Advanced Computer Graphics

CSE 190 [Winter 2016], Lecture 18

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To Do

- Assignment 3 due Mar 15 (milestone Mar 4)
  - Should already be well on way
  - Contact us for difficulties etc
  - This lecture about animation and motion capture
  - Next lecture discusses inverse kinematics
  - Please fill out CAPE evaluations (Now!)

Course Outline

- 3D Graphics Pipeline

Modeling (Creating 3D Geometry) → **Rendering** (Creating, shading images from geometry, lighting, materials)

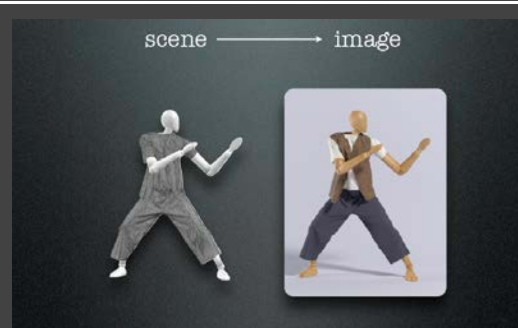
Unit 1: Foundations of Signal and Image Processing
Understanding the way 2D images are formed and displayed, the important concepts and algorithms, and to build an image processing utility like Photoshop
Weeks 1 – 3. **Assignment 1**

Unit 2: Meshes, Modeling
Weeks 3 – 5. **Assignment 2**

Unit 3: Advanced Rendering
Weeks 6 – 7, 8-9. **(Final Project)**

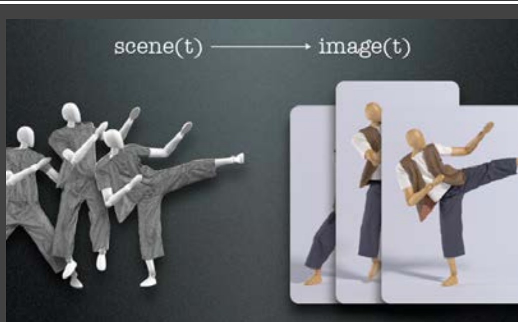
Unit 4: Animation, Imaging
Weeks 7-8, 9-10. **(Final Project)**

The Story So Far

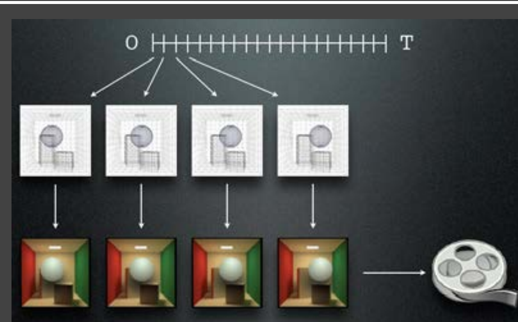


Slides courtesy Rahul Narain and James O'Brien

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

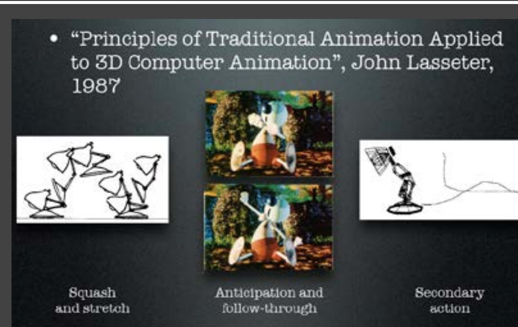
Drawing Animation Manually?

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?

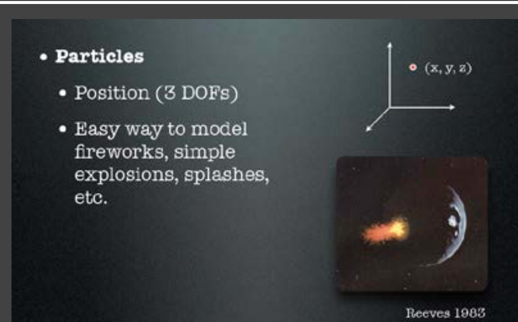
The Art Side



Specifying Animation

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

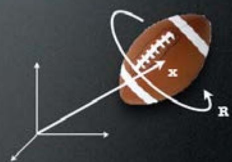
Animatable Models



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

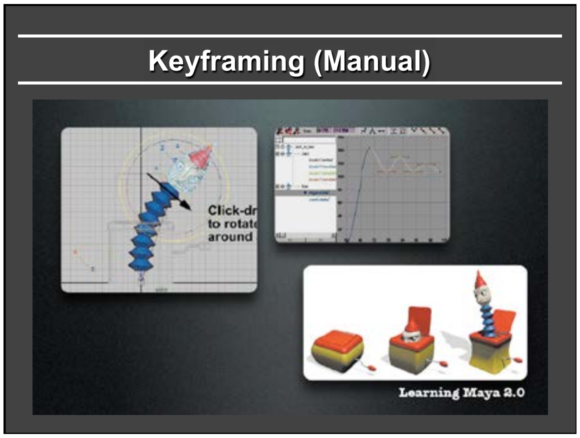
Animation Techniques

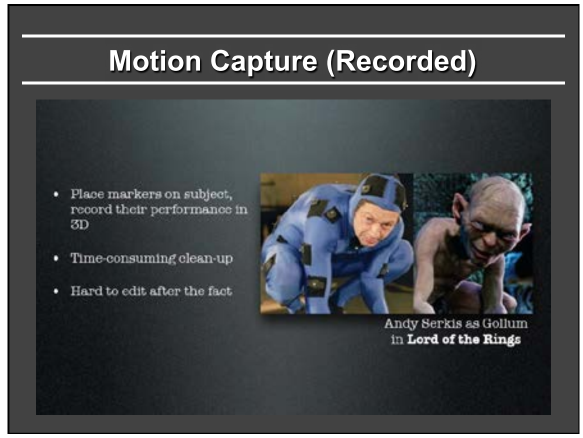
- **Keyframe animation**
  - Define key moments, then interpolate
- **Motion capture**
  - Record motion of performer
- **Procedural / simulation**
  - Compute motion automatically via physics

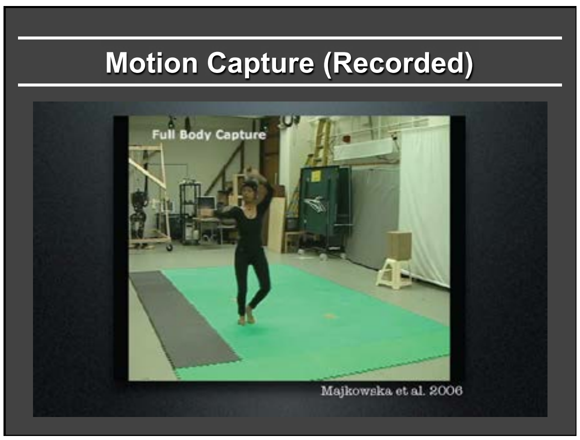
Keyframing (Manual)

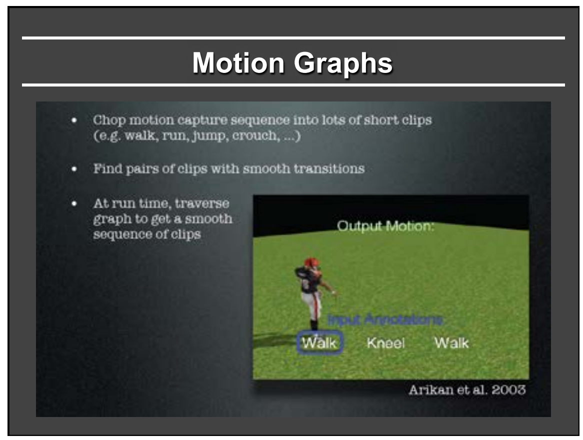
- Manually specify "key" moments of the action
- System interpolates the in-between frames

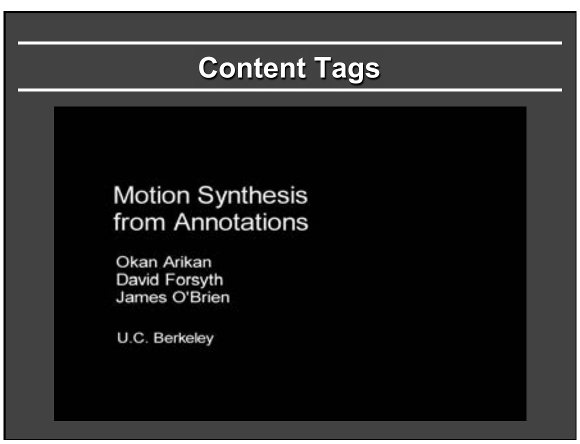
Lasseter 1987

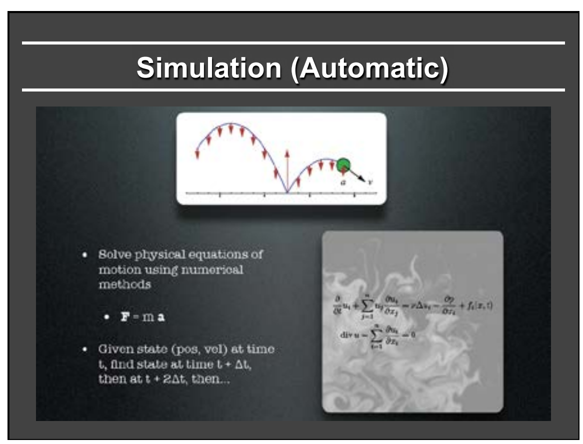

Keyframing (Manual)
Click-dr
to rotate
around
Learning Maya 2.0


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

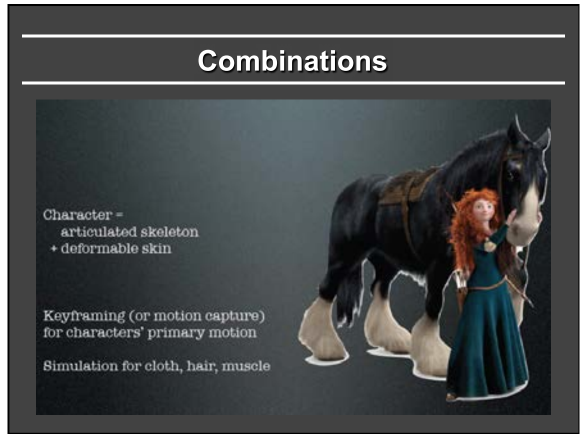

Motion Capture (Recorded)
Full Body Capture
Majkowska et al. 2006

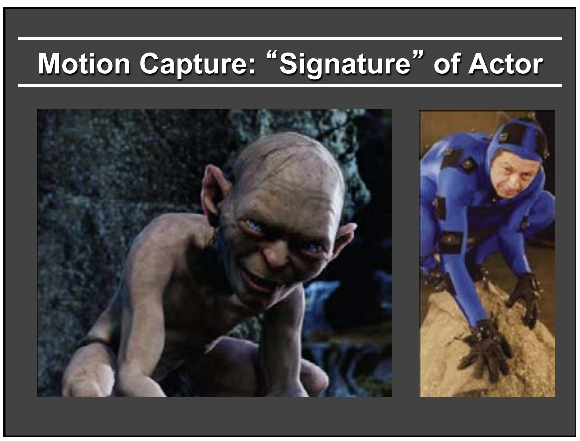

Motion Graphs
Chop motion capture sequence into lots of short clips (e.g. walk, run, jump, crouch, ...)
Find pairs of clips with smooth transitions
At run time, traverse graph to get a smooth sequence of clips
Output Motion:
Input Annotations
Walk
Kneel
Walk
Arikan et al. 2003

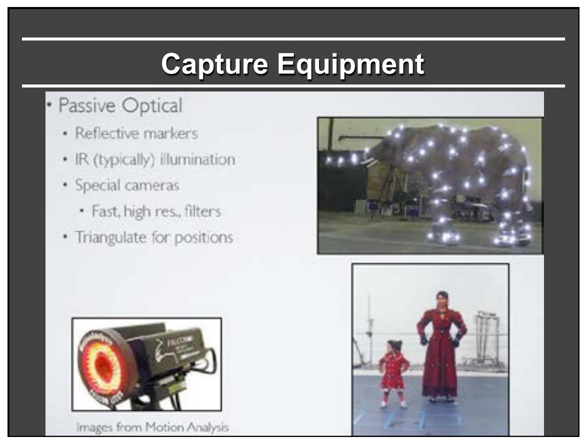

Content Tags
Motion Synthesis
from Annotations
Okan Arikan
David Forsyth
James O'Brien
U.C. Berkeley

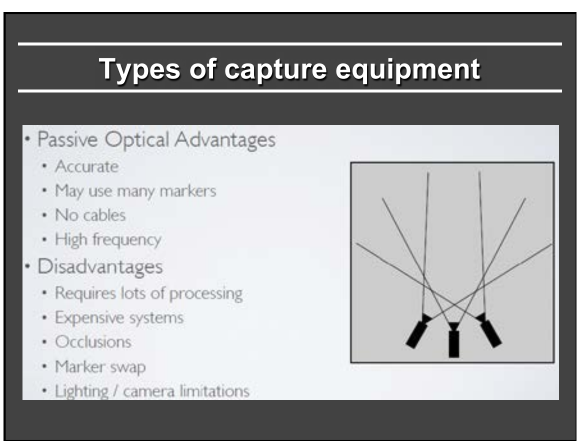

Simulation (Automatic)
Solve physical equations of motion using numerical methods
F = m a
Given state (pos, vel) at time t, find state at time t + Δt, then at t + 2Δt, then...

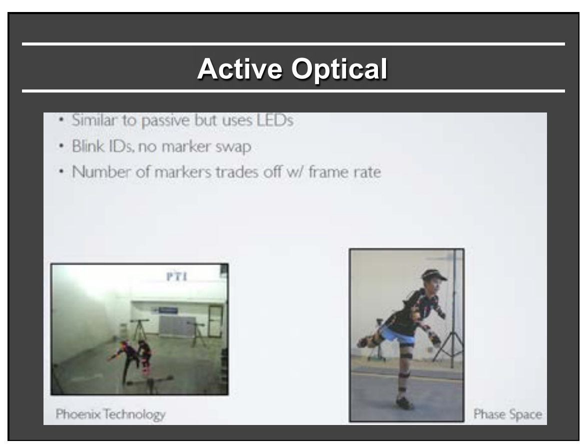

Game footage recorded from Xbox 360 version of
Star Wars: The Force Unleashed
Game footage copyright 2008 LucasArts, Inc.
Used with permission.


Combinations
Character =
articulated skeleton
+ deformable skin
Keyframing (or motion capture)
for characters' primary motion
Simulation for cloth, hair, muscle

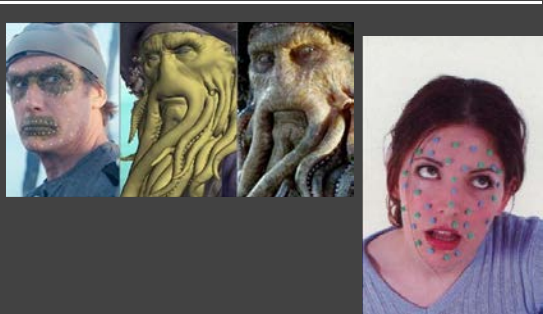

Motion Capture: "Signature" of Actor


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

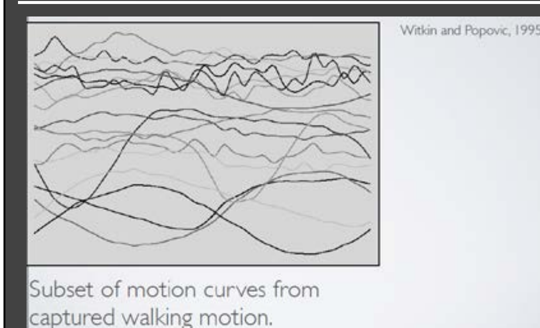
Adam G. Kirk
James F. O'Brien
David A. Forsyth

University of California - Berkeley

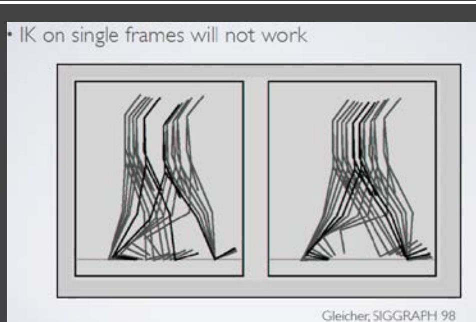
Manipulating Motion Data

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

Nature of Motion Data



Adjusting



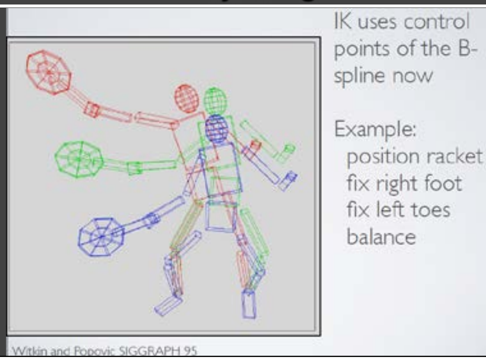
Adjustment

- 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

$$\boldsymbol{m}(t) = \boldsymbol{m}_0(t) + \boldsymbol{d}(t)$$

- $\boldsymbol{d}(t)$: **Adjustment**
- $\boldsymbol{m}_0(t)$: **Inital sampled data**
- $\boldsymbol{m}(t)$: **Result after adjustment**

Adjusting



Blending

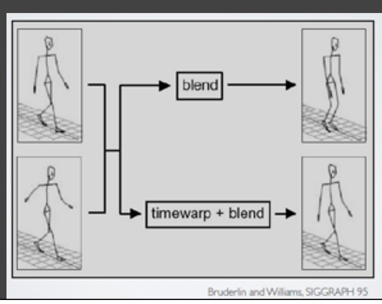
- Given two motions make a motion that combines qualities of both

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

- Assume same DOFs
- Assume same parameter mappings

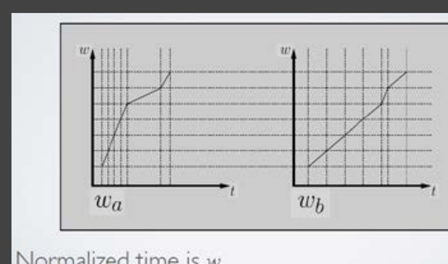
Blending

- Blending slow walk and fast walk



Time Warping

- Define timewarp functions to align features



Blending in Time

- Blend in normalized time

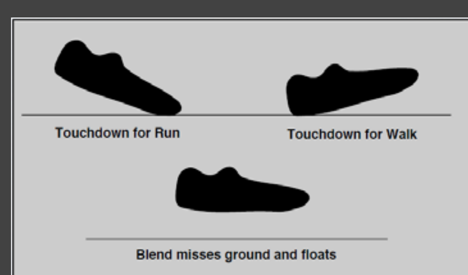
$$\boldsymbol{m}_\alpha(w) = \alpha \boldsymbol{m}_a(w_a) + (1-\alpha)\boldsymbol{m}_b(w_b)$$

- Blend playback rate

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

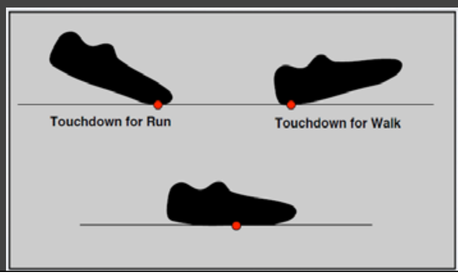
Blending and Contacts

- Blending may still break features in original motion



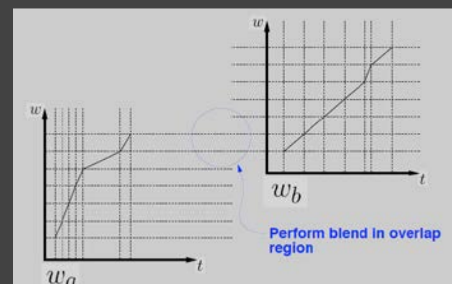
Blending

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



Transitions

- Transition from one motion to another

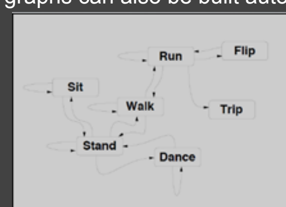


Cyclification

- 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

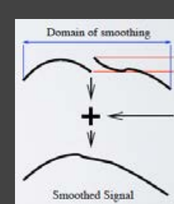


Motion Graphs

- 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



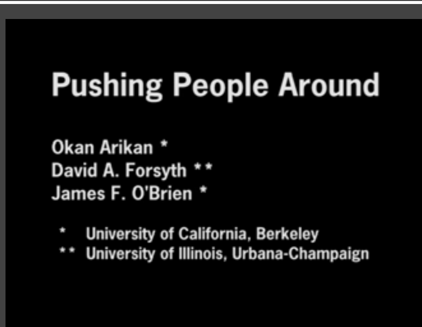
Motion Graphs

- Can have requirements
- Start at particular location, End at particular
- 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.