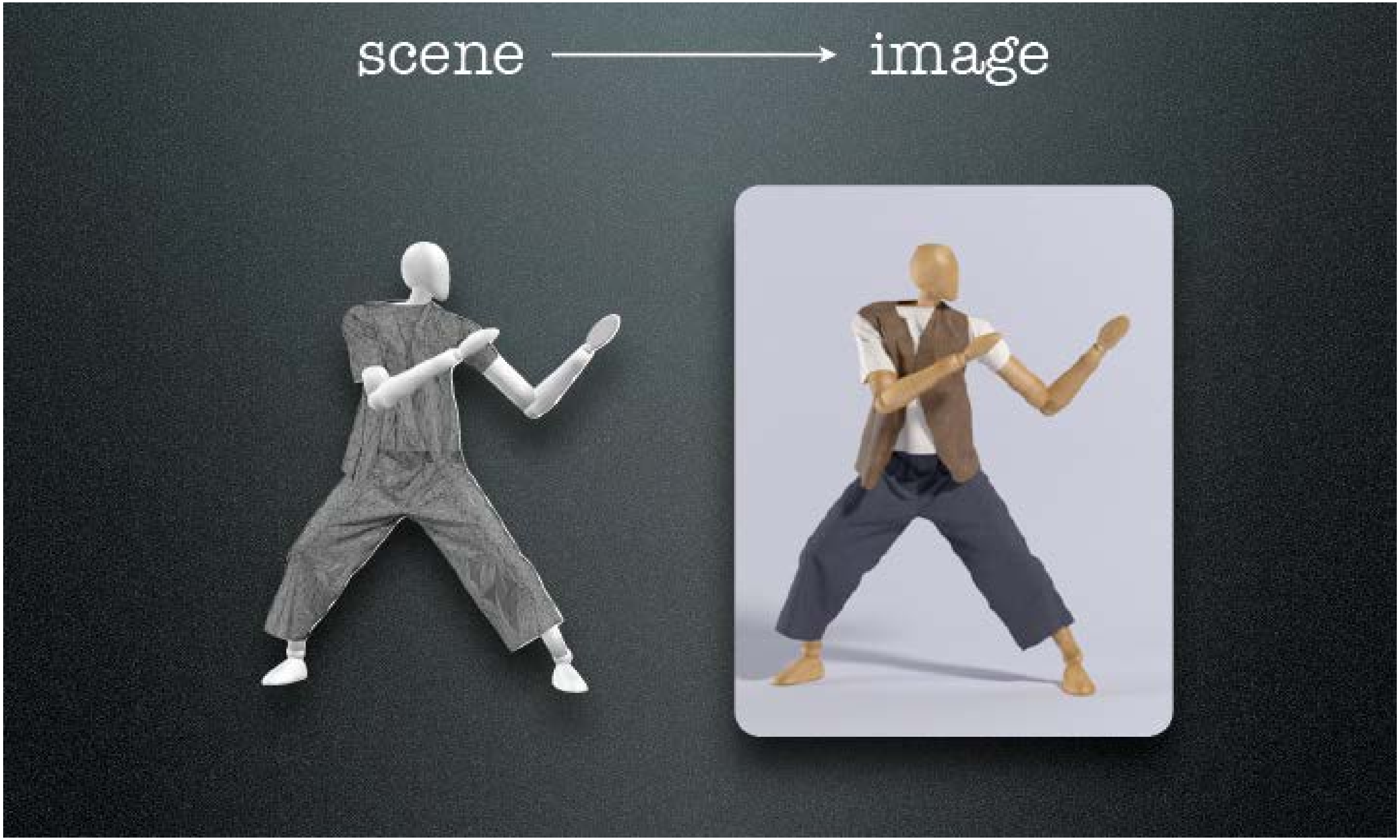
Animation

COS 526: Advanced Computer Graphics

PRINCETON UNIVERSITY

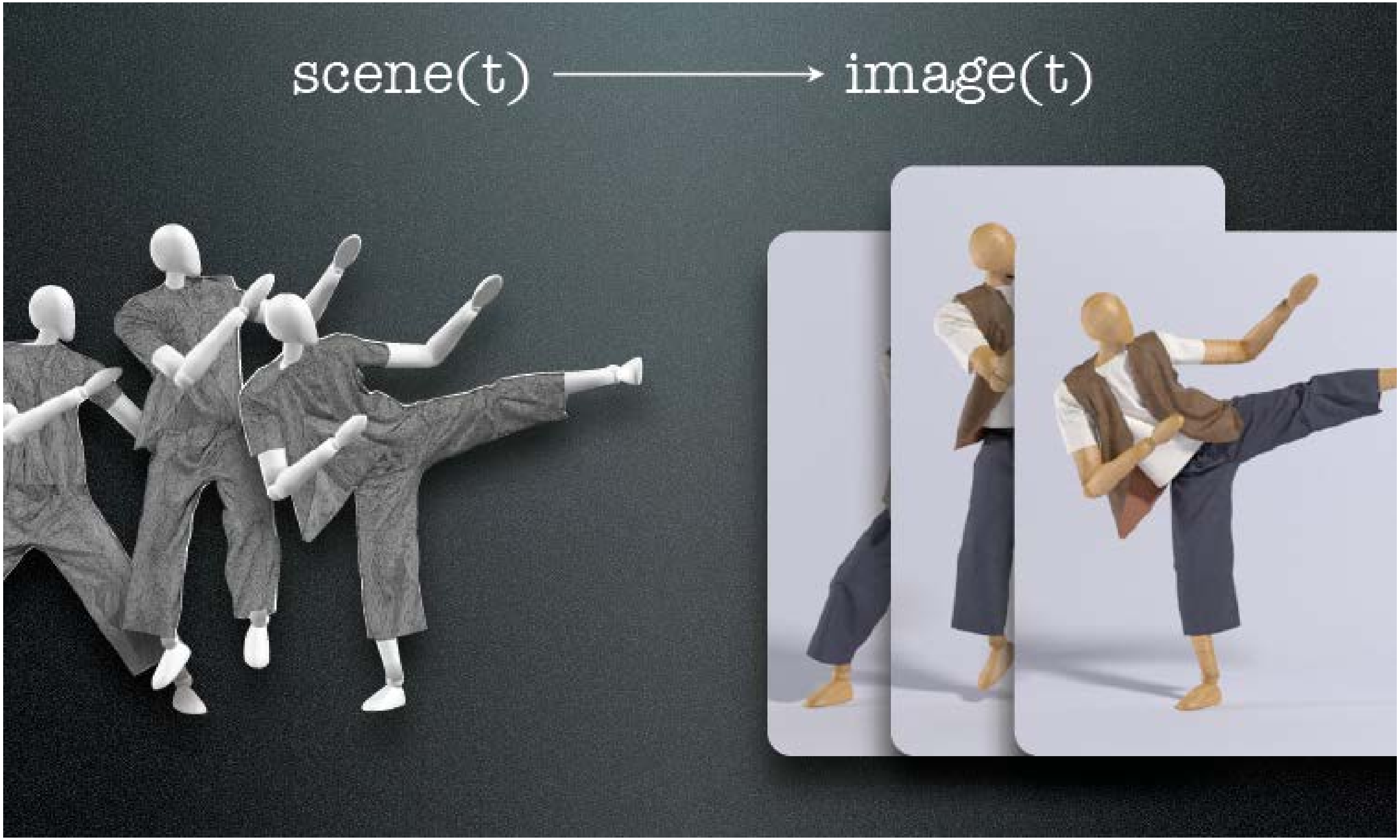
Slide credits: Rahul Narain, James O'Brien, Ravi Ramamoorthi.

The Story So Far

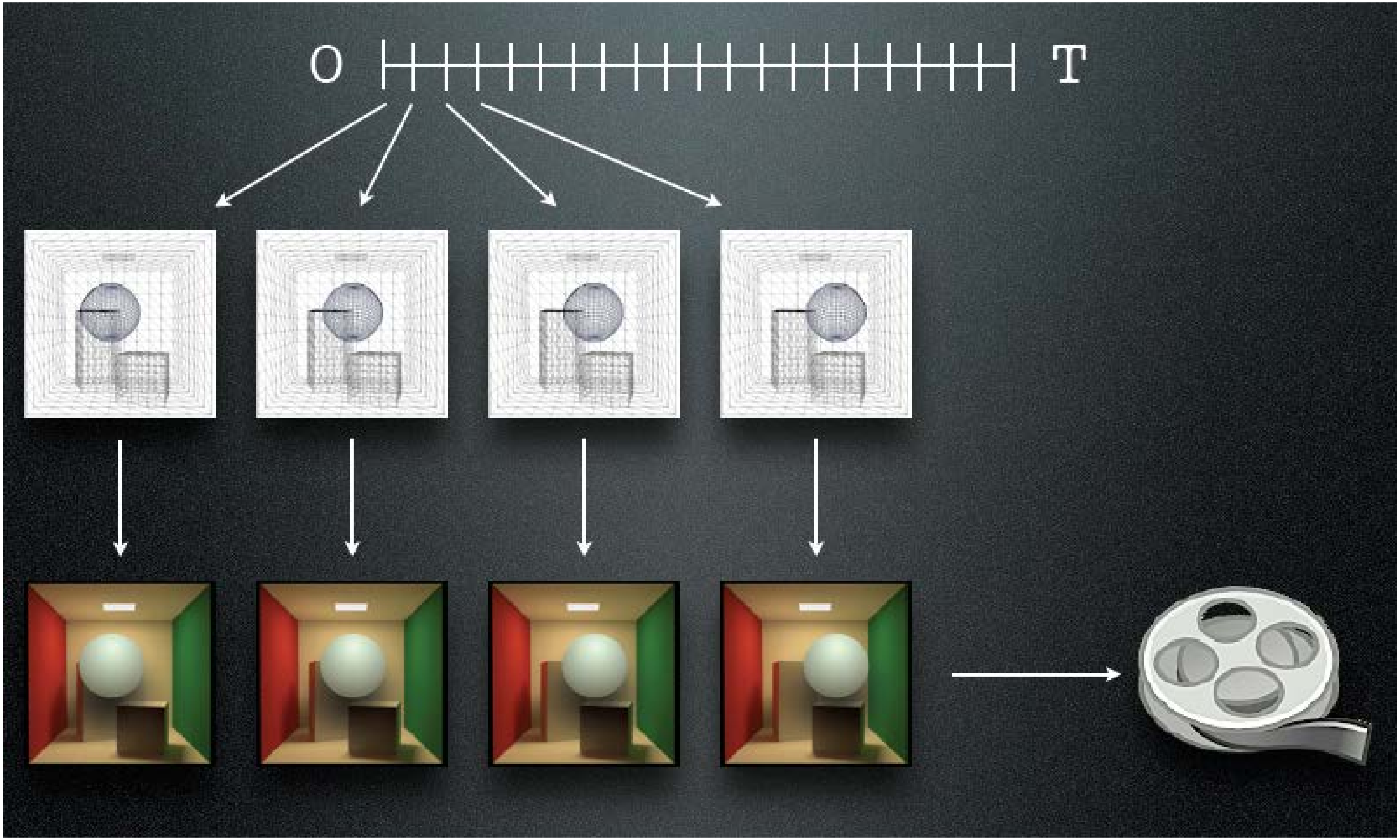


Slides courtesy Rahul Narain and James O'Brien

Animation



Animation



The Problem

- Animation at 30 frames per second
- 2 minutes of animation = 3,000 frames
- High-Res scene = Millions of vertices
- Need to animate all vertices, render each frame

Drawing Animation Manually?

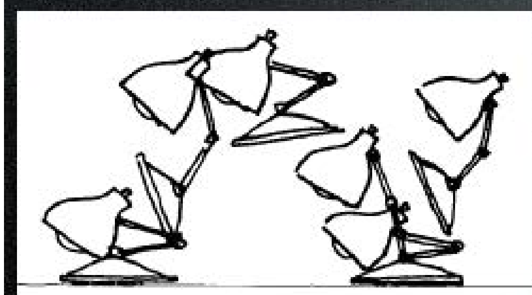
The Problem

- Animation at 30 frames per second
- 2 minutes of animation = 3,000 frames
- High-Res scene = Millions of vertices
- Need to animate all vertices, render each frame

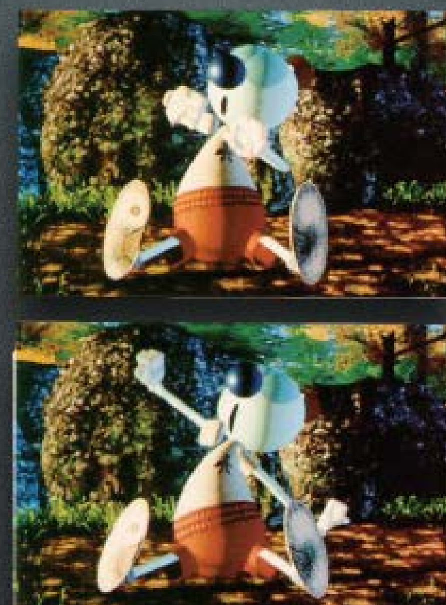
- How to define the animation in an easy-to-use, controllable high-level fashion?

The Art Side

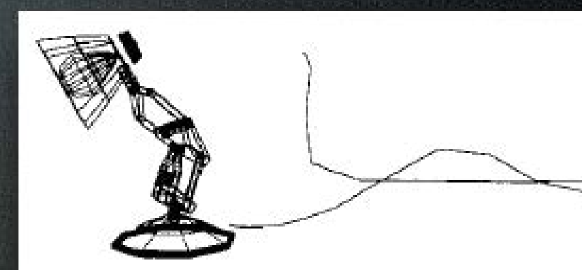
- "Principles of Traditional Animation Applied to 3D Computer Animation", John Lasseter, 1987



Squash and stretch



Anticipation and follow-through



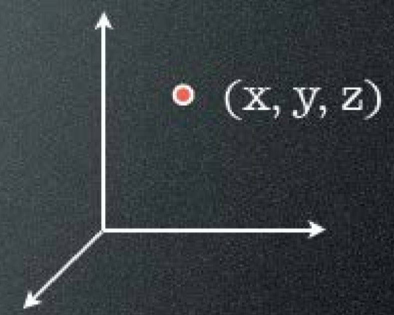
Secondary action

Specifying 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.

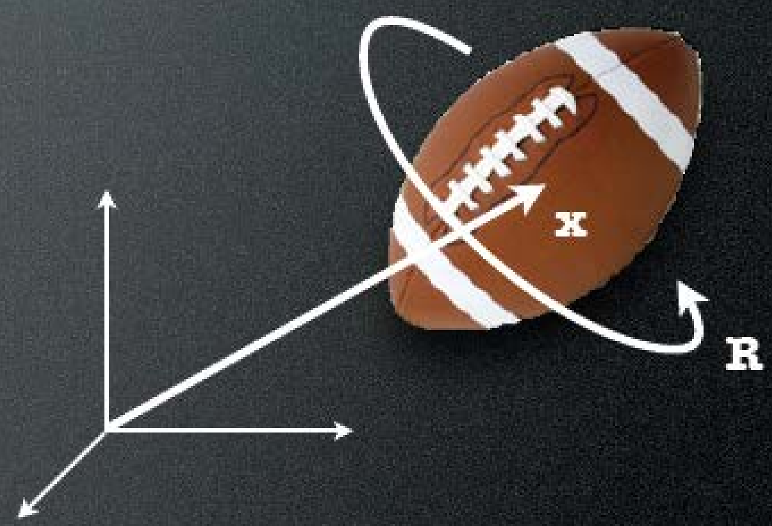


Reeves 1983

https://www.youtube.com/watch?v=Qe9qSLYK5q4

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

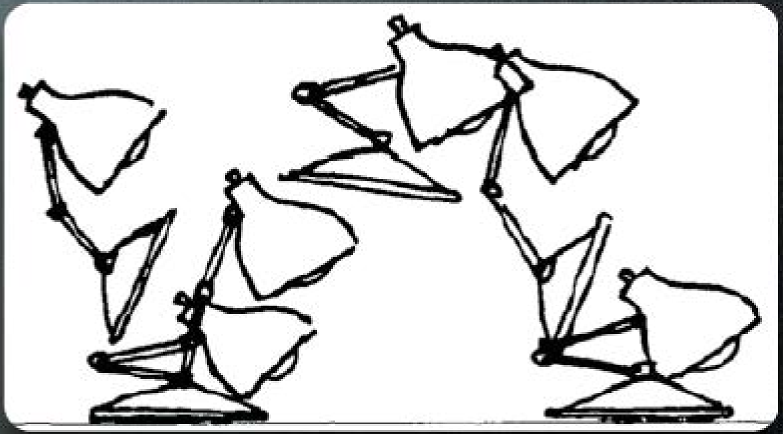
- Particles
- Rigid bodies
- Articulated bodies
- Deformable bodies
- **Fluids**
  - Represented as particles or as volumetric grids

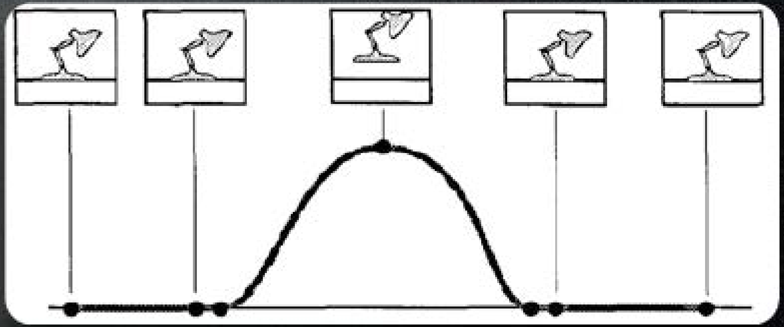
Animation Techniques

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

Keyframing (Manual)

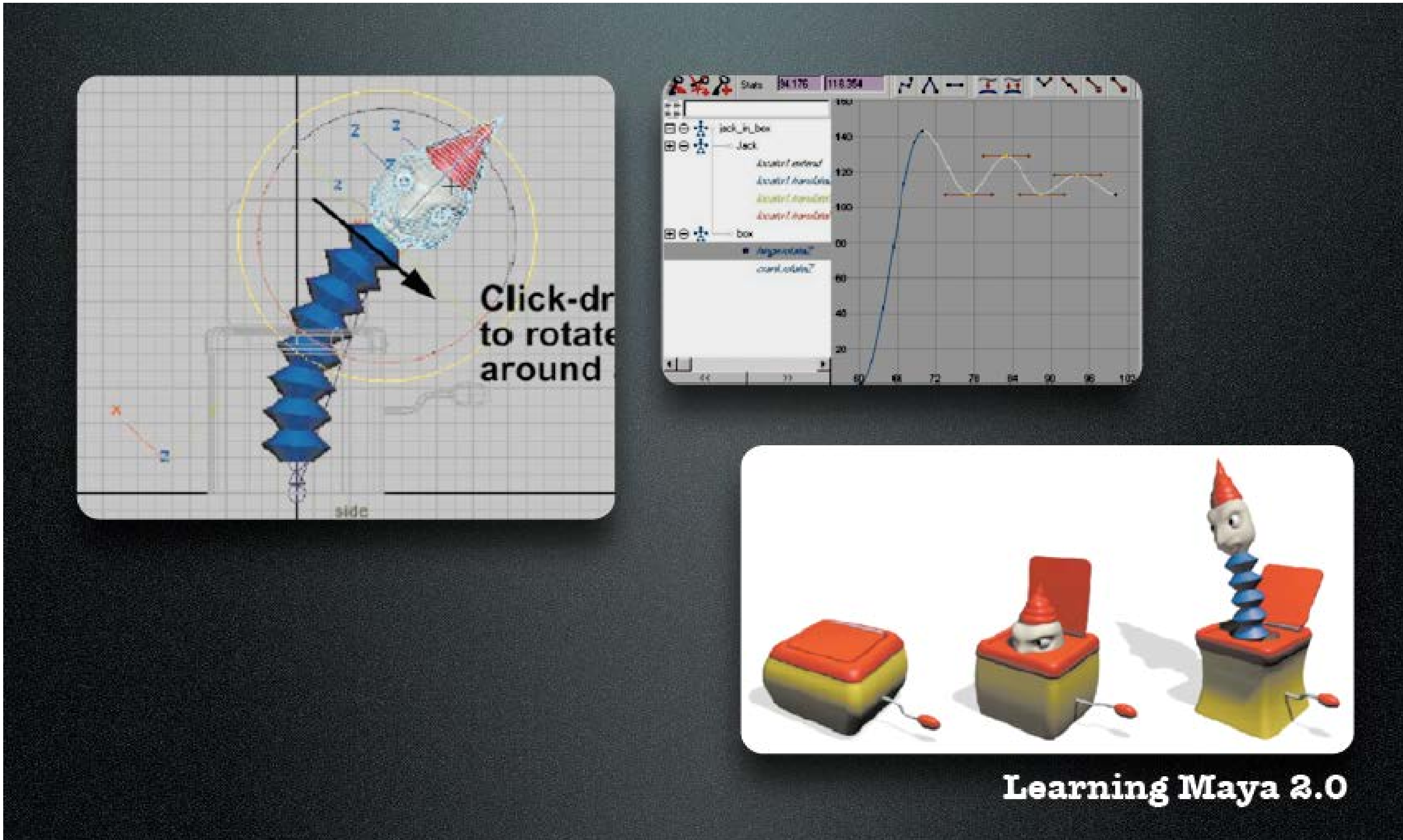
- Manually specify "key" moments of the action
- System interpolates the in-between frames





Lasseter 1987

Keyframing (Manual)



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)

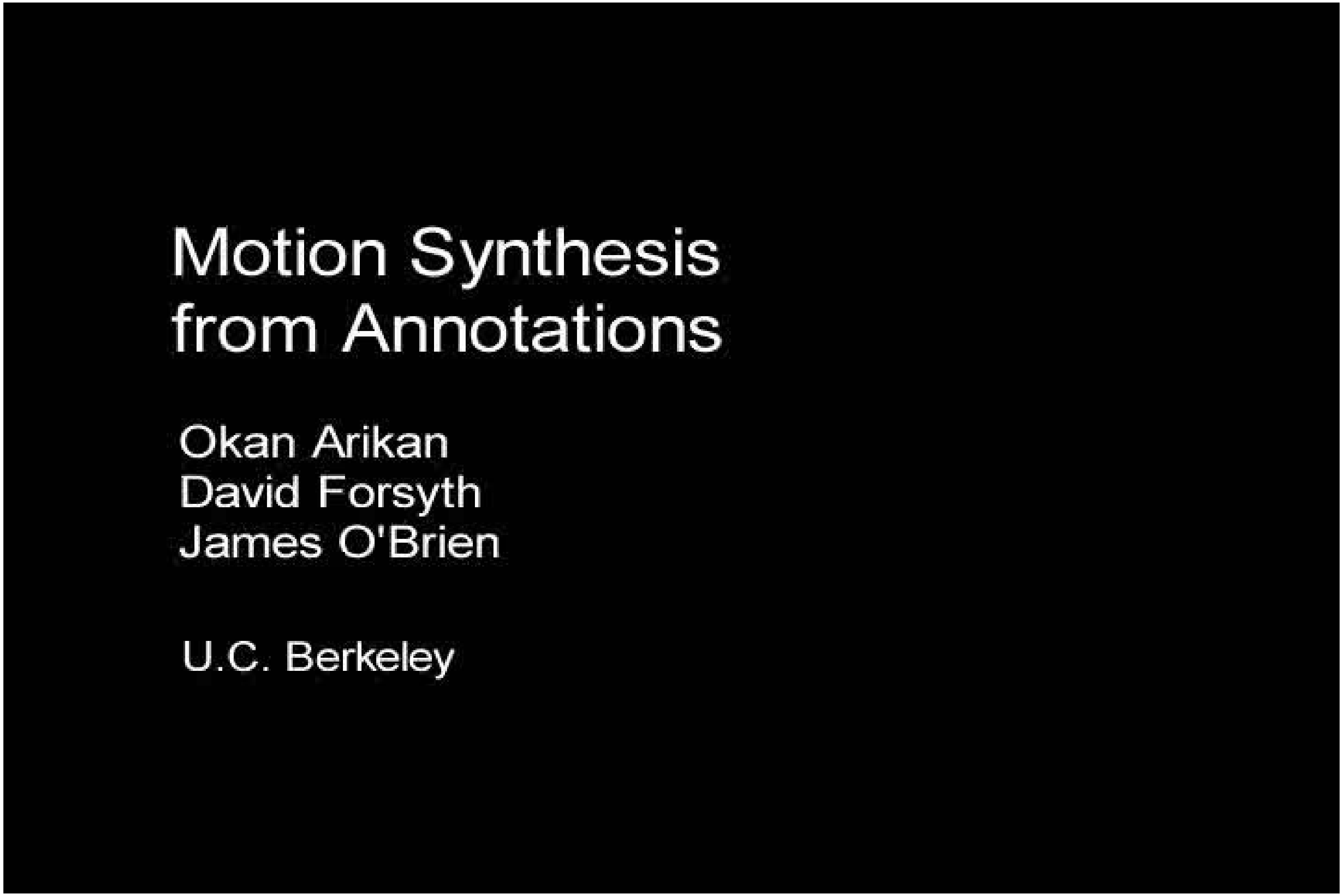
Majkowska et al. 2006

Motion Graphs

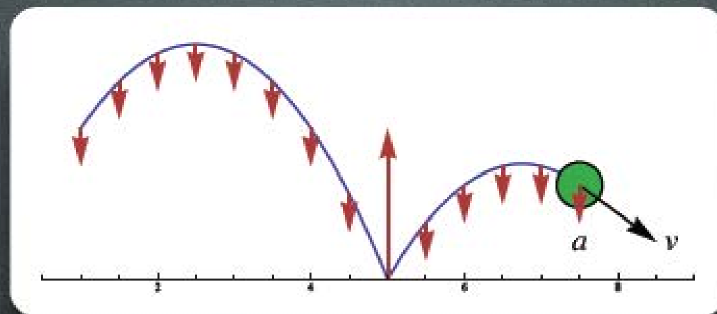
- Chop motion capture sequence into lots of short clips (e.g. walk, run, jump, crouch, ...)
- Find pairs of clips with smooth transitions
- At run time, traverse graph to get a smooth sequence of clips

Arikan et al. 2003

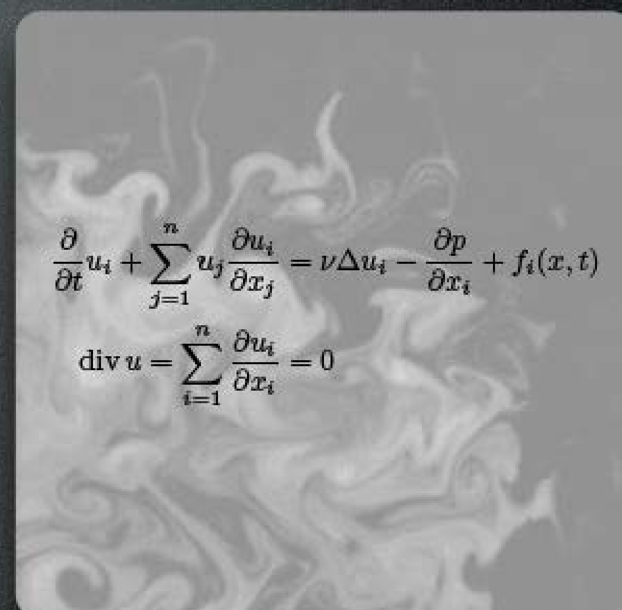
Content Tags



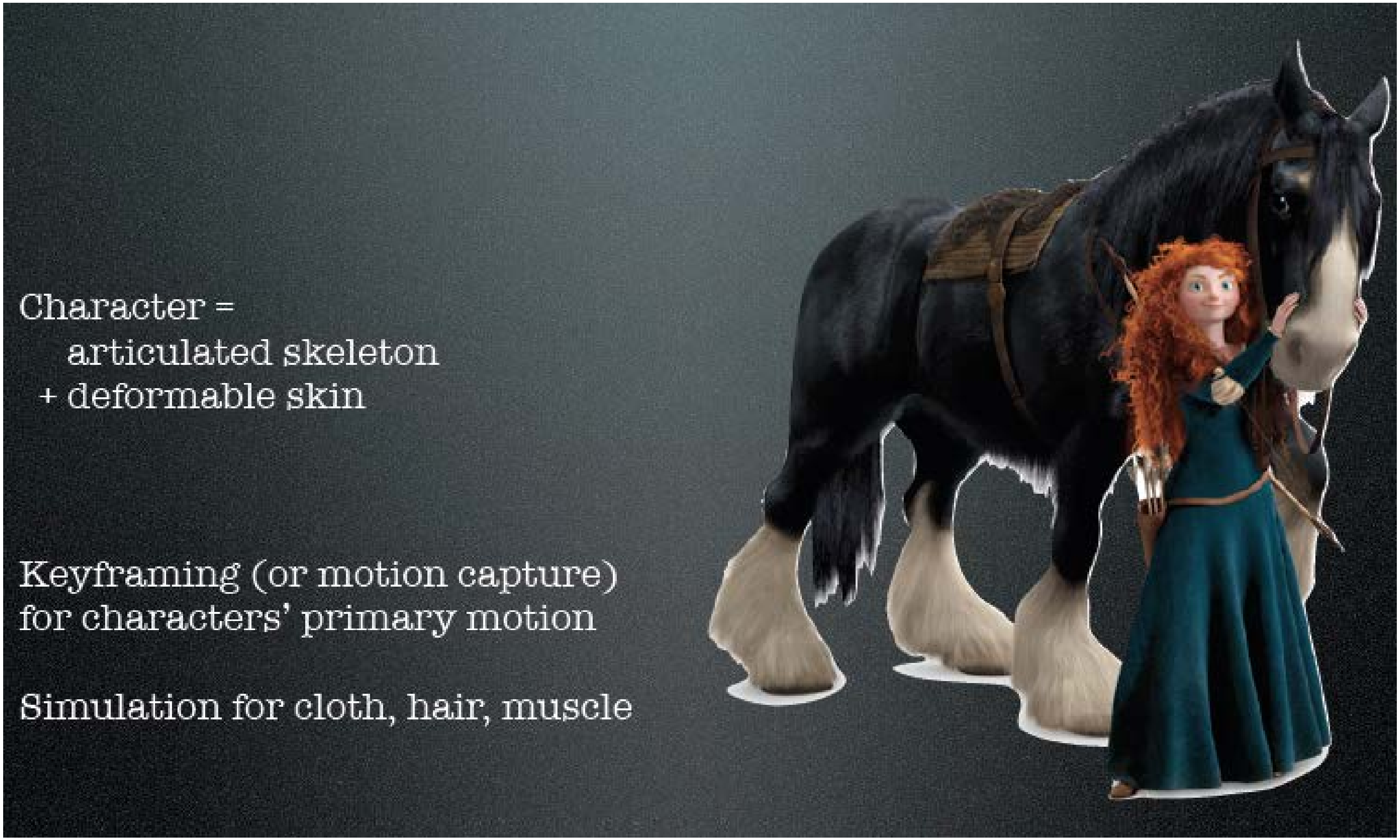
Simulation (Automatic)



- 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...



Combinations



Motion Capture: "Signature" of Actor

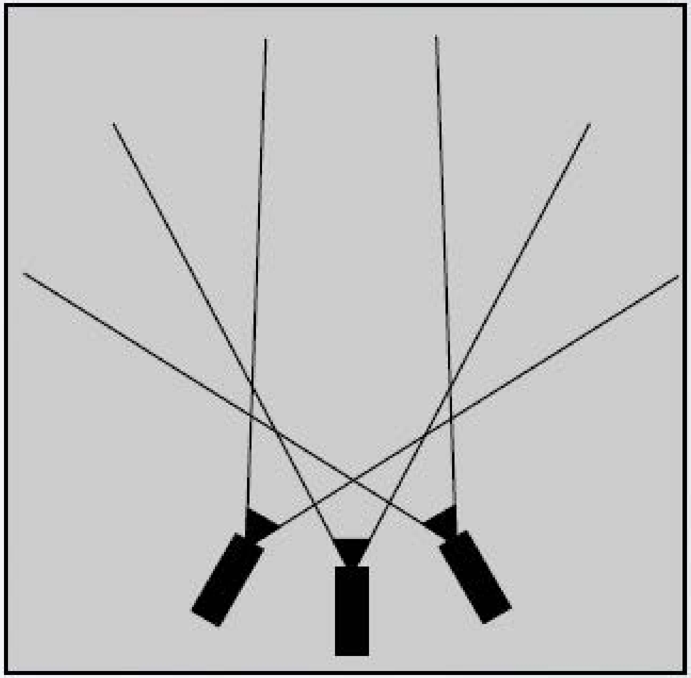
Capture Equipment

- Passive Optical
  - Reflective markers
  - IR (typically) illumination
  - Special cameras
    - Fast, high res., filters
  - Triangulate for positions

Images from Motion Analysis

Types of capture equipment

- Passive Optical Advantages
  - Accurate
  - May use many markers
  - No cables
  - High frequency
- Disadvantages
  - Requires lots of processing
  - Expensive systems
  - Occlusions
  - Marker swap
  - Lighting / camera limitations



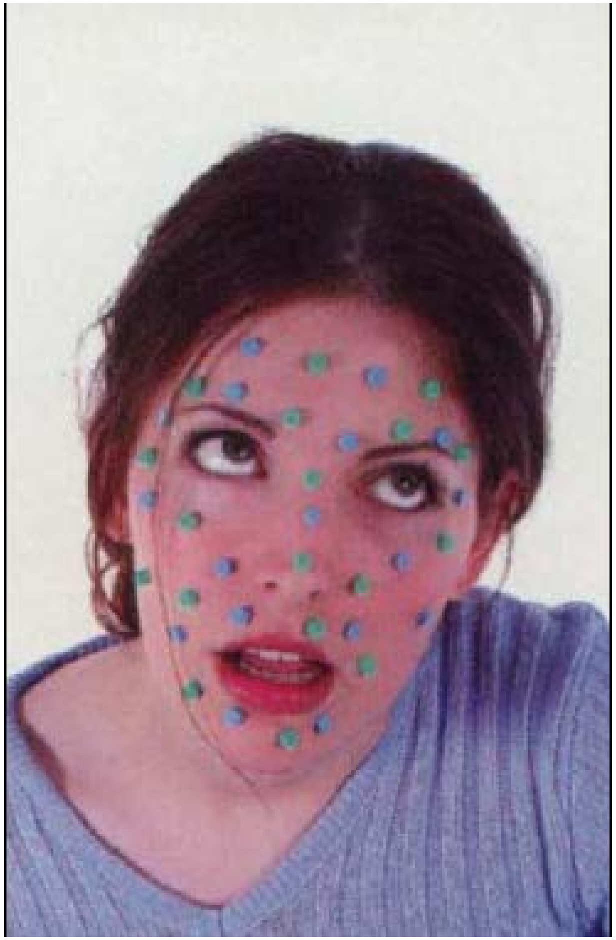
Active Optical

- Similar to passive but uses LEDs
- Blink IDs, no marker swap
- Number of markers trades off w/ frame rate

Phoenix Technology

Phase Space

Facial MoCap



Skeletal Parameter Estimation from Optical Motion Capture Data

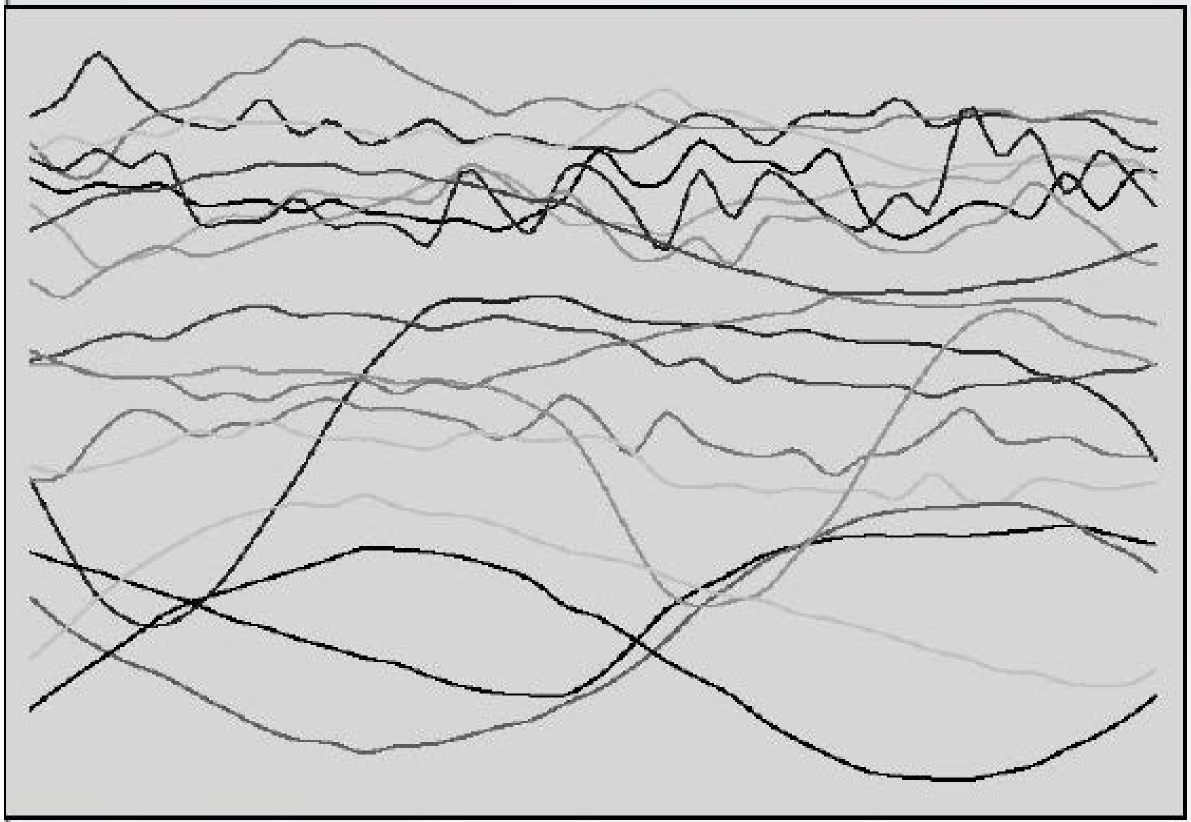
Adam G. Kirk
James F. O'Brien
David A. Forsyth

University of California - Berkeley

Manipulating Motion Data

- WYSIWYG vs WYSIAYG
- Basic Tasks
  - Adjusting
  - Blending
  - Transitioning
  - Retargeting
- Building graphs

Nature of Motion Data

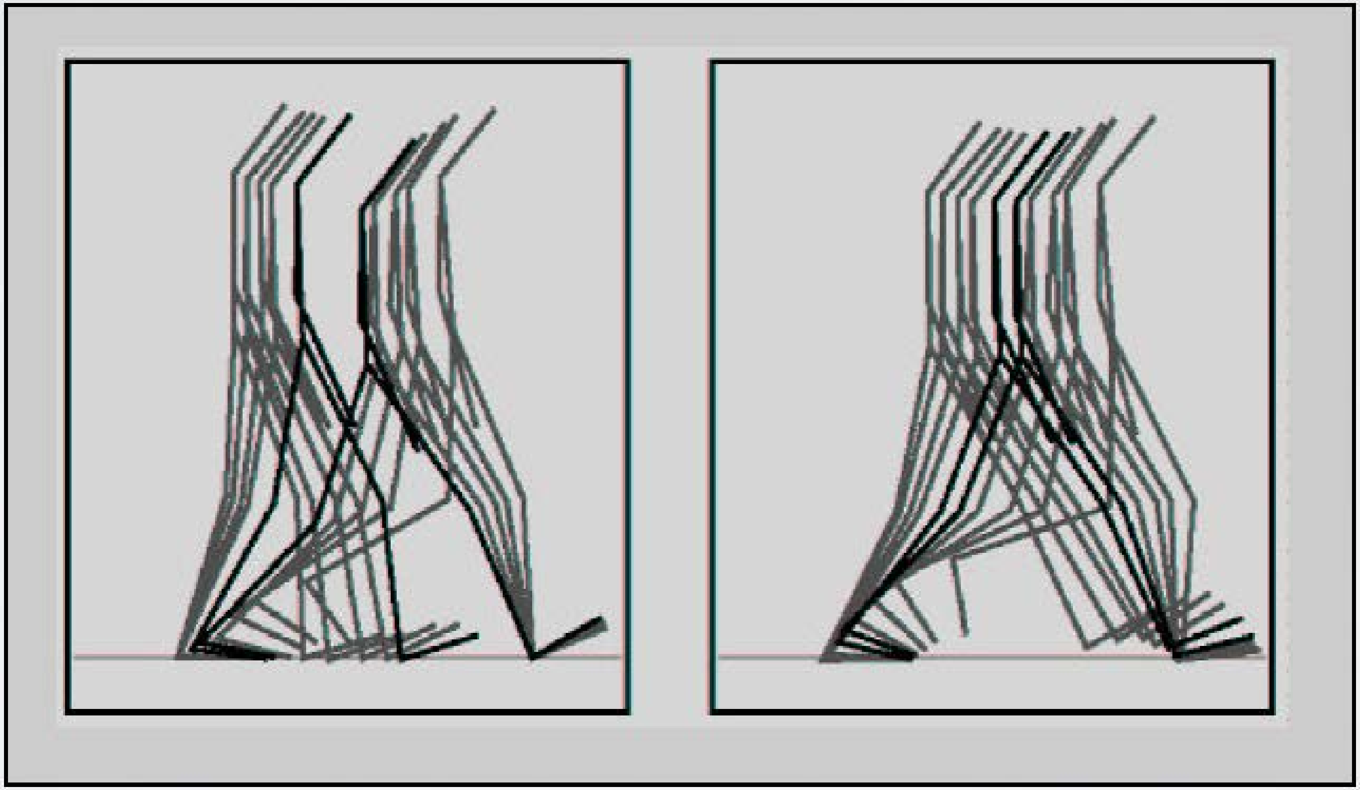


Witkin and Popovic, 1995

Subset of motion curves from captured walking motion.

Adjusting

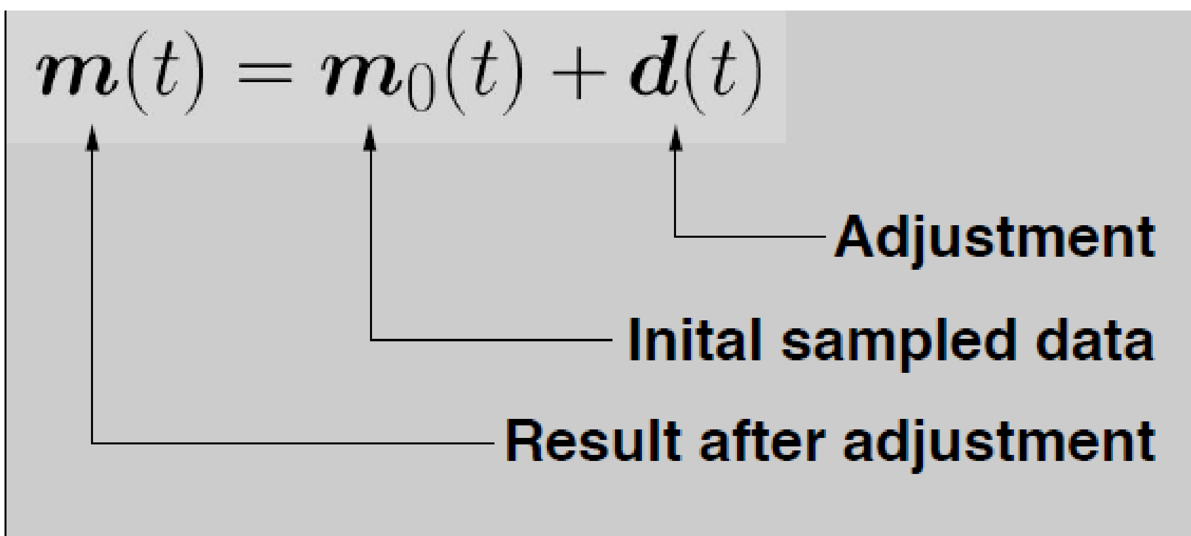
- IK on single frames will not work



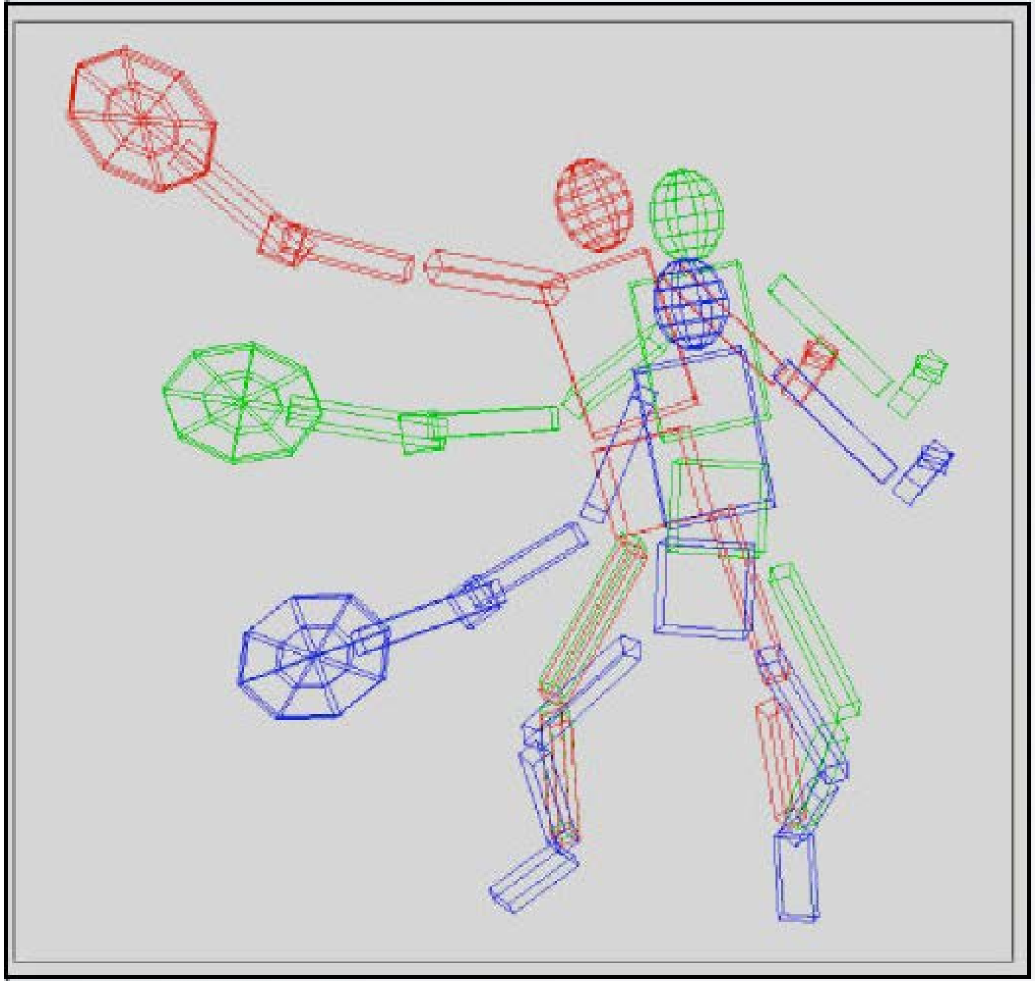
Gleicher, SIGGRAPH 98

Adjustment

- Define desired motion function in parts
- Select adjustment function from nice space, such as C2 B-splines
- Spread modification over reasonable time period
  - User selects support radius



Adjusting



Witkin and Popovic SIGGRAPH 95

IK uses control points of the B-spline now

Example:

- position racket
- fix right foot
- fix left toes
- balance

Blending

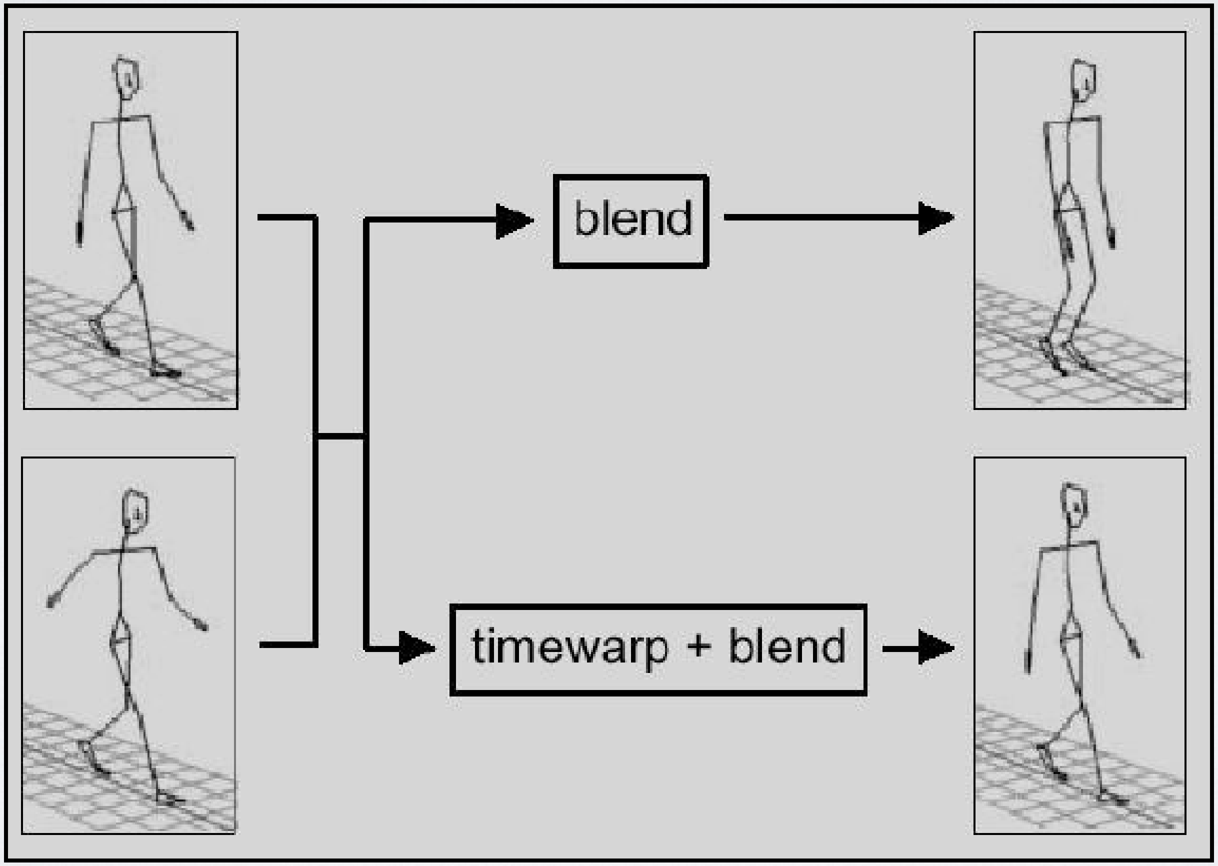
- Given two motions make a motion that combines qualities of both

$$\boldsymbol{m}_\alpha(t) = \alpha\boldsymbol{m}_a(t) + (1-\alpha)\boldsymbol{m}_b(t)$$

- Assume same DOFs
- Assume same parameter mappings

Blending

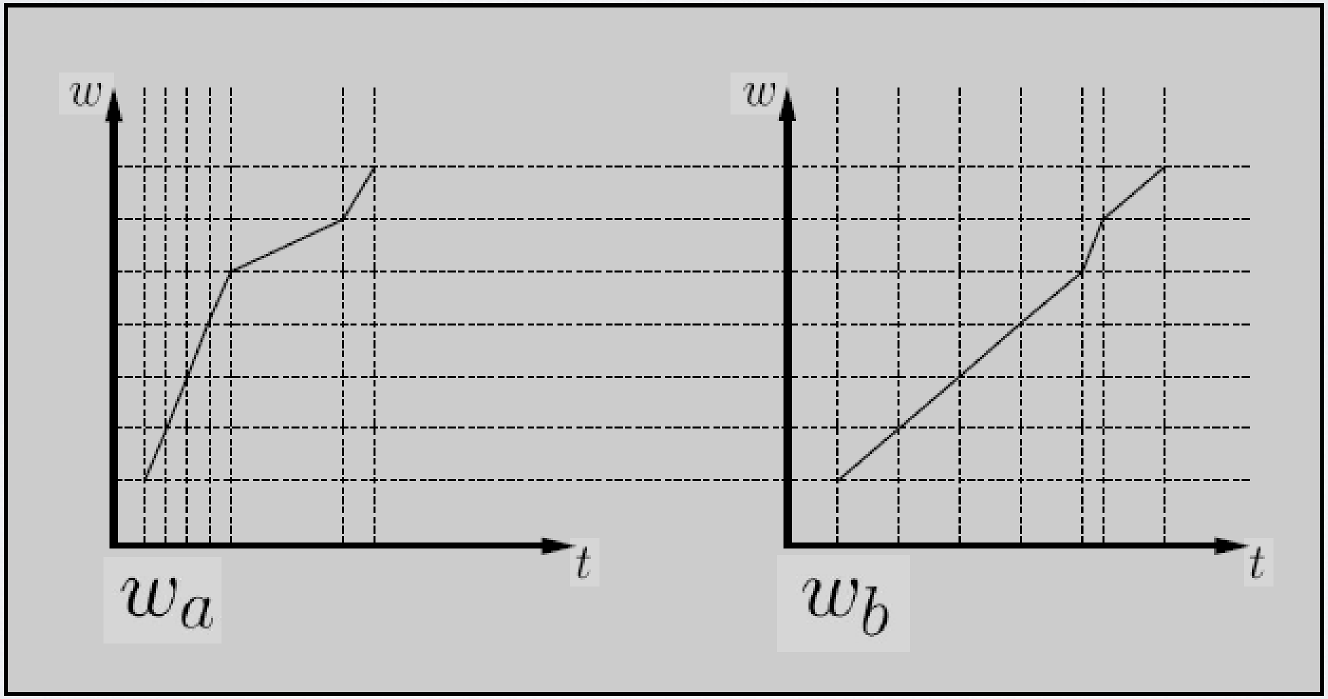
- Blending slow walk and fast walk



Bruderlin and Williams, SIGGRAPH 95

Time Warping

- Define timewarp functions to align features



Normalized time is *w*

Blending in Time

- Blend in normalized time

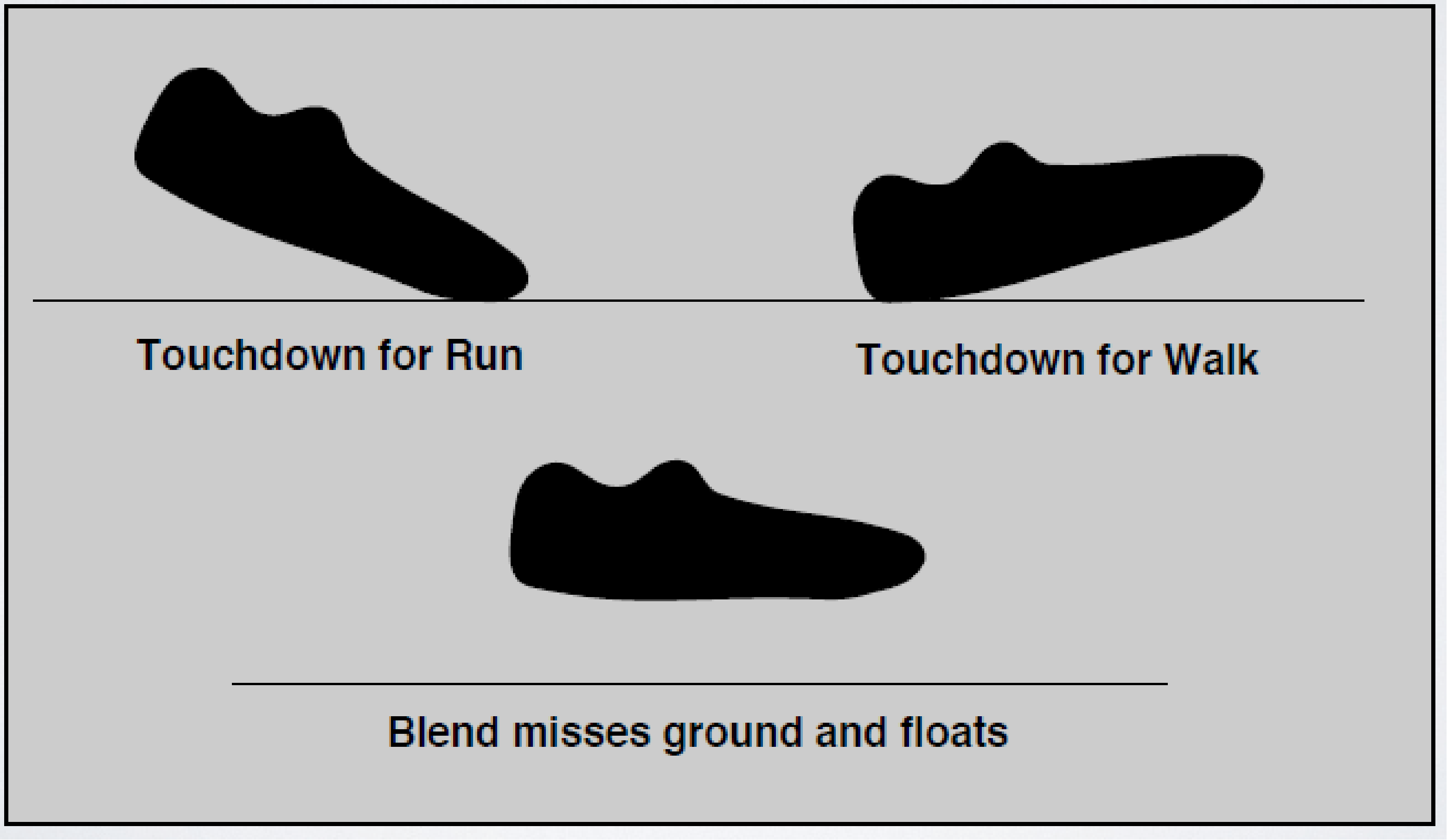
$$\boldsymbol{m}_\alpha(w) = \alpha\boldsymbol{m}_a(w_a)+(1-\alpha)\boldsymbol{m}_b(w_b)$$

- Blend playback rate

$$\frac{\mathrm{d}t}{\mathrm{d}w} = \alpha\frac{\mathrm{d}t}{\mathrm{d}w_a} + (1-\alpha)\alpha\frac{\mathrm{d}t}{\mathrm{d}w_b}$$

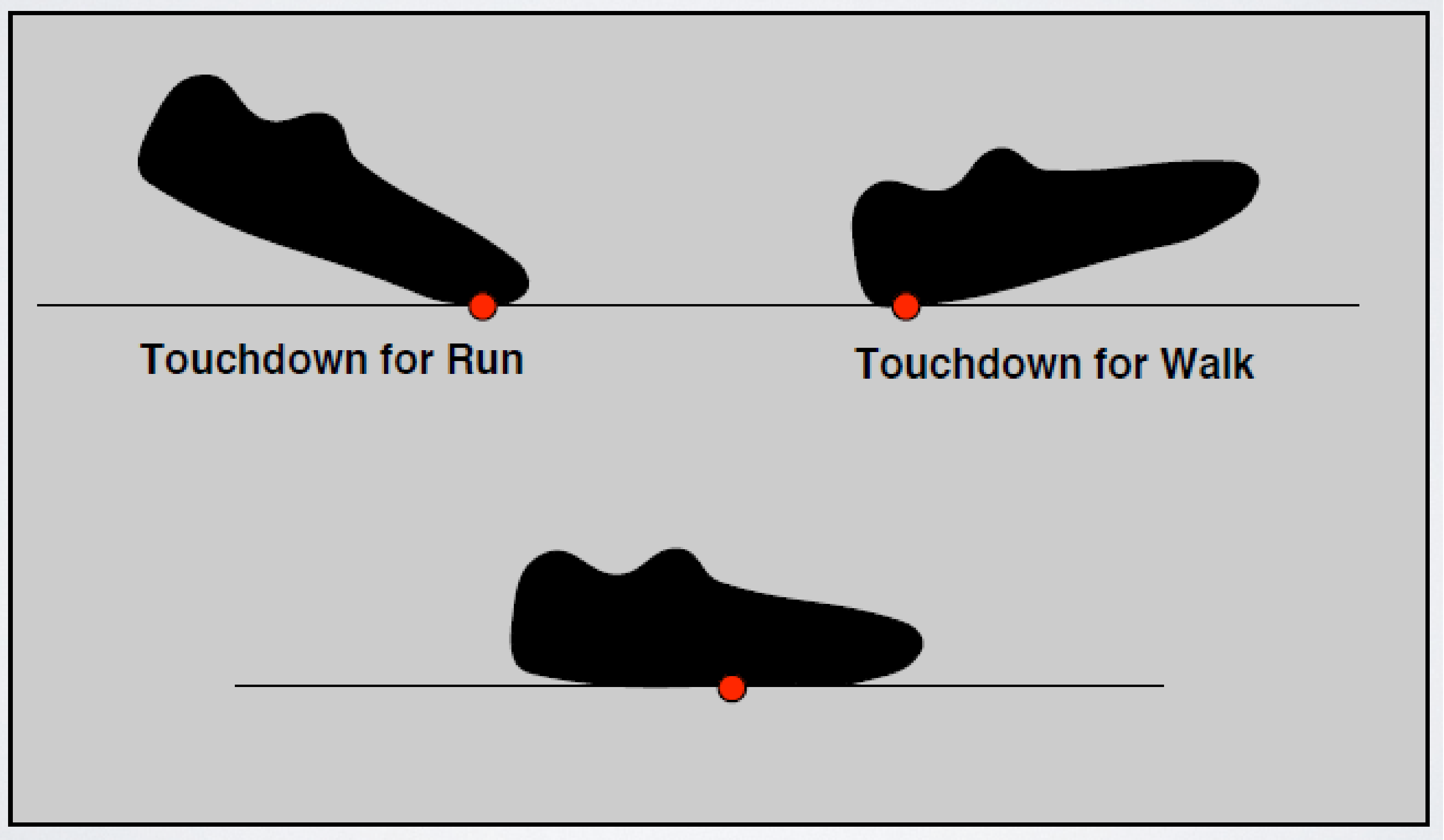
Blending and Contacts

- Blending may still break features in original motion



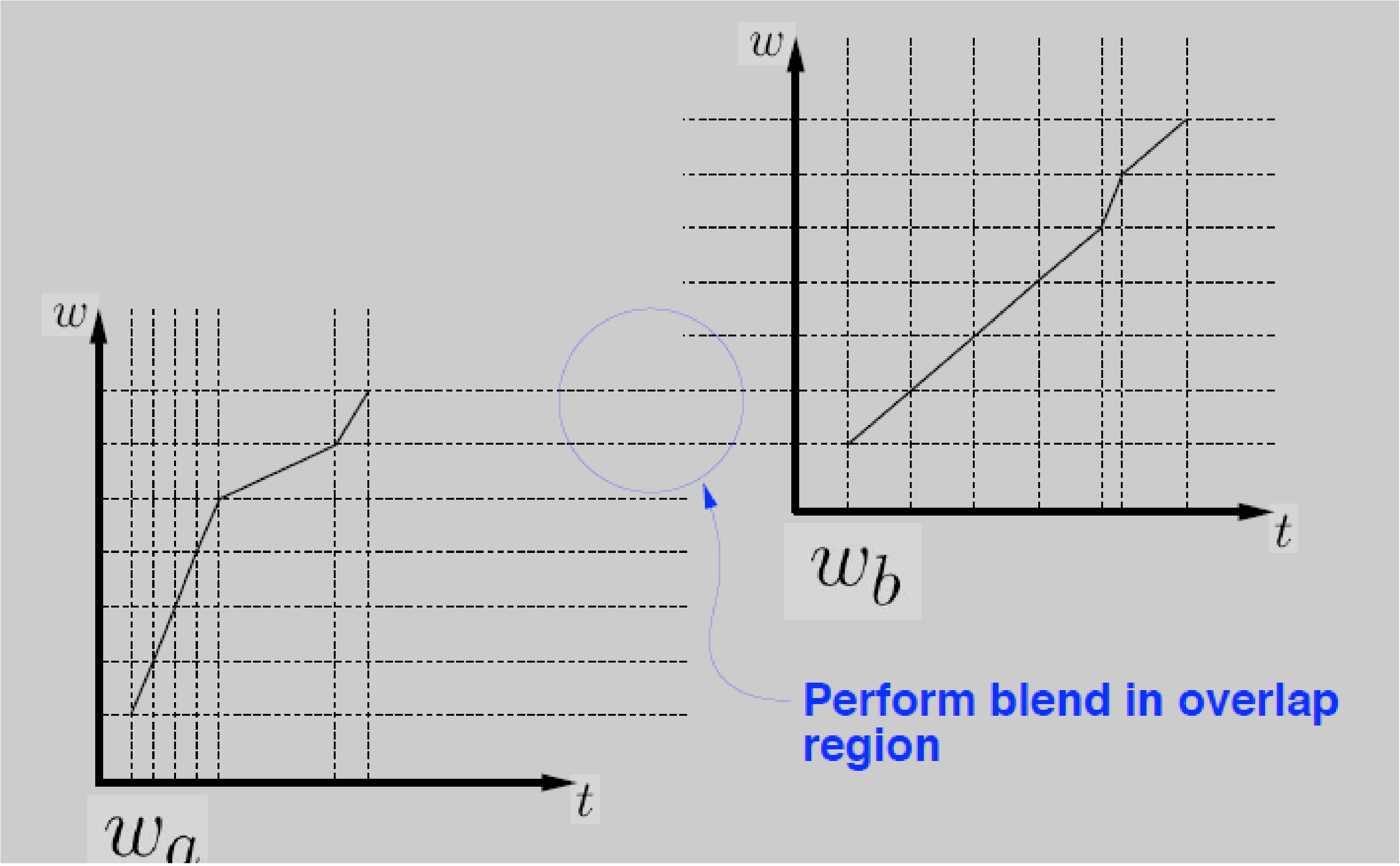
Blending

- Add explicit constraints to key points
  - Enforce with IK over time



Transitions

- Transition from one motion to another

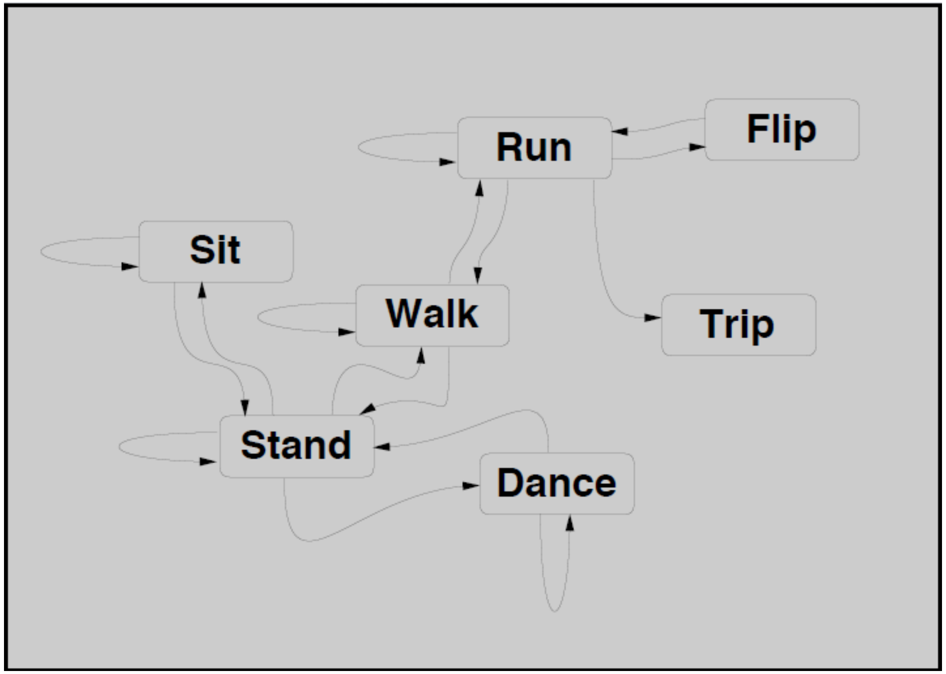


Cyclification

- Special case of transitioning
- Both motions are the same
- Need to modify beginning and end simultaneously

Motion Graphs

- Hand built motion graphs often used in games
  - Significant amount of work required
  - Limited number of transitions by design
- Motion graphs can also be built automatically

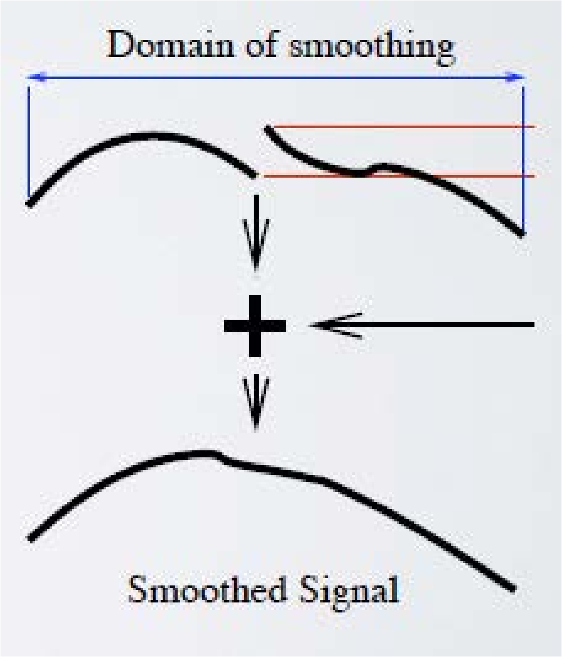


Motion Graphs

- Similarity Metric
  - Measurement of how similar two frames of motion are
  - Based on joint angles or point positions
  - Must include some measure of velocity
  - Ideally independent of capture setup and skeleton
- Capture a "large" database of motions
- Compute similarity between all pairs of frames
  - Can be expensive, but preprocessing step
  - May be many good edges

Motion Graphs

- Random Walks
  - Start in some part of the graph, randomly make transitions
  - Avoid dead ends
  - Useful for “idling” behaviors
- Transitions
  - Use blending algorithm we discussed



Motion Graphs

- Can have requirements
- Start at particular location, End at another
- Pass through some points
- Can be solved using dynamic programming
- Efficiency may require approximate solution
- Notion of goodness of a solution

Near-Exhaustive Precomputed Cloth

[Kim, Koh, Narain, Fatahalian, Treuille, O'Brien 13]

Integrating Physics

Suggested Reading 1

- Fourier principles for emotion-based human figure animation, Unuma, Anjyo, and Takeuchi, SIGGRAPH 95
- Motion signal processing, Bruderlin and Williams, SIGGRAPH 95
- Motion warping, Witkin and Popovic, SIGGRAPH 95
- Efficient generation of motion transitions using spacetime constrains, Rose et al., SIGGRAPH 96
- Retargeting motion to new characters, Gleicher, SIGGRAPH 98
- Verbs and adverbs: Multidimensional motion interpolation, Rose, Cohen, and Bodenheimer, IEEE: Computer Graphics and Applications, v. 18, no. 5, 1998

Suggested Reading 2

- Retargeting motion to new characters, Gleicher, SIGGRAPH 98
- Footskate Cleanup for Motion Capture Editing, Kovar, Schreiner, and Gleicher, SCA 2002.
- Interactive Motion Generation from Examples, Arikan and Forsyth, SIGGRAPH 2002.
- Motion Synthesis from Annotations, Arikan, Forsyth, and O'Brien, SIGGRAPH 2003.
- Pushing People Around, Arikan, Forsyth, and O'Brien, unpublished.
- Automatic Joint Parameter Estimation from Magnetic Motion Capture Data, O'Brien, Bodenheimer, Brostow, and Hodgins, GI 2000.
- Skeletal Parameter Estimation from Optical Motion Capture Data, Kirk, O'Brien, and Forsyth, CVPR 2005.
- Perception of Human Motion with Different Geometric Models, Hodgins, O'Brien, and Tumblin, IEEE: TVCG 1998.