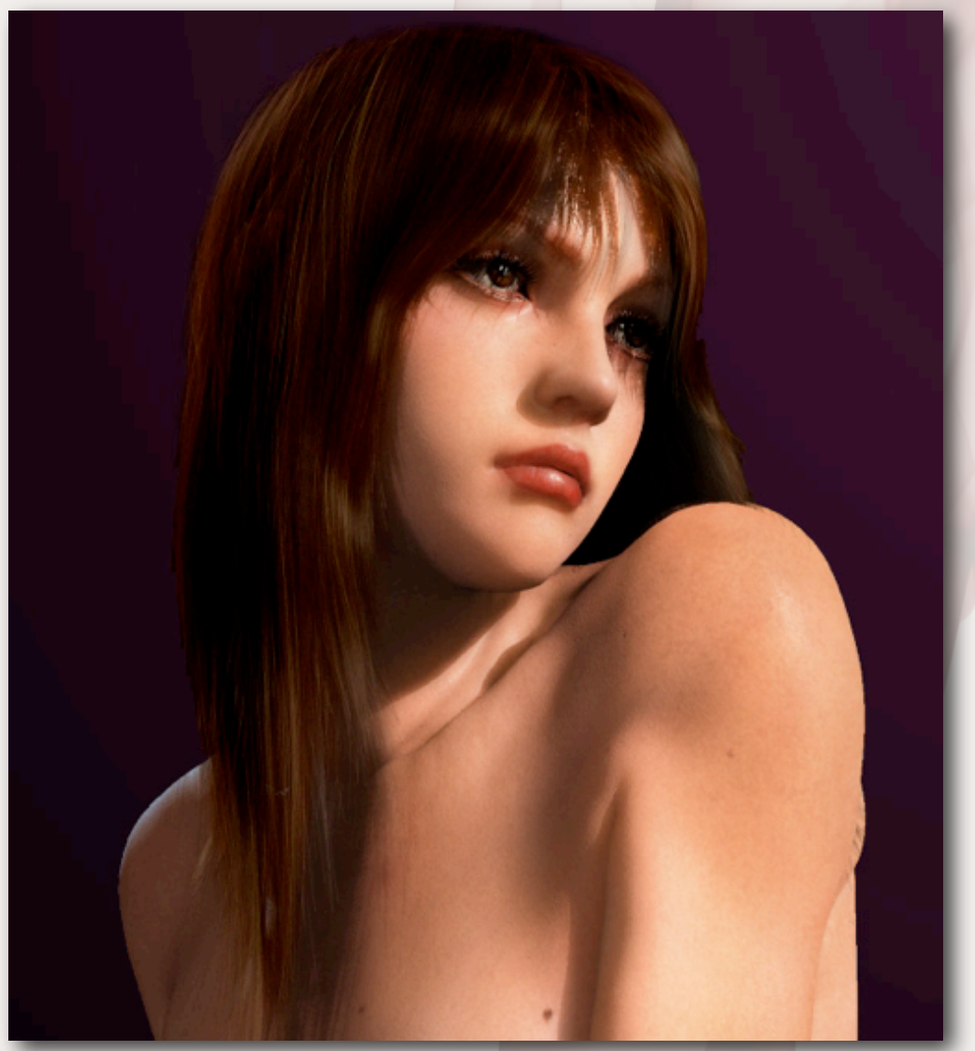
State of the Art

- **Steady but *slow* progress towards digital humans.**



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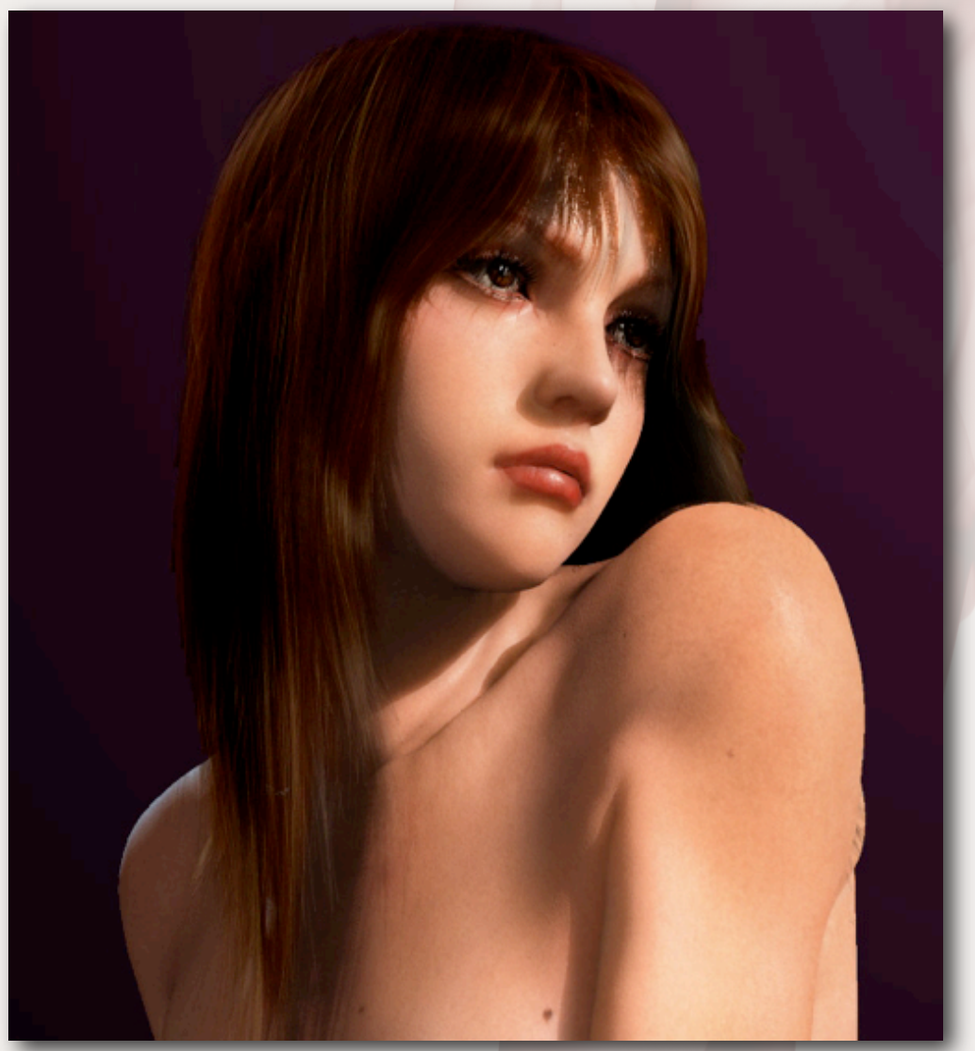

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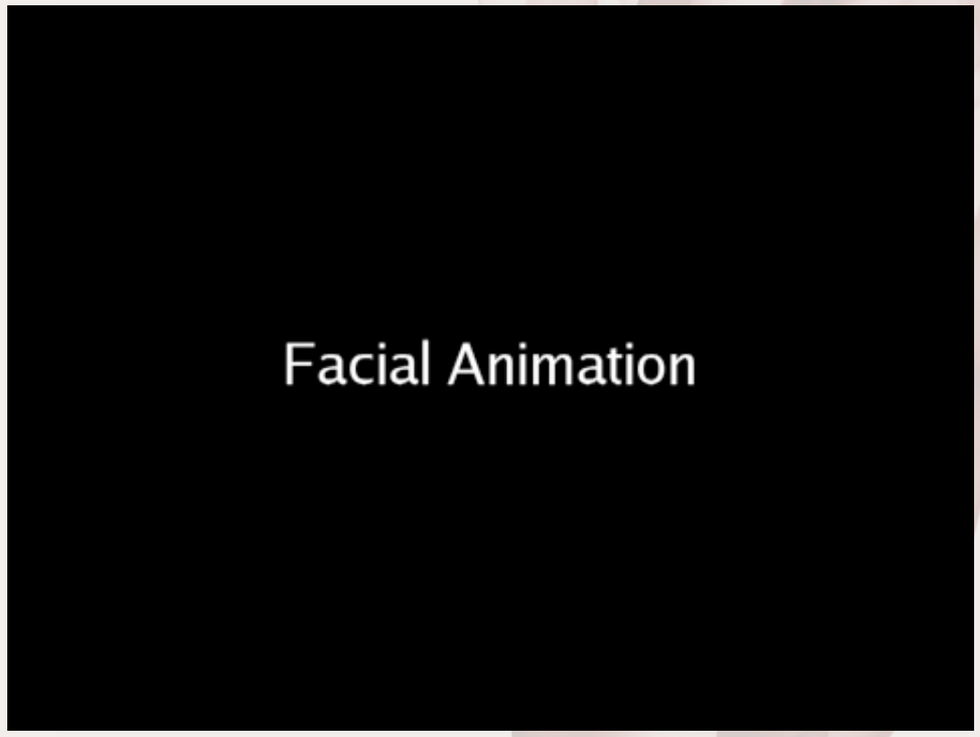

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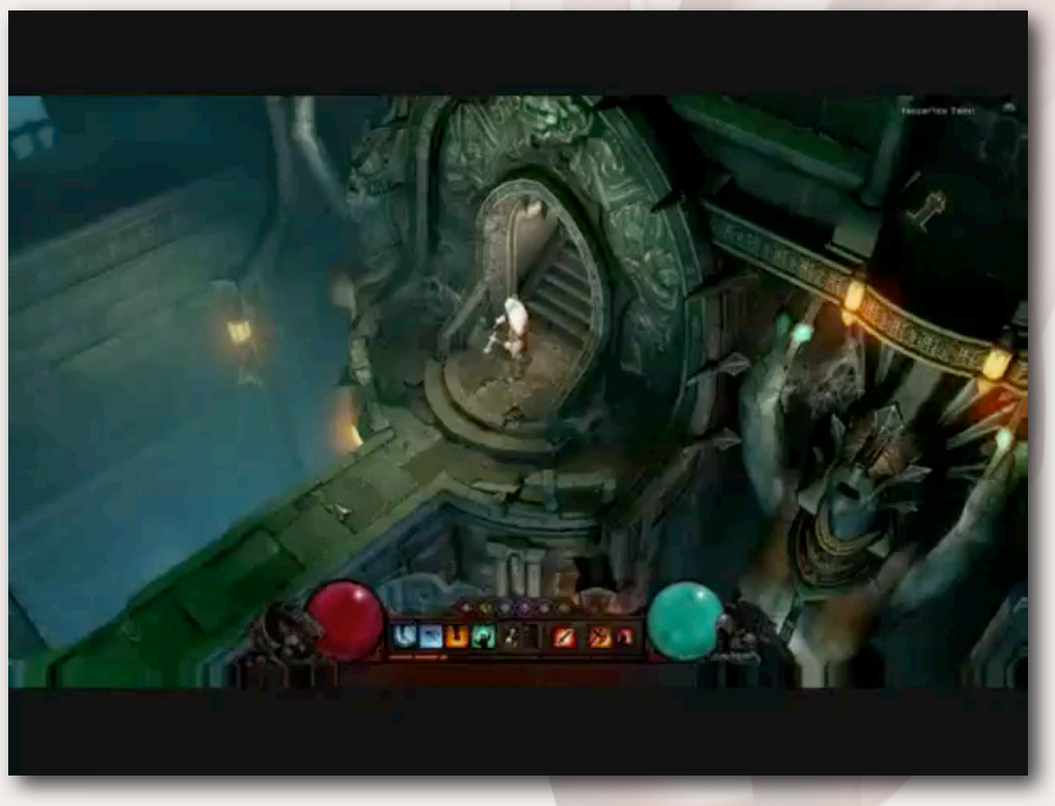

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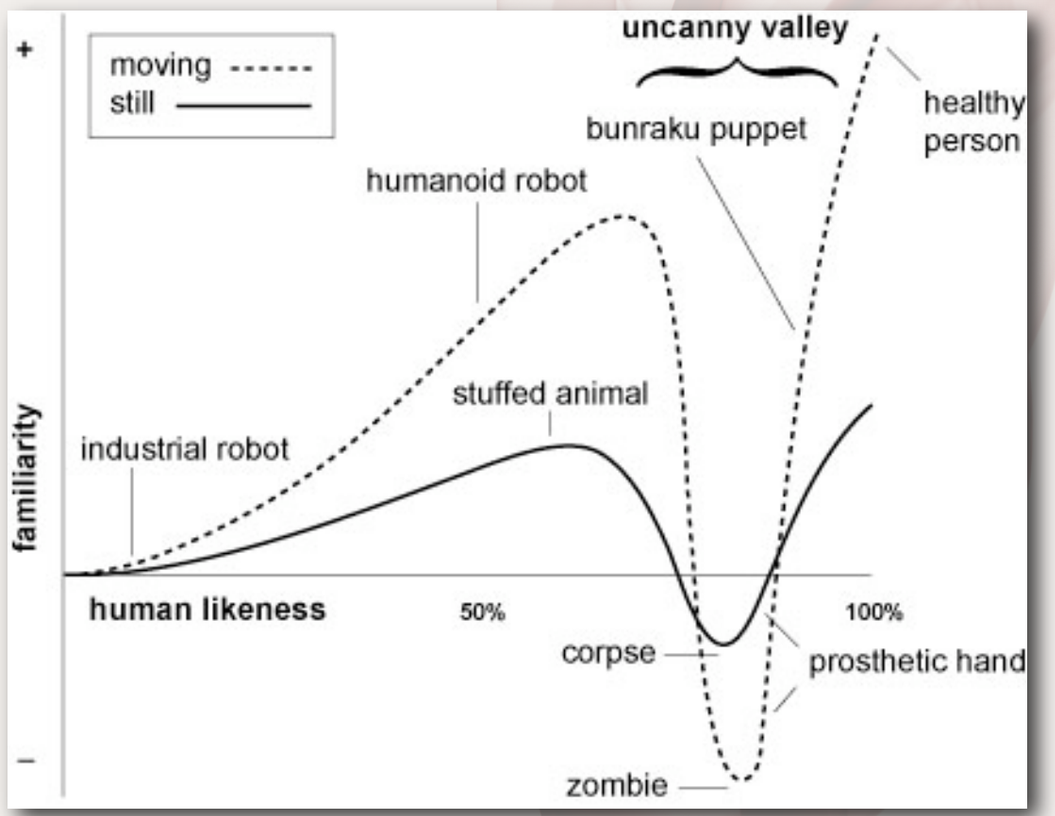

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- **Facial Animation.**
- **Most human animation is *data driven*.**

(Like saying that graphics is solved by the camera.)

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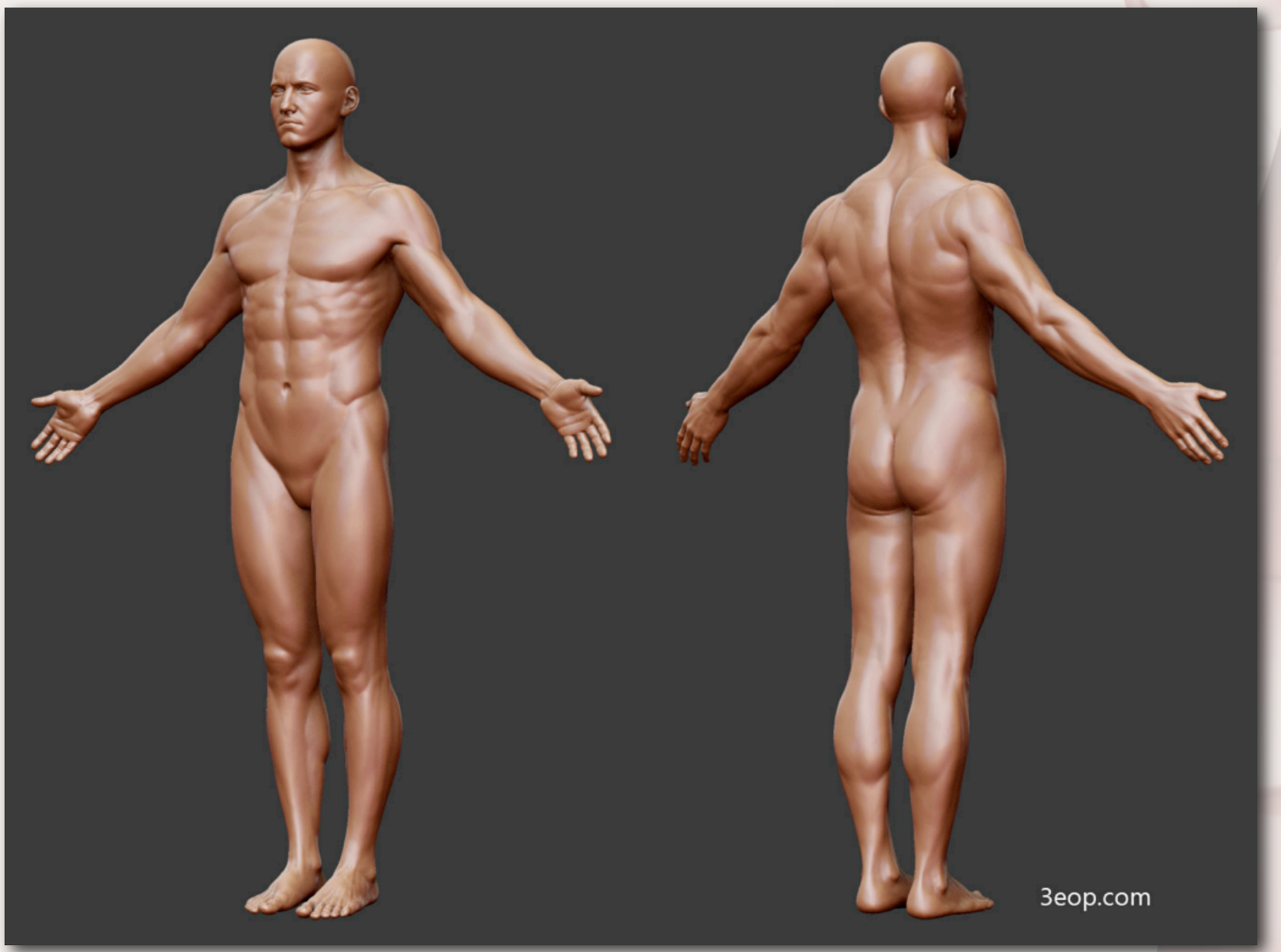
Body Representation

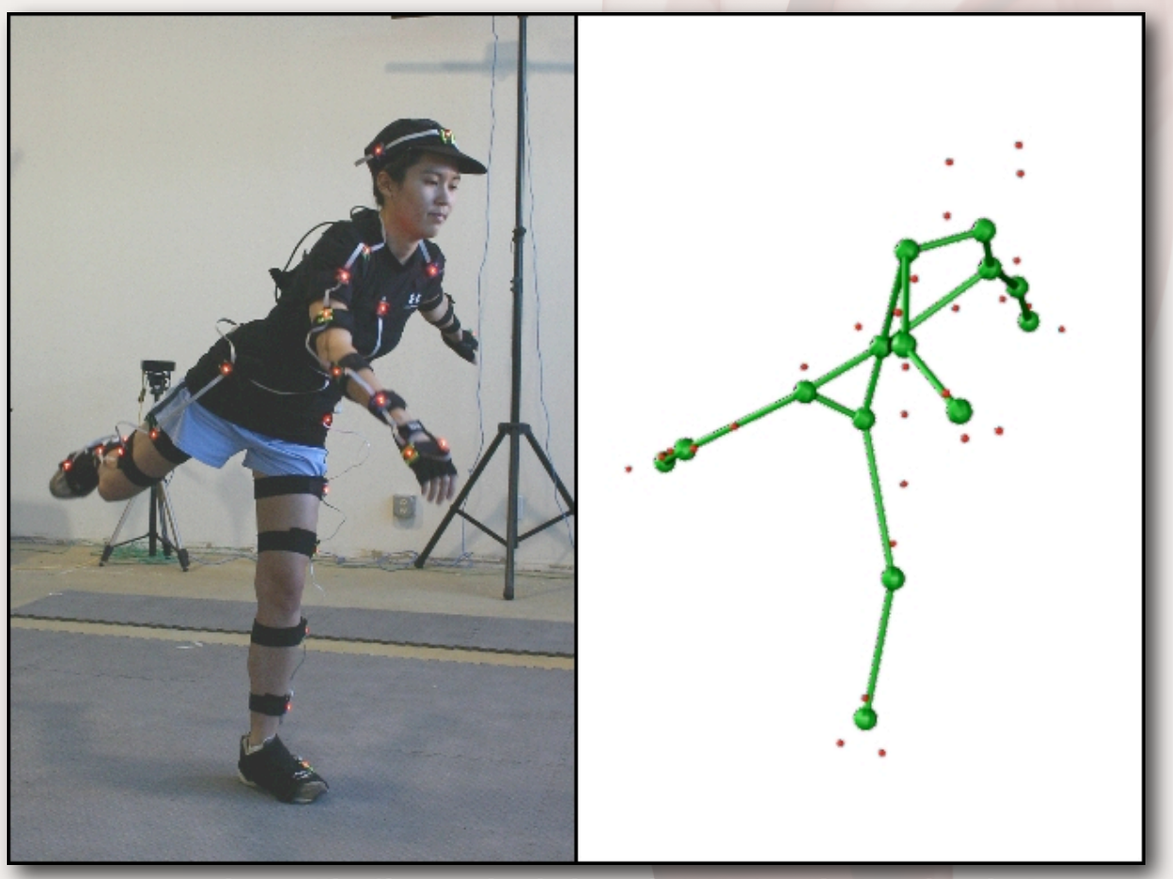


source: http://www.3eop.com/data/3d/images/08_05_26_anatomy_study_male.jpg

How to represent a human body on a computer?

Body Representation

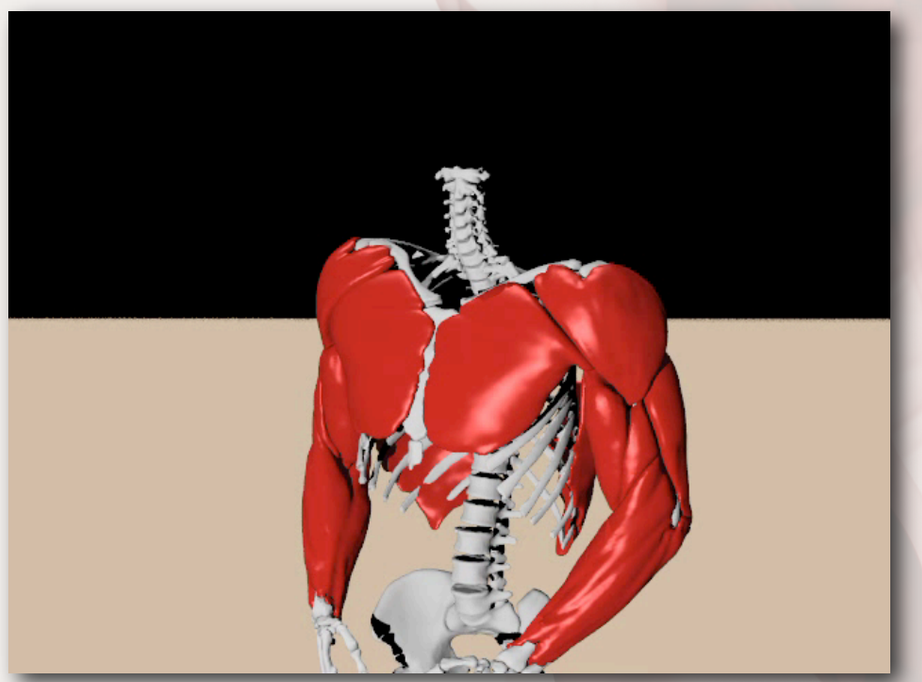
- **Kinematic Skeleton**

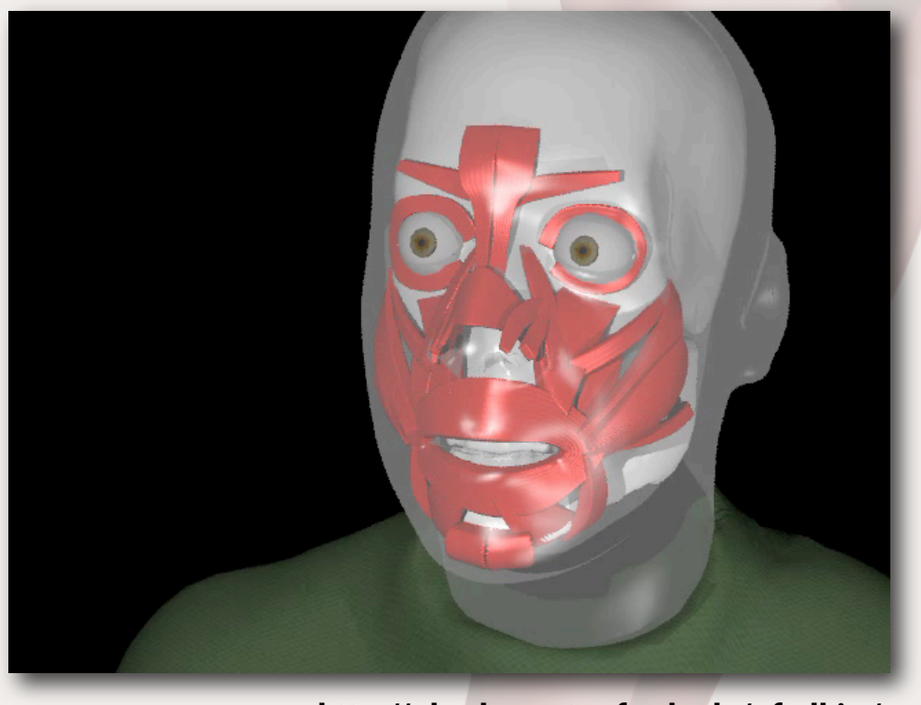


source: https://buffy.eecs.berkeley.edu/PHP/resabs/resabs.php?f_year=2005&f_submit=advgrp&f_advid=10917651

Body Representation

- Kinematic Skeleton
- Anatomical

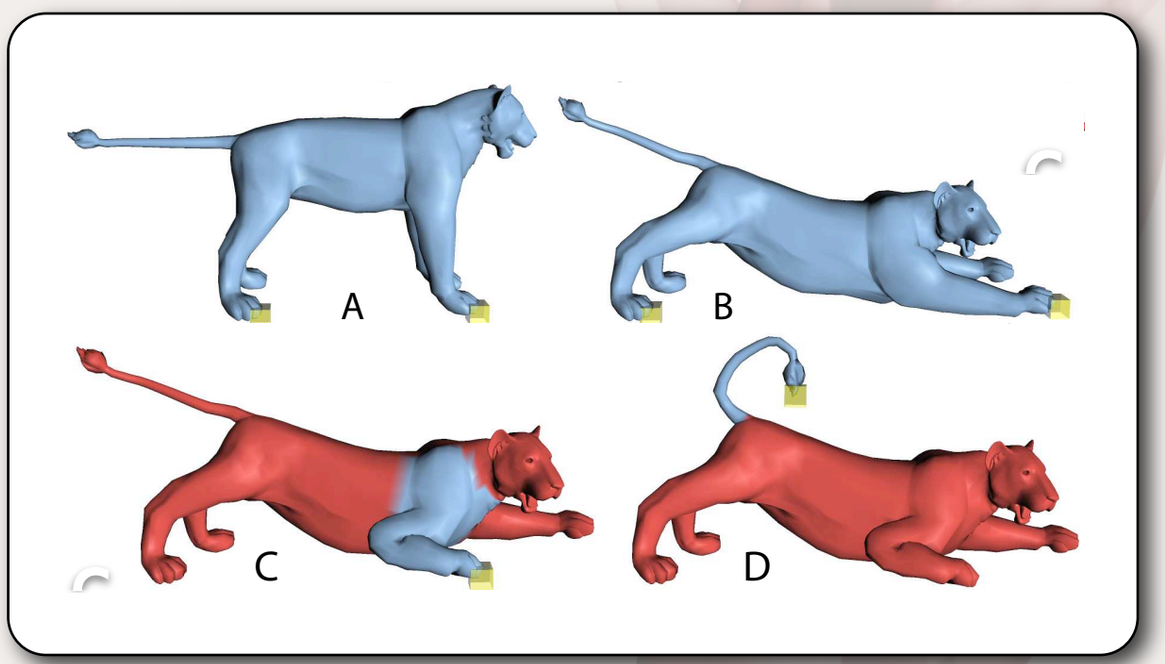




source: http://physbam.stanford.edu/~fedkiw/

Body Representation

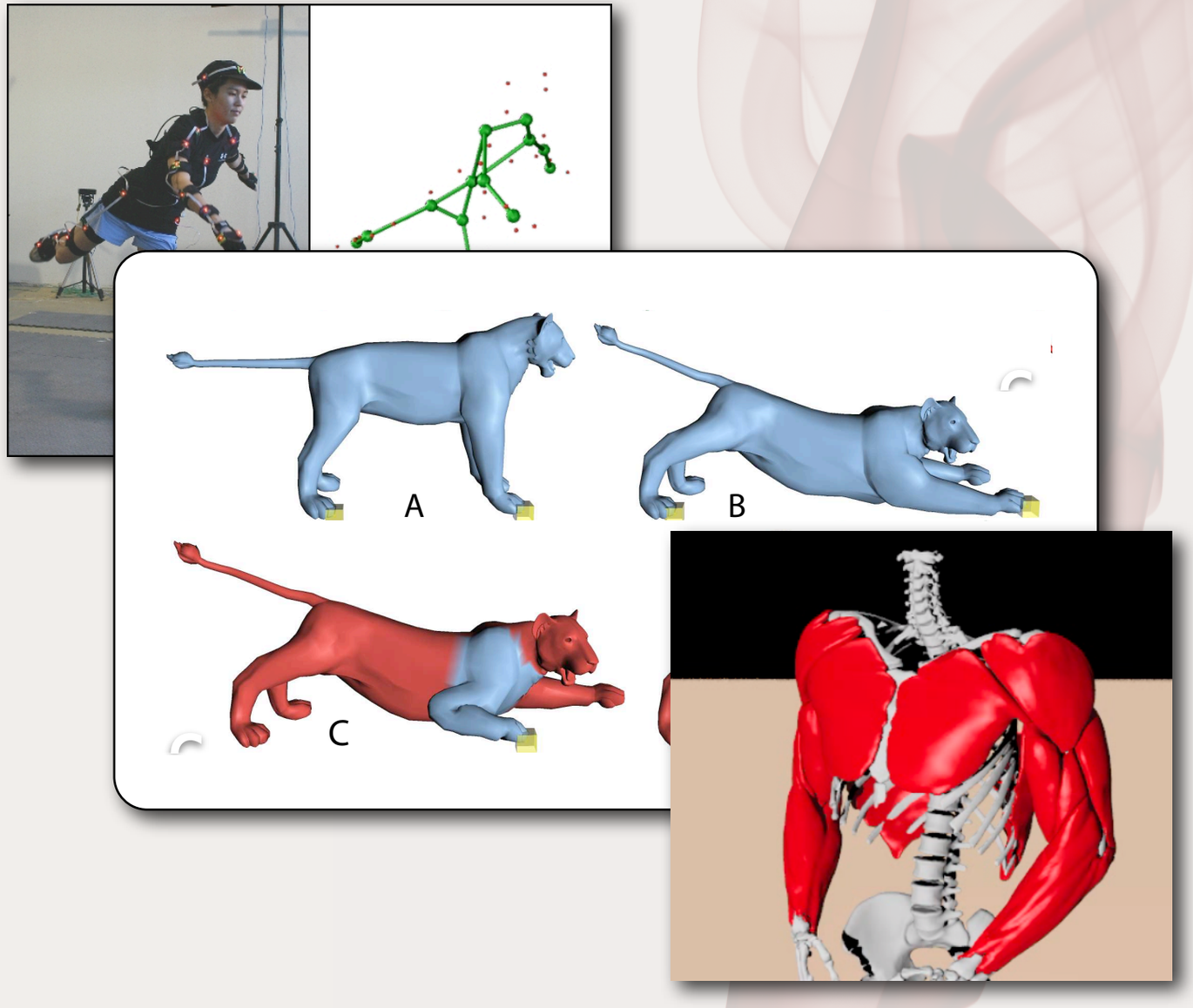
- Kinematic Skeleton
- Anatomical
- Pure Mesh



source: http://people.csail.mit.edu/sumner/research/meshik/

Body Representation

- Kinematic Skeleton
- Anatomical
- Pure Mesh
- What are the advantages and disadvantages?



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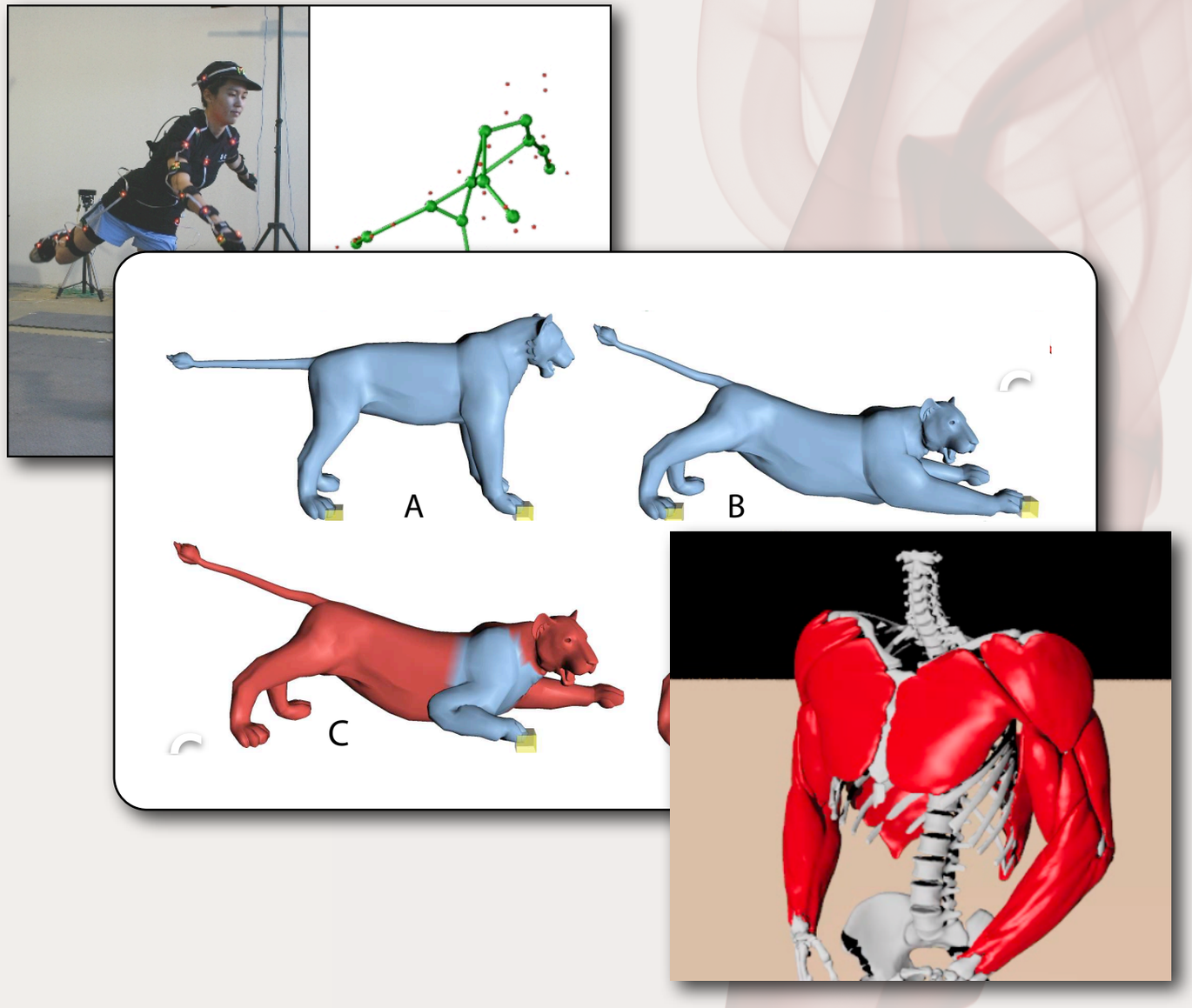
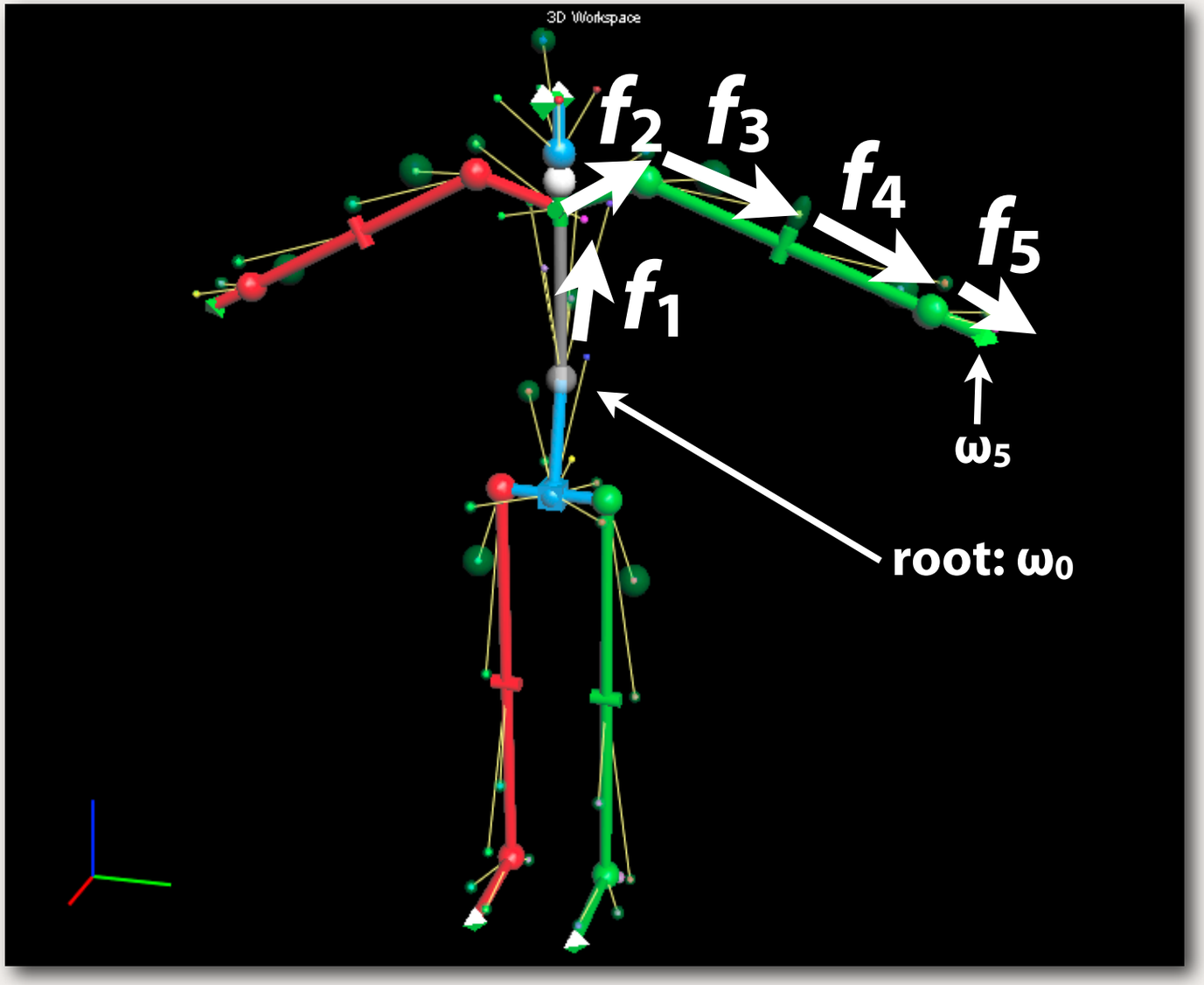


Skeleton Representation



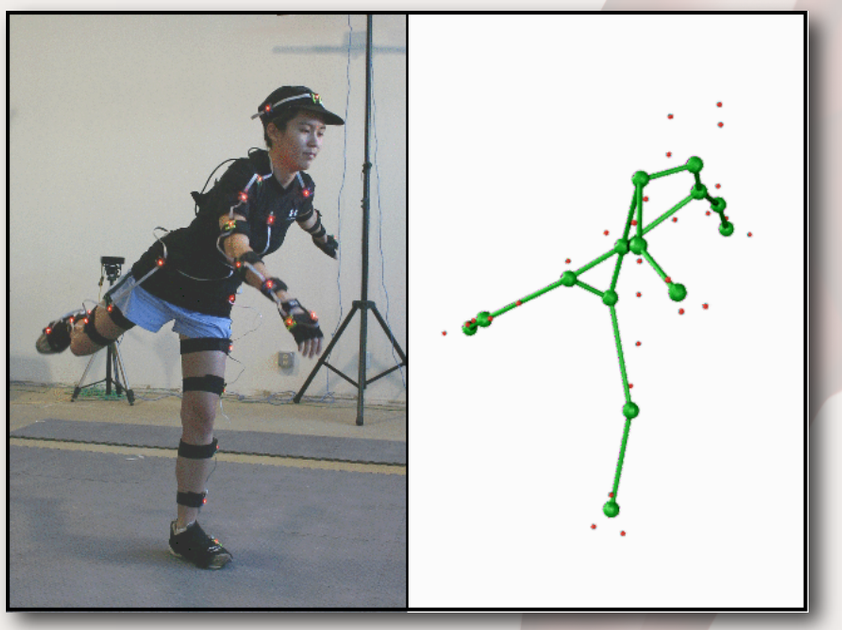
Ω is the vector of *internal* joint angles, i.e. shoulders, hips, etc.

$$\omega_0 = [\mathbf{x}_0, \theta_0] \in \mathbf{R}^6$$

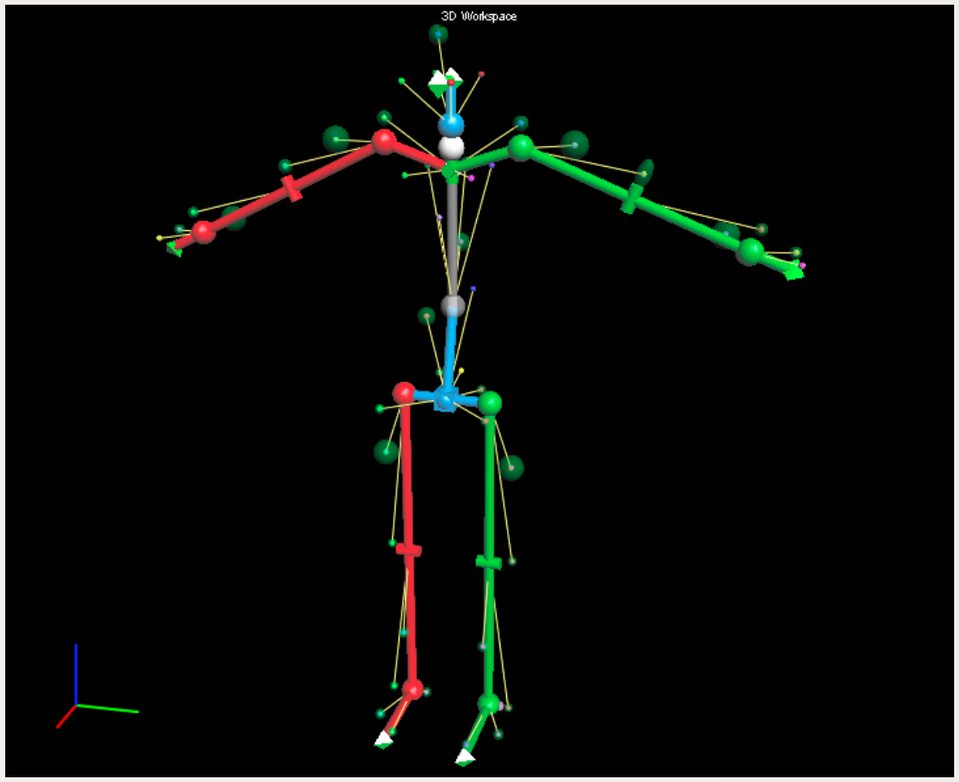
$$\omega_i = f_{i,\Omega}(\omega_{i-1})$$

Motion Capture

- **Attach markers to a humans body.**
- **Calibrate a skeleton which makes those markers "make sense."**
- **Cameras capture 2D markers positions.**
- **Estimate 3D marker positions.**
- ***Inverse kinematics*: convert marker positions to skeleton...**
  - **How?**



Marker Energy Function



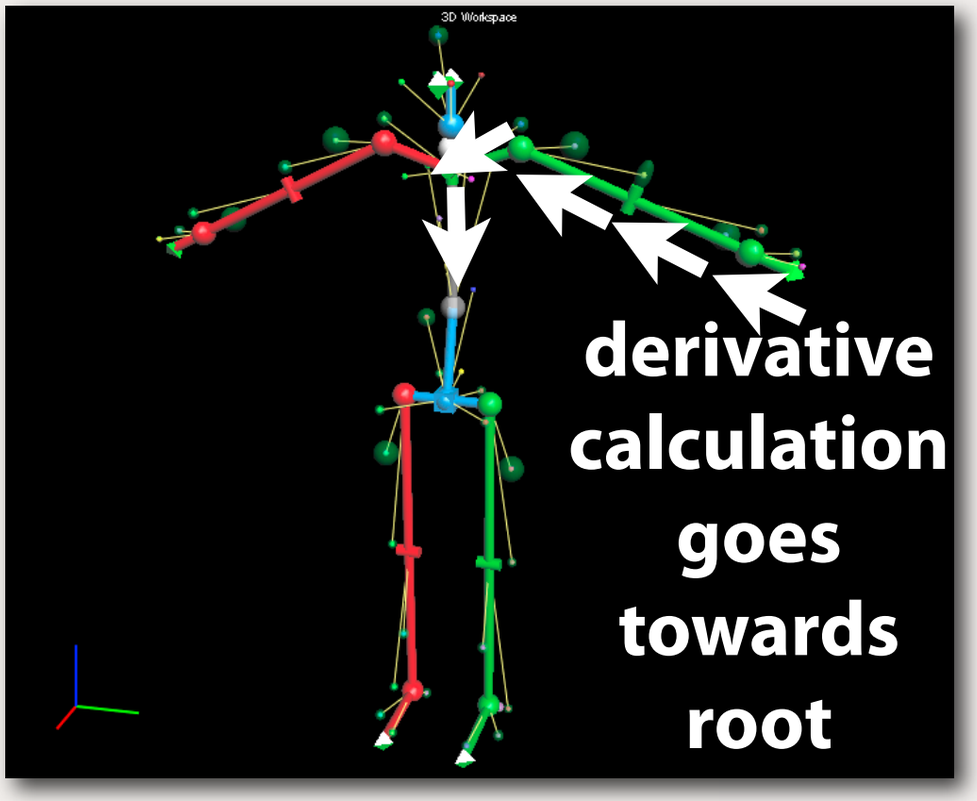
$$\omega_i = f_{i,\Omega}(\omega_{i-1})$$

$$\hat{\mathbf{m}}_j = \tau_i(\omega_i)\mathbf{m}_j$$

$$E = \sum_j ||\hat{\mathbf{m}}_j^\star - \hat{\mathbf{m}}_j||^2$$

$$\frac{dE}{d\Omega}$$

Derivatives



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

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

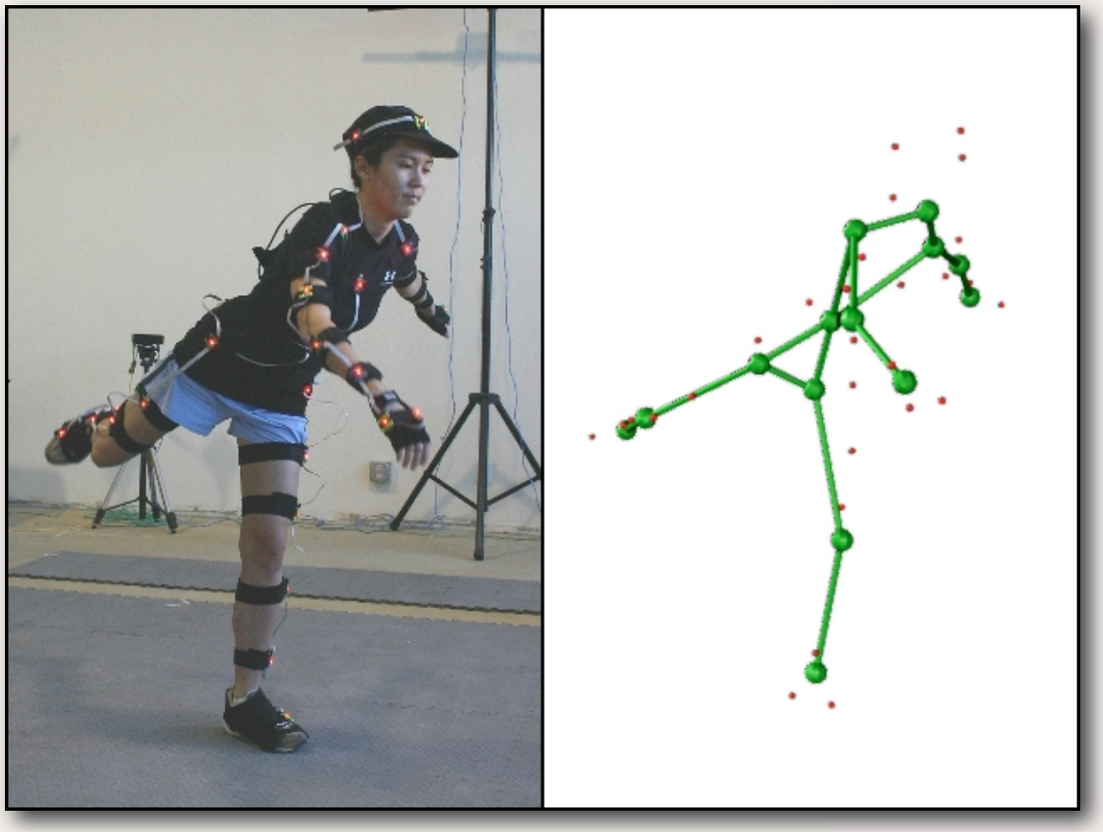
vector matrix

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

matrix

matrix multiplies

Inverse Kinematics Summary



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

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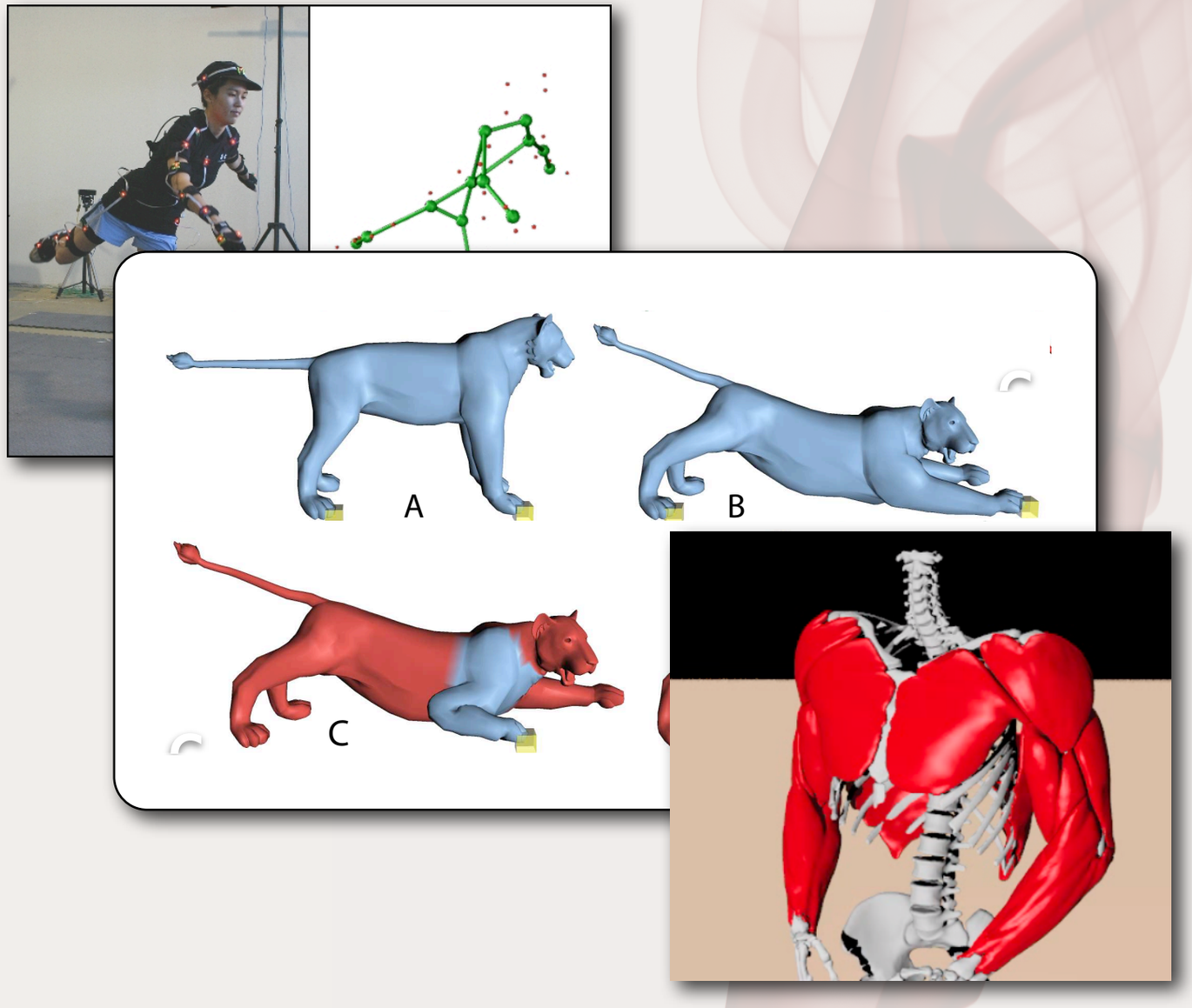
- **Anatomical**
- **Pure Mesh**
- **What are the advantages and disadvantages?**



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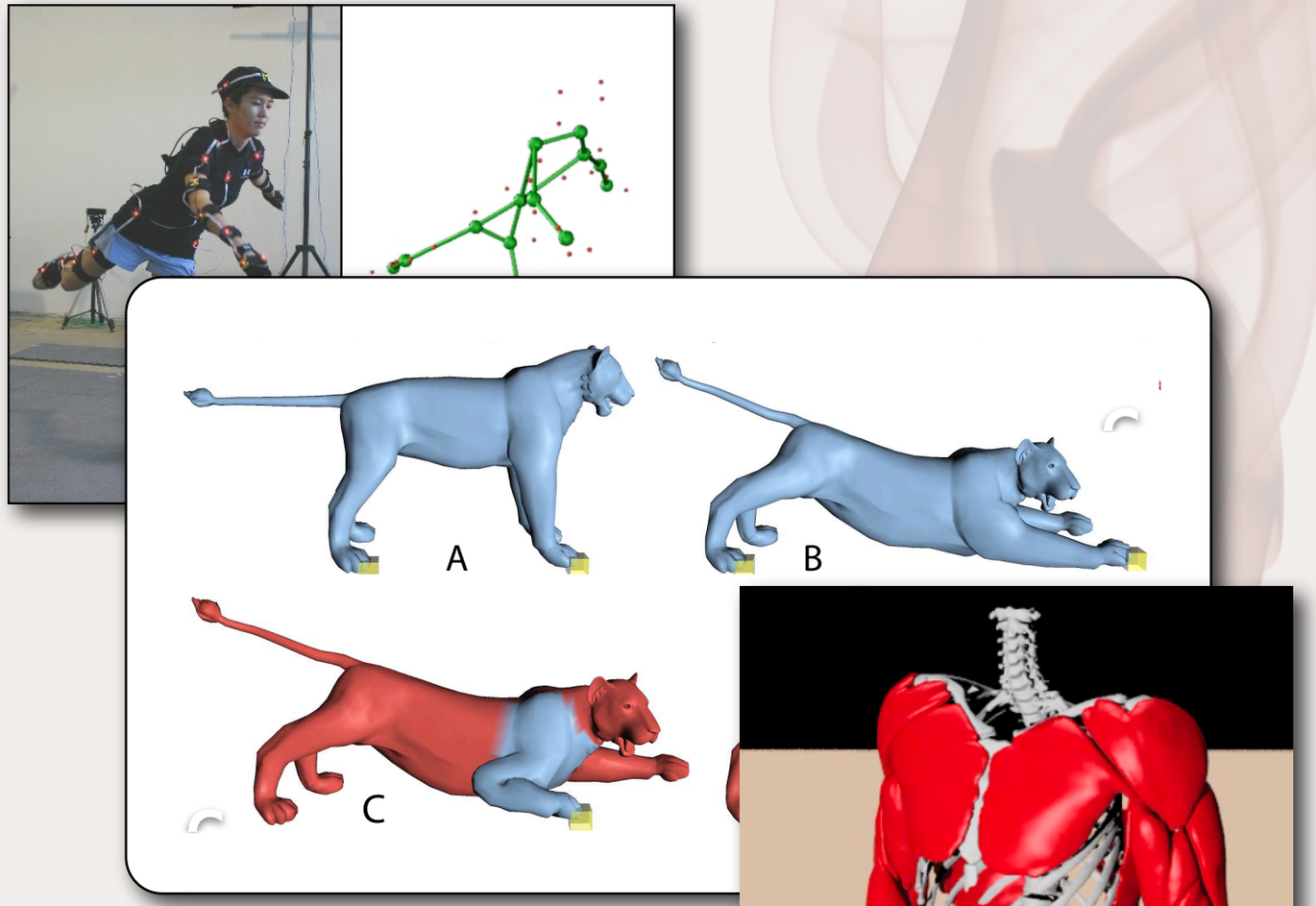
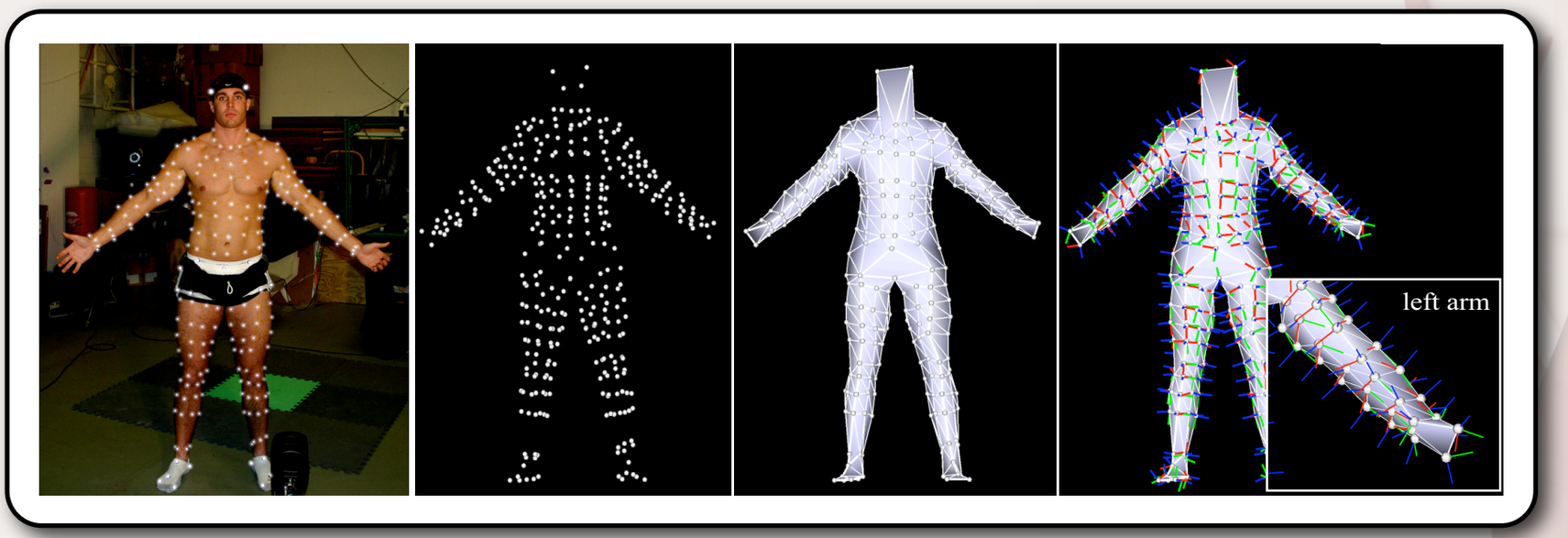


Dense Marker Capture

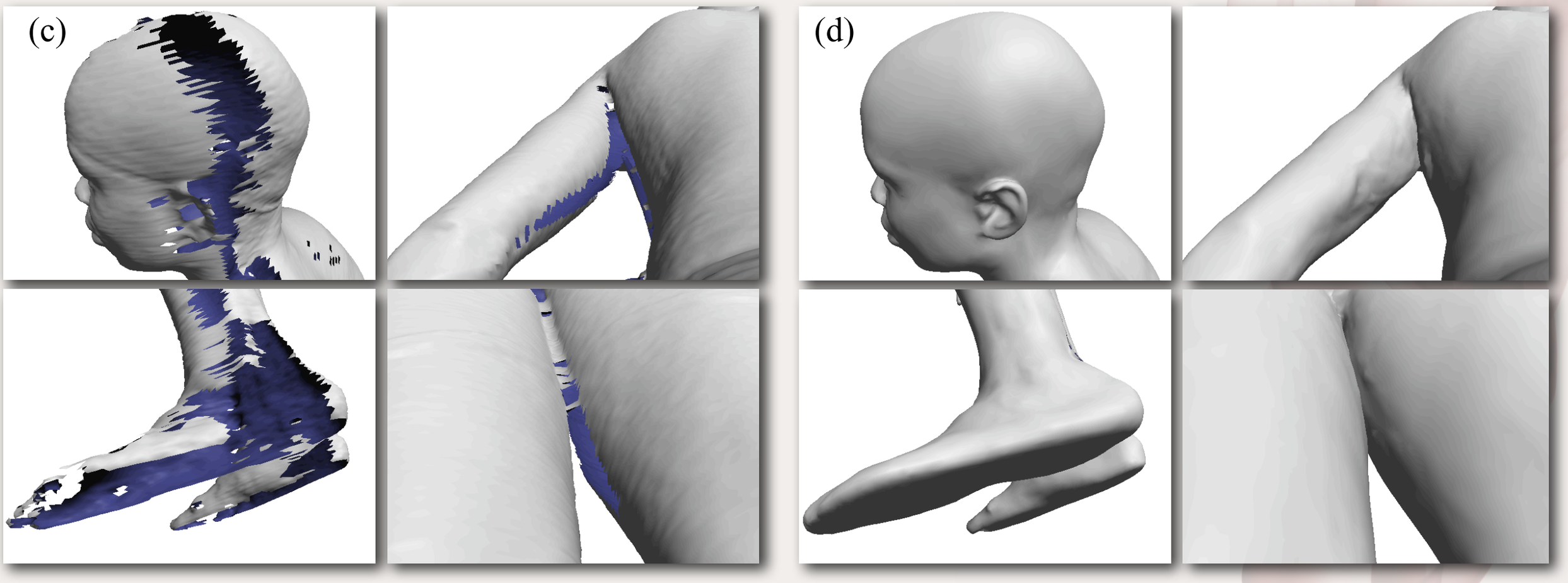


Capturing and Animating Skin Deformation

Robotics Institute,
Carnegie Mellon University

Laser Range Scanning

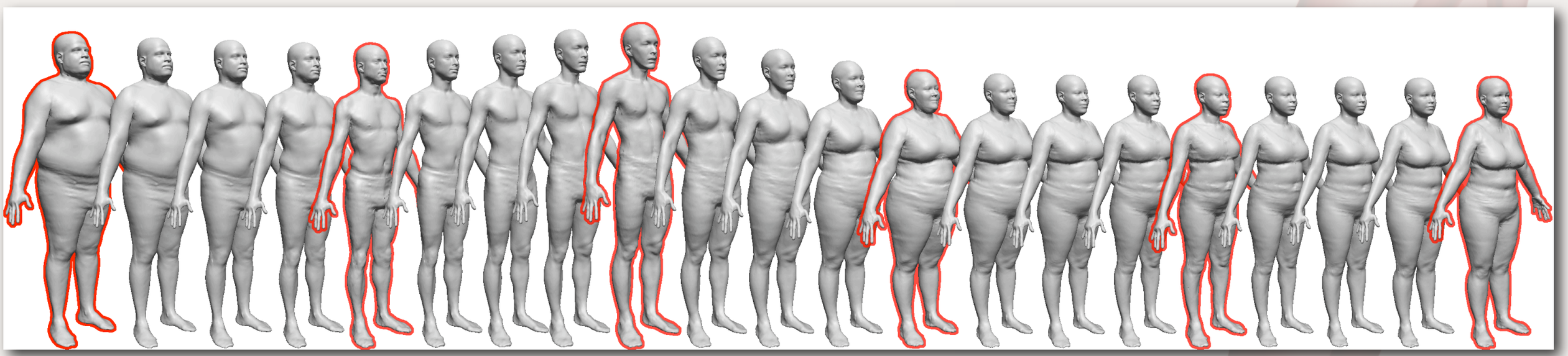
Filling in Missing Data



source: Allen, Curless, Popović. The space of human body shapes: reconstruction and parameterization from range scans.

How could this be accomplished?

What can you do with a huge set of human meshes in vertex correspondence?



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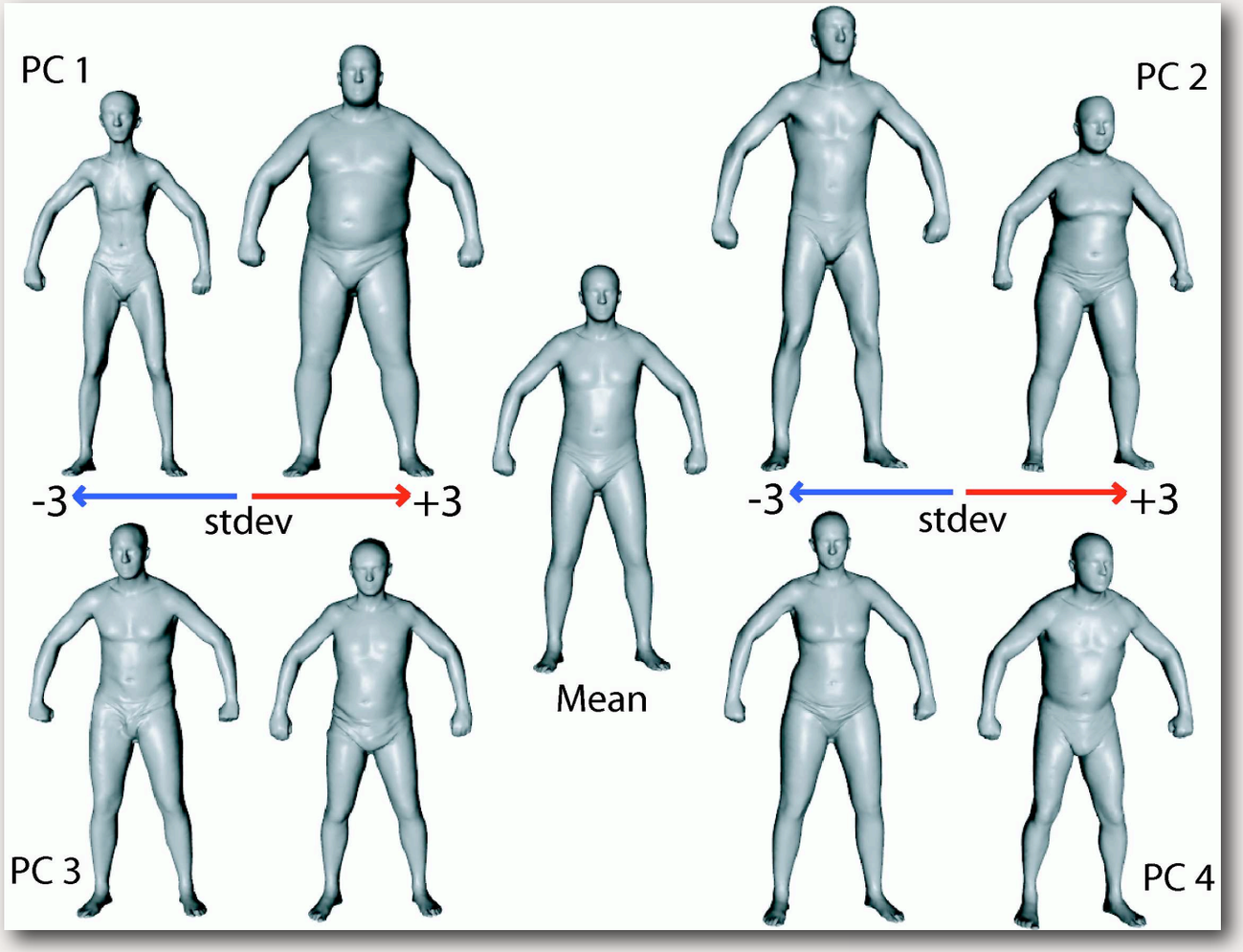
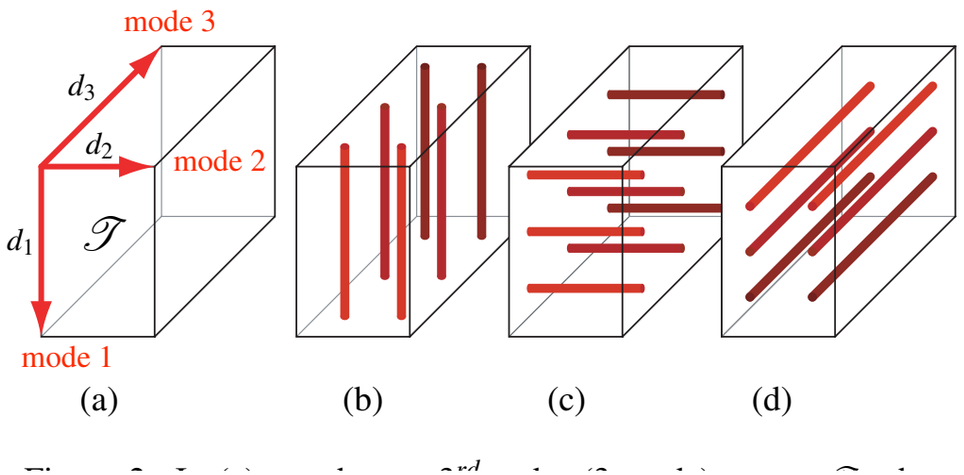
PCA Shape Analysis

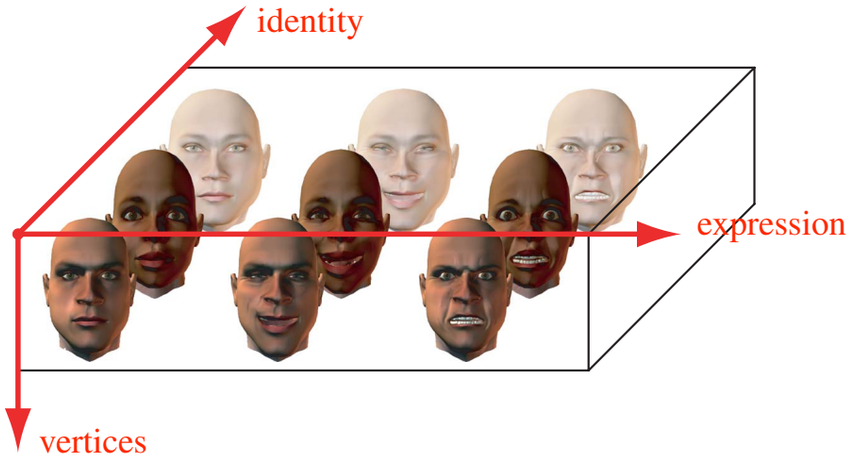
Displacements of Example Poses = **PCA Basis** **Coefficient Matrix**



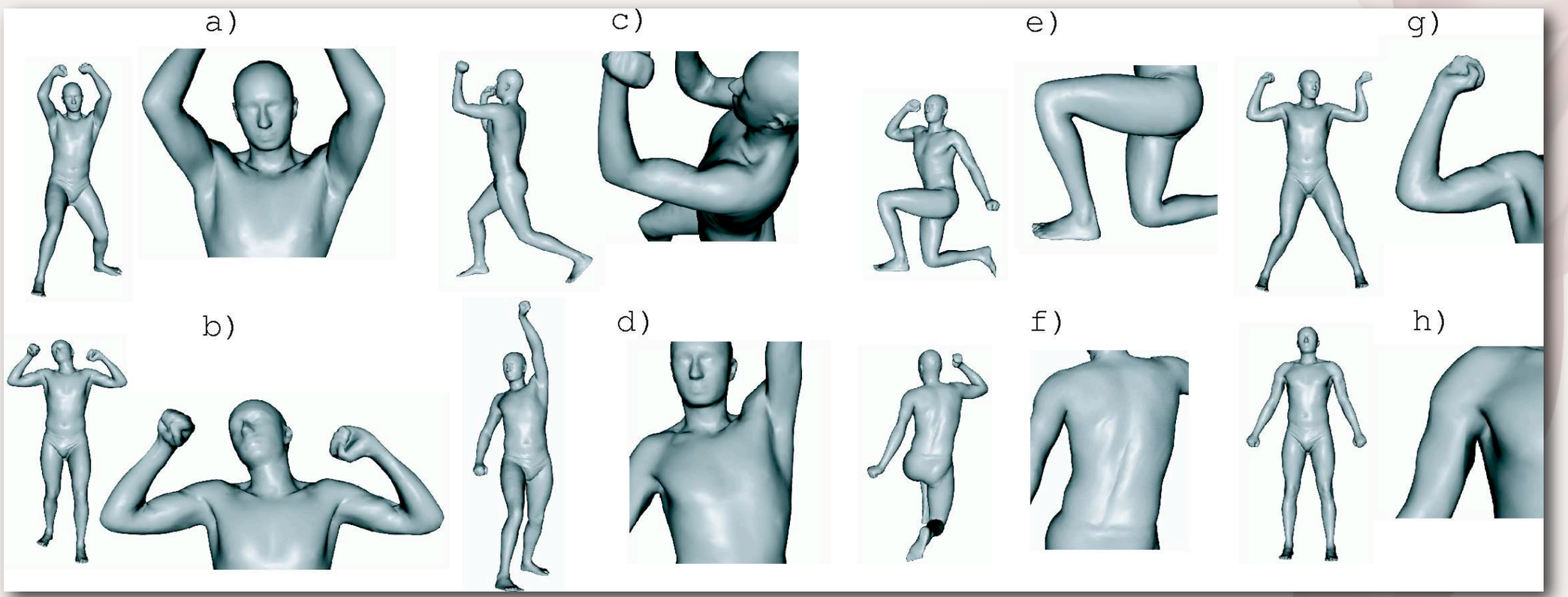
source: Anguelov, Srinivasan, Koller, Thrun, Rodgers, Davis. SCAPE: Shape Completion and Animation of People.

Multilinear Analysis





source: Vlasic, Brand, Pfister, Popović. Face Transfer with Multilinear Models.



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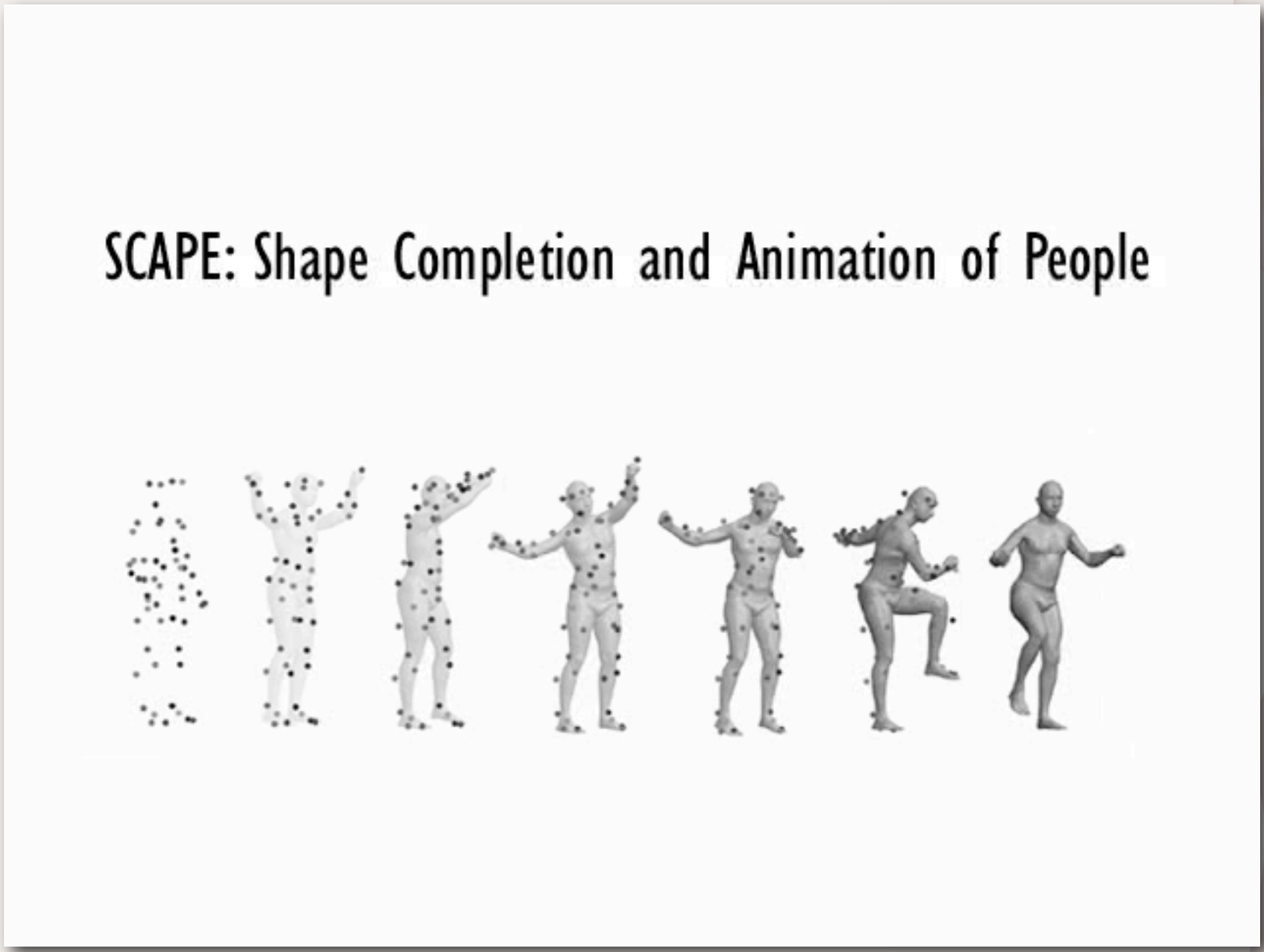
Example



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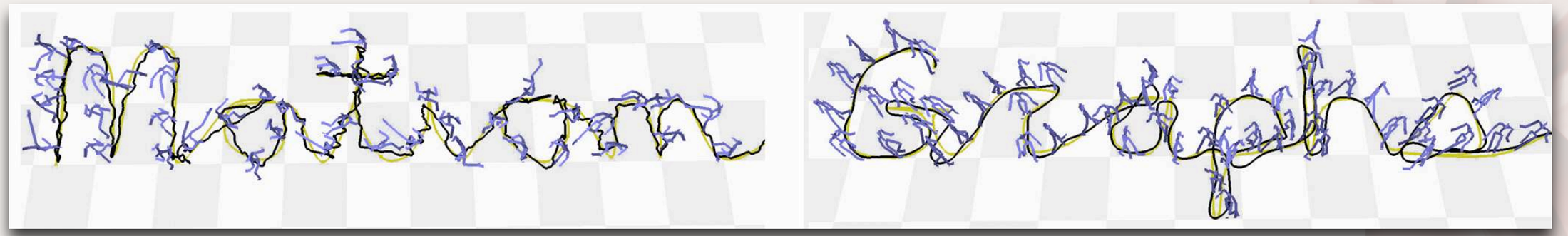
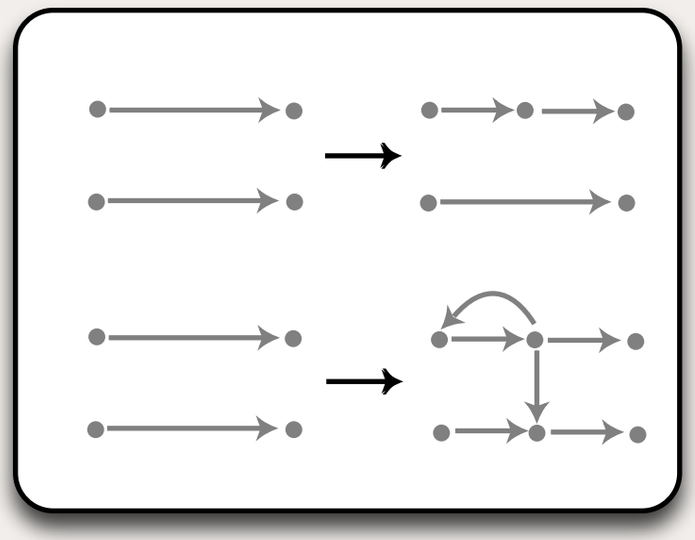
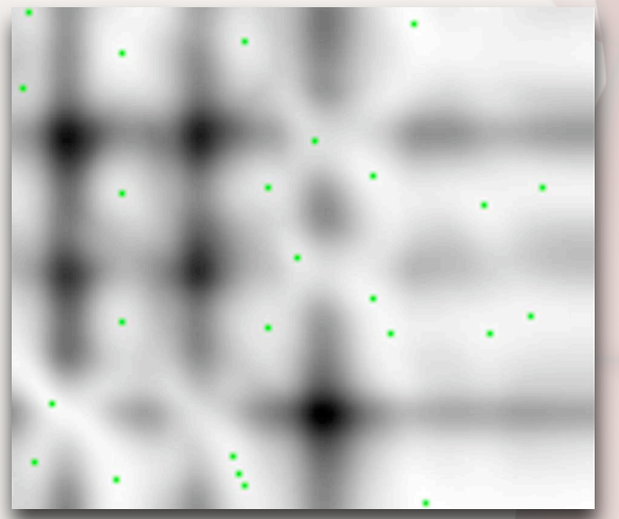
Data Driven Human Animation



source: Kovar, Gleicher, Pighin. Motion Graphs.

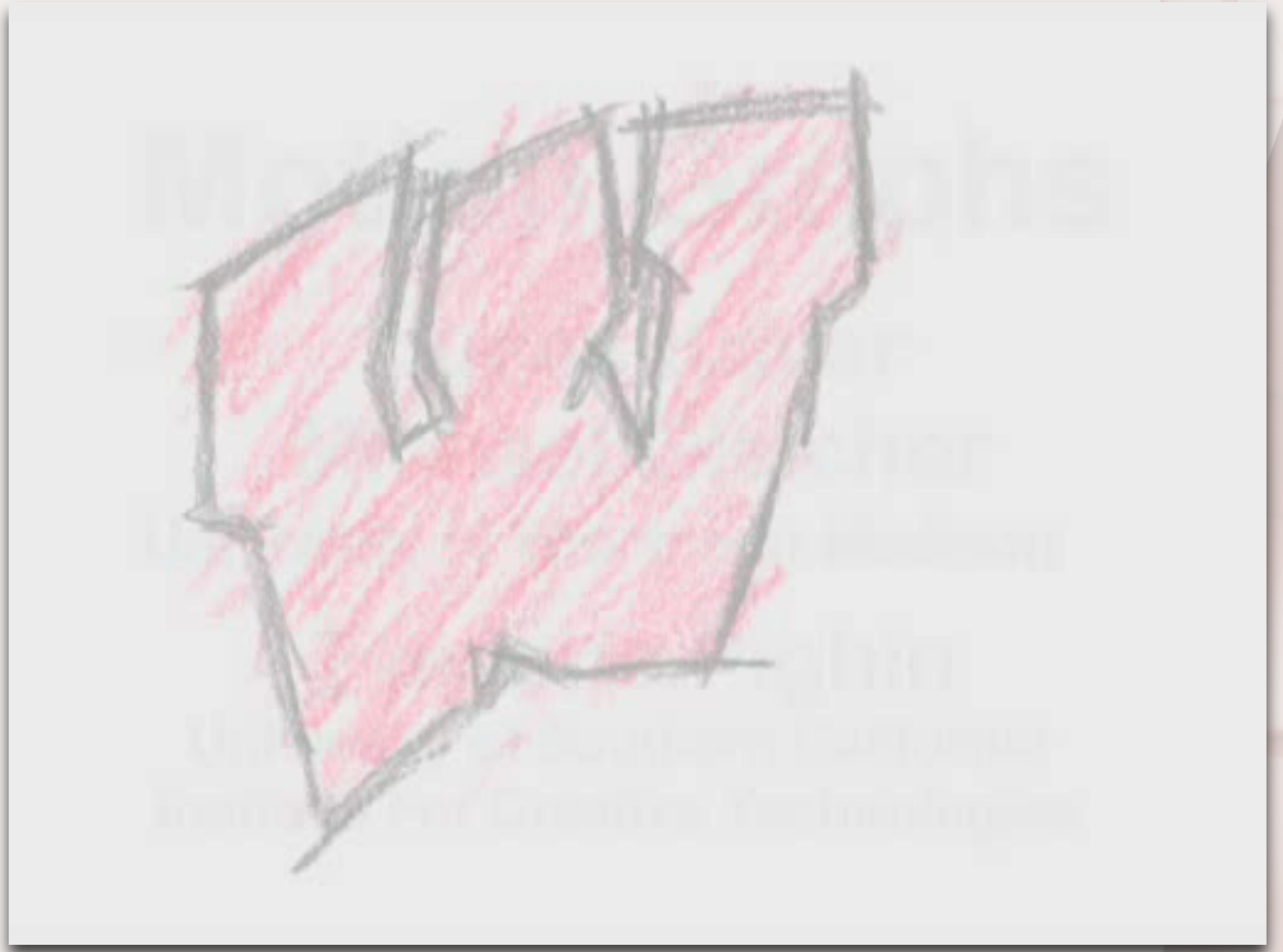


Motion Graph Schematic



Finding Candidate Transitions

Examples



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Vote

- We have only two lectures left!
- Possible topics:
  - Model Reduction / Real-time Simulation - 10
  - Physics-based human animation. - 10
    - Animal Motion / Morphology
  - Optimization Control - 5
  - Anything else?

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Questions

- How do we fix the foot skate problem?
- How can we generalize away from existing motion capture data?
- How could we search for motion clips?
- How could we motion capture wild animals?
- How could we go from “motion capture” to “physics capture?”