Advanced Computer Graphics
CSE 190 [Spring 2015], Lecture 16
Ravi Ramamoorthi
http://www.cs.ucsd.edu/~ravir

To Do
- Assignment 3 milestone due May 29
  - Should already be well on way
  - Contact us for difficulties etc
- This lecture about animation and motion capture
- Next lecture discusses inverse kinematics
- Imaging, Texture Synthesis next week

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

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 6–8. (Final Project)

Unit 4: Animation, Imaging
Weeks 9, 10. (Final Project)

The Story So Far

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?

- 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

The Art Side

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

Specifying Animation

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

Animatable Models

- Particles
  - Position (5 DOFs)
  - Easy way to model fireworks, simple explosions, splashes, etc.
**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, ...

**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 motion
- System interpolates the in-between frames
Keyframing (Manual)

Motion Capture (Recorded)
- Place markers on subject, record their performance in 3D
- Time-consuming cleanup
- Hard to edit after the fact

Motion Capture (Recorded)
- Full body capture
- Majewski et al. 2006

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

Content Tags

Simulation (Automatic)
- Solve the equations of motion using numerical methods
- \[ \mathbf{F} = m \mathbf{a} \]
- Given point (x, y) at time t, and values at later t + \Delta t, then \[ x(t + \Delta t) = x(t) + \Delta t \dot{x}(t) + \frac{\Delta t^2}{2} \ddot{x}(t) \]
Interactive Simulation

Combinations

Character:
- articulated skeleton
- deformable skin

Motion Capture: "Signature" of Actor

Capture Equipment

Types of capture equipment

Active Optical

Motion Capture: "Signature" of Actor

Capture Equipment

Types of capture equipment

Active Optical
Facial MoCap

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

Nature of Motion Data
- Subset of motion curves from captured walking motion.

Adjusting
- IK on single frames will not work.

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
  - Initial sampled data
  - Result after adjustment
Adjusting

IK uses control points of the B-spine now.
Example: position racket, fix right foot, fix left toes, balance.

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

Blending

- Blending slow walk and fast walk

Blending in Time

- Blend in normalized time
  \[ m_{\alpha}(w) = \alpha m_{\alpha}(w) + (1 - \alpha) m_{\beta}(w) \]
- Blend playback rate
  \[ \frac{dt}{dw} = \alpha \frac{dt}{dw_\alpha} + (1 - \alpha) \alpha \frac{dt}{dw_\beta} \]

Time Warping

- Define timewarp functions to align features

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

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, 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
- Foot Sokate Clearance for Motion Capture Editing, Kovar; Siggraph; 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.