Generating Natural Human Motion

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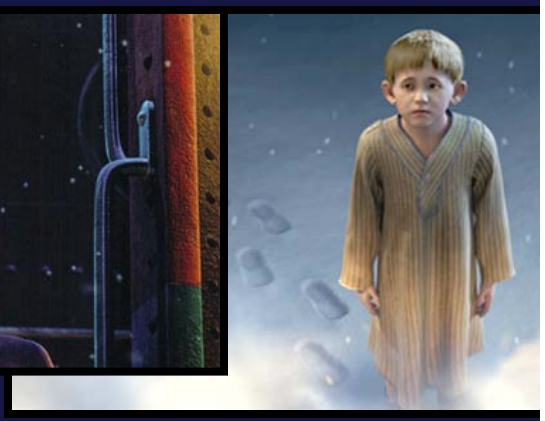
Why Human Motion?

- Computer animation

- Interactive environments
- Physical training
- Robotics

Why Natural?

- Computer animation



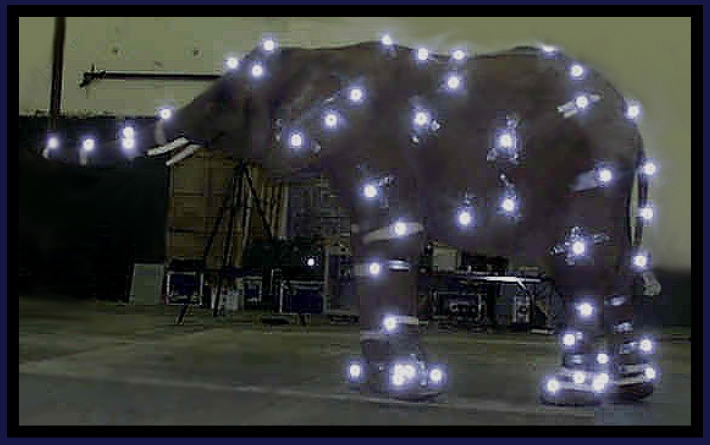
- Interactive environments
- Physical training
- Humanoid Robots

Examples

- Motion Capture
- Simulation
- Optimization
- Robot Control

Motion Capture → Natural?

Motion Capture



Motion Analysis

House of Moves

House of Moves

Human Motion Data

Vicon MX-40 camera system, 12 cameras

120fps at 4Mpixel resolution

4-9mm markers, 40-100+ ⇨ joint angles

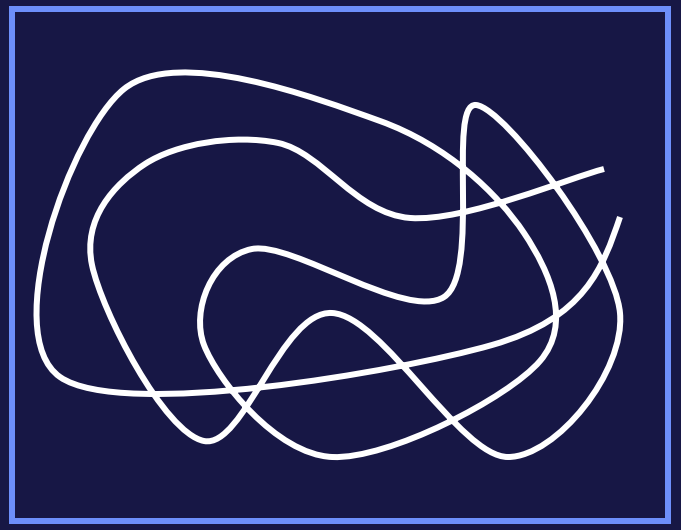
http://mocap.cs.cmu.edu

But does it remain natural through modifications?

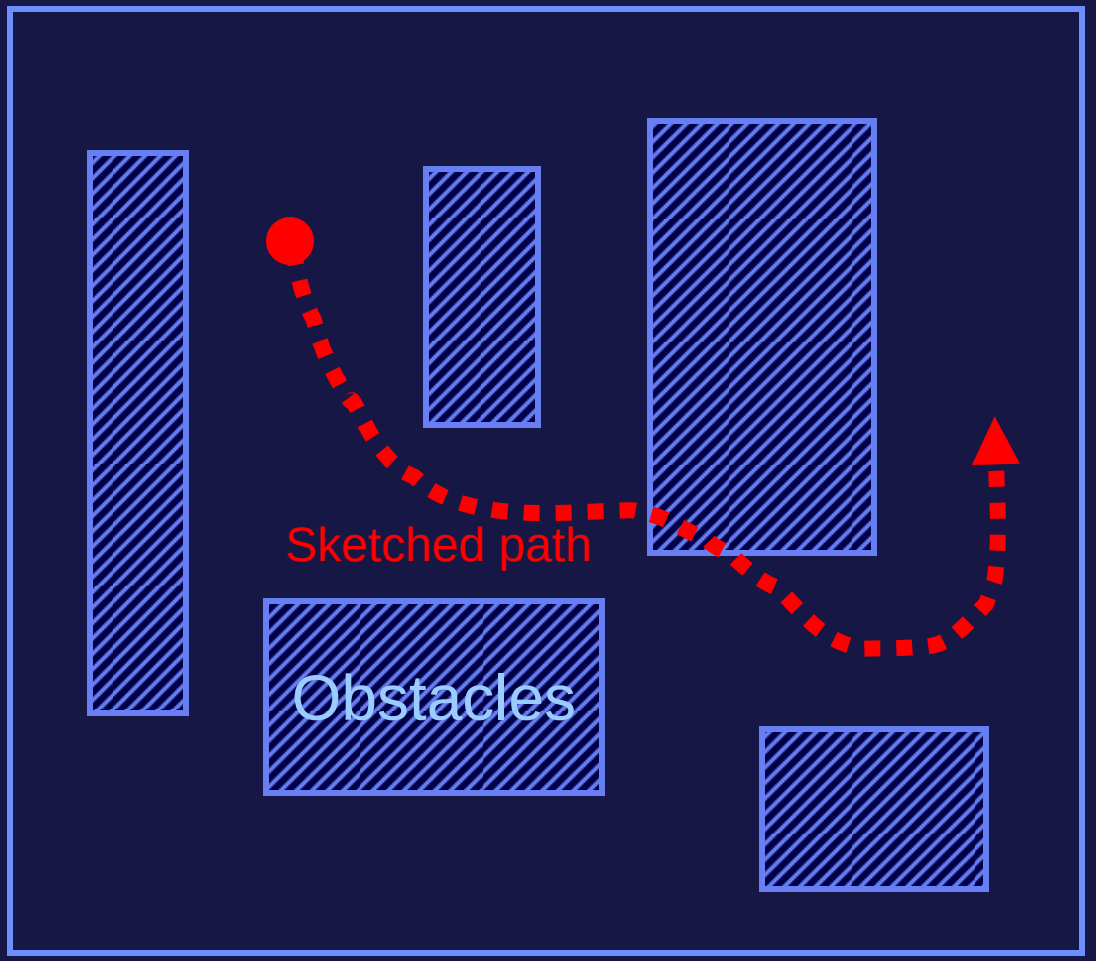
Motion Graphs

Re-sequence

Motion Capture Region

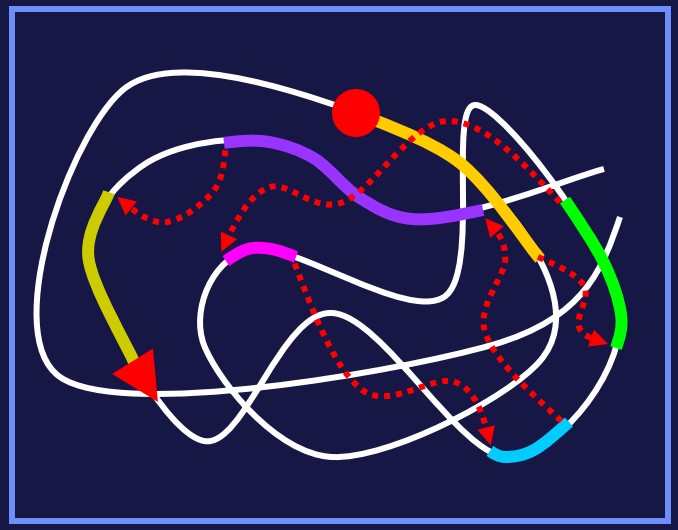


Virtual Environment

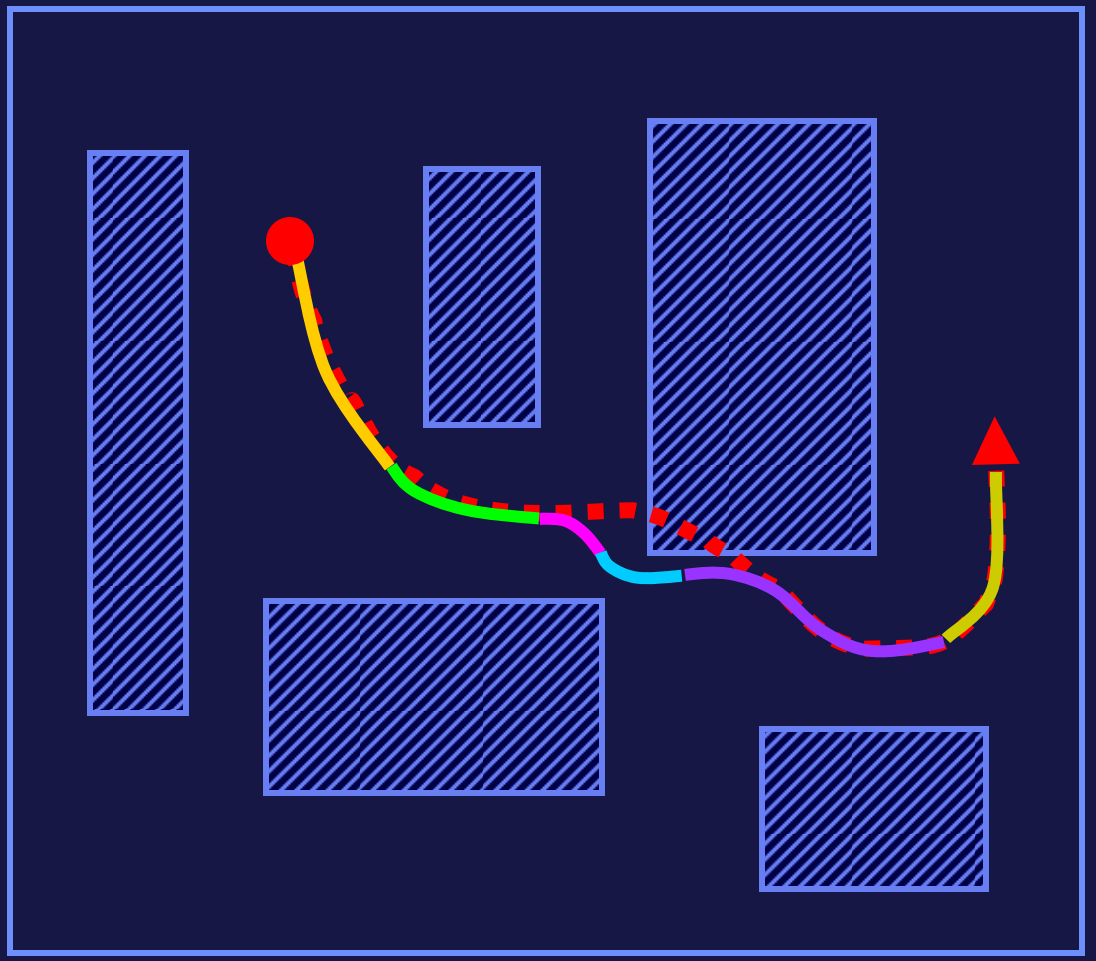


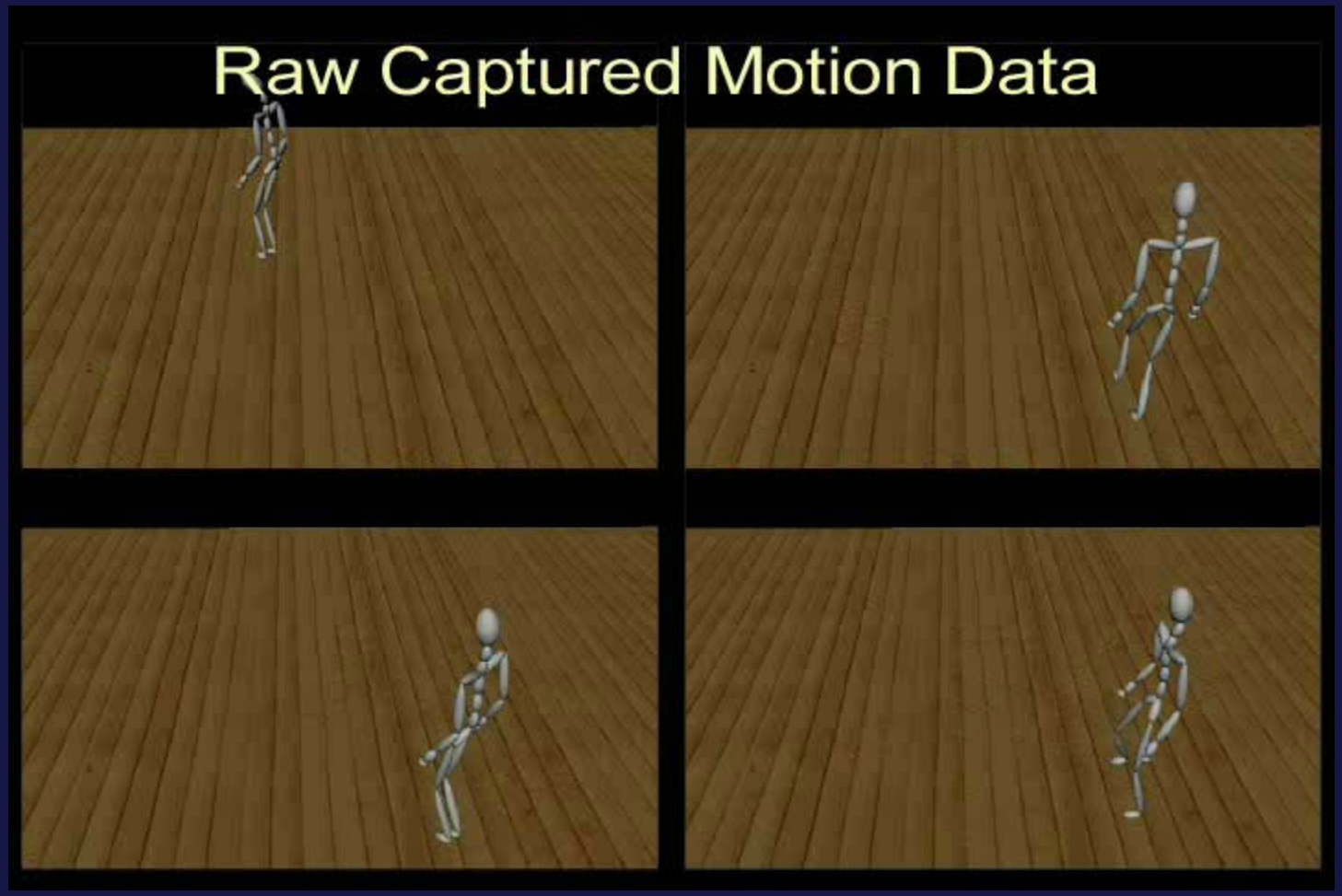
Re-sequence

Motion Capture Region



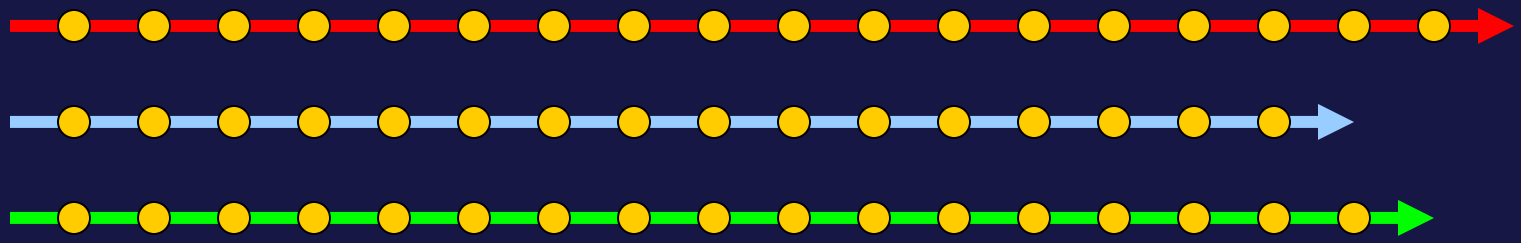
Virtual Environment



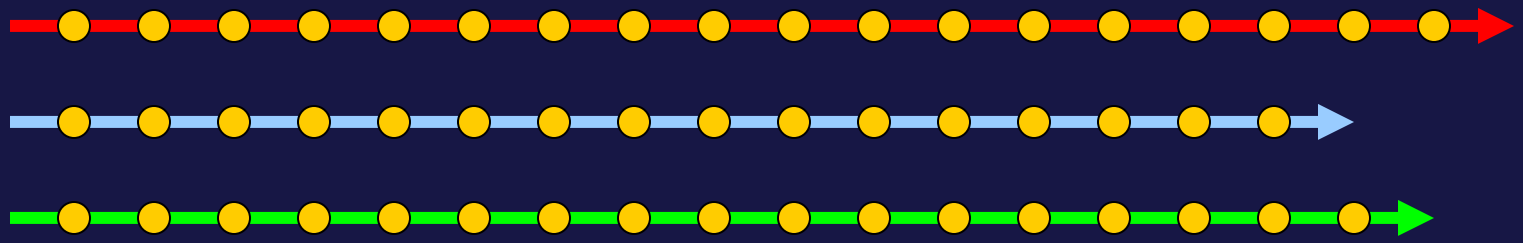


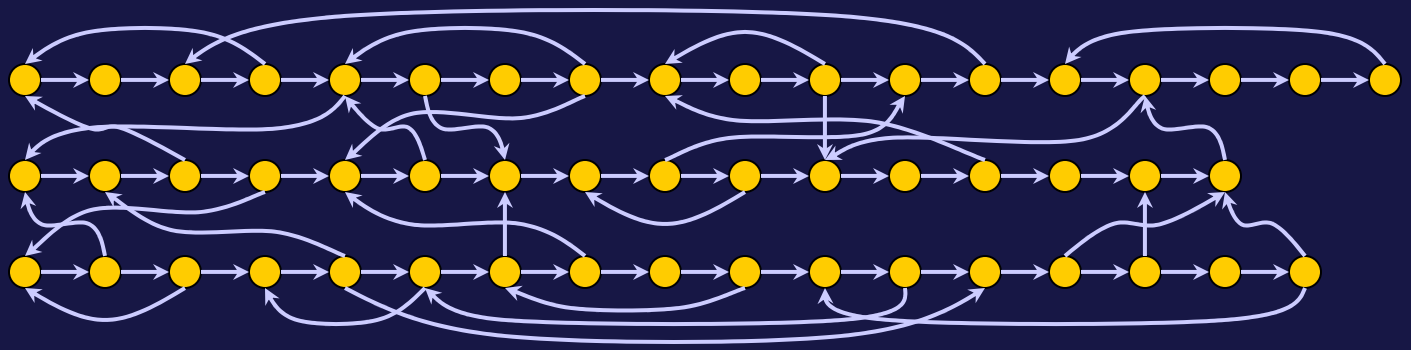
with Jehee Lee

Unstructured Input Data

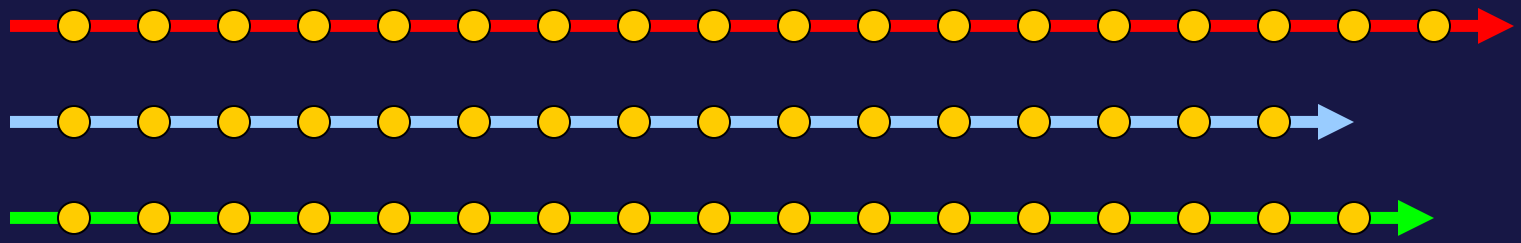


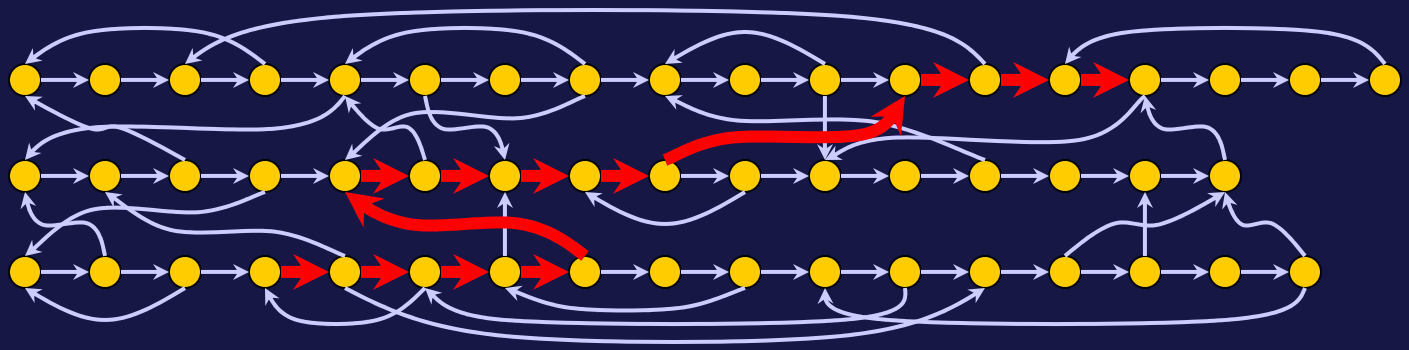
Connecting Transitions





Search (local) to Find Path

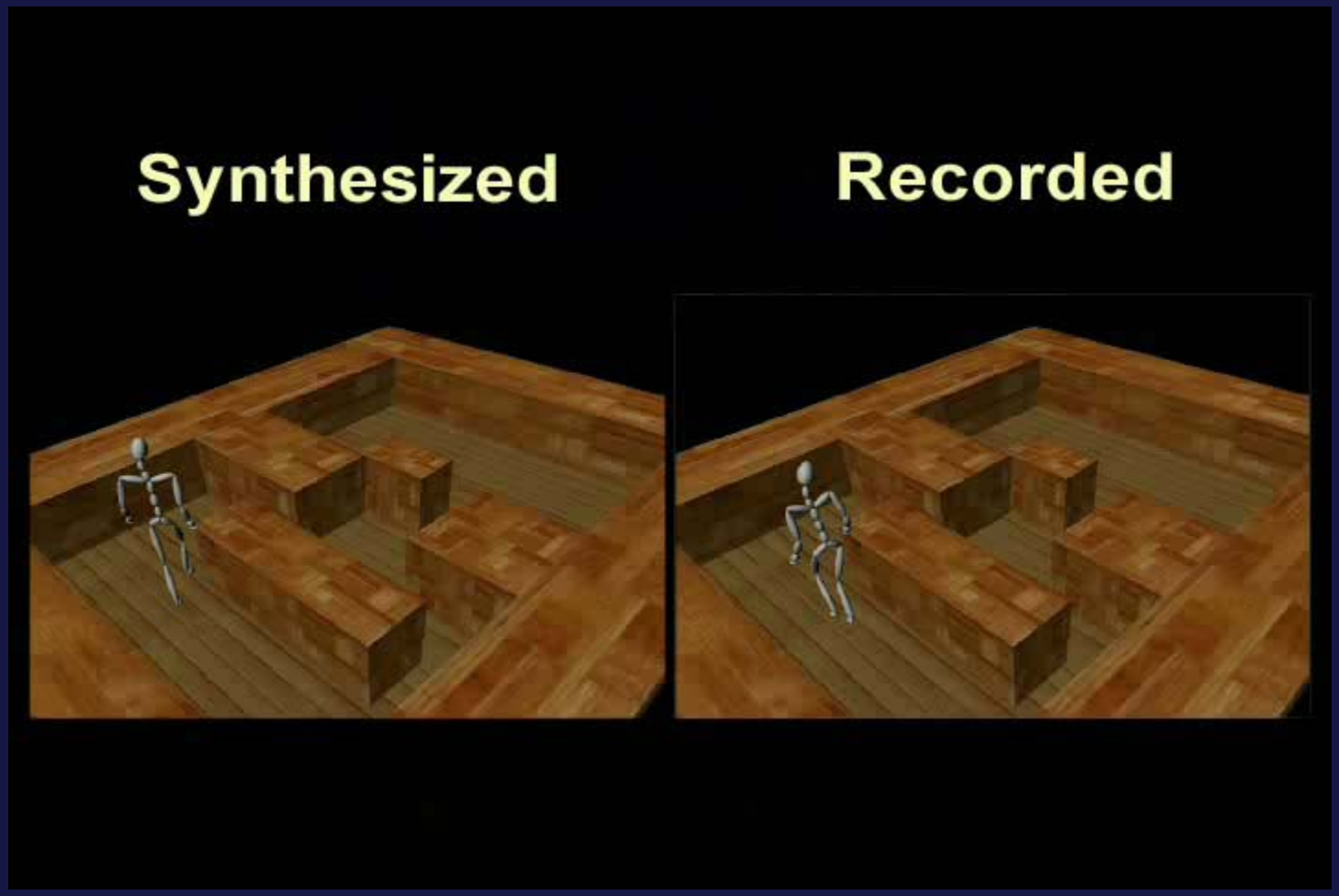




Motion Data for Rough Terrain

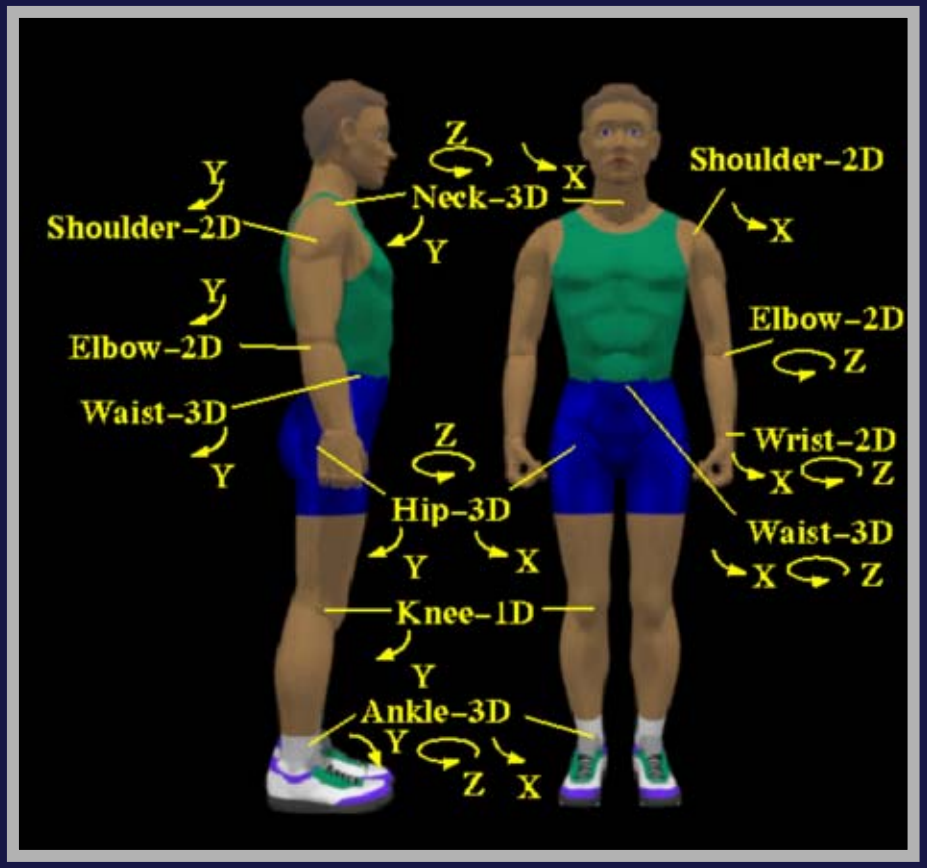
Comparison to Real Motion

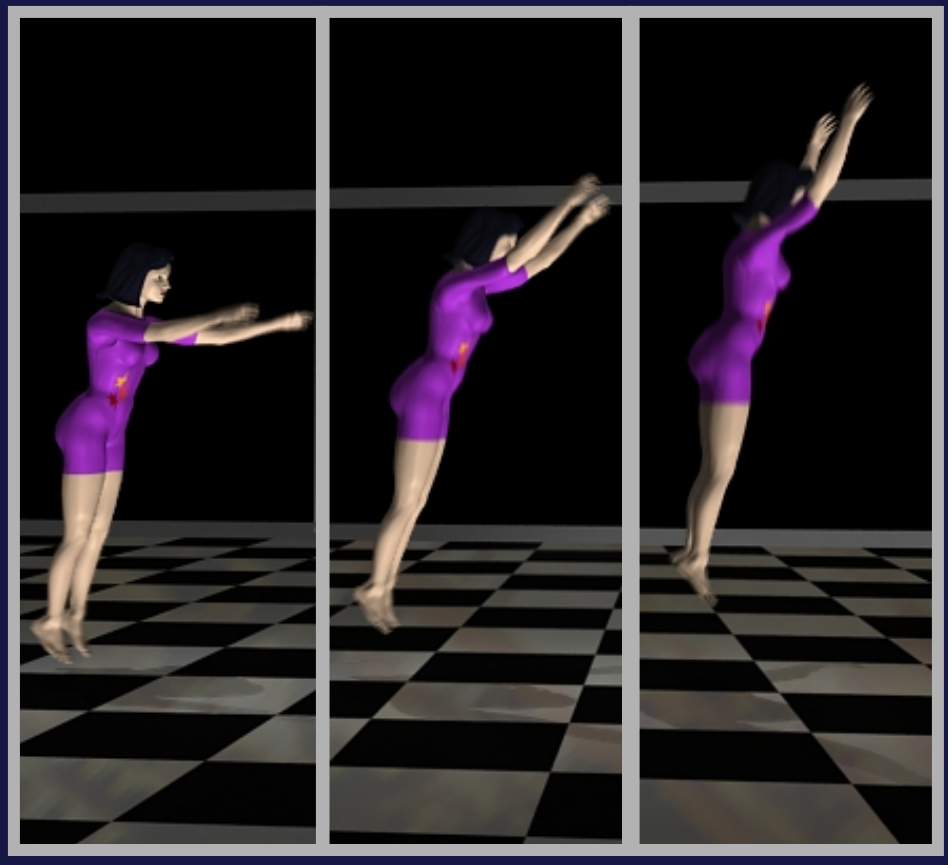
Comparison to Real Motion



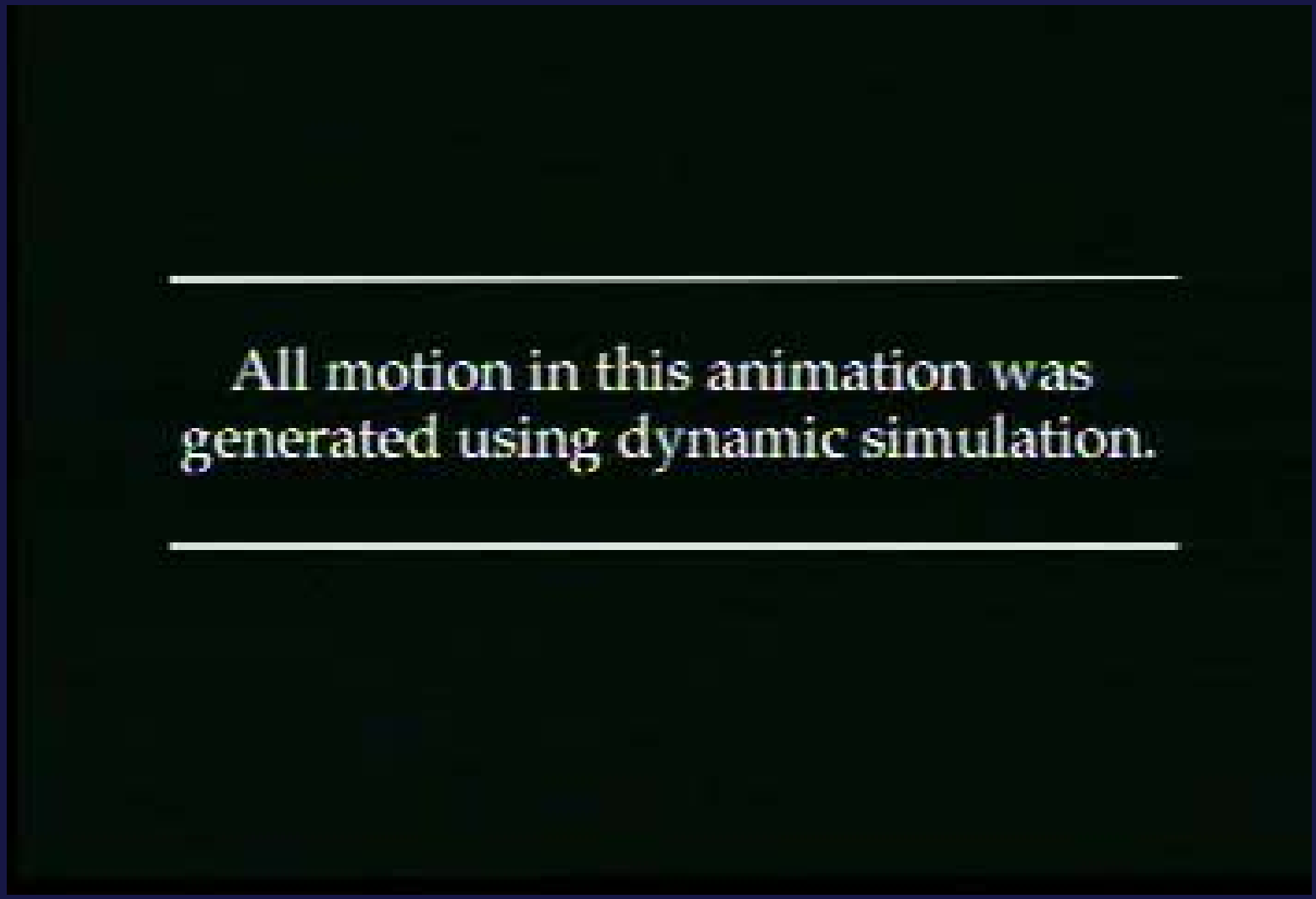
Physically Correct != Natural

Simulation of Human Motion





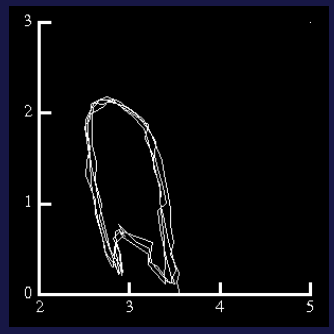
Simulation of Human Motion



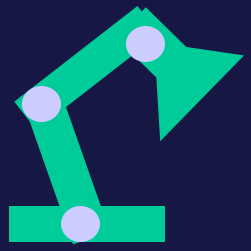
Where do control laws come from?

observation

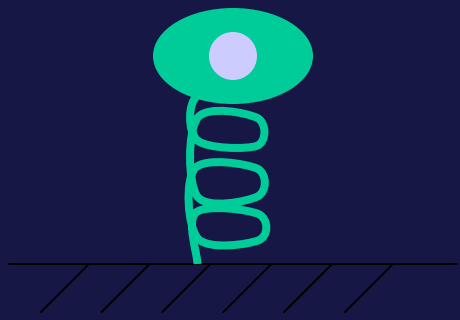
biomechanical literature



optimization

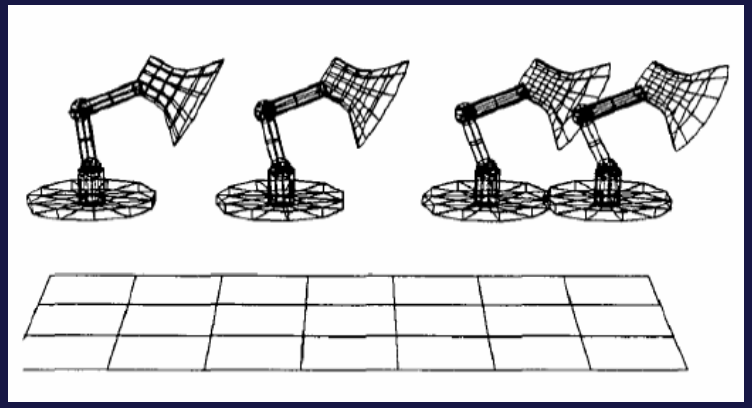


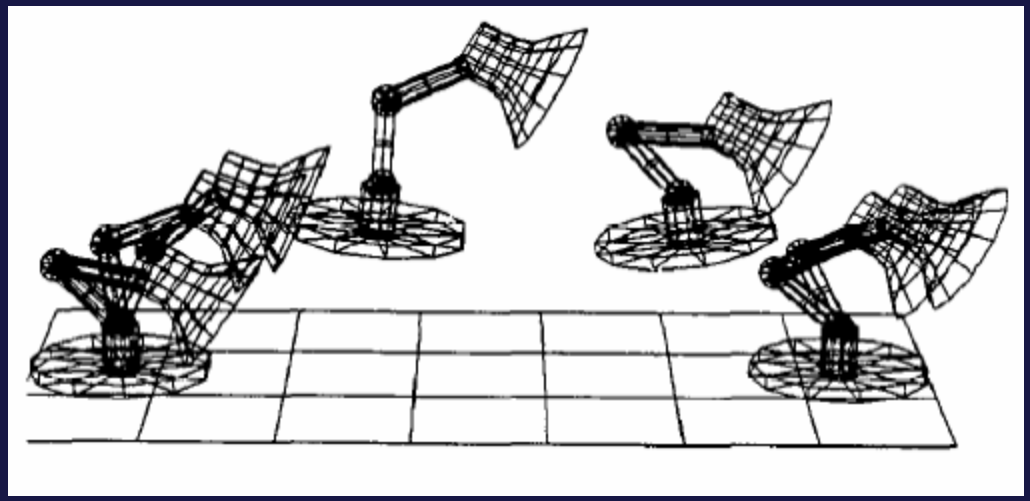
physical intuition



Optimization != Natural

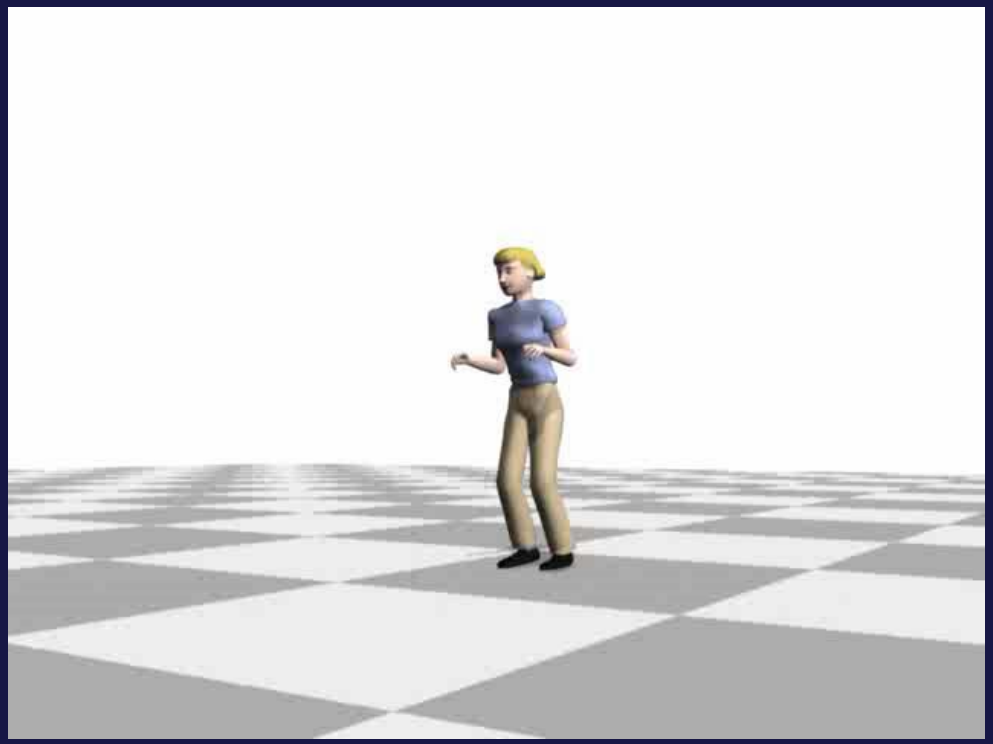
Witkin and Kass SIGGRAPH 1988





But what happens with human characters?

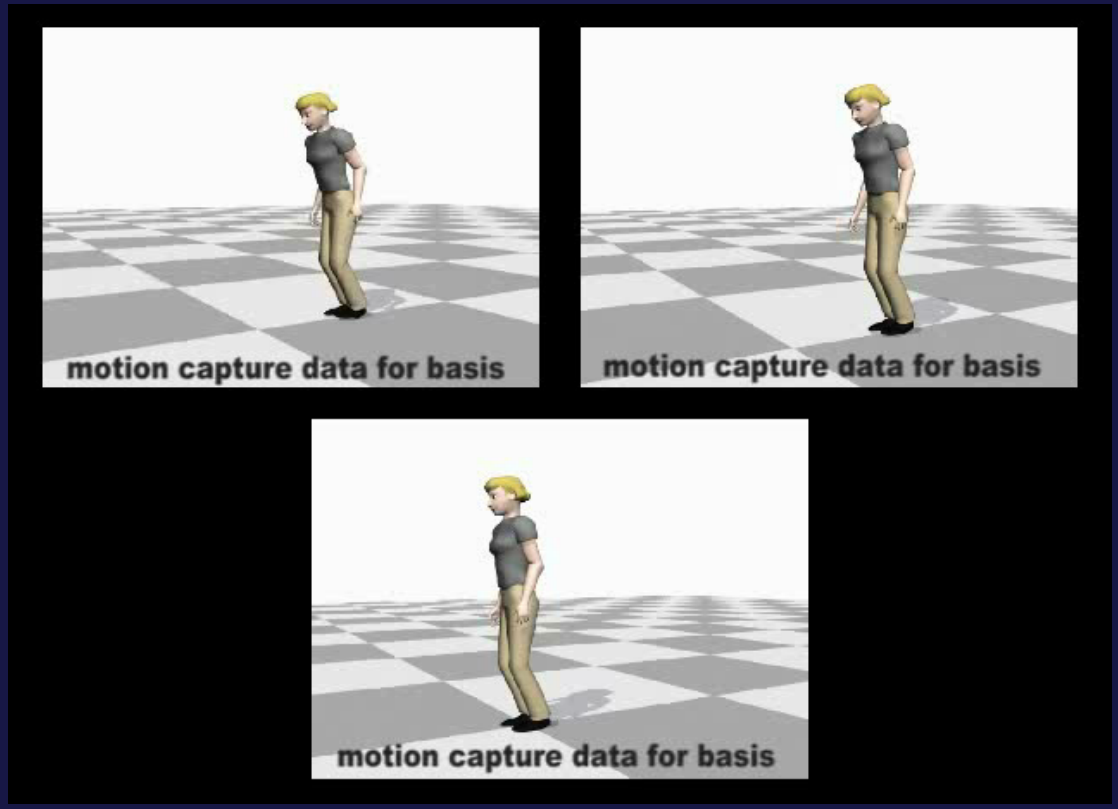
50 to 60 dimensions



Pick few motions with similar behavior

Use principal component analysis to compute low-dimensional space

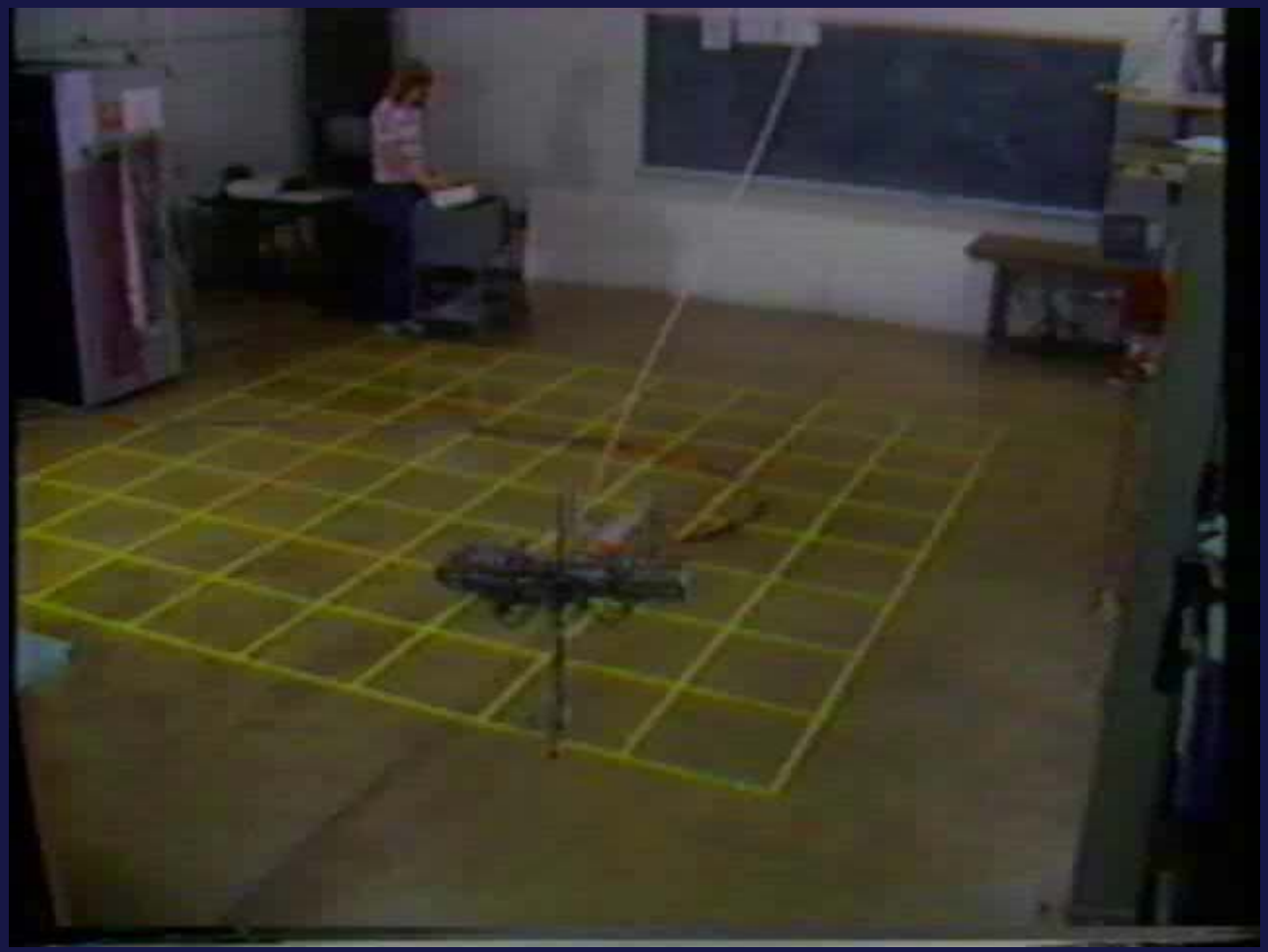
Optimize in low-dimensional space



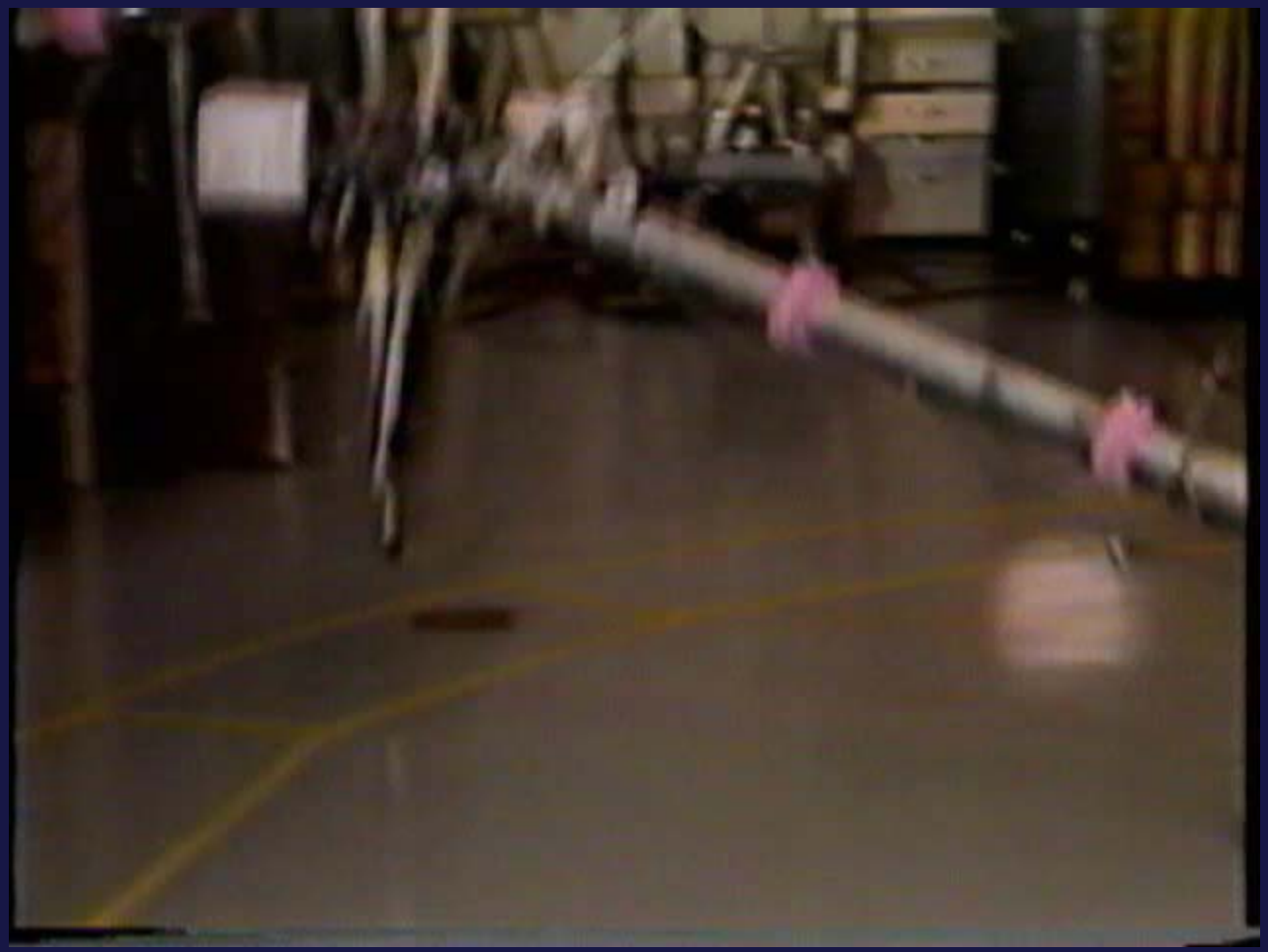
Basis and two generated motions

with Alla Safonova and Nancy Pollard

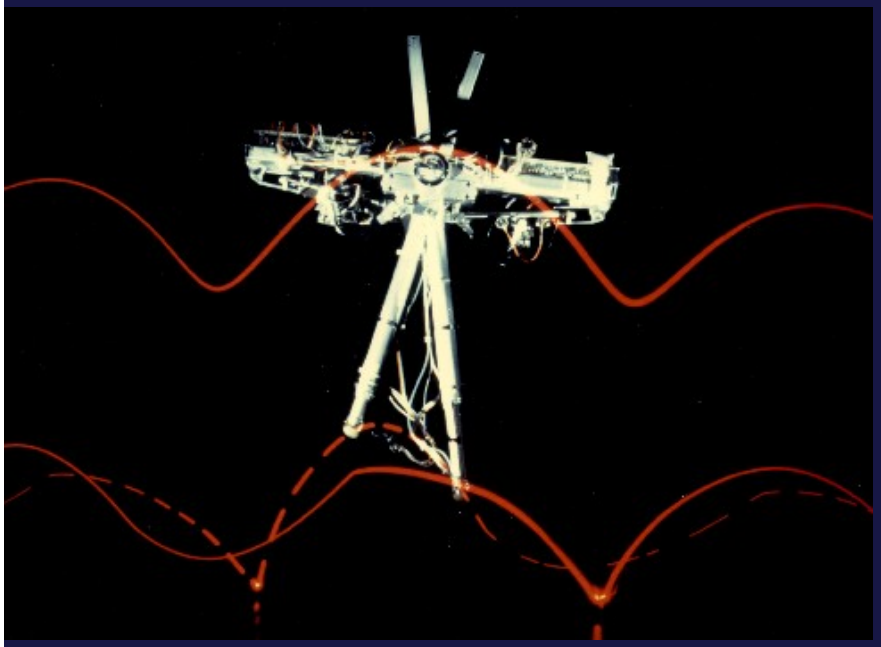
Controlling Robots to be Natural?

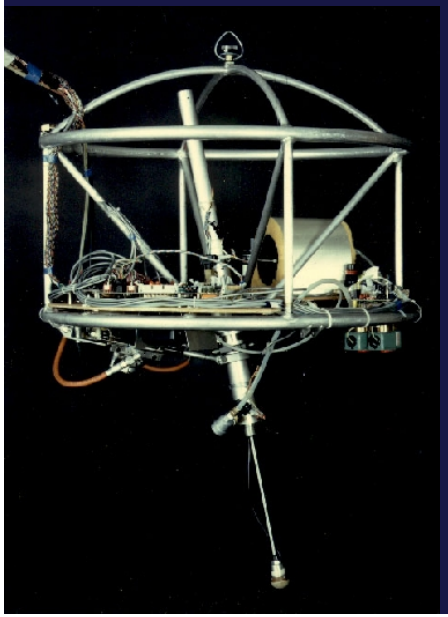


with Jeff Koechling and Marc Raibert

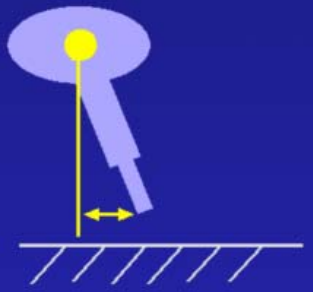


with Marc Raibert

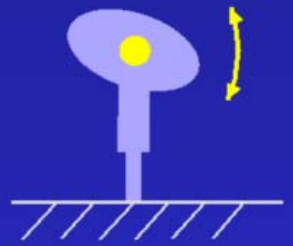




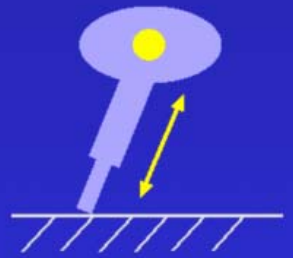
Velocity



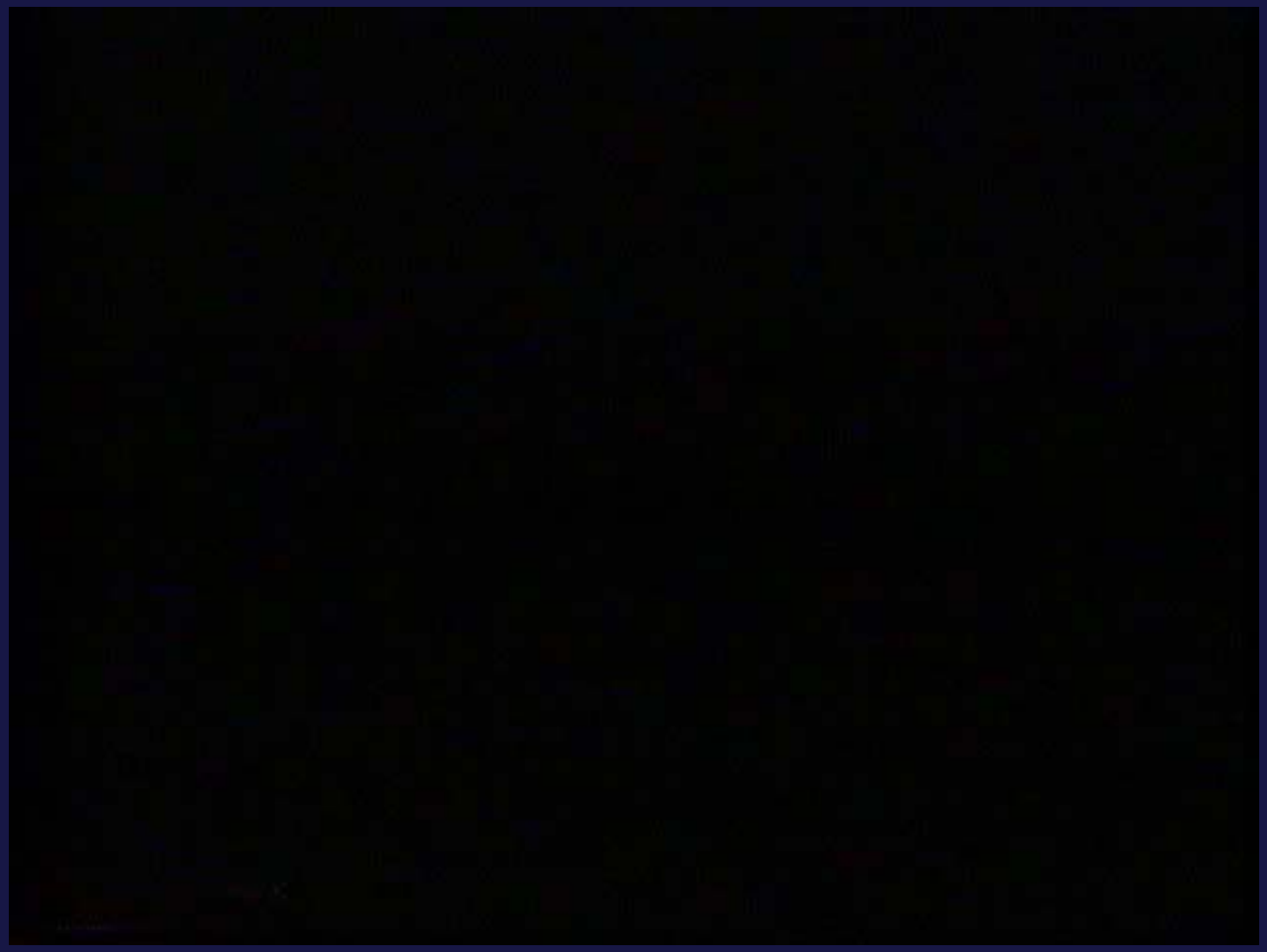
Body attitude



Hopping height

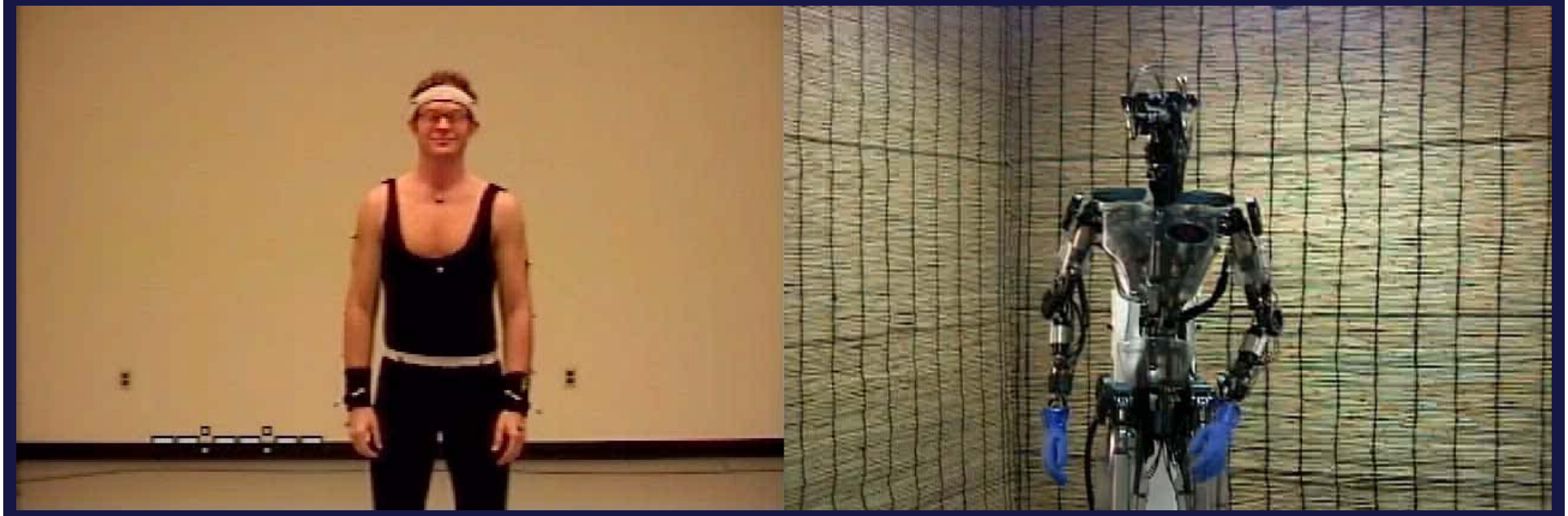


with Marc Raibert



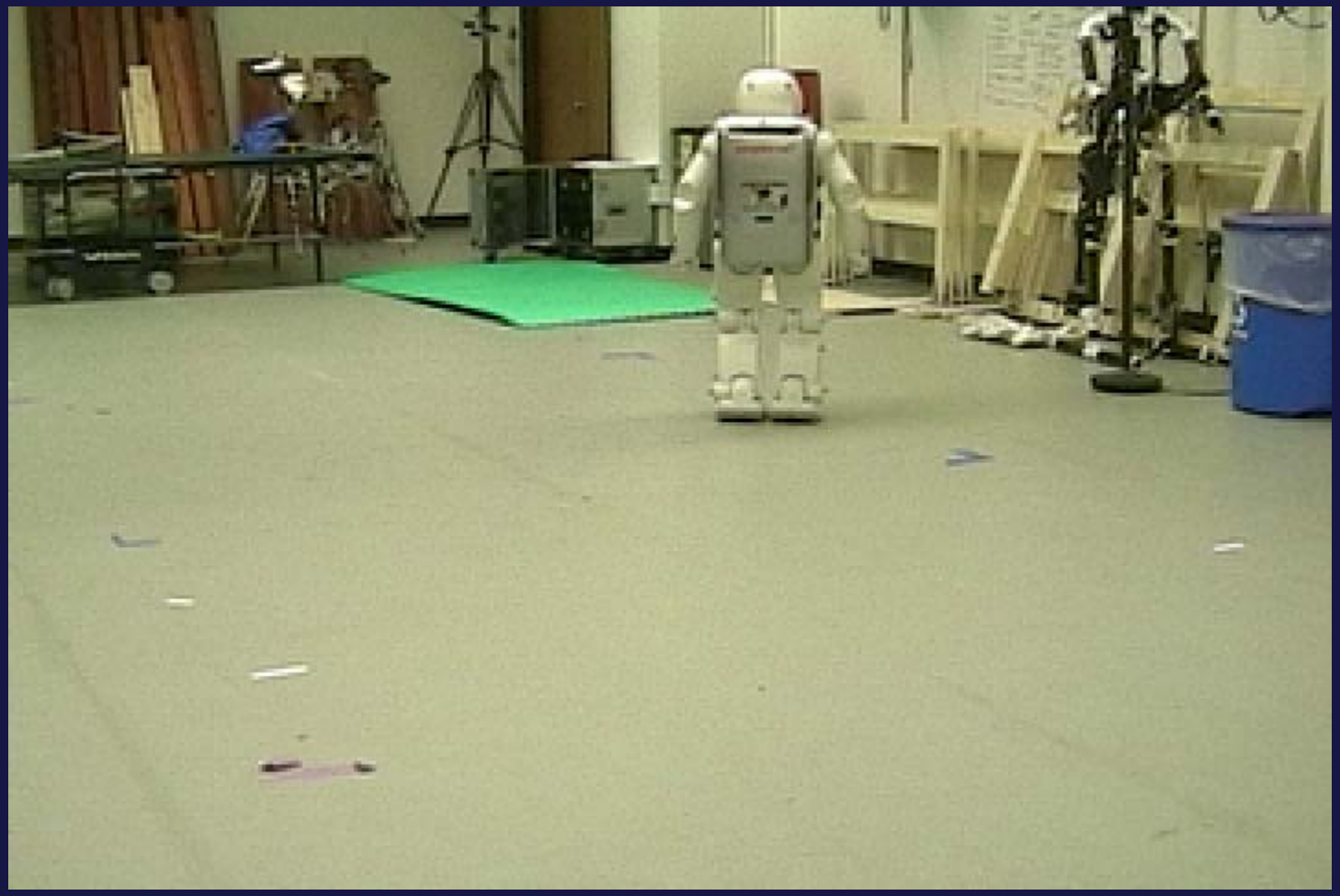
with Marc Raibert

Mimicking people

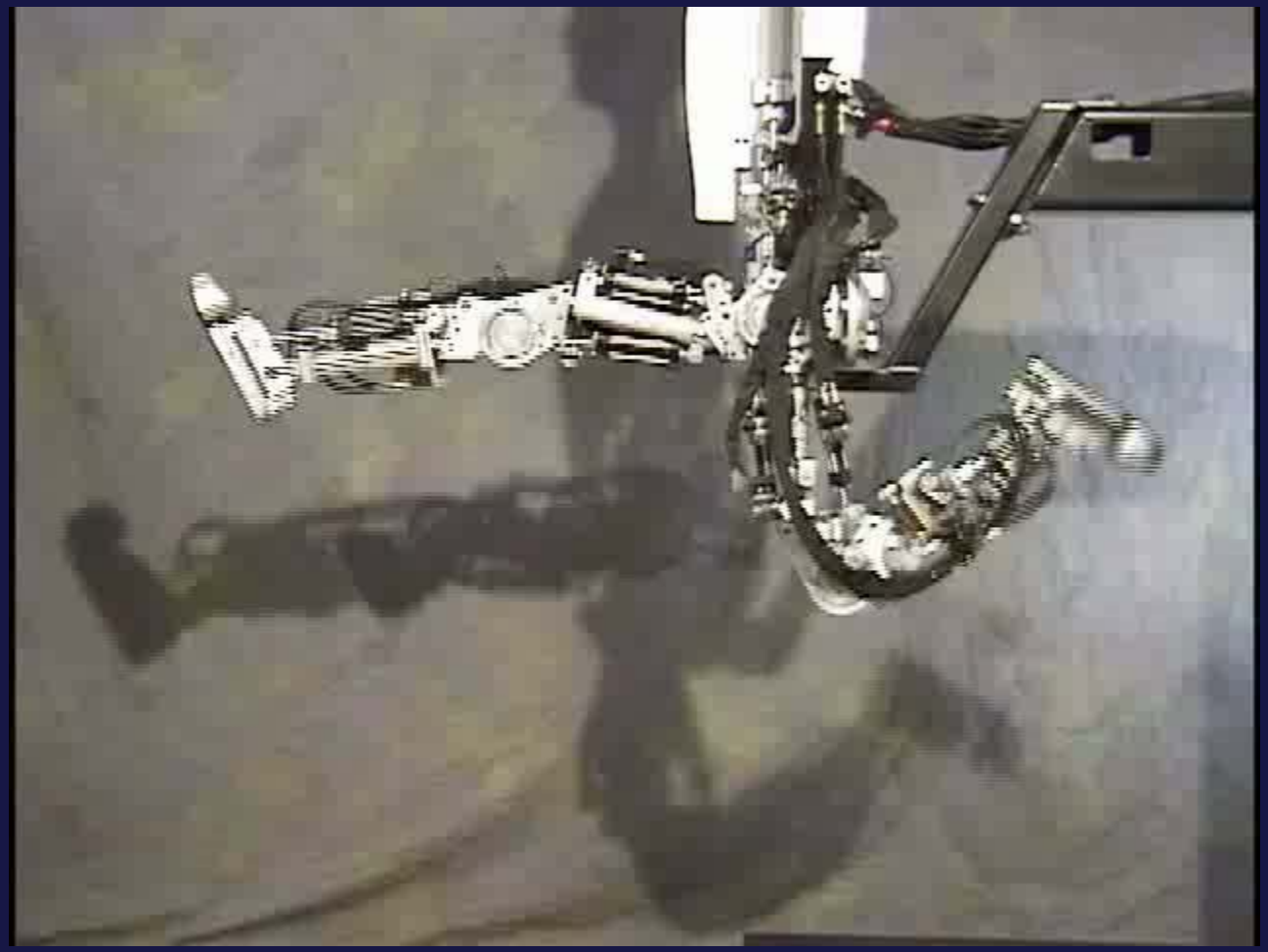


with Alla Safonova and Nancy Pollard

ASIMO



Sarcos Humanoid

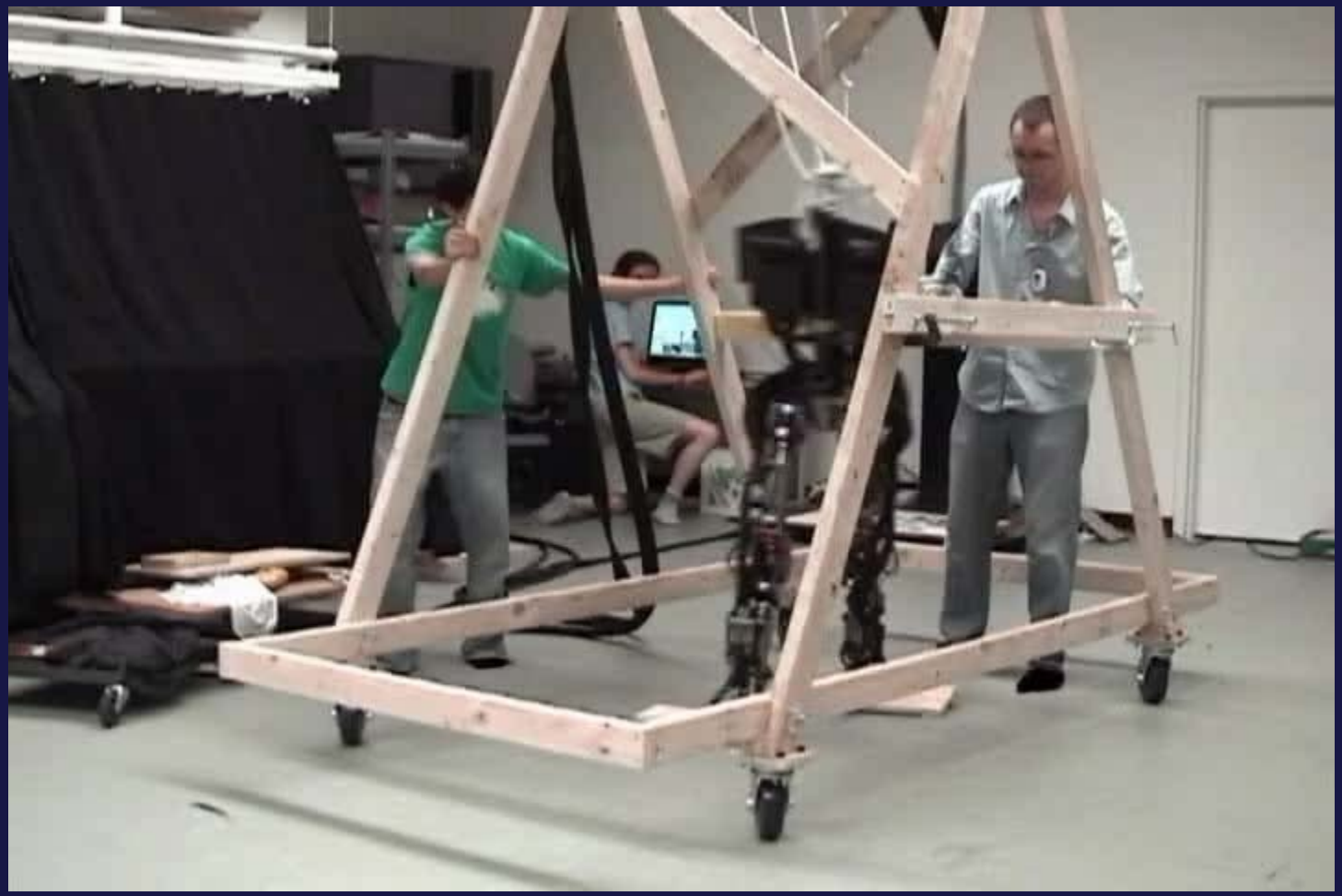


Sarcos Humanoid: Pushes

Ben Stephens

Sarcos Humanoid: Human Data

Sarcos Humanoid



with Stuart Anderson and others

Sarcos Humanoid