

# CS 184: Foundations of Computer Graphics

Lecture 23: Intro to Animation

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Animation = series of frames





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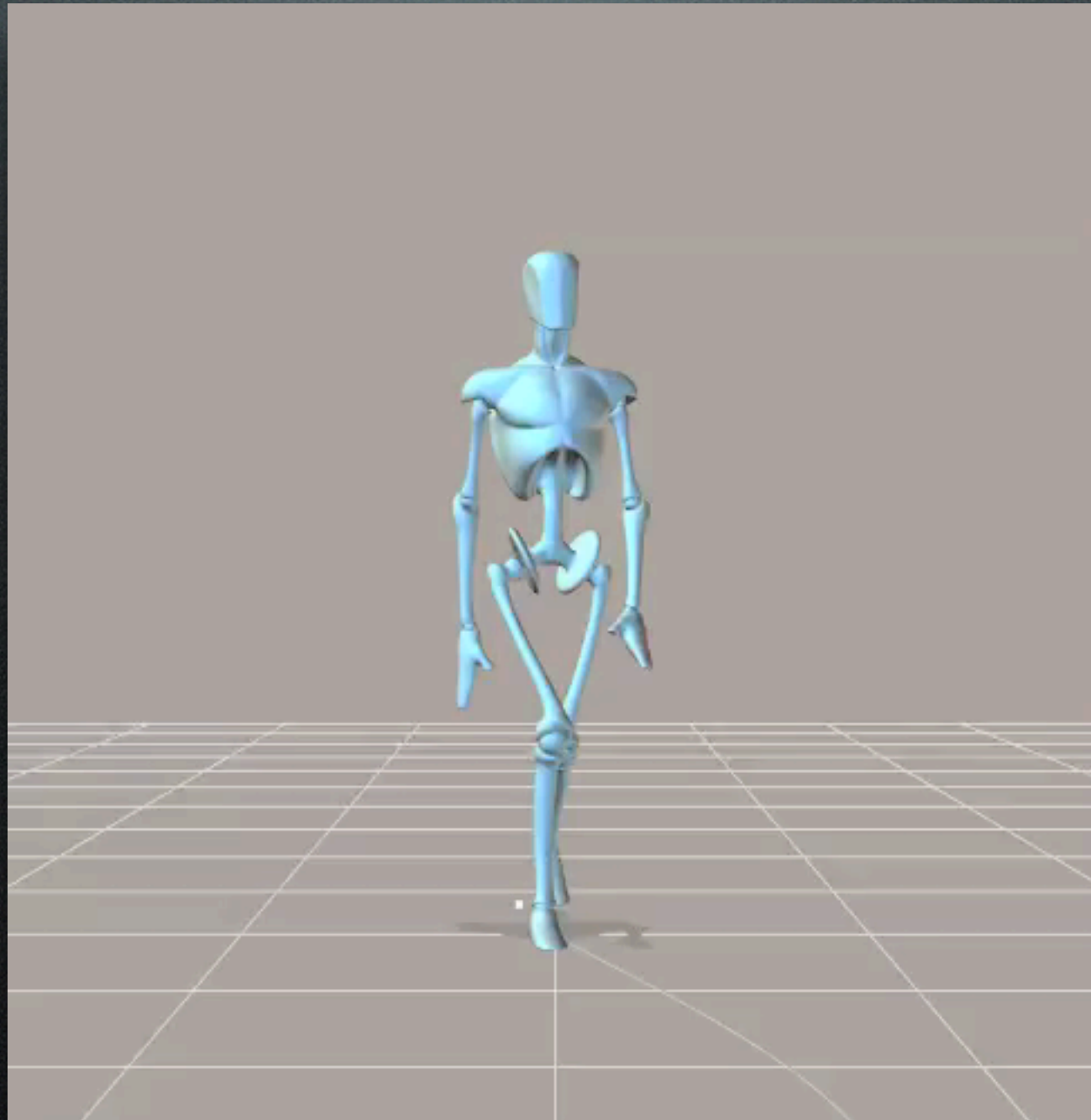
# Animation = series of frames



- Sequence of images (“frames”) shown in rapid succession
  - Generated off-line (e.g. movies)
  - Or in real-time (e.g. games)



Animation = series of frames









# Aesthetic principles of animation

- Squash and stretch
- Timing
- Anticipation
- Follow-through and overlapping action
- Secondary action



Lasseter 1987



# The problem

- How to generate, represent, and manipulate motion...
- ...in a way that's efficient, easy to use, realistic?
  - Human motion
  - Inanimate objects
  - Amorphous stuff
- With directability & aesthetic control



# Animatable models

- Particles
  - Position and velocity
  - Easy way to model fireworks, smoke, spray, etc.

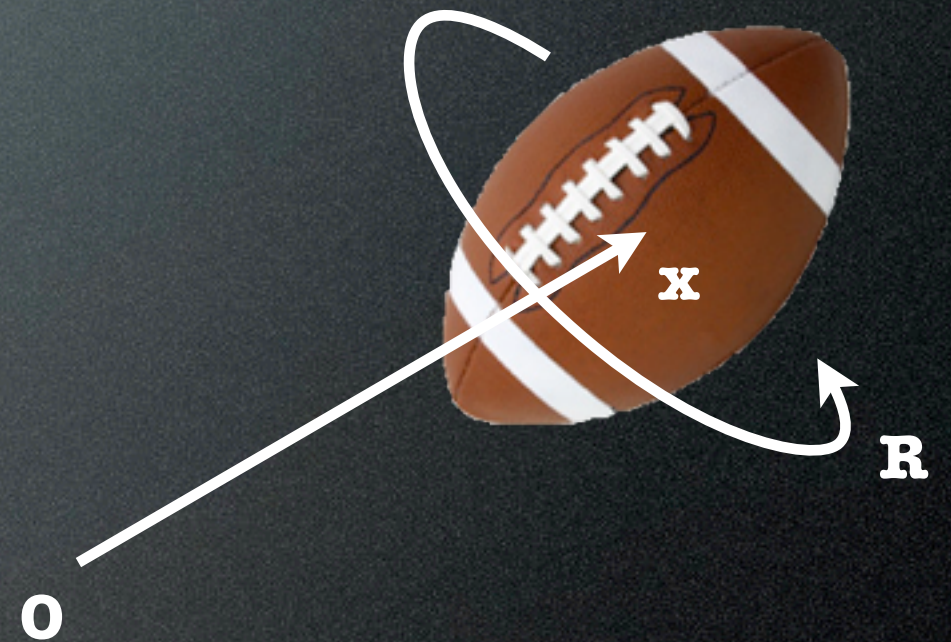


Reeves 1983



# Animatable models

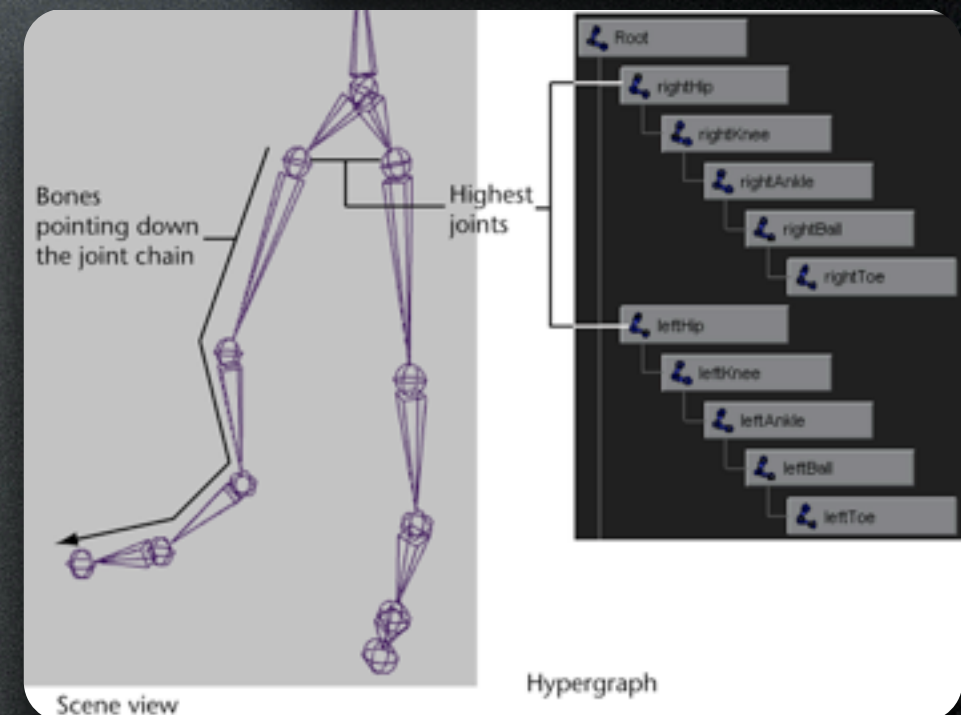
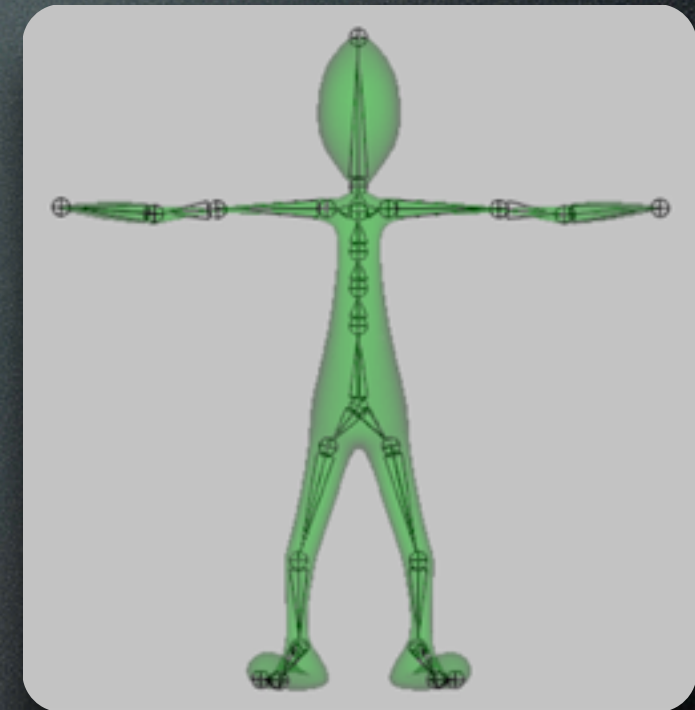
- Particles
- Rigid bodies
  - Position and orientation





# Animatable models

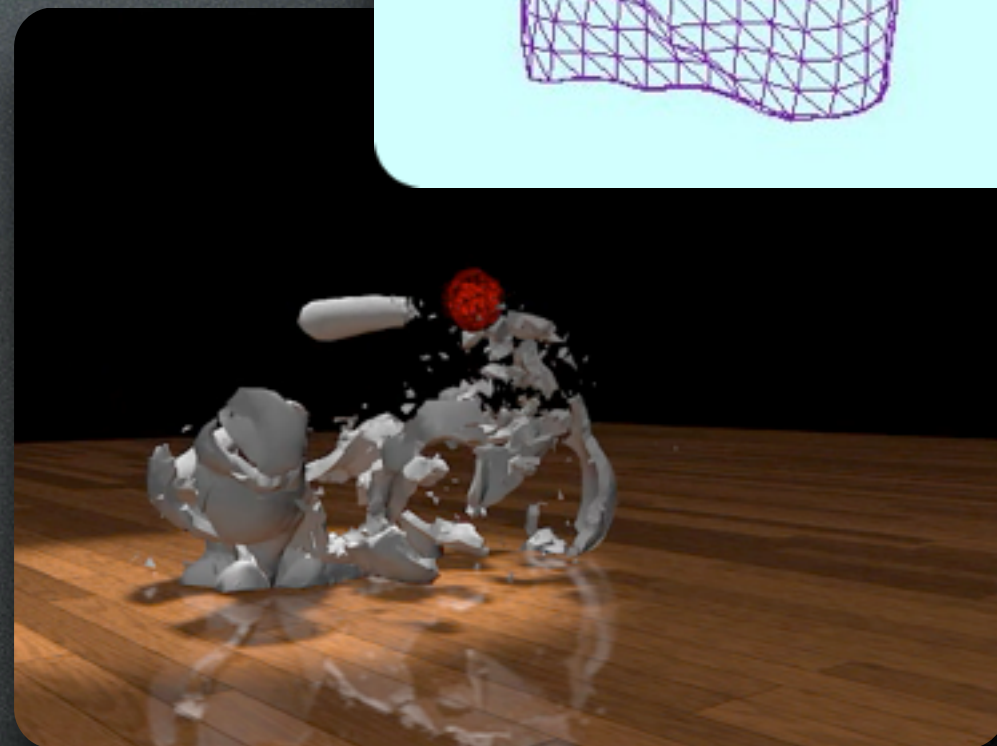
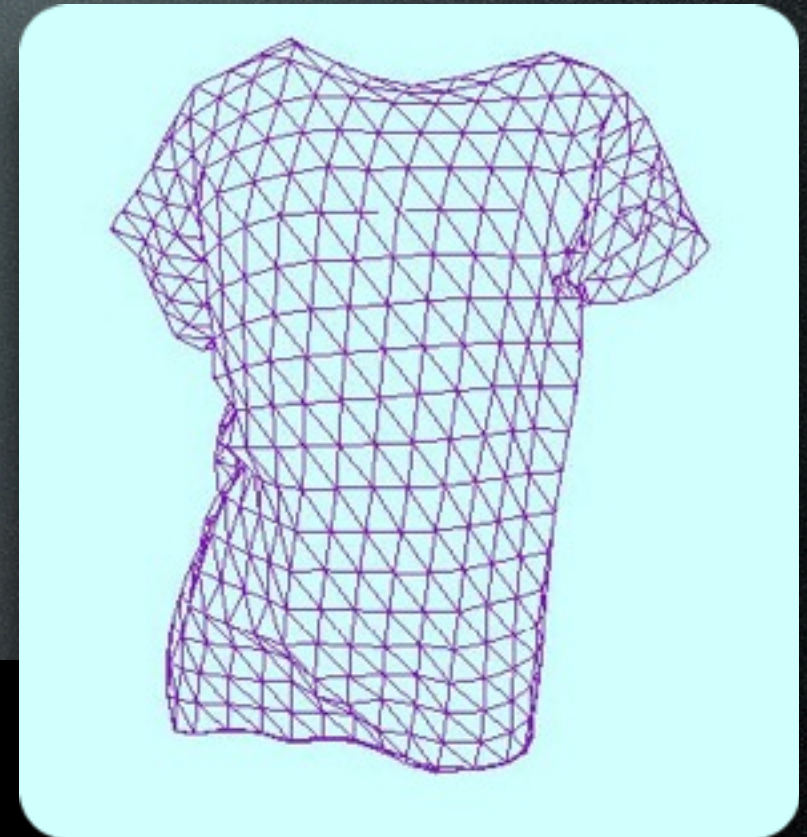
- Particles
- Rigid bodies
- Articulated bodies
  - Rigid links connected by joints
  - Hierarchy from root node to extremities
  - E.g. robots, character skeletons





# Animatable models

- Particles
- Rigid bodies
- Articulated bodies
- Deformable bodies
  - Discretized as meshes with moving vertices
  - Cloth, hair, jello, plastic, muscle and skin, ...

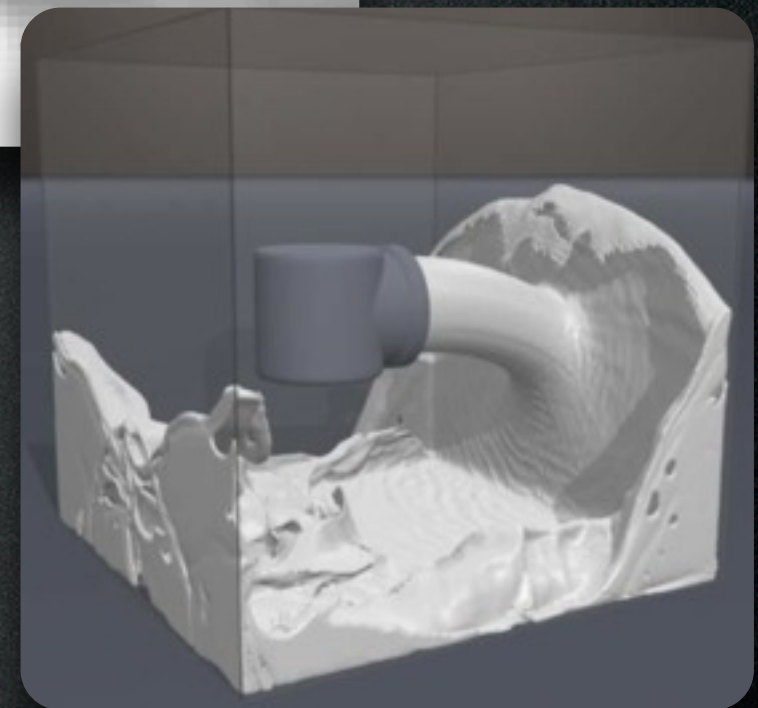
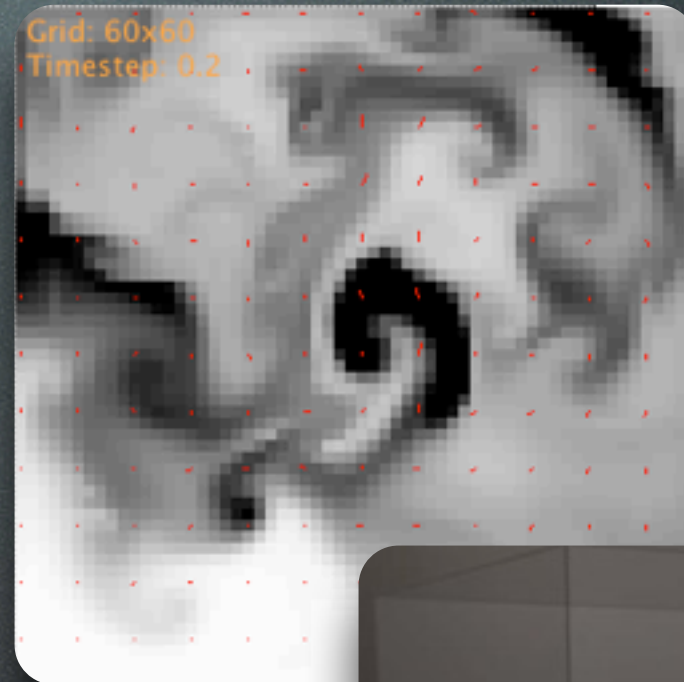


O'Brien et al. 2002



# Animatable models

- Particles
- Rigid bodies
- Articulated bodies
- Deformable bodies
- Fluids
  - Discretized as particles or grid





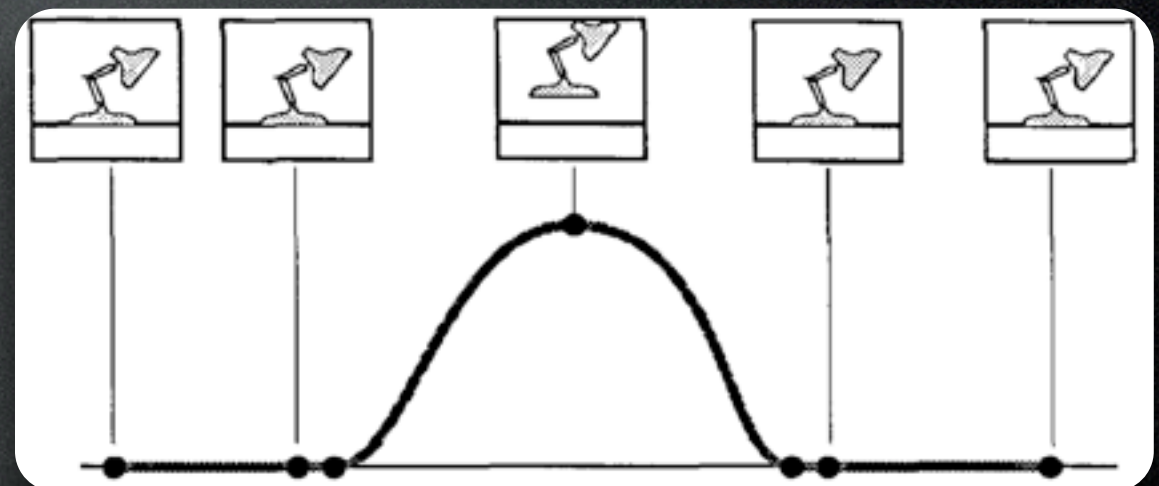
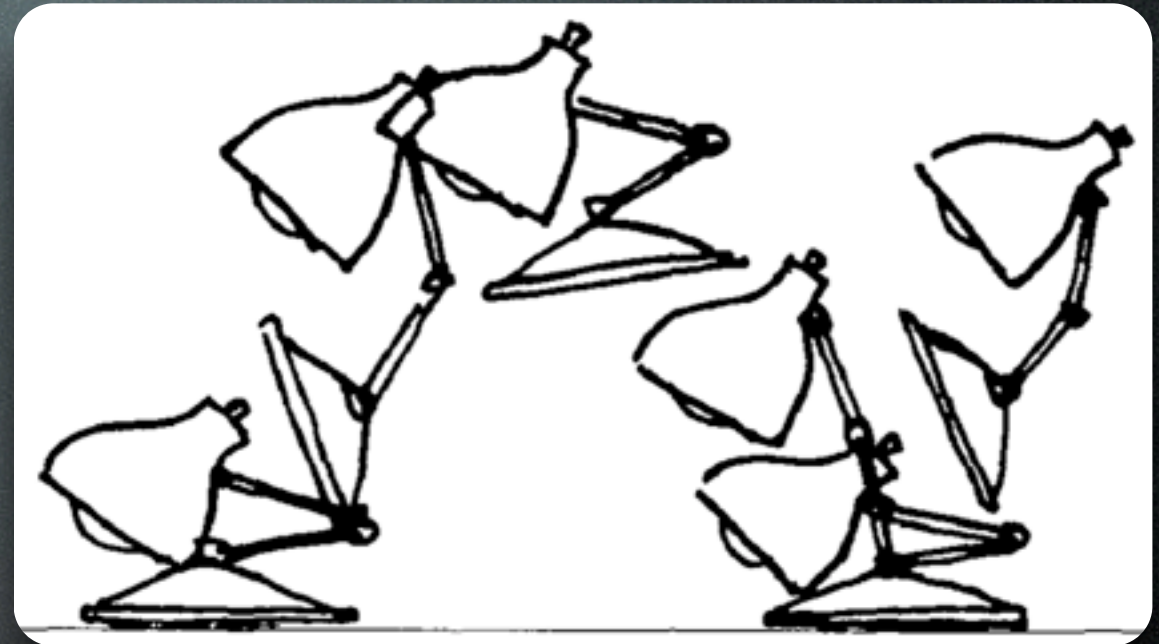
# Animation techniques

- Key-frame animation
  - Specify key moments by hand
- Motion capture
  - Record motion of performer
- Procedural / simulation
  - Automatically compute inanimate dynamics
- Combinations



# Key-framing (manual)

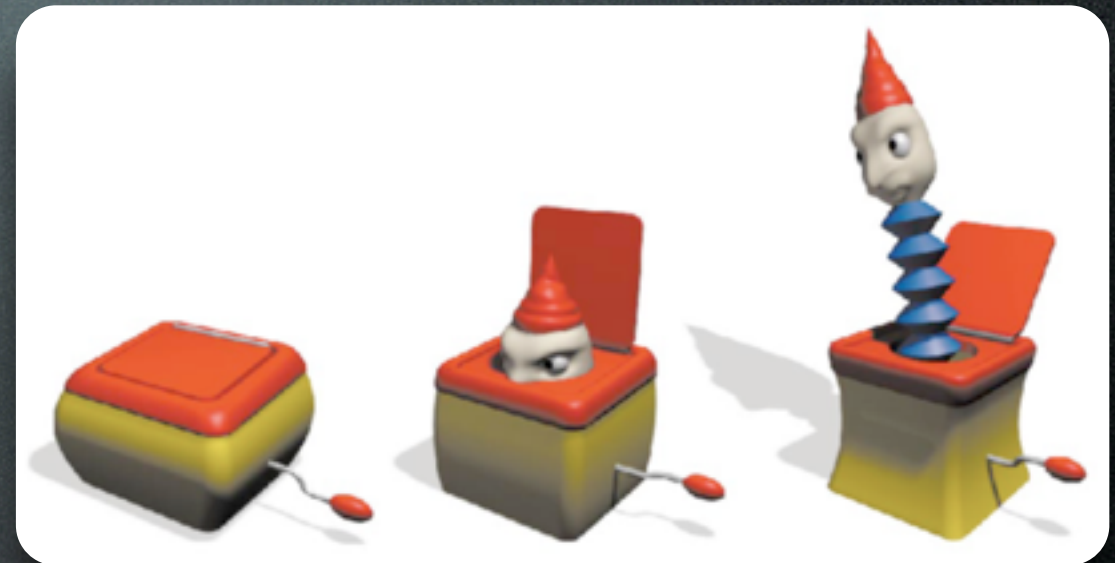
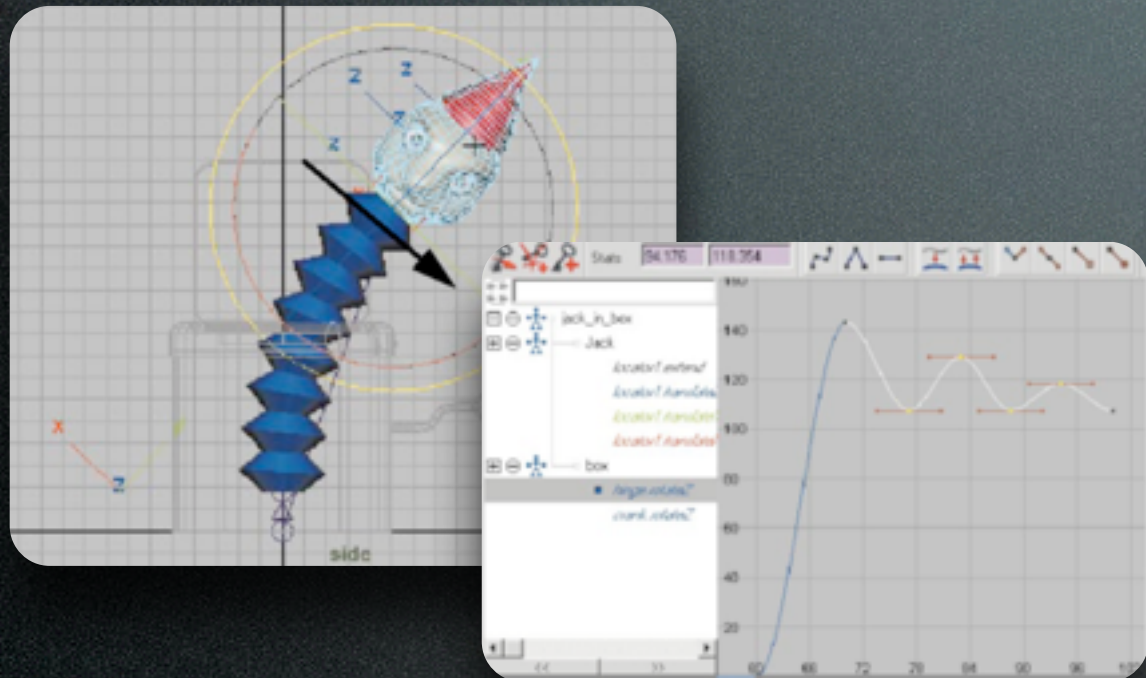
- Manually specify “key” moments of the action
- System interpolates the in-between frames



Lasseter 1987



# Key-framing (manual)



**Learning Maya 2.0**

- Most basic animation tool
- Animator has control over all aspects of the action
- Requires extensive amount of time and skill



# Motion capture (recorded)

- Place markers on subject, record their performance in 3D
- Time-consuming clean-up
- Active research problem: how to **manipulate** this data?



Andy Serkis as Gollum  
in **Lord of the Rings**



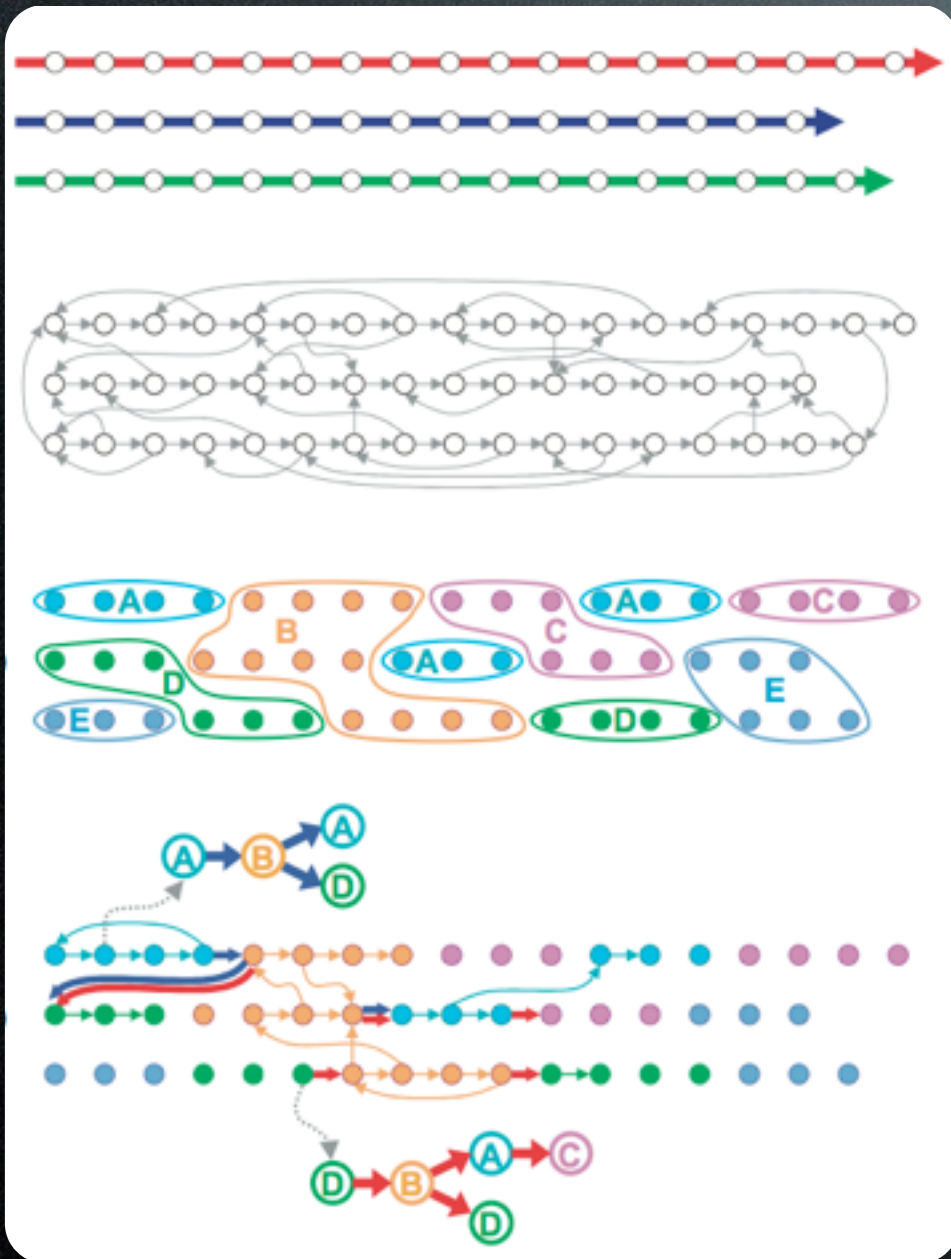
# Motion capture (recorded)



Majkowska et al. 2006



# Motion graphs



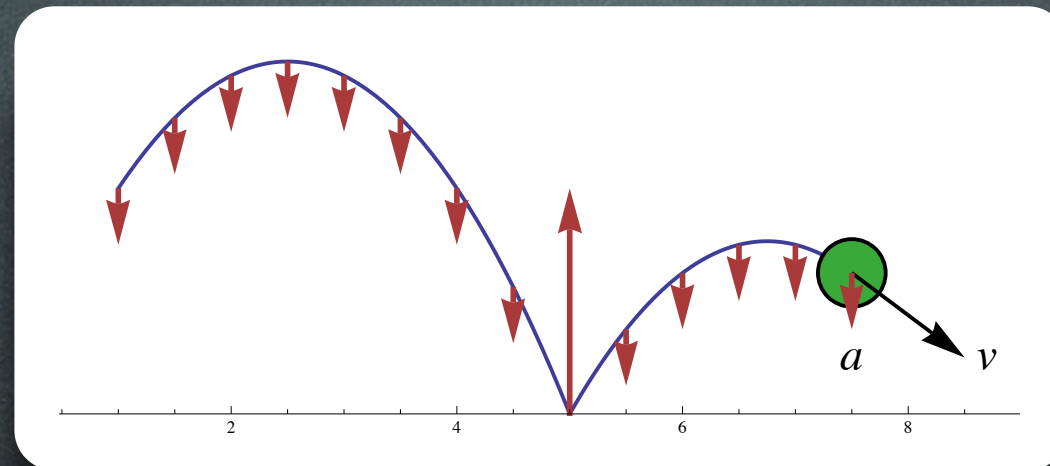
Lee et al. 2002



Arikan et al. 2003



# Simulation (automatic)



- Solve physical equations of motion using numerical methods
  - $\mathbf{F} = m \cdot d^2\mathbf{x}/dt^2$
- Discretize continuous materials (cloth, fluids, etc.) into meshes/grids and solve

$$\frac{\partial}{\partial t} u_i + \sum_{j=1}^n u_j \frac{\partial u_i}{\partial x_j} = \nu \Delta u_i - \frac{\partial p}{\partial x_i} + f_i(x, t)$$
$$\text{div } u = \sum_{i=1}^n \frac{\partial u_i}{\partial x_i} = 0$$



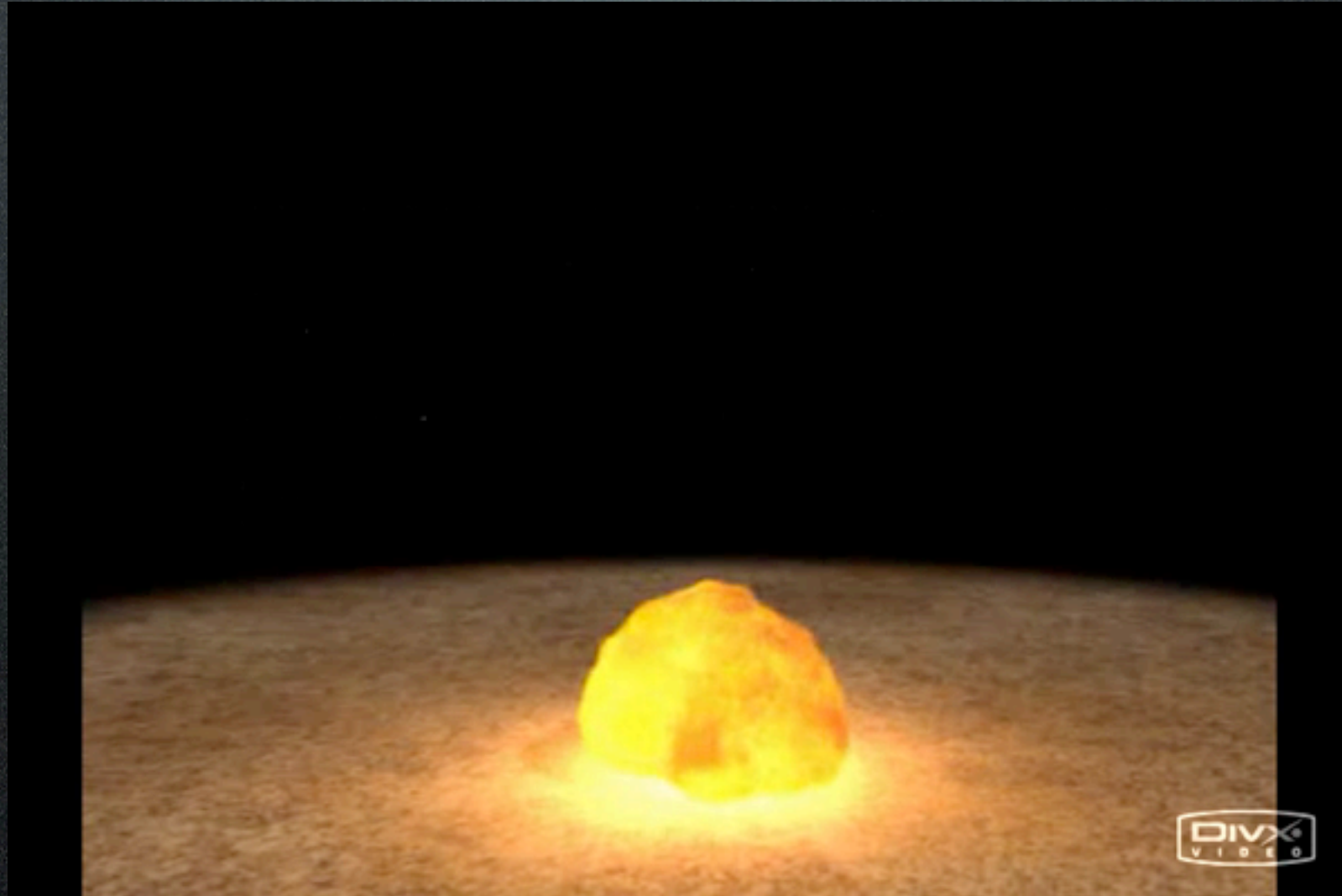
# Simulation (automatic)



Goldenthal et al. 2007



# Simulation (automatic)



Feldman et al. 2003

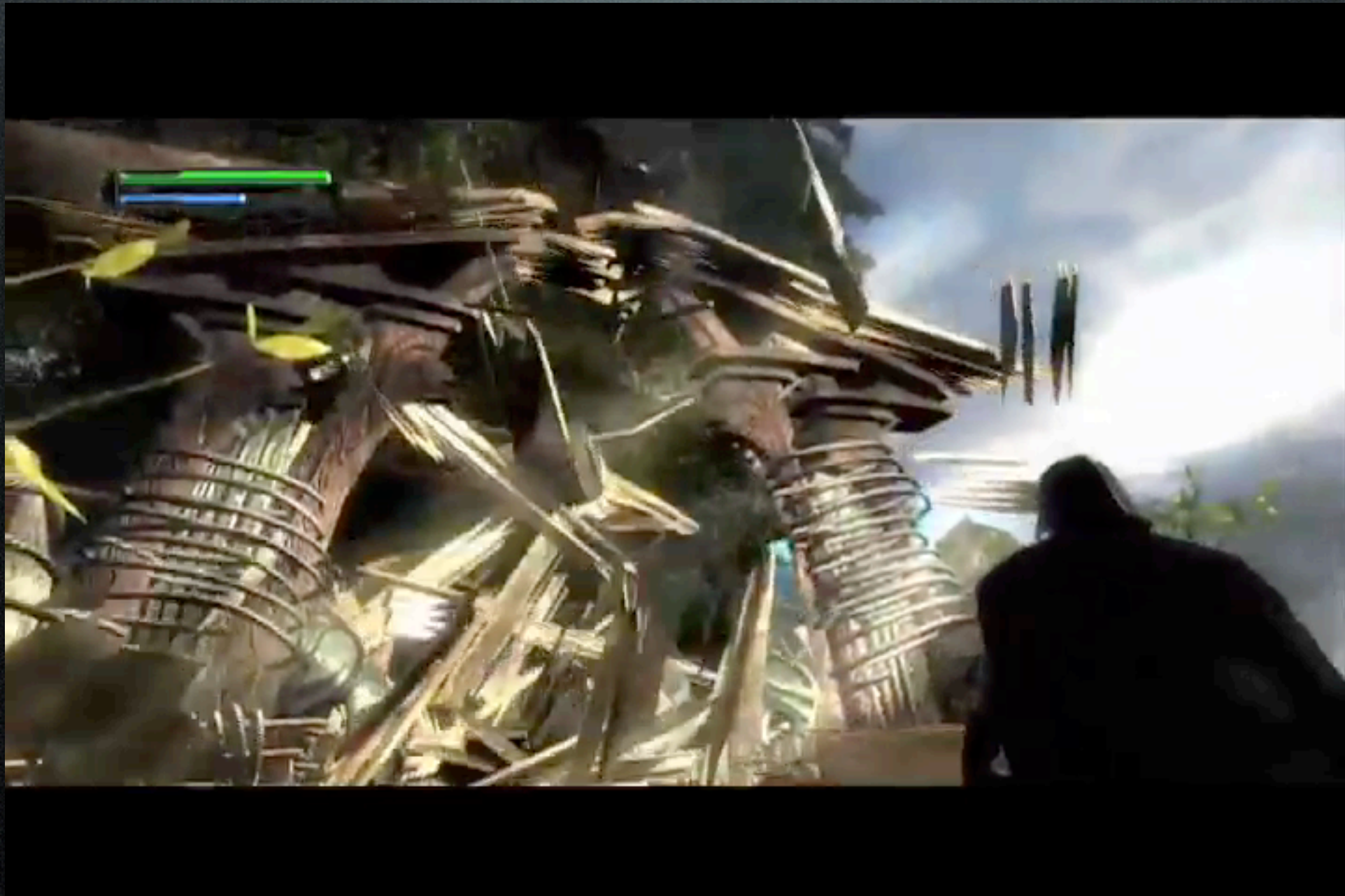


# Simulation (automatic)

- Need **perceptual** accuracy, not necessarily **predictive**
- Stability, ease of use, speed
- How to control the result is a whole 'nother challenge



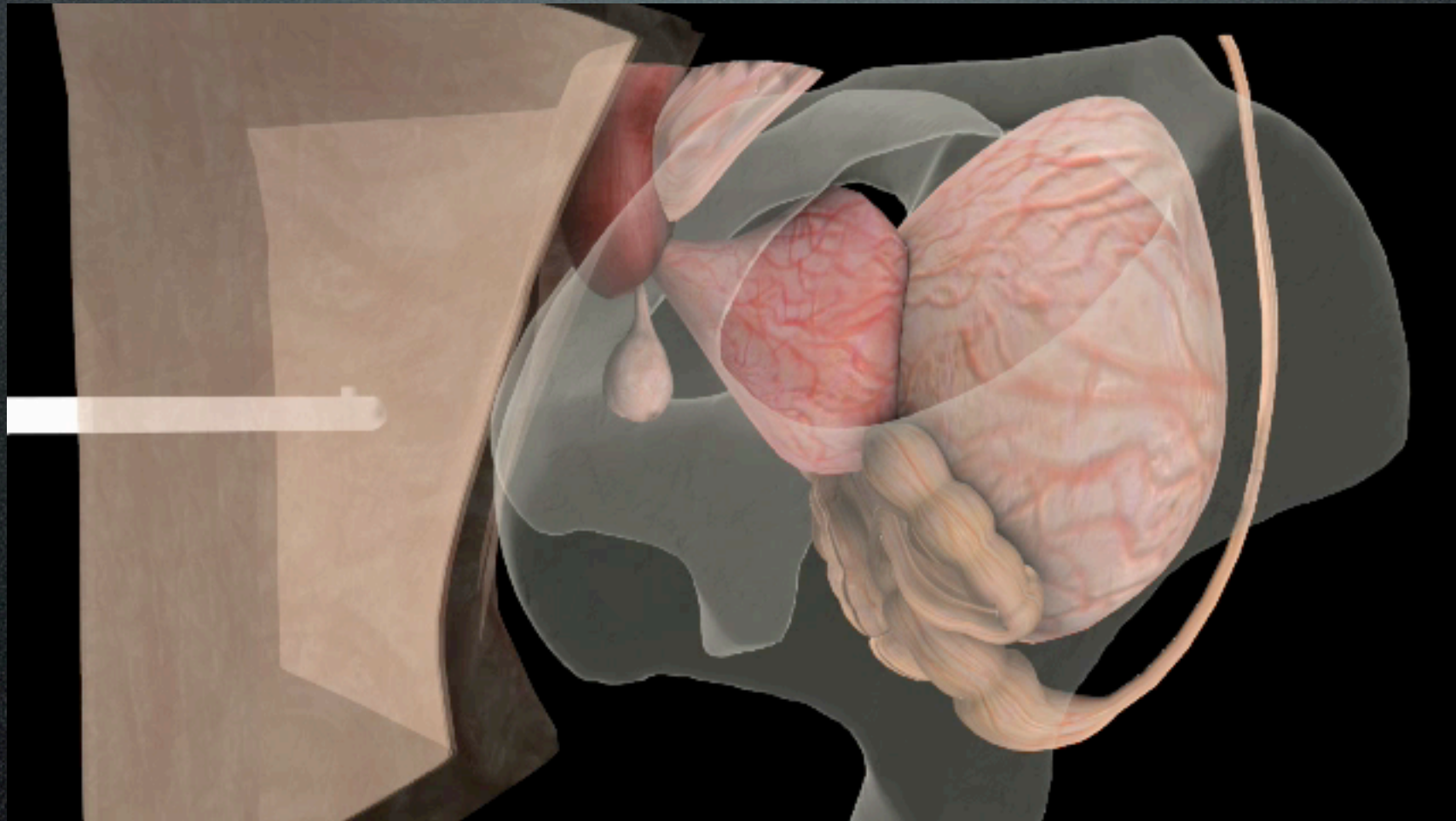
# Interactive animation



Parker and O'Brien 2009



# Interactive animation



Chentanez et al. 2009