CS-184: Computer Graphics

Lecture #19: Motion Capture

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Today

- Motion Capture
Motion Capture

- Record motion from physical objects
- Use motion to animate virtual objects

Simplified Pipeline:

1. Setup and calibrate equipment
2. Record performance
3. Process motion data
4. Generate animation

Basic Pipeline

From Rose, et al., 1998
### What types of objects?

- Human, whole body
- Portions of body
- Facial animation
- Animals
- Puppets
- Other objects

### Capture Equipment

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

Images from Motion Analysis
### 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

### Capture Equipment

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

- Magnetic Trackers
  - Transmitter emits field
  - Trackers sense field
  - Trackers report position and orientation

Capture Equipment

- Electromagnetic Advantages
  - 6 DOF data
  - No occlusions
  - Less post processing
  - Cheaper than optical

- Disadvantages
  - Cables
  - Problems with metal objects
  - Low(er) frequency
  - Limited range
  - Limited number of trackers
Capture Equipment

• Electromechanical

Capture Equipment

• Puppets
### Performance Capture

- Many studios regard *Motion Capture* as evil
  - Synonymous with low quality motion
  - No directive / creative control
  - Cheap
- **Performance Capture is different**
  - Use mocap device as an expressive input device
  - Similar to digital music and MIDI keyboards

### Manipulating Motion Data

- **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.
Adjusting

- Define desired motion function in parts

\[ m(t) = m_0(t) + d(t) \]

Adjustment

Initial sampled data

Result after adjustment

Adjusting

- Select adjustment function from "some nice space"
- Example C2 B-splines
- Spread modification over reasonable period of time
- User selects support radius
IK uses control points of the B-spline now.

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

What if adjustment periods overlap?
Blending

- Given two motions make a motion that combines qualities of both
  \[ m_\alpha(t) = \alpha m_1(t) + (1 - \alpha) m_2(t) \]
- Assume same DOFs
- Assume same parameter mappings

Blending

- Consider blending slow-walk and fast-walk
Blending

• Define timewarp functions to align features in motion

Normalized time is \( w \)

\[ m_{\alpha}(w) = \alpha m_{a}(w_a) + (1 - \alpha) m_{b}(w_b) \]

• Blend in normalized time

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

• Blend playback rate
**Blending**

- Blending may still break features in original motions

![Diagram showing touchdown for Run and Walk with blended point](image)

**Blending**

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

![Diagram showing touchdown for Run and Walk with explicit constraints](image)
**Blending / Adjustment**

- Short edits will tend to look acceptable
- Longer ones will often exhibit problems
- Optimize to improve blends / adjustments
  - Add quality metric on adjustment
  - Minimize accelerations / torques
  - Explicit smoothness constraints
  - Other criteria...

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**Multivariate Blending**

- Extend blending to multivariate interpolation

\[ m(w) = \sum_i \alpha_i(w) m_i(w) \]

\[ \sum_i \alpha_i(w) = 1 \]

"Happiness"
Multivariate Blending

• Extend blending to multivariate interpolation

Use standard scattered-data interpolation methods

Transitions

• Transition from one motion to another

Perform blend in overlap region
Cyclification

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

Transition Graphs
Motion Graphs

- Hand build motion graphs often used in games
  - Significant amount of work required
  - Limited 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
Motion Graphs

- Random walks
- Start in some part of the graph and randomly make transitions
- Avoid dead ends
- Useful for "idling" behaviors
- Transitions
  - Use blending algorithm

Match imposed requirements

- Start at a particular location
- End at a particular location
- Pass through particular pose
- Can be solved using dynamic programming
- Efficiency issues may require approximate solution
- Notion of "goodness" of a solution
Typical Motion Graph

- Walking #1
- Running
- Idle
- Fall down
- Walking #2
- Punches

Recorded Time

Finite number of states
Cloth is hysteretic

Naïve Precomputation

Initially computed cloth motion
Jumpy transitions
Graph Unrolling

5000 hours compute
100K frames
330 GB
Precomputed Cloth

72 MB Compressed
Laptop 60 fps
Low CPU load

Wrong inset due to time constraints.
Really it works. Trust me!

72 MB Compressed
Laptop 60 fps
Low CPU load
### Precomputed Simulation

- No significant CPU load at runtime
- Decouples quality from runtime cost
- No new data at runtime
  - Simulation can't crash application
  - All motion can be inspected/edited
  - Allows QA and art direction of simulations
- Extend to other types of simulation?
- Dynamic variations?

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### Suggested Reading

- 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 constrains, Rose et al., SIGGRAPH 96
- Retargeting motion to new characters, Gleicher, SIGGRAPH 98
Suggested Reading

- 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.
- Pushing People Around, Arikan, Forsyth, and O'Brien, unpublished.
- Skeletal Parameter Estimation from Optical Motion Capture Data, Kirk, O'Brien, and Forsyth, CVPR 2005.