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

Phoenix Technology

Phase Space
Capture Equipment

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

May be wireless

Control

May be wireless
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

Analogus
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.

Witkin and Popovic, 1995
Adjusting

- IK on single frames will not work

Gleicher, SIGGRAPH 98
Adjusting

- Define desired motion function in parts

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

- Select adjustment function from “some nice space”
  - Example C2 B-splines
- Spread modification over reasonable period of time
  - User selects support radius
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
Adjusting

What if adjustment periods overlap?

Witkin and Popovic SIGGRAPH 95
Blending

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

\[ m_\alpha(t) = \alpha m_a(t) + (1 - \alpha) m_b(t) \]

- Assume same DOFs
- Assume same parameter mappings
Blending

- Consider blending *slow-walk* and *fast-walk*

Bruderlin and Williams, SIGGRAPH 95
Blending

- Define timewarp functions to align features in motion

Normalized time is $w$
Blending

- **Blend in normalized time**

\[ m_\alpha(w) = \alpha m_a(w_a) + (1-\alpha) m_b(w_b) \]

- **Blend playback rate**

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

- Blending may still break features in original motions

- Touchdown for Run
- Touchdown for Walk

Blend misses ground and floats
Blending

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

Touchdown for Run

Touchdown for Walk
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...
Multivariate Blending

- Extend blending to multivariate interpolation

\[ m(w) = \sum_{i} \alpha_i(w) m_i(w) \]

\[ \sum_{i} \alpha_i(w) = 1 \]
**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

![Transition Graphs Diagram]
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

- Compute similarity metric between all pairs of frames
  - Maybe expensive
  - Preprocessing step
  - There may be too many good edges

Walking, frame i

Clustering

Arikan and Forsyth, 2002
Random walks

- Start in some part of the graph and randomly make transitions
- Avoid dead ends
- Useful for “idling” behaviors

Transitions

- Use blending algorithm we discussed
Motion graphs

- Match imposed requirements
  - Start at a particular location
  - End at a particular location
  - Pass through particular pose
  - Can be solved using dynamic programing
  - Efficiency issues may require approximate solution
  - Notion of “goodness” of a solution
Suggested Reading

- *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

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.