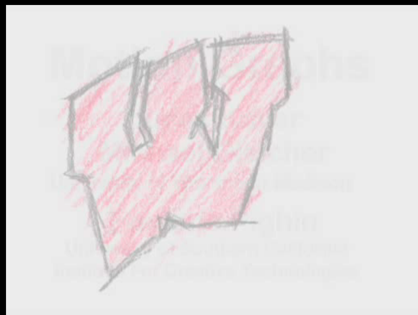


CS-184: Computer Graphics

Lecture 21: Motion Capture

Maneesh Agrawala
University of California, Berkeley

Slides based on those of James O'Brien

Announcements

Final Project: multiple due dates

- Project proposal due Wed Nov 17, 11pm
- Progress report 1 due Mon Nov 22, 11pm
- Progress report 2 due Wed Dec 1, 11pm
- Final report due Wed Dec 8, 11pm

Today

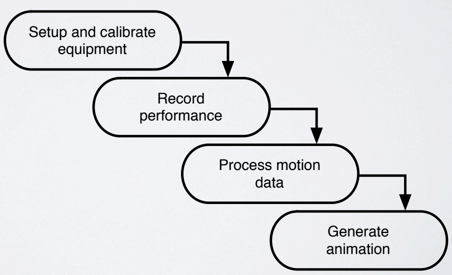
Motion Capture

Motion Capture

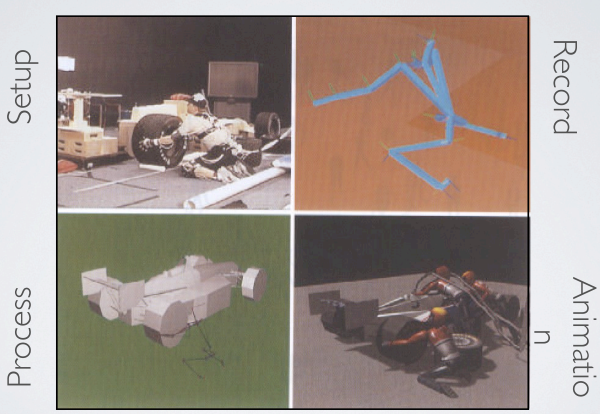
Record motion from physical objects

Use motion to animate virtual objects

Simplified Pipeline:



Basic Pipeline



From Rose, *et al.*, 1998

What types of objects?

Human, whole body

Portions of body

Facial animation

Animals

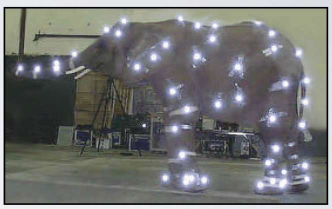
Puppets

Other objects

Capture Equipment

Passive Optical

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



Images from Motion Analysis

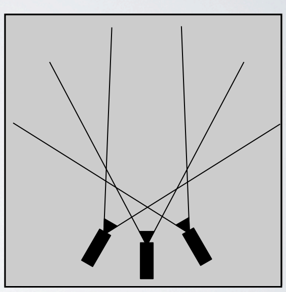
Capture Equipment

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

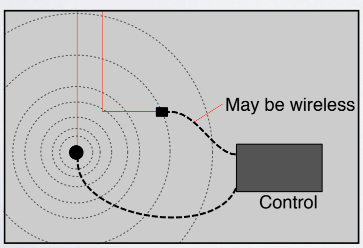
Phoenix Technology

Phase Space

Capture Equipment

Magnetic Trackers

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



Capture Equipment

Electromagnetic Advantages

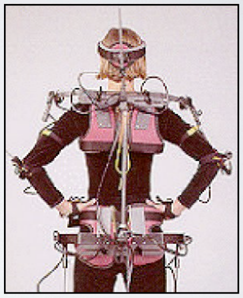
- 6 DOF data
- No occlusions
- Less post processing
- Cheaper than optical

Disadvantages

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

Capture Equipment

Electromechanical

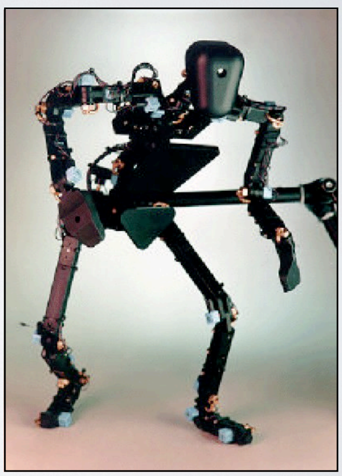


Analogus

Capture Equipment

Puppets

Digital Image Design



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

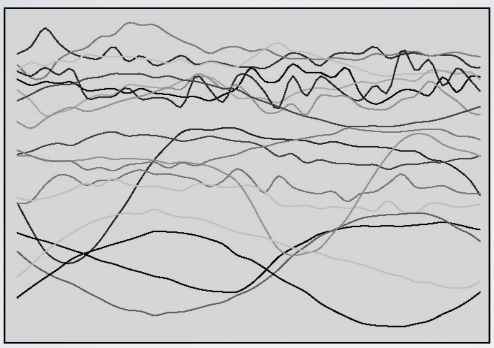
Manipulating Motion Data

Basic tasks

- Adjusting
- Blending
- Transitioning
- Retargeting

Building graphs

Nature of Motion Data

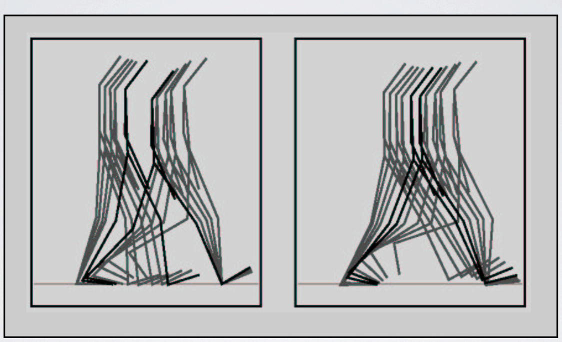


Witkin and Popovic, 1995

Subset of motion curves from captured walking motion.

Adjusting

IK on single frames will not work



Gleicher, SIGGRAPH 98

Adjusting

Define desired motion function in parts

$$\boldsymbol{m}(t) = \boldsymbol{m}_0(t) + \boldsymbol{d}(t)$$

- $\boldsymbol{d}(t)$: **Adjustment**
- $\boldsymbol{m}_0(t)$: **Inital sampled data**
- $\boldsymbol{m}(t)$: **Result after adjustment**

Adjusting

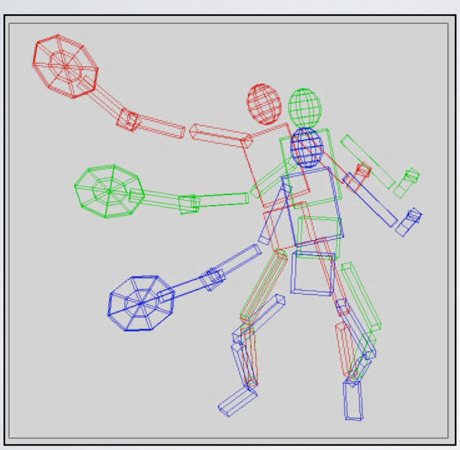
Select adjustment function from "some nice space"

- Example C2 B-splines

Spread modification over reasonable period of time

- User selects support radius

Adjusting

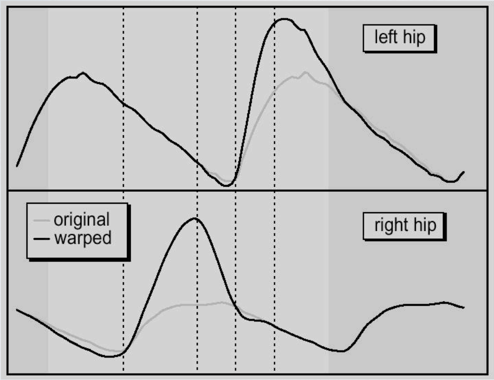


IK uses control points of the B-spline now

Example:
position racket
fix right foot
fix left toes
balance

Witkin and Popovic SIGGRAPH 95

Adjusting



Witkin and Popovic SIGGRAPH 95

What if adjustment periods overlap?

Blending

Given two motions make a motion that combines qualities of both

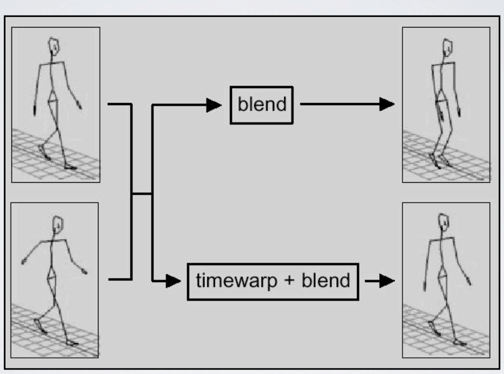
$$\boldsymbol{m}_\alpha(t) = \alpha \boldsymbol{m}_a(t) + (1-\alpha)\boldsymbol{m}_b(t)$$

Assume same DOFs

Assume same parameter mappings

Blending

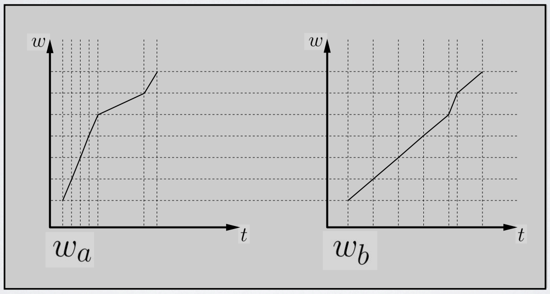
Consider blending ***slow-walk*** and ***fast-walk***



Bruderlin and Williams, SIGGRAPH 95

Blending

Define timewarp functions to align features in motion



Normalized time is w

Blending

Blend in normalized time

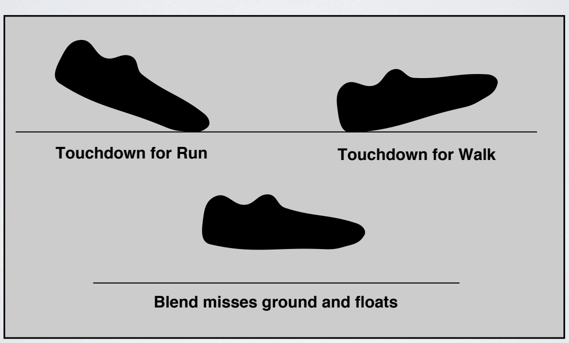
$$\boldsymbol{m}_\alpha(w) = \alpha \boldsymbol{m}_a(w_a) + (1-\alpha)\boldsymbol{m}_b(w_b)$$

Blend playback rate

$$\frac{\mathrm{d}t}{\mathrm{d}w} = \alpha \frac{\mathrm{d}t}{\mathrm{d}w_a} + (1-\alpha)\alpha \frac{\mathrm{d}t}{\mathrm{d}w_b}$$

Blending

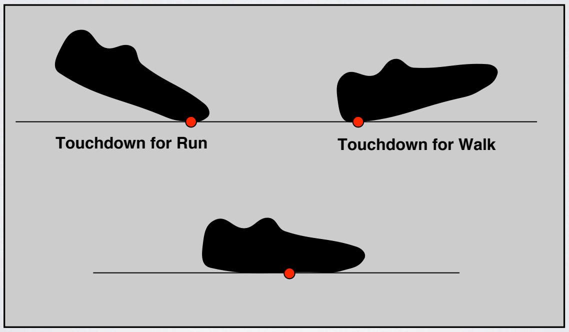
Blending may still break features in original motions



Blending

Add explicit constrains to key points

- Enforce with IK over time



Blending / Adjustment

Short edits will tend to look acceptable

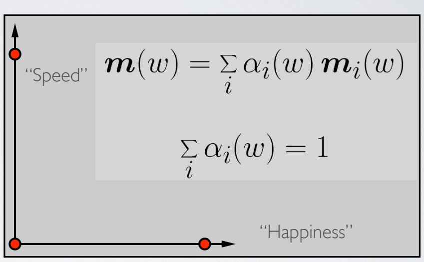
Longer ones will often exhibit problems

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

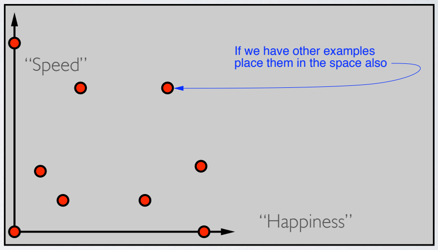


$$\boldsymbol{m}(w) = \sum_i \alpha_i(w)\, \boldsymbol{m}_i(w)$$

$$\sum_i \alpha_i(w) = 1$$

Multivariate Blending

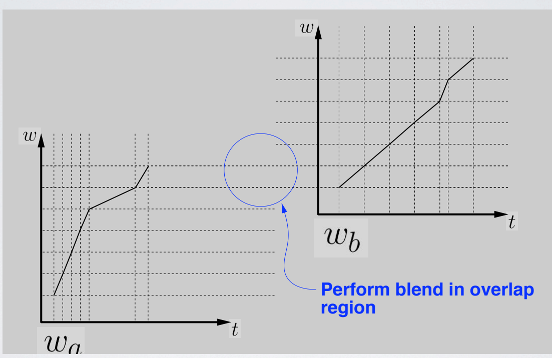
Extend blending to multivariate interpolation



Use standard scattered-data interpolation methods

Transitions

Transition from one motion to another



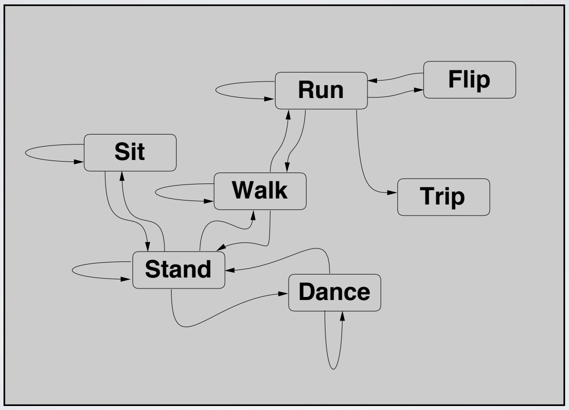
Cyclification

Special case of transitioning

Both motions are the same

Need to modify beginning and end of a motion simultaneously

Transition Graphs

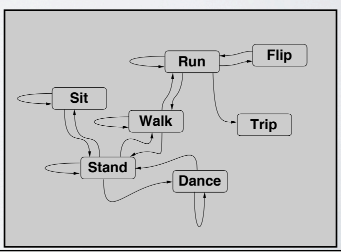


Motion Graphs

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

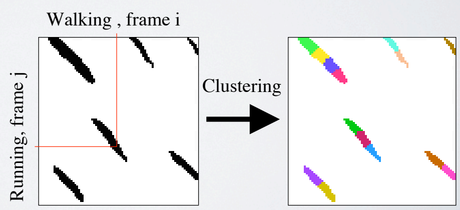
- Measurement of how similar two frames of motion are
  - Based on joint angles or point positions
  - Must include some measure of velocity
  - Ideally independent of capture setup and skeleton

Capture a "large" database of motions

Motion Graphs

Compute similarity metric between all pairs of frames

- Maybe expensive
- Preprocessing step
- There may be too many good edges



Arikan and Forsyth, 2002

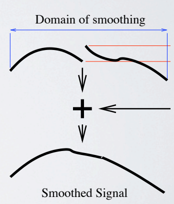
Motion Graphs

Random walks

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

Transitions

- Use blending algorithm 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

Verbs and adverbs: Multidimensional motion interpolation, Rose, Cohen, and Bodenheimer, IEEE: Computer Graphics and Applications, v. 18, no. 5, 1998

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.

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.