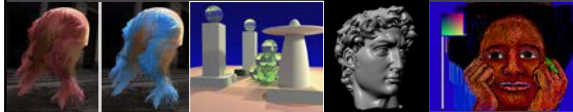


Advanced Computer Graphics

CSE 163 [Spring 2017], Lecture 18

Ravi Ramamoorthi

<http://www.cs.ucsd.edu/~ravr>



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**

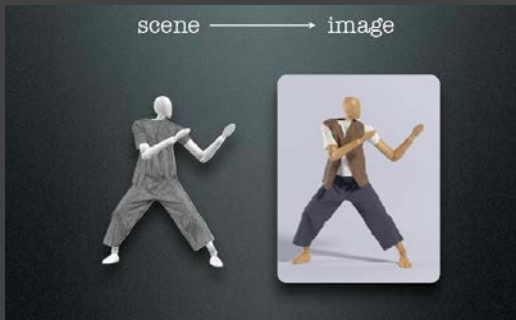
Unit 2: Meshes, Modeling
Weeks 3 – 5. **Assignment 2**

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

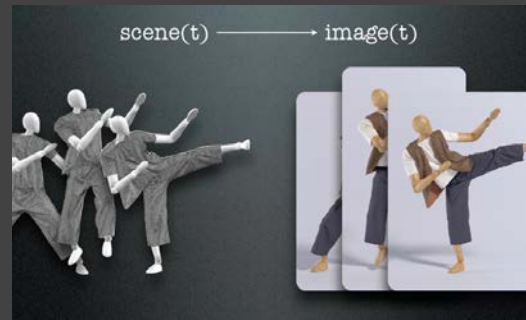
scene $\longrightarrow$ image



Slides courtesy Rahul Narain and James O'Brien

Animation

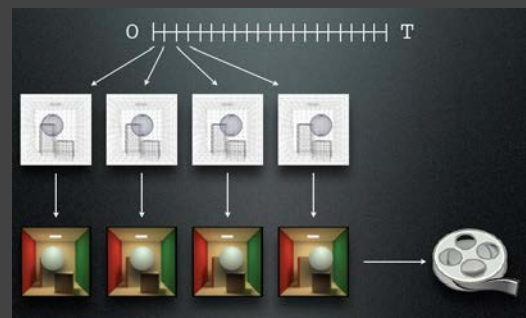
scene(t) $\longrightarrow$ image(t)



To Do

- Assignment 3 due Jun 14 (milestone Jun 3)
 - 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!)

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=Qe9nSLYK5t4>

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



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)



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



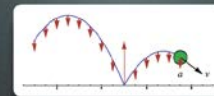
Content Tags

Motion Synthesis from Annotations

Okan Arikan
David Forsyth
James O'Brien

U.C. Berkeley

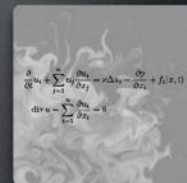
Simulation (Automatic)



- Solve physical equations of motion using numerical methods

$$\mathbf{F} = m\mathbf{a}$$

- Given state (pos, vel) at time t , find state at time $t + \Delta t$, then at $t + 2\Delta t$, 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



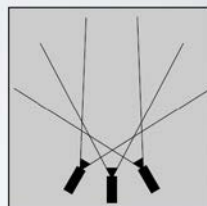
Types of capture equipment

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

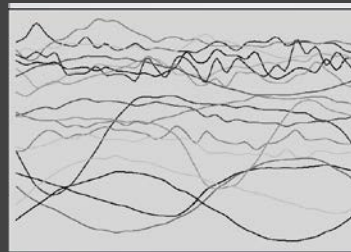
Adam G. Kirk
James F. O'Brien
David A. Forsyth

University of California - Berkeley

Manipulating Motion Data

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

Nature of Motion Data

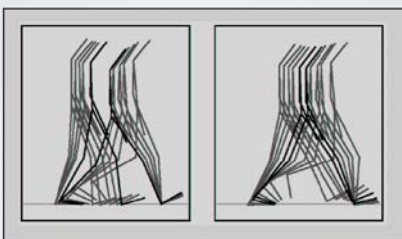


Witkin and Popovic, 1995

Subset of motion curves from captured walking motion.

Adjusting

- IK on single frames will not work



Gleicher, SIGGRAPH 98

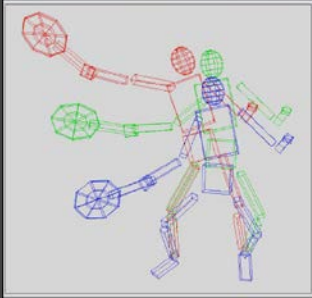
Adjustment

- 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

$$m(t) = m_0(t) + d(t)$$

Adjustment
Initial sampled data
Result after adjustment

Adjusting



IK uses control points of the B-spline now

Example:
position racket
fix right foot
fix left toes
balance

Witkin and Popovic, SIGGRAPH 95

Blending

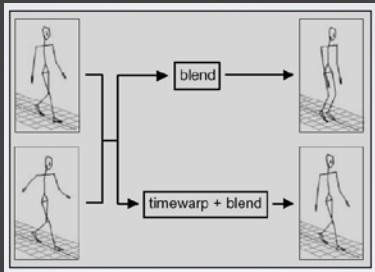
- Given two motions make a motion that combines qualities of both

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

- Assume same DOFs
- Assume same parameter mappings

Blending

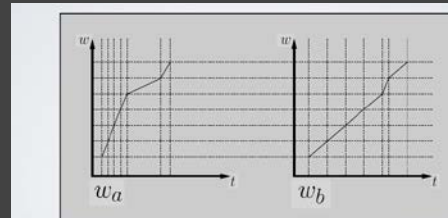
- Blending slow walk and fast walk



Bruderlin and Williams, SIGGRAPH 95

Time Warping

- Define timewarp functions to align features



Normalized time is w

Blending in Time

- Blend in normalized time

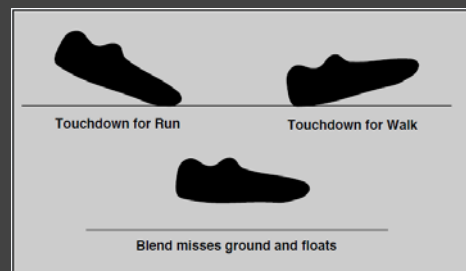
$$\mathbf{m}_\alpha(w) = \alpha \mathbf{m}_a(w_a) + (1 - \alpha) \mathbf{m}_b(w_b)$$

- Blend playback rate

$$\frac{dt}{dw} = \alpha \frac{dt}{dw_a} + (1 - \alpha) \alpha \frac{dt}{dw_b}$$

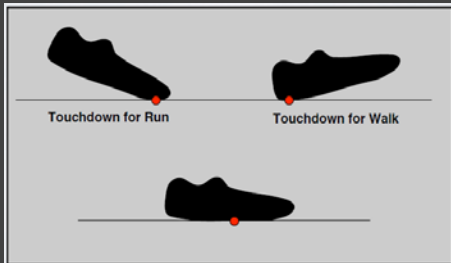
Blending and Contacts

- Blending may still break features in original motion



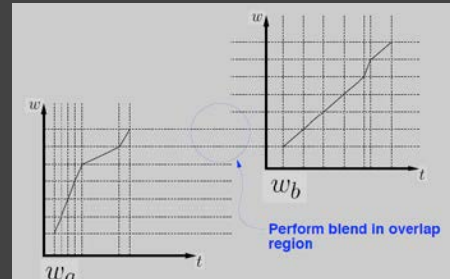
Blending

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



Transitions

- Transition from one motion to another

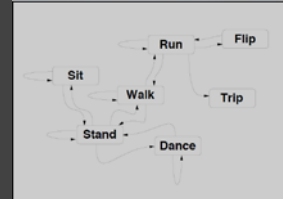


Cyclification

- 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

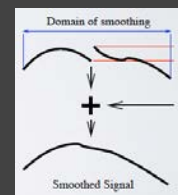


Motion Graphs

- 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



Integrating Physics

Pushing People Around

Okan Arikan *
David A. Forsyth **
James F. O'Brien *

* University of California, Berkeley
** University of Illinois, Urbana-Champaign

Suggested Reading 1

- Fourier principles for emotion-based human figure animation, Unuma, Anjo, 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 constraints, 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.