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

Unit 2: Meshes, Modeling
  - Weeks 3 – 5
  - Assignment 1

Unit 3: Advanced Rendering
  - Weeks 6 – 7, 8-9
  - Assignment 2

The Story So Far
- slides courtesy Rahul Narain and James O'Brien

Animation
- scene(t) → image(t)

Animation
- 0 \rightarrow T
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

Specifying Animation

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

The Art Side

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

Animatable Models

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

Drawing Animation Manually?

- 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?

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

- Particles
- Rigid bodies
  - Position and orientation (3 + 3 DOFs)
- Articulated bodies
  - Rigid links connected by joints (#DOFs = #joints)
  - e.g., robots, character “skeletons”
- Deformable bodies
  - Discretized as meshes with moving vertices
  - Cloth, hair, plastic, muscle, and skin, ...
- 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)

Motion Capture (Recorded)

Motion Graphs

Content Tags

Simulation (Automatic)
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 (for motion capture) for character’s 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

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

**Active Optical**
- Similar to passive but uses LEDs
- Cheap, no marker swap
- Number of markers trades off of frame rate
Facial MoCap

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

Nature of Motion Data
- 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

Example:
\[ m(t) = m_i(t) + d(t) \]
Adjusting

IK: uses control points of the B-spine now

Example: position racket fix right foot fix left toes balance

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Blending

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

\[ m_\alpha(t) = \alpha m_\alpha(t) + (1 - \alpha)m_\beta(t) \]
- Assume same DOFs
- Assume same parameter mappings

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Blending slow walk and fast walk

- Define timewarp functions to align features

Blending in Time

- Blend in normalized time

\[ m_\alpha(w) = \alpha m_\alpha(w_\alpha) + (1 - \alpha)m_\beta(w_\beta) \]
- Blend playback rate

\[ \frac{dt}{dw} = \alpha \frac{dt}{dw_\alpha} + (1 - \alpha)\alpha \frac{dt}{dw_\beta} \]

Blending and Contacts

- Blending may still break features in original motion

Normalized time is \( w \)
### Blending
- Add explicit constraints to key points
  - Enforce with IK over time

### Transitions
- Transition from one motion to another

![Transition graph](image)

### 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 graph](image)

### 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
- 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

![Random walk](image)
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, 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 constraints, Rose et al., SIGGRAPH 96
- Retargeting motion to new characters, Gleich; SIGGRAPH 98

Suggested Reading 2

- Retargeting motion to new characters, Gleich; SIGGRAPH 98
- Footloose Cleanup for Motion Capture Editing, Kovac, Schreiner, and Gleich; 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.