



Computational Photography and Capture: **Motion Capture**

Gabriel Brostow & Tim Weyrich

TA: Frederic Besse

Eadweard Muybridge

- Do all 4 legs come off the ground when a horse is in gallop?

Eadweard Muybridge

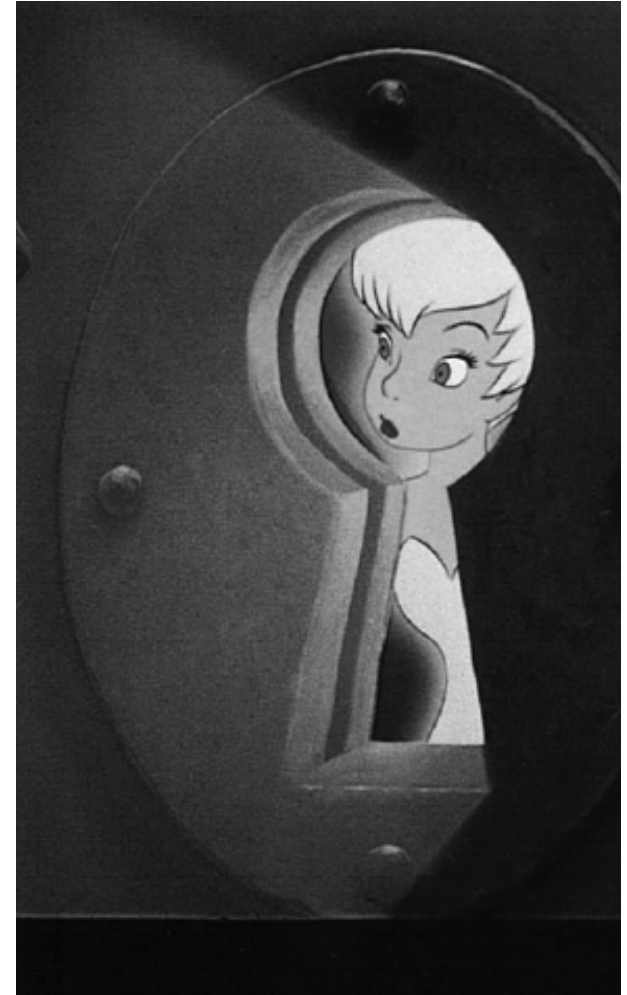
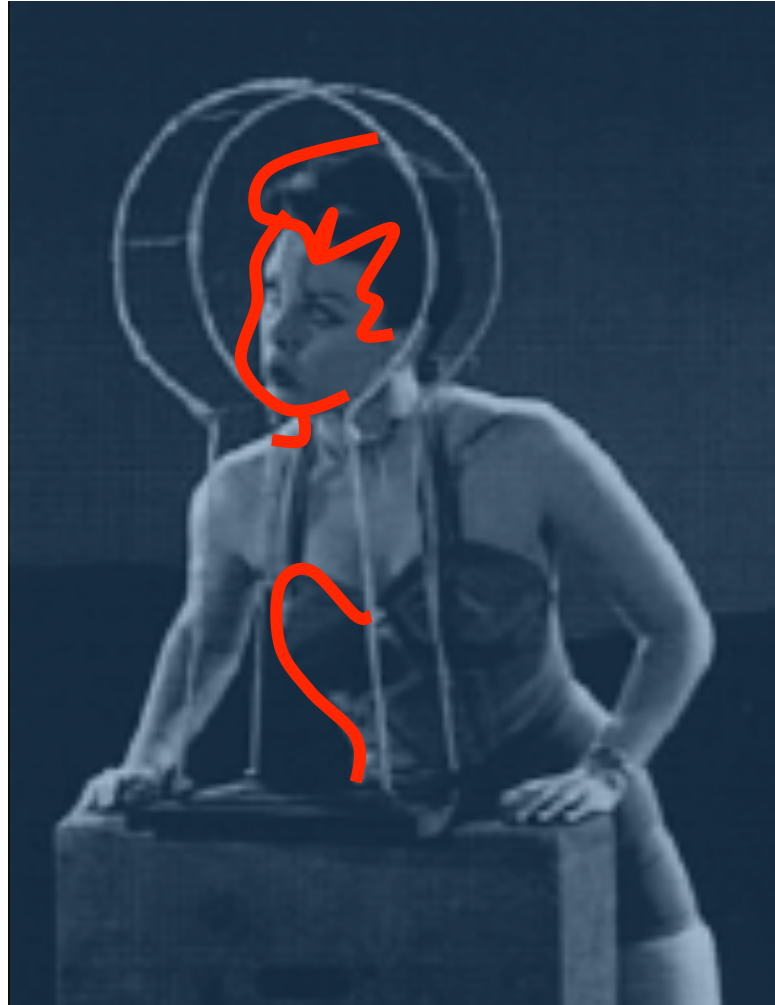
- Do all 4 legs come off the ground when a horse is in gallop?



- Leland Stanford backed Muybridge's data collection: animals, men, women, children, [etc.](#)
- Chicago 1893: moving pictures viewed by paying public in first movie theater
- See also [Étienne-Jules Marey](#)

Rotoscoping

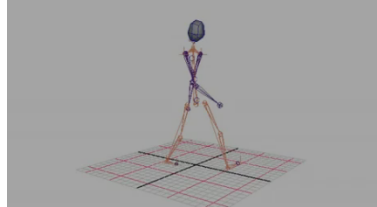
(Tinkerbell in Disney's "Peter Pan")



Margaret Kerry posed for 11 months as Tinkerbell, "The Illusion of Life", Thomas & Johnston

Pose Animation

- Keyframing



[By sacul109498 link](#)

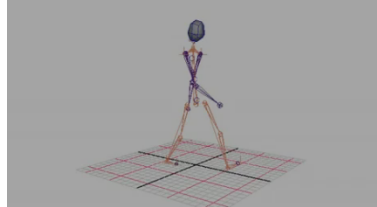
Keyframing
in Maya



Pixar productions

Pose Animation

- Keyframing



[By sacul109498 link](#)

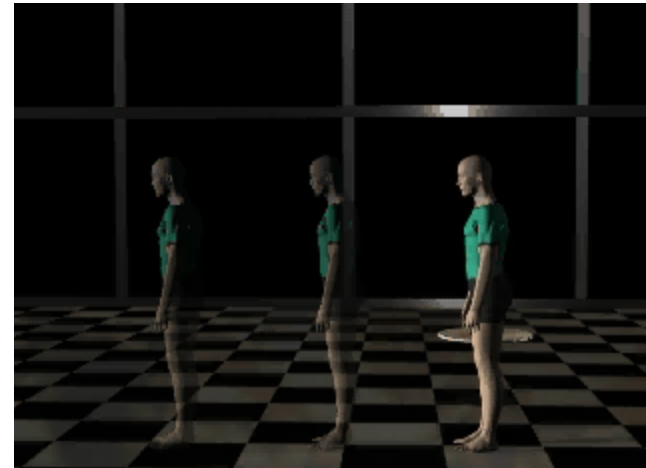
Keyframing
in Maya



Pixar productions

- Physical Controllers

- Virtual
- Real



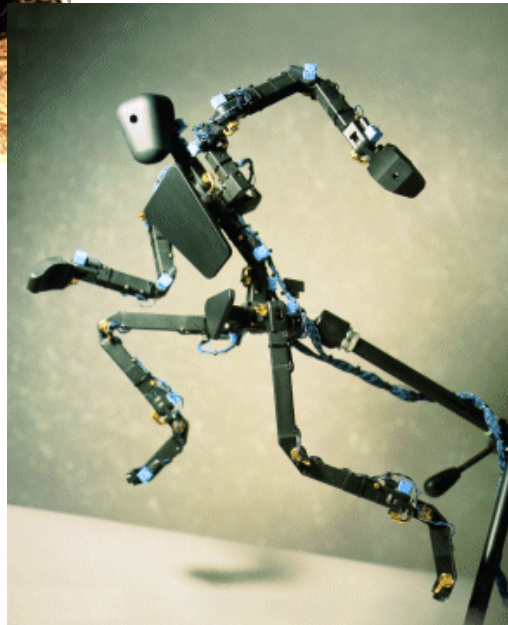
[Animating Human Athletics, Hodgins et al.](#)

...→ Motion Capture!

Puppeteering



Image: Jim Henson Productions



Monkey 2 by Inition

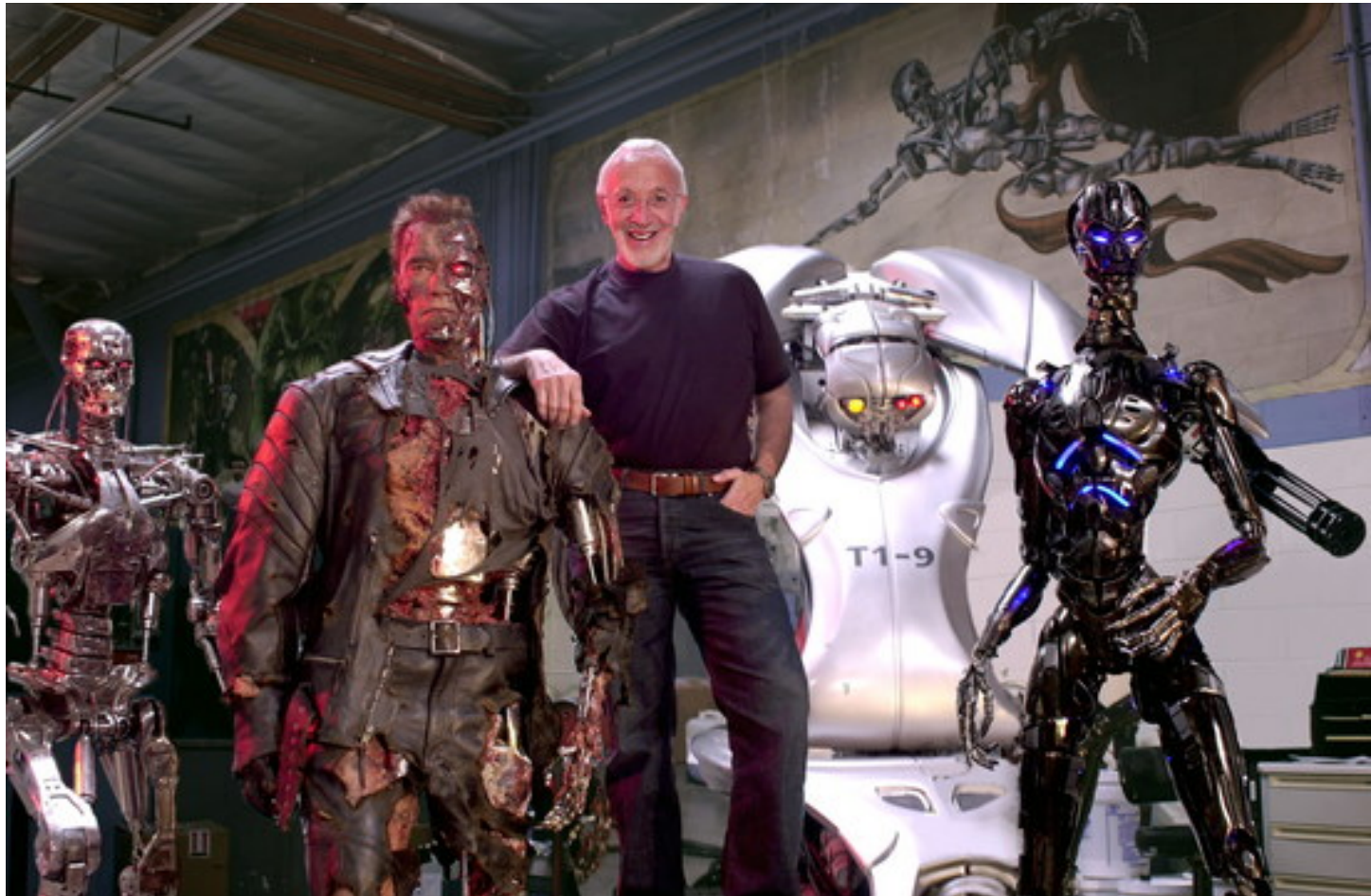


Image: Jim Henson Productions

<http://muppet.wikia.com/wiki/Bicycles>



Puppeteering



Stan Winston: 1946 - 2008

Puppeteering

AI ARTIFICIAL INTELLIGENCE



Things — such as walk down a flight of stairs and slide across a floor. “We got him to do all kinds of stuff,” said Macgregor, “but a lot of that isn’t in the movie, just because there was only so much ‘Tubby’ stuff Steven could fit into the film. One of my favorite things that did make it into the movie was a shot of Tubby leaping out of a box during the Flash fire scene. That was one of those cases where we’d been playing with it and figured out how to do this, and when we showed it to Steven, he said ‘Wow, that’s better than what I was thinking of let’s do that!’”

Another incredible bit of Tubby puppeteering in the film is a shot of the character sewing. “That was tricky,” said Macgregor. “It was a really cramped, hot set, and Steven was standing right behind me as I remote-controlled Tubby’s head. Meanwhile, Stuart Weitzman was in the telemetry unit, puppeteering the arms to create this sewing motion. I remember looking over at Stuart and seeing sweat just pour off of him. He was both sweating not because it was so hot in there, and we were concentrating so hard on puppeteering Tubby for this scene. It was nerve-wracking!”

Winston directed Tubby’s performance throughout the shoot, communicating Spielberg’s comments to the puppeteer, and smiling at the disparate minds at the controls to create an organic performance. “Stan was on set every day,” Macgregor said. “He was our acting coach and our guide. Without him there, Tubby’s performance would never have been as good or as interesting. In fact, Tubby really was Stan. That was Stan’s personality that came through in that character.”

The team’s hard work was well rewarded when many critics and

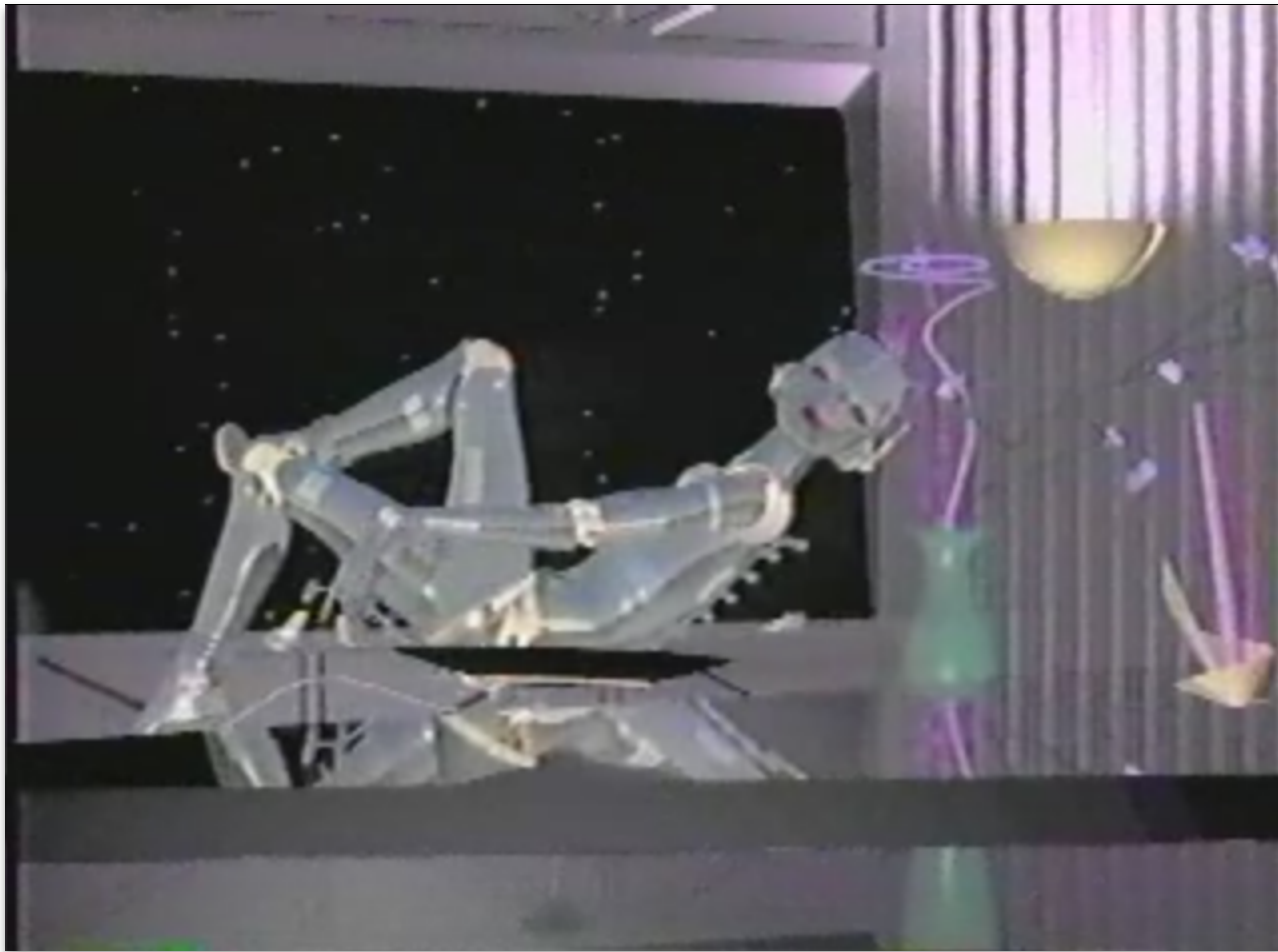
audiences loved the film. Macgregor operated the Tubby walking rig directly to make the character on the set of *Winston*. Winston movies Mike (Dreke) and Brian (Lee) as the walking crew for that period. Tubby’s range of expressions and body movements. Actor Alan Scott (Lindberg) then gave the bear a human-like quality with Tubby in between shots. He was the only person who was with Stan Winston and members of the Tubby team.



Moving Light Displays

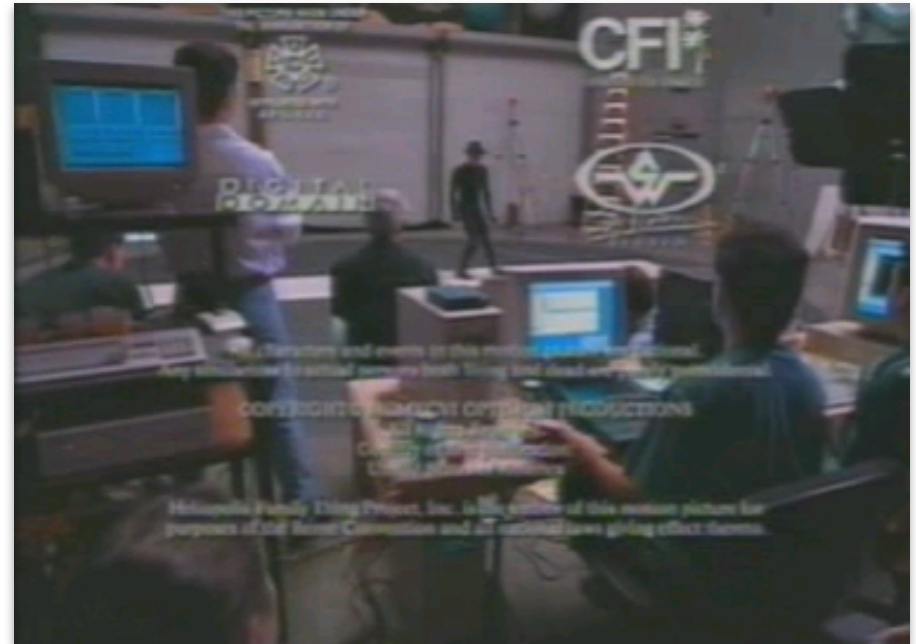
- Johansson (1973) experiments
- [Video](#) by Randolph Blake @ Vanderbilt
- Subsequent research showed similar phenomena
- Algorithmic versions:
 - For finding individuals in crowds: [Brostow + Cipolla 2006](#)
 - For recognizing objects in video: [Brostow et al. 2008](#)

First Motion Capture in Animation



“Brilliance” by Abel and Associates, 1985

Motion Capture for F/X



Michael Jackson - Ghost

Motion Capture Technology

Magnetic



Active Markers

Mechanical



Optical

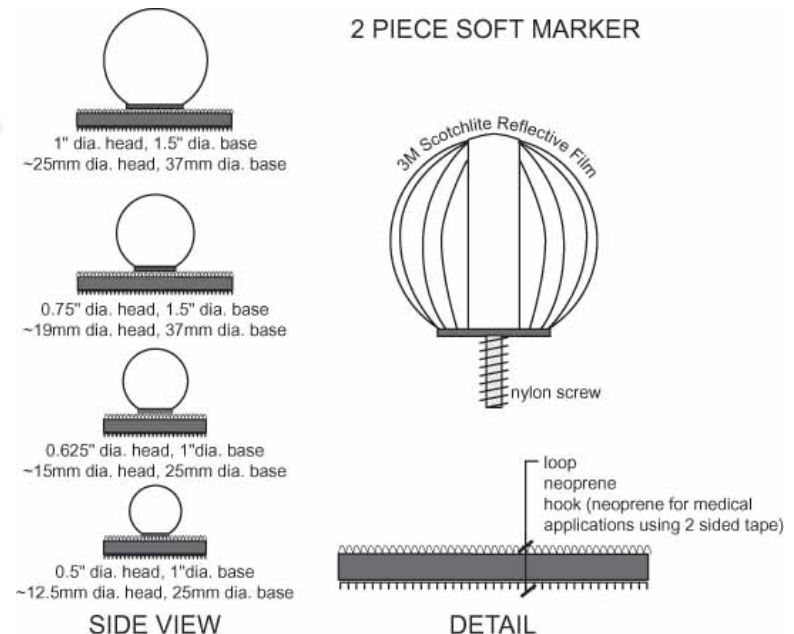


Passive Markers

Active vs. Passive Markers

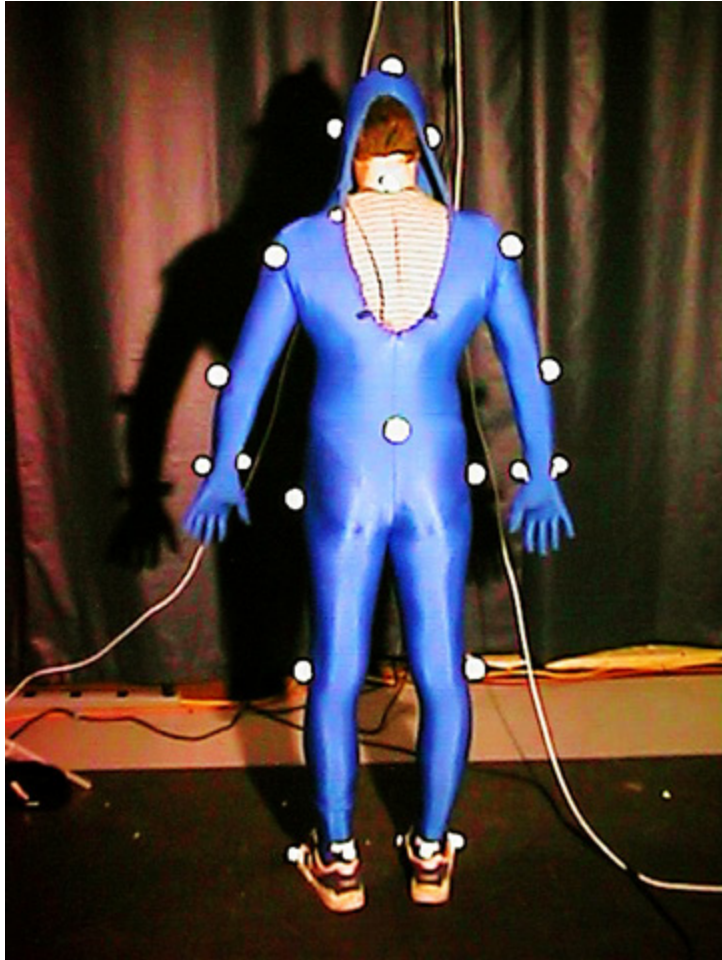
- Active Markers (broadcasting or sensing)
 - Need cable / transmitter for power + signal
 - Unique IDs
 - Magnetic systems report Rotation + Translation

- Passive Markers
 - Correspondence problem
 - Sizes vary(!)
 - Provide only Translation
 - Also avail. as bone-screws



From [3x3 Designs](#)

Marker Configurations



Now usually agreed that better results achieved by offsetting markers and asymmetric placement.



[CMU mocap DB](#)

From production of
[“Scott Pilgrim vs. the World”](#)

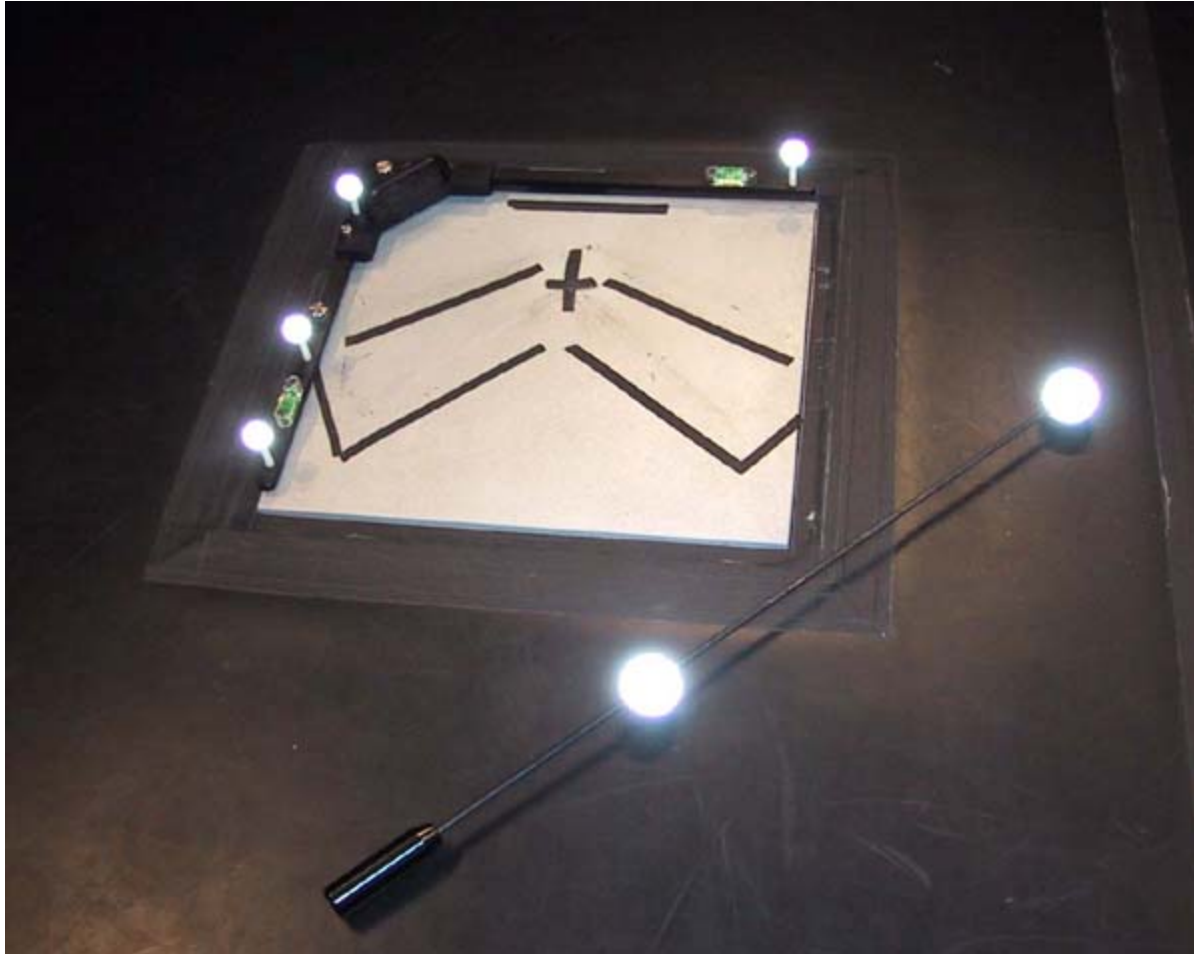


Where to Place Cameras?



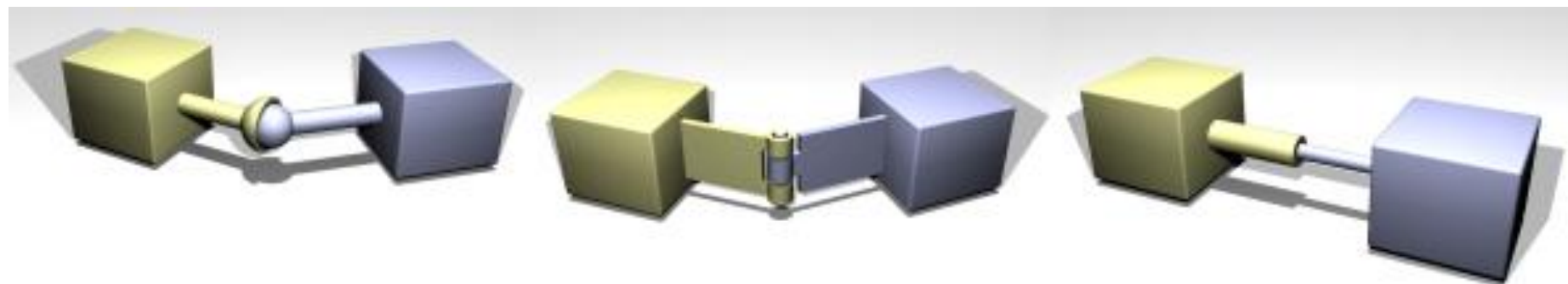
Wide baseline for
better triangulation
vs.
Narrow baseline for
easier
correspondences
and predictable
occlusions

Camera Calibration

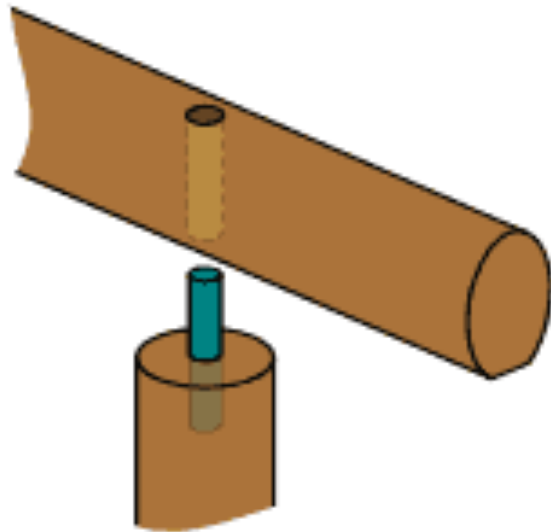


2D “centers”
↓
3D rays
↓
3D
correspondence

Calibration frame (centered on force platform) and wand,
from [LIU Instrumented Analysis of Human Movement](#)



Joints: Degrees of Freedom (DOFs)



From Ydalir Vikings [Tent poles](#)

?

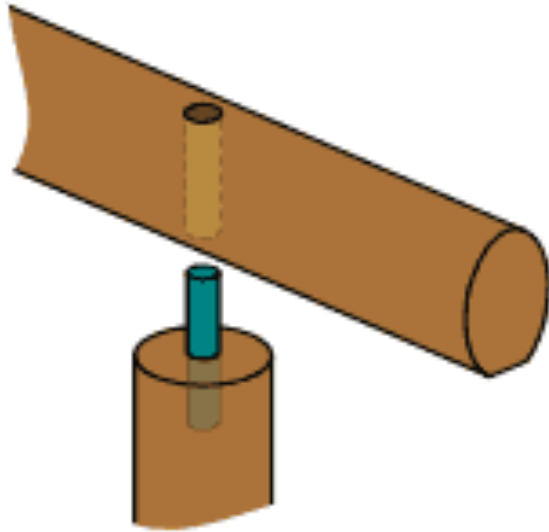


"hair line cracks on the cheap ball joint"
(see more at [Eternal Rollerz C.C.](#))

?

DOF' s?

Joints: Degrees of Freedom (DOFs)



From Ydalir Vikings [Tent poles](#)

1

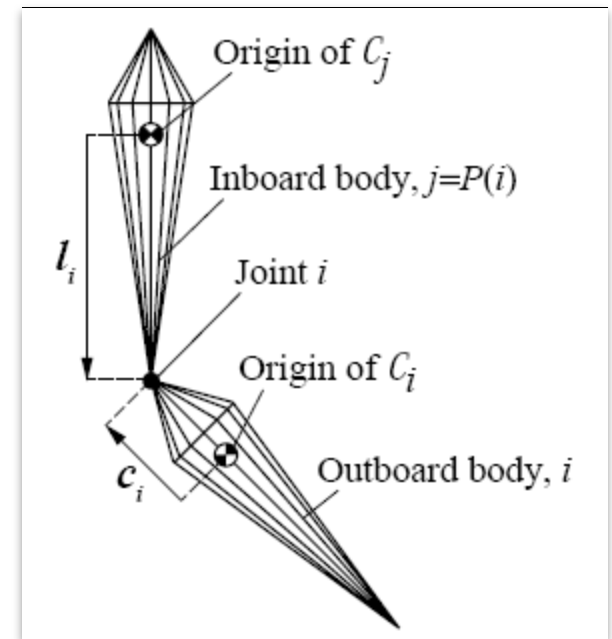
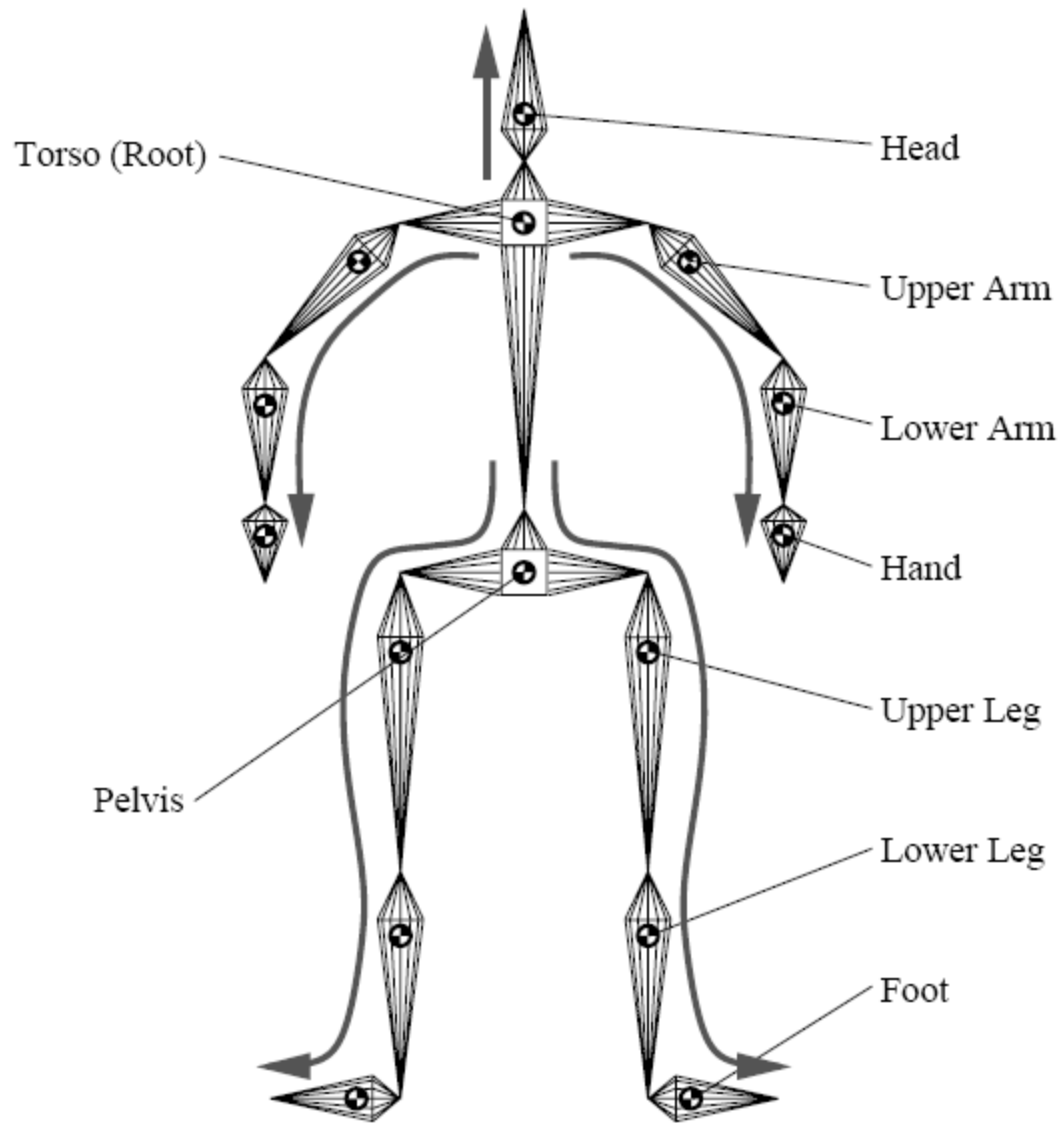


"hair line cracks on the cheap ball joint"
(see more at [Eternal Rollerz C.C.](#))

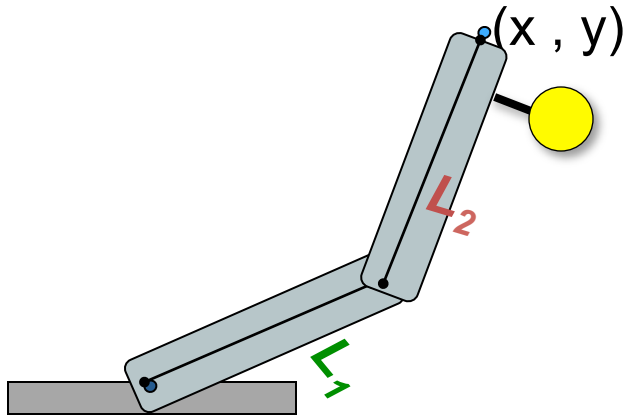
3

DOF' s?

- Most joints are approximated by ball joints, while Root has 3 translational degrees of freedom. Good enough?

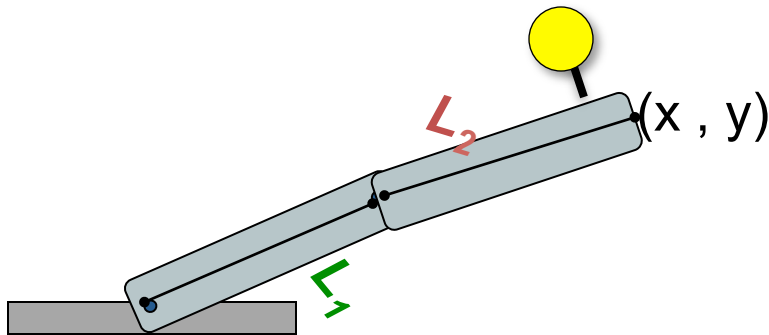


Joint Angle Estimation



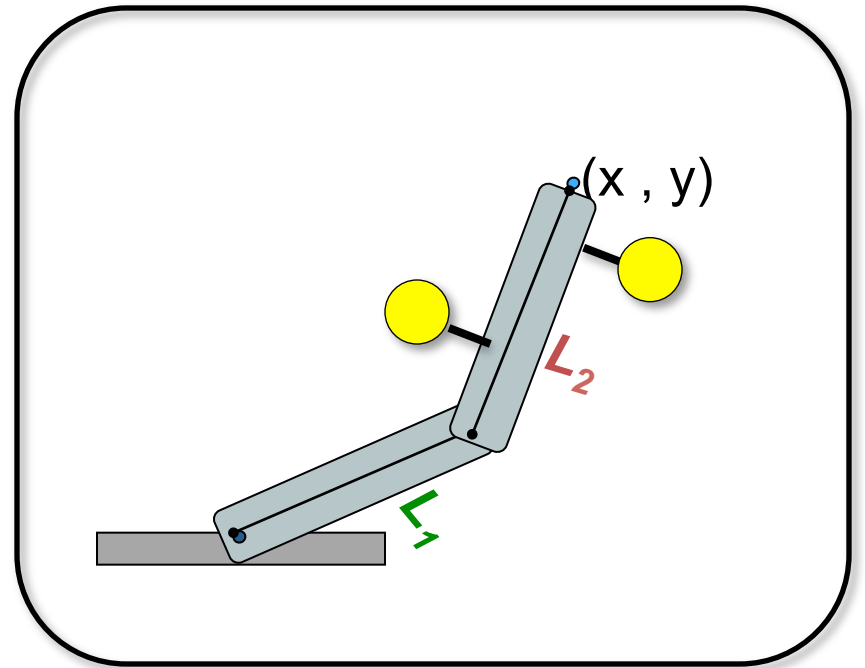
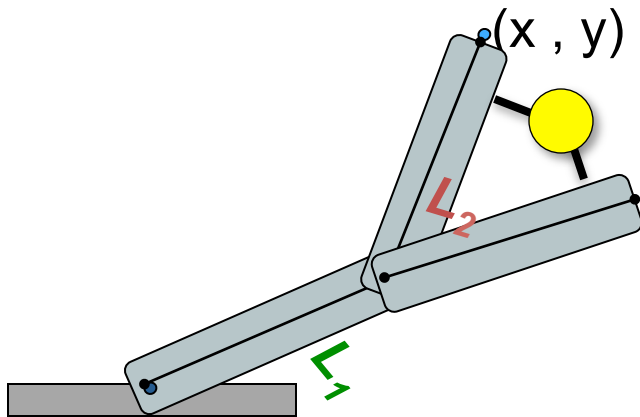
3D: If L_1 's pose is known, and L_2 is attached with a ball-joint, is the shown marker enough?

Joint Angle Estimation



3D: one marker leaves L_2 underconstrained

Joint Angle Estimation

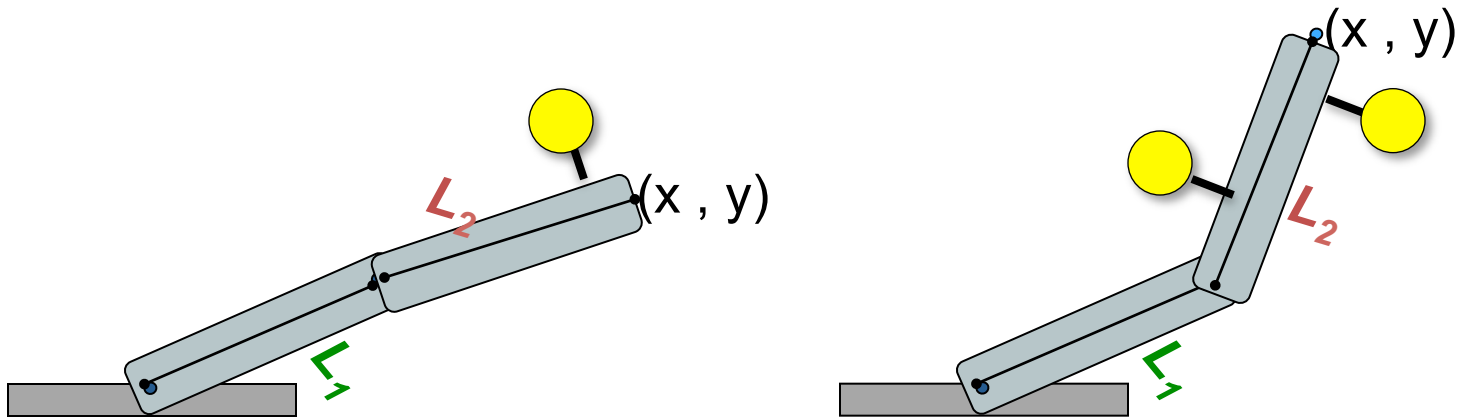


Now L_2 's pose is constrained

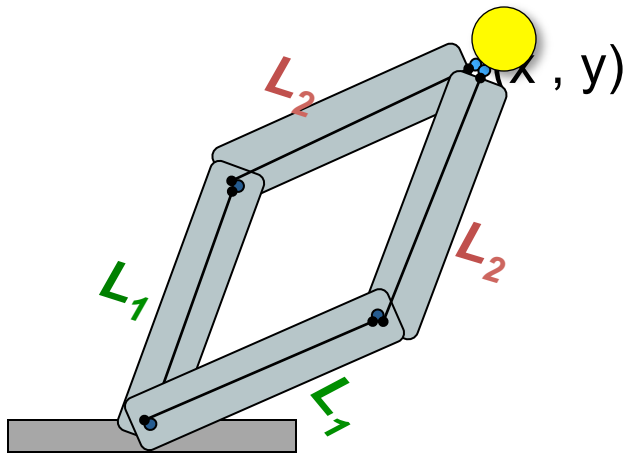
(assuming known L_1 and marker placement)

New question: if all joints on the right are pin-joints, do we need any markers on L_1 ?

Joint Angle Estimation

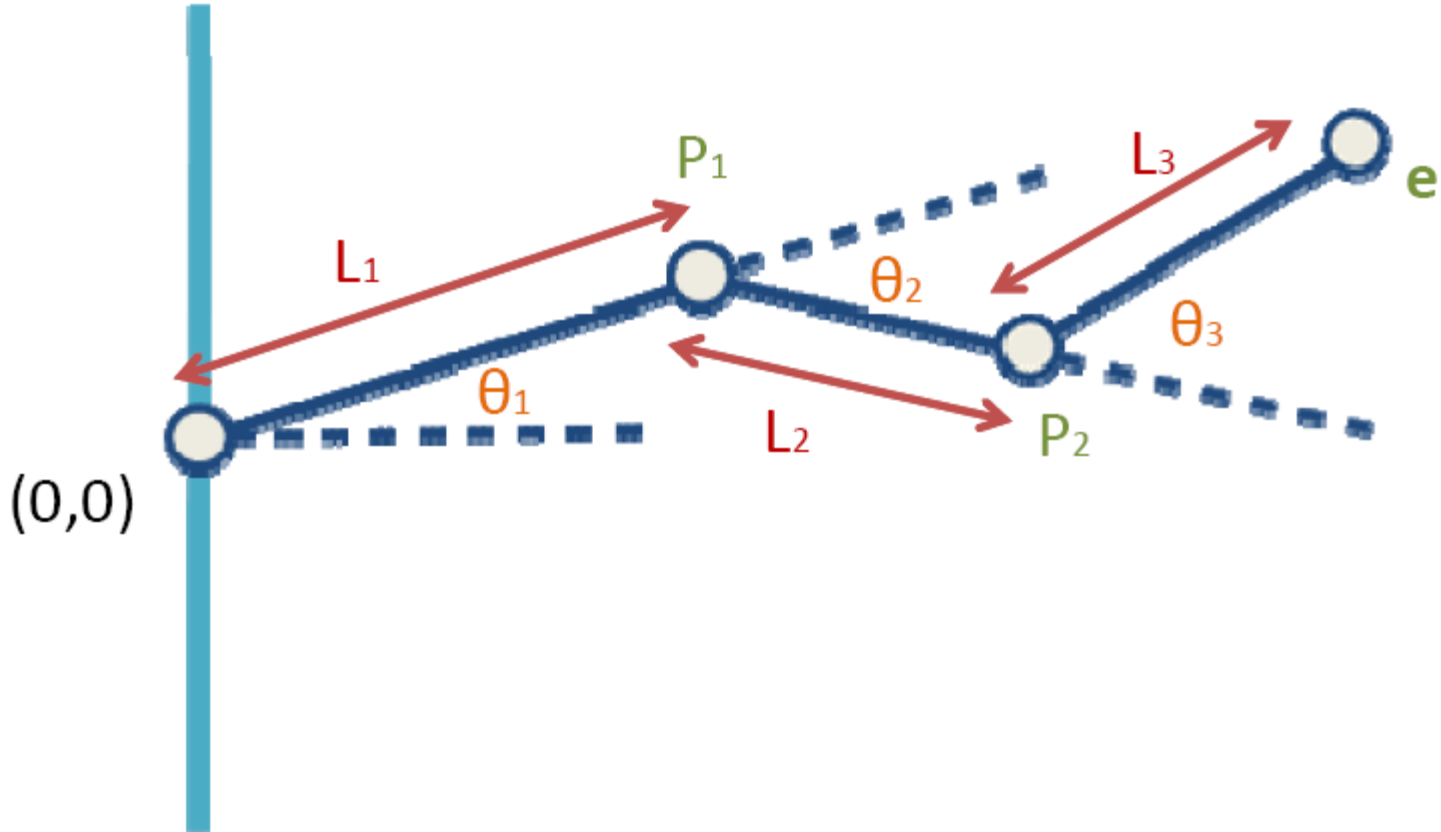


New Challenges Emerge



1. Inverse kinematics
2. Practical calibration of marker locations (and limb hierarchy)
3. Data cleaning...

Forward Kinematics



Kinematics & End Effectors

Forward Kinematics

$$\boldsymbol{\theta} = [\theta_1, \theta_2, \dots, \theta_M]$$

All degrees of freedom in 1 vector

We want to find the end effector position in 3D:

$$\mathbf{e} = [e_1, e_2, e_3]$$

FK has form: $\mathbf{e} = f(\boldsymbol{\theta})$

Inverse Kinematics

We have end effector(s):

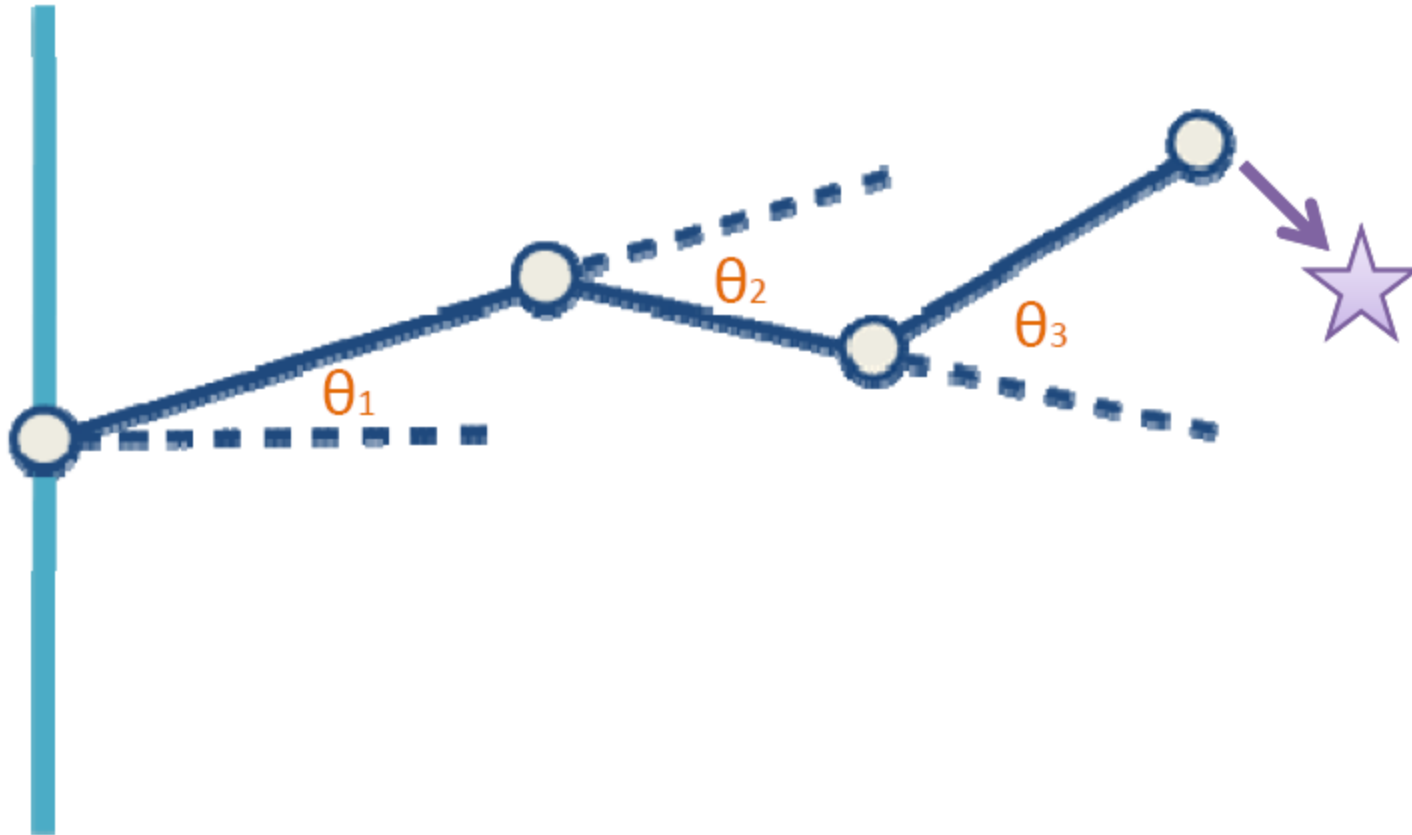
$$\mathbf{e} = [e_1, e_2, \dots, e_N]$$

We want joint angles:

$$\boldsymbol{\theta} = [\theta_1, \theta_2, \dots, \theta_M]$$

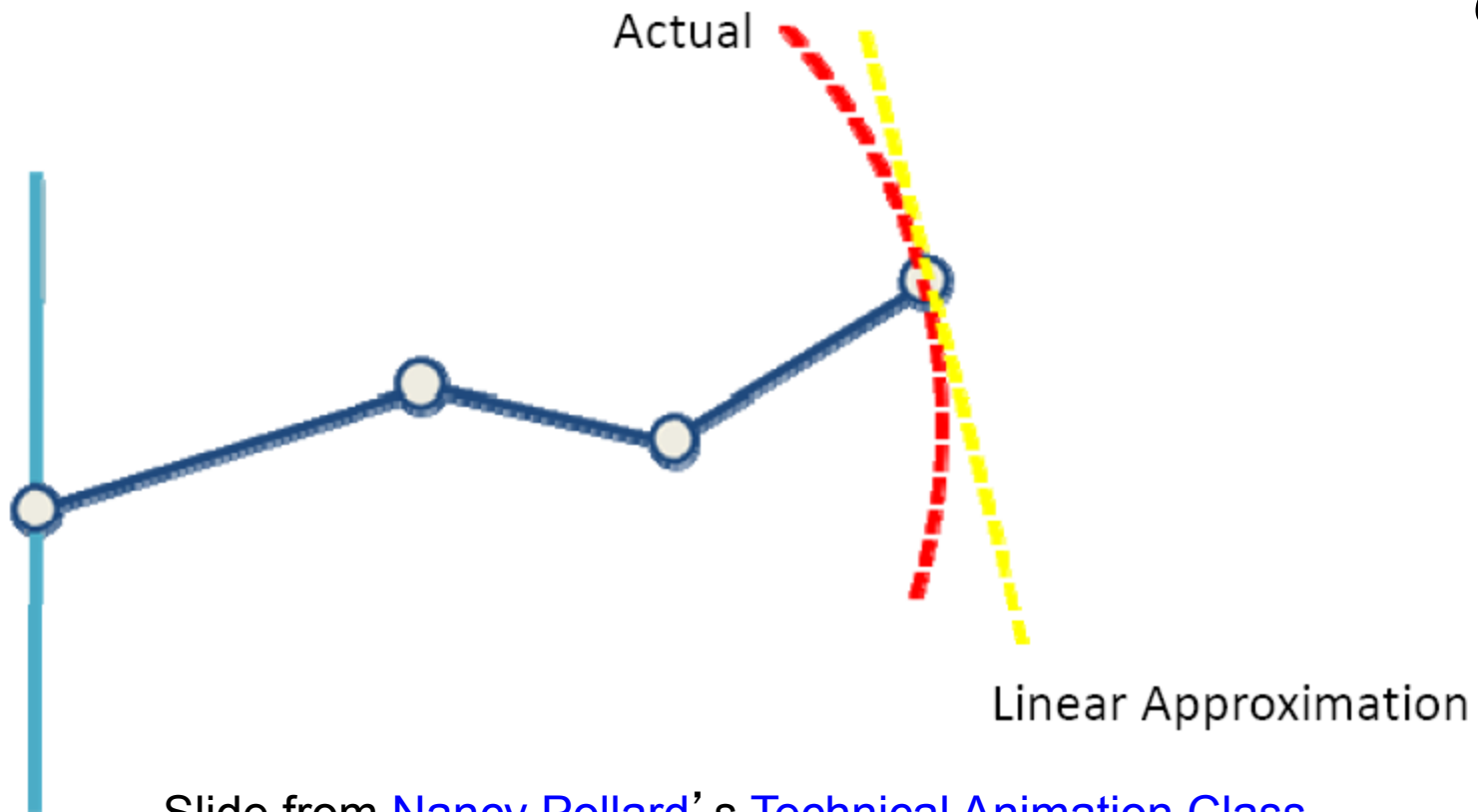
So we need: $\boldsymbol{\theta} = f^{-1}(\mathbf{e})$

Inverse Kinematics



IK is Usually an Optimization of the Jacobian

- Jacobian: linear approximation of $f()$: $J = \frac{de}{d\theta}$



Skeleton + Marker Location Estimation

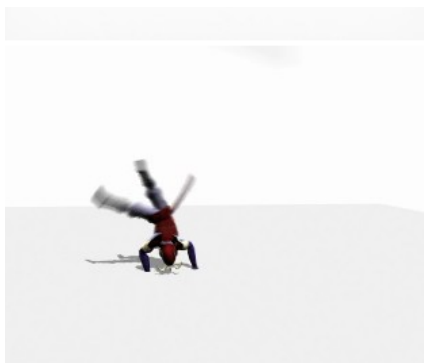


CMU Graphics Lab

Mocap Database

- <http://mocap.cs.cmu.edu>

Subject #43 (swing on playground equipment) file index					- - asf	framerate
Trial #	Motion Description					
1	walk	tvd	c3d	amc		Animated 120
2	playground - grip bar, swing body	tvd	c3d	amc	mpg	Animated 120
3	playground - grip bar, swing body	tvd	c3d	amc	mpg	Animated 120



Samurai doing a cartwheel entrance to a forward somersault.



Samurai doing a reverse somersault.

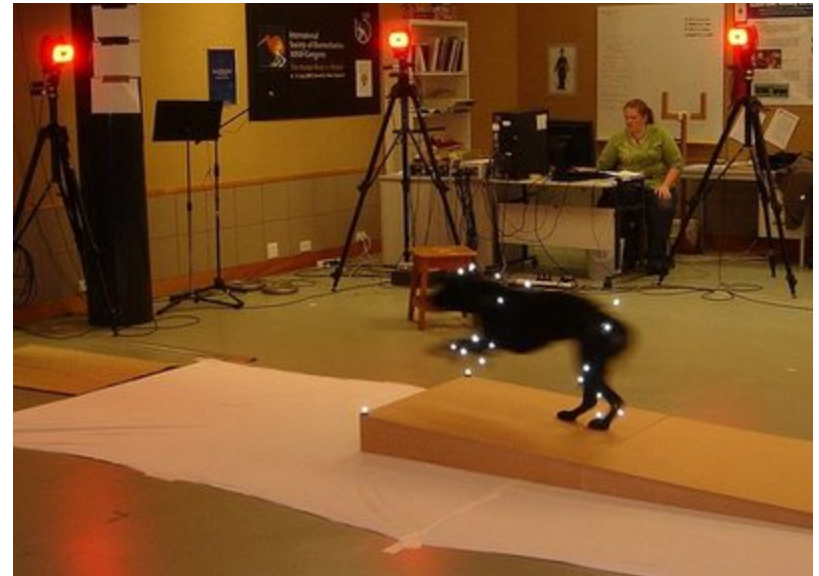
Mocap Beyond Human Limbs?



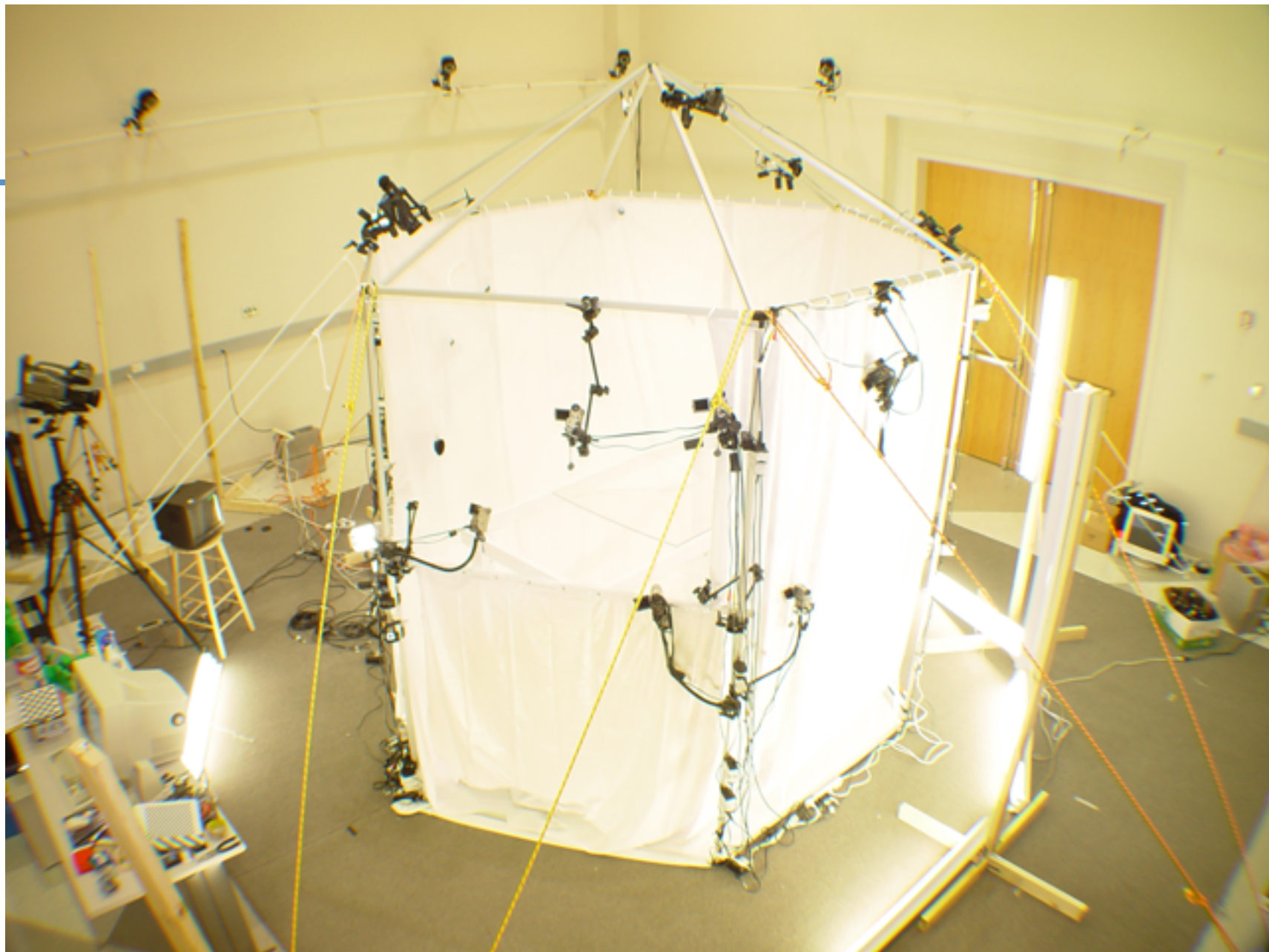
Faces, Animals, Cameras, Props...



See serkis.com and [here](#)



Free motion capture data [here](#)









Do's & Don't's of Mocapping Talent

- Adult actors are patient – but on a clock
 - Need ONE director
- Children have parents
- Monkeys eat markers
- Dogs are fast