CS 184: Foundations of Computer Graphics

Introduction to Animation

Rahul Narain

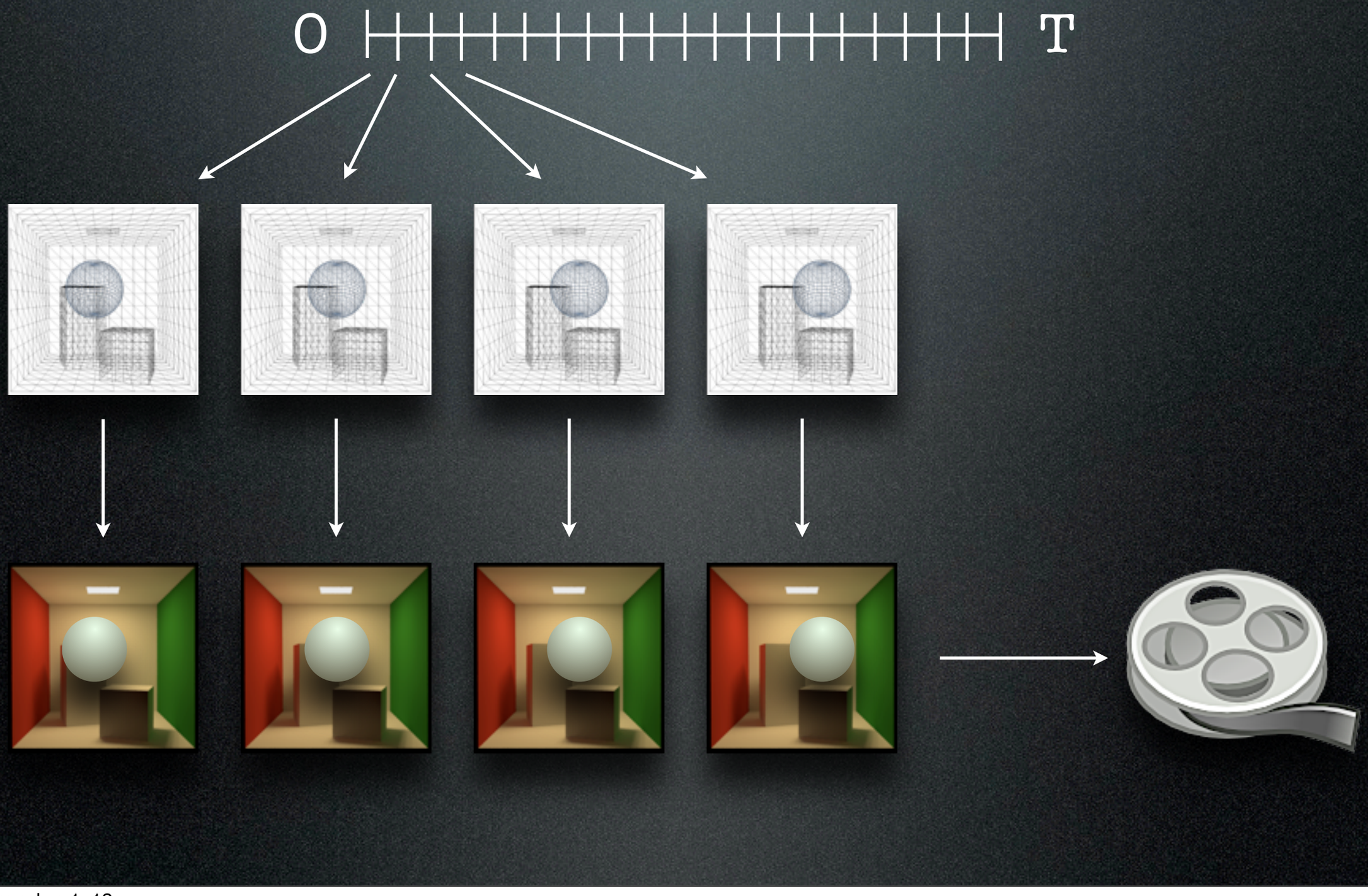
The Story So Far

scene ⟶ image

Animation

scene(t) ⟶ image(t)

Animation



The Problem

Animation = Time → Scene?

2 minutes of animation ≈ 3,000 frames

High-resolution scene ≈ 1000's of vertices

The Problem

Animation = Time → Scene?

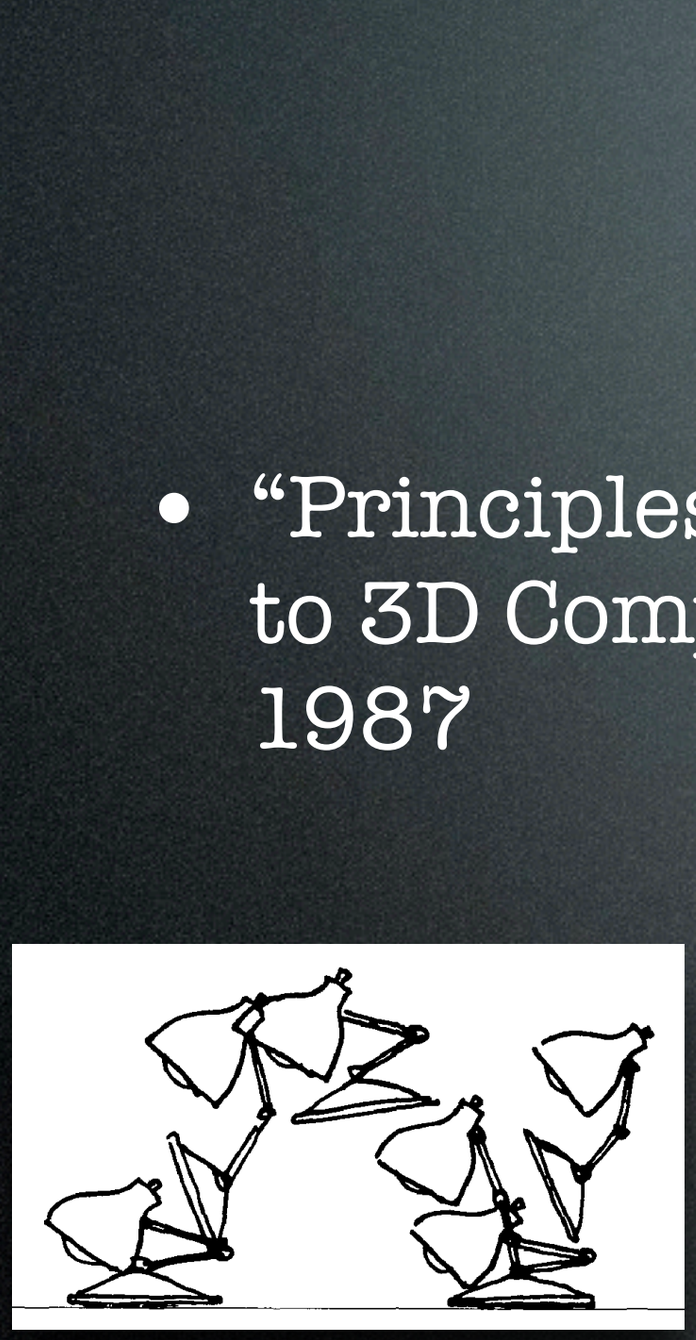
2 minutes of animation ≈ 3,000 frames

High-resolution scene ≈ 1000's of vertices

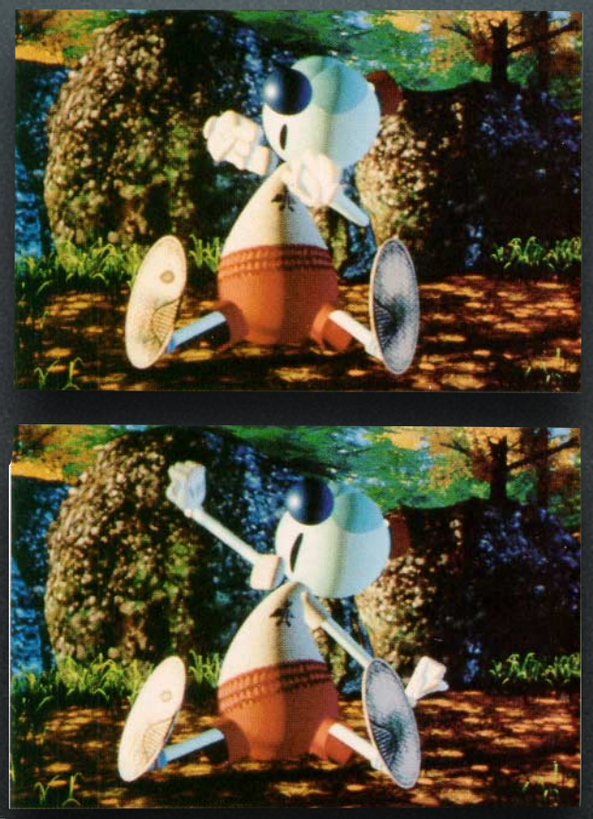
How to define the animation in a controllable, easy-to-use, high-level way?

The Art Side

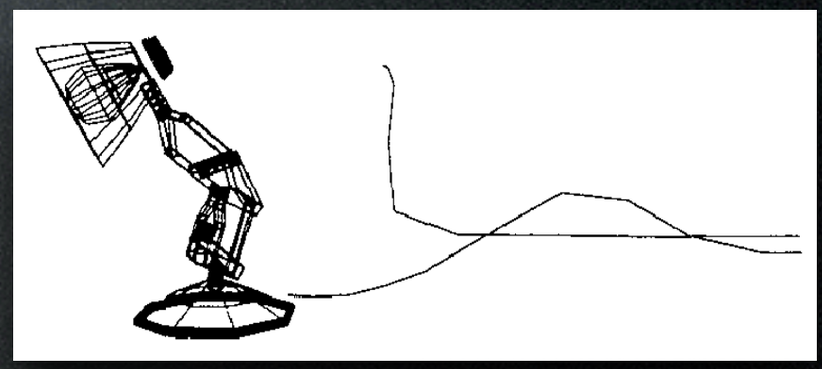
- “Principles of Traditional Animation Applied to 3D Computer Animation”, John Lasseter, 1987



Squash and stretch



Anticipation and follow-through



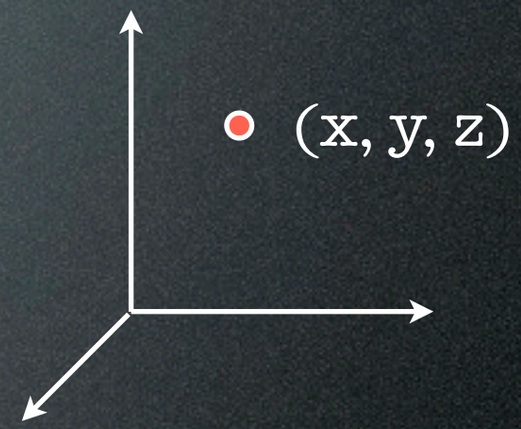
Secondary action

Animation

- How to define the pose of an object?
- How to define the time variation of pose?

Animatable Models

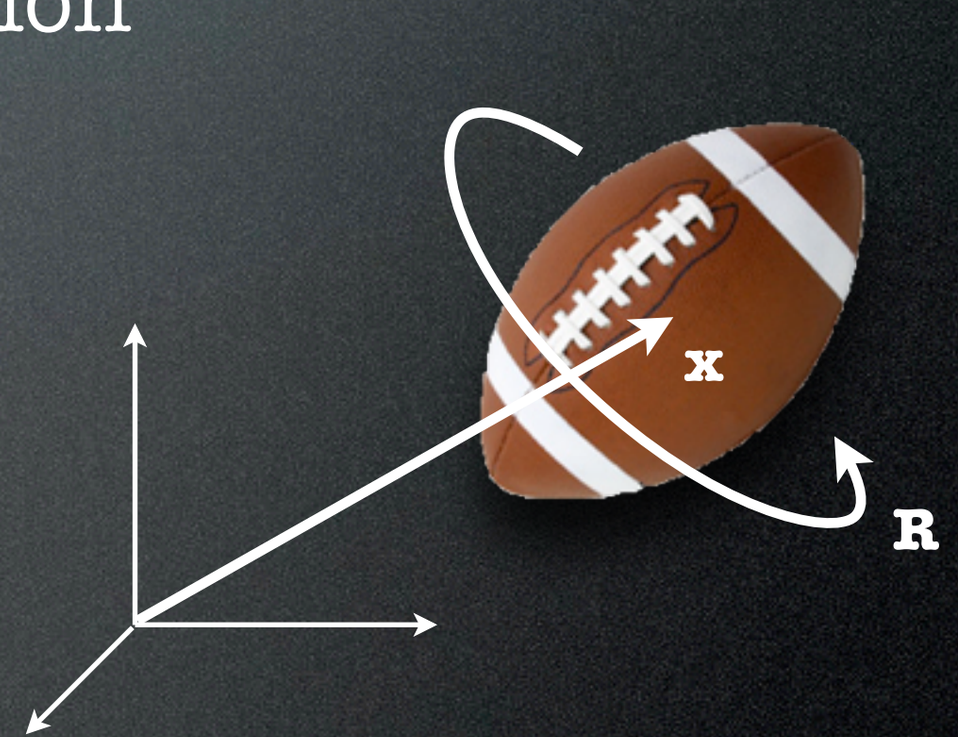
- **Particles**
  - Position (3 DOFs)
  - Easy way to model fireworks, simple explosions, splashes, etc.



Reeves 1983

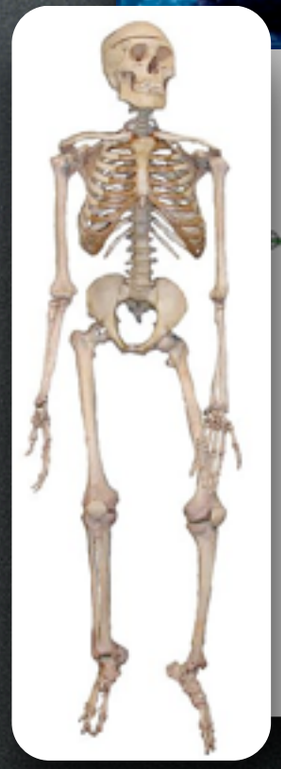
Animatable Models

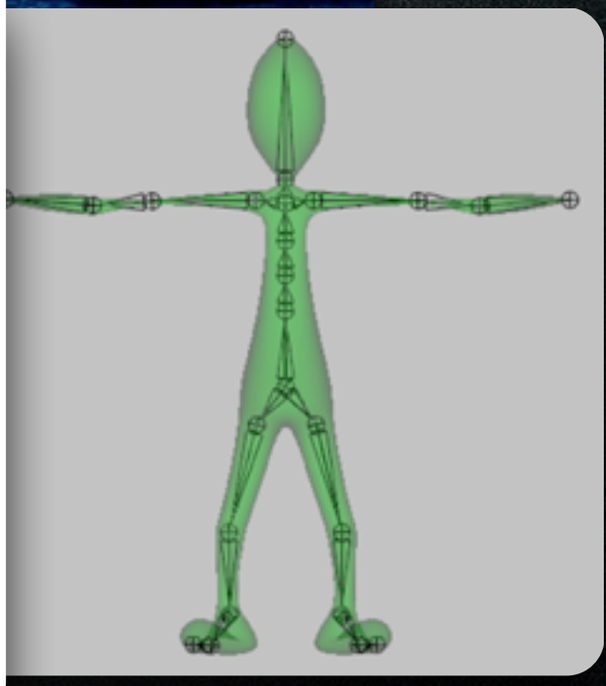
- Particles
- **Rigid bodies**
  - Position and orientation (3 + 3 DOFs)



Animatable Models

- Particles
- Rigid bodies
- **Articulated bodies**
  - Rigid links connected by joints (#DOFs = #joints)
  - e.g. robots, character “skeletons”



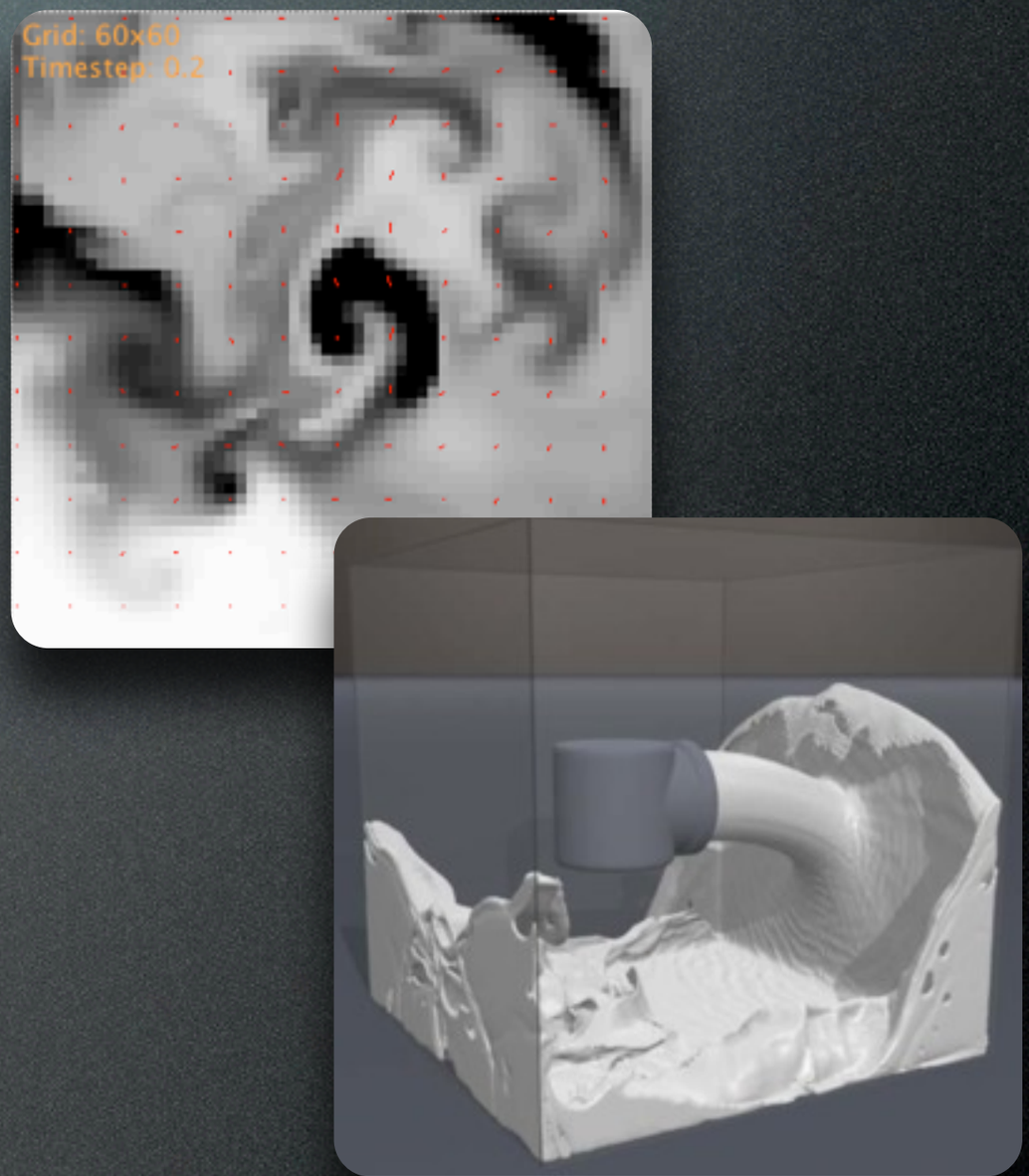


Animatable Models

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

Animatable Models

- Particles
- Rigid bodies
- Articulated bodies
- Deformable bodies
- **Fluids**
  - Represented as particles or as volumetric grids

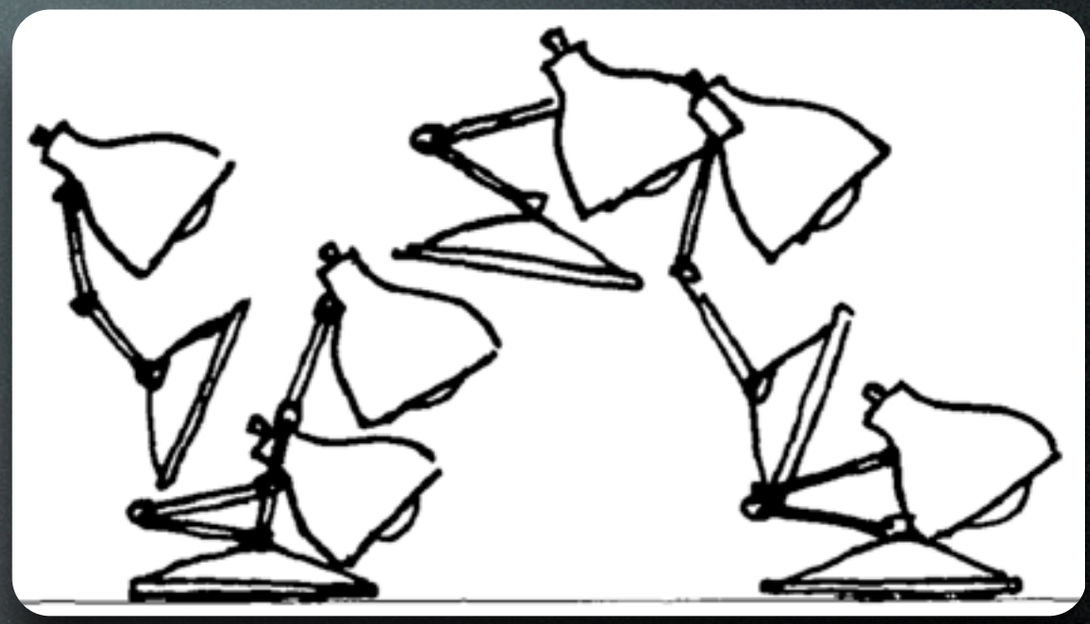


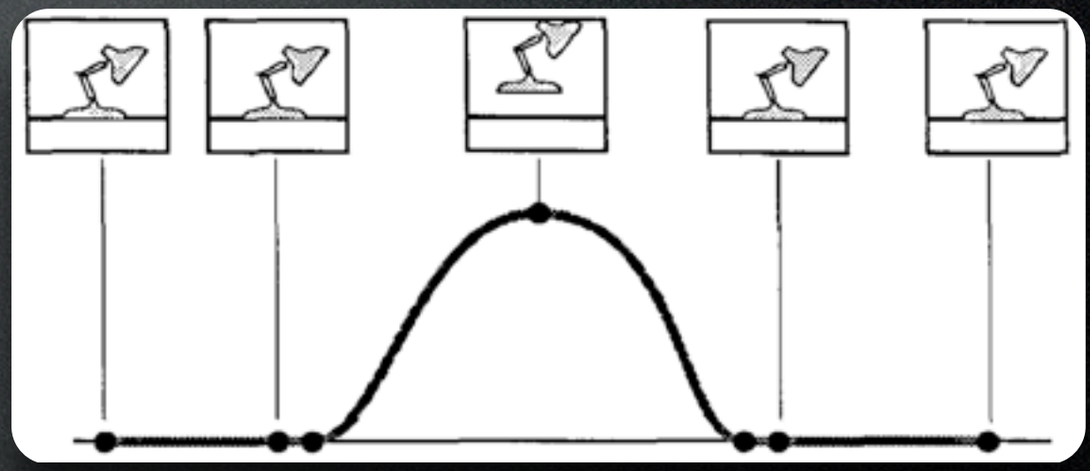
Animation Techniques

- **Keyframe animation**
  - Define key moments, then interpolate
- **Motion capture**
  - Record motion of performer
- **Procedural / simulation**
  - Compute motion automatically via physics

Keyframing (Manual)

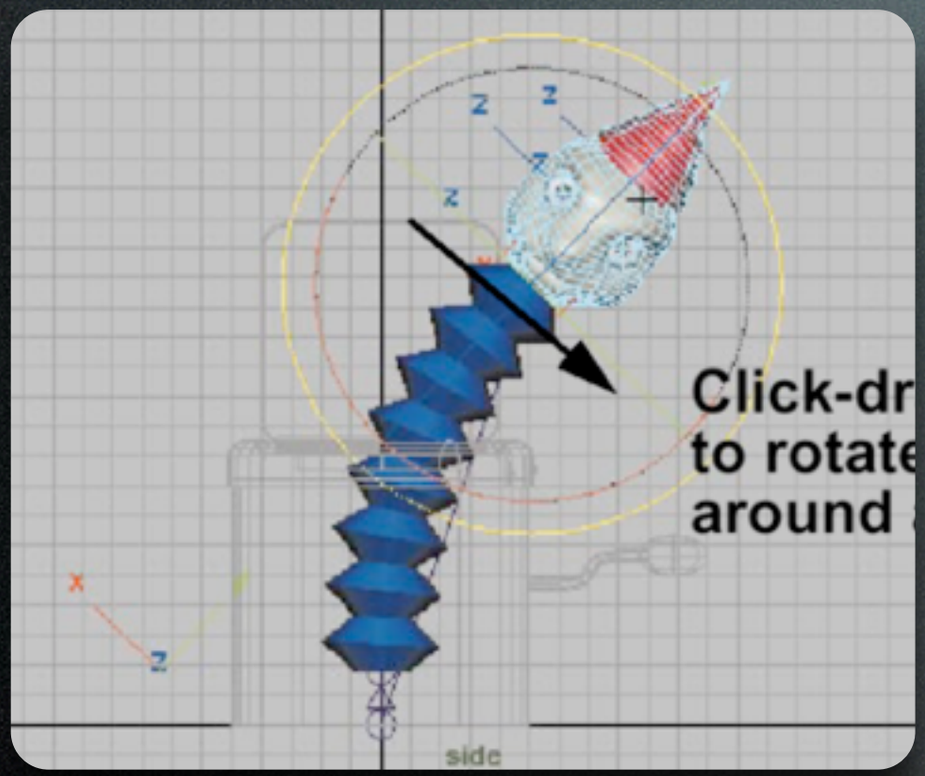
- Manually specify “key” moments of the action
- System interpolates the in-between frames

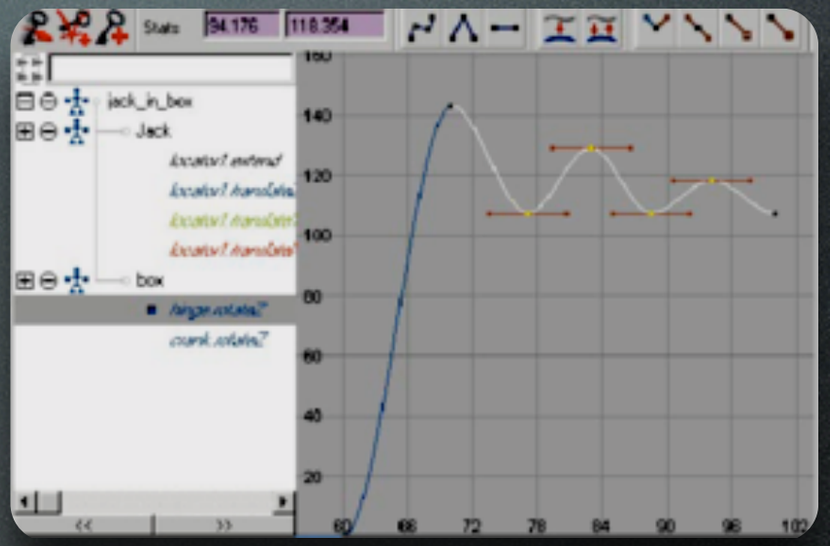


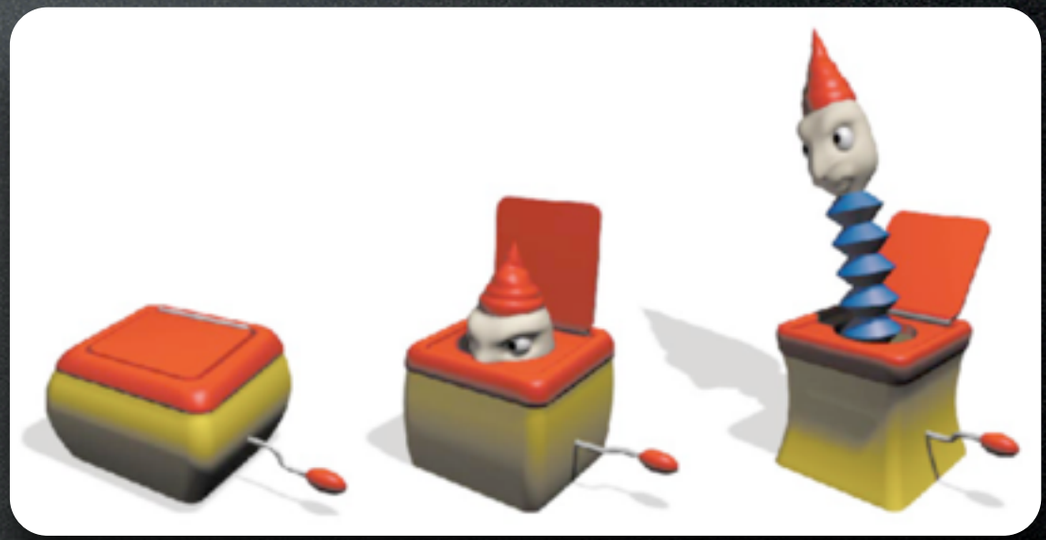


Lasseter 1987

Keyframing (Manual)







Learning Maya 2.0

Motion Capture (Recorded)

- Place markers on subject, record their performance in 3D
- Time-consuming clean-up
- Hard to edit after the fact

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

Motion Capture (Recorded)

Majkowska et al. 2006

Motion Graphs

- Chop motion capture sequence into lots of short clips (e.g. walk, run, jump, crouch, ...)
- Find pairs of clips with smooth transitions
- At run time, traverse graph to get a smooth sequence of clips

Arikan et al. 2003

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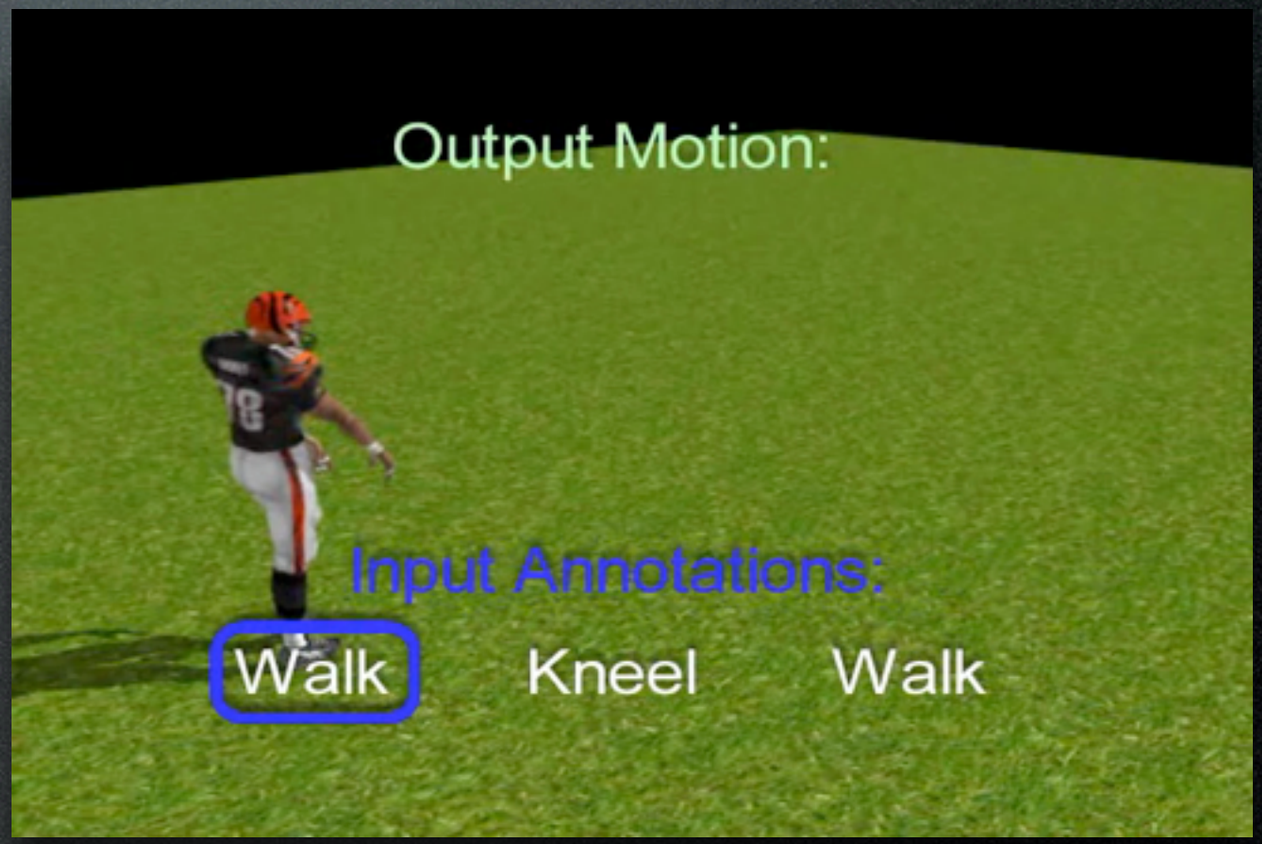
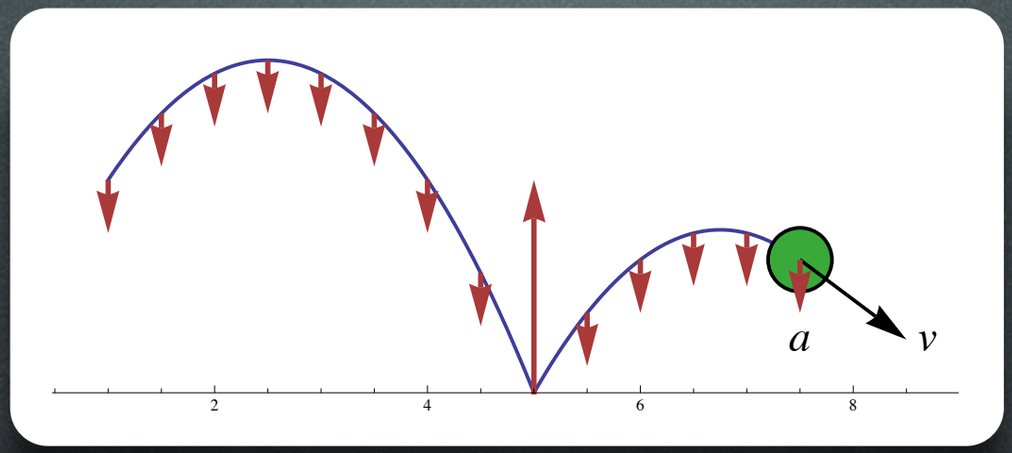


Arikan et al. 2003

Simulation (automatic)



- Solve physical equations of motion using numerical methods
  - **F** = m **a**
- Given state (pos, vel) at time t, find state at time t + Δt, then at t + 2Δt, then...

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

$$\operatorname{div} u = \sum_{i=1}^{n} \frac{\partial u_i}{\partial x_i} = 0$$

Simulation (automatic)

Goldenthal et al. 2007

Simulation (automatic)

Feldman et al. 2003

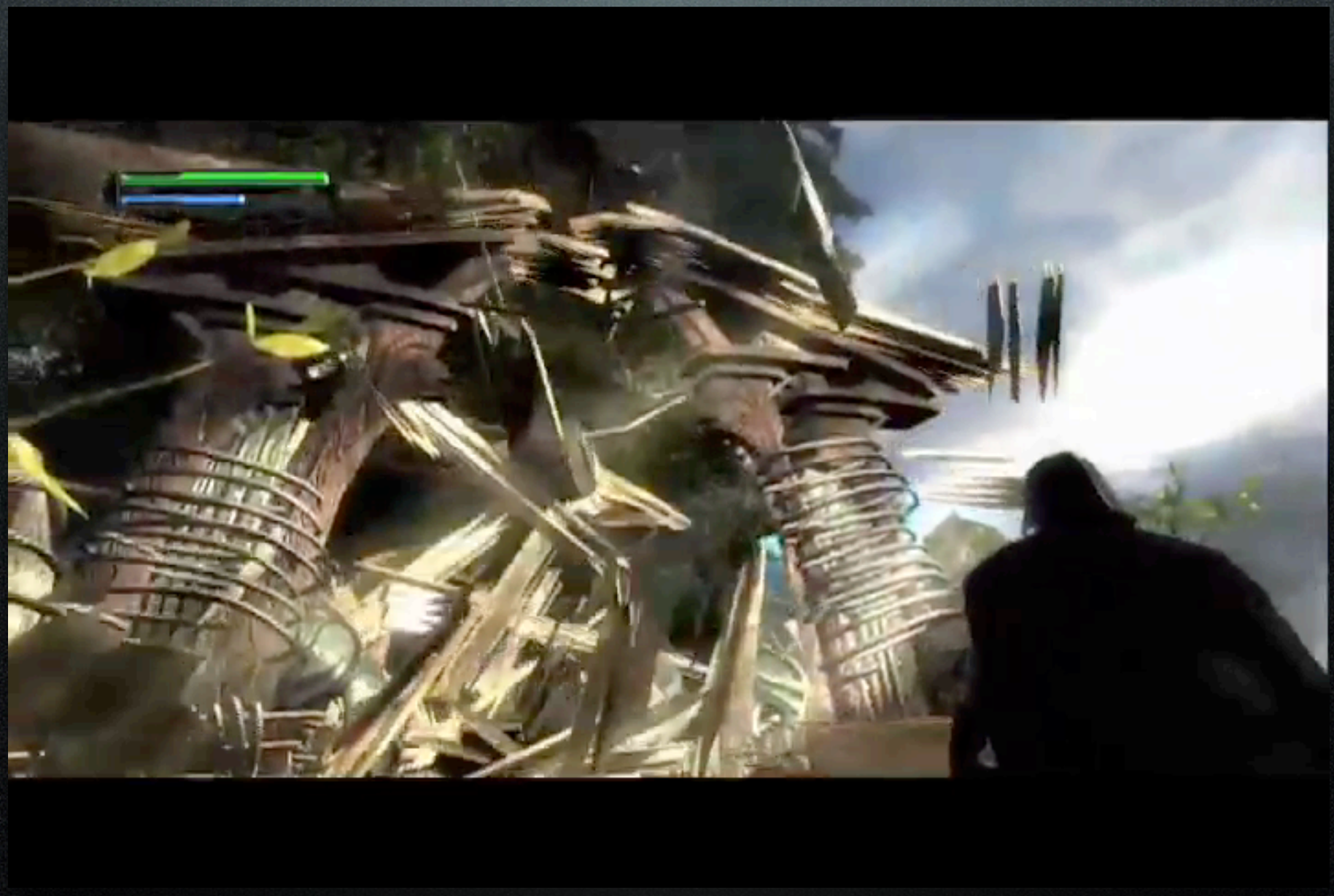
Simulation (automatic)

Feldman et al. 2003

Interactive animation

Parker and O'Brien 2009

Interactive animation



Parker and O'Brien 2009

Combinations

Character =
articulated skeleton
+ deformable skin

Keyframing (or motion capture)
for characters' primary motion

Simulation for cloth, hair, muscle

The End

Next week:
Kinematics of articulated bodies