CS-184: Computer Graphics

Lecture #20: Motion Capture

Prof. James O'Brien
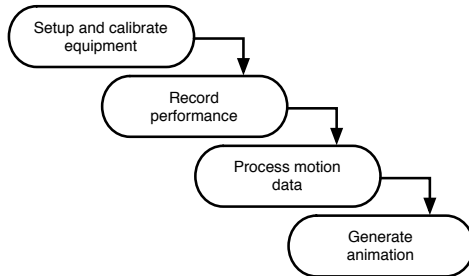University of California, Berkeley

V2011-S-20-1.0

Today

• Motion Capture

Motion Capture

- Record motion from physical objects

- Use motion to animate virtual objects

Simplified Pipeline:

```
┌─────────────────────┐
│ Setup and calibrate │
│     equipment       │
└─────────────────────┘
        │
        ▼
   ┌──────────────┐
   │   Record     │
   │ performance  │
   └──────────────┘
           │
           ▼
      ┌──────────────┐
      │ Process motion│
      │     data      │
      └──────────────┘
              │
              ▼
         ┌──────────────┐
         │   Generate   │
         │  animation   │
         └──────────────┘
```

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Basic Pipeline

Setup

Record
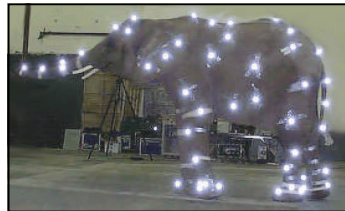
Process
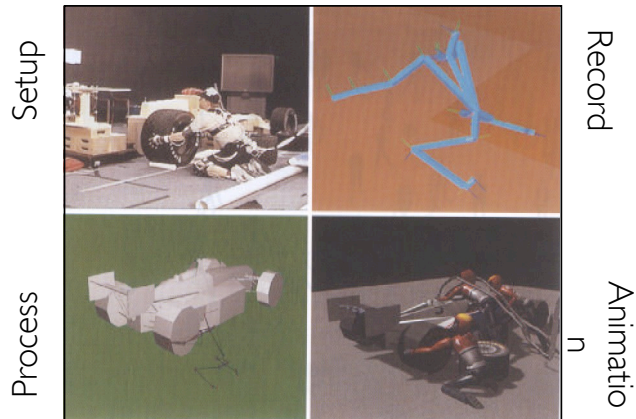
Animatio
n

From Rose, *et al.,* 1998

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What types of objects?

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

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Capture Equipment

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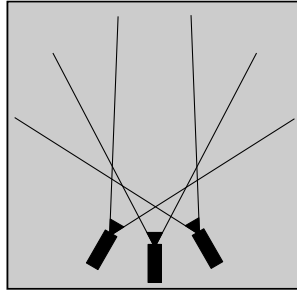

Images from Motion Analysis

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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

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Capture Equipment

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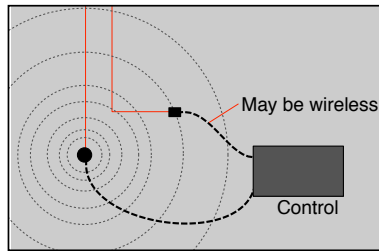 - Number of markers trades off w/ frame rate

Phoenix Technology

Phase Space

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Capture Equipment

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

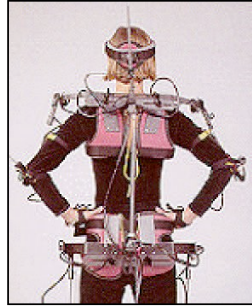May be wireless

Control

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
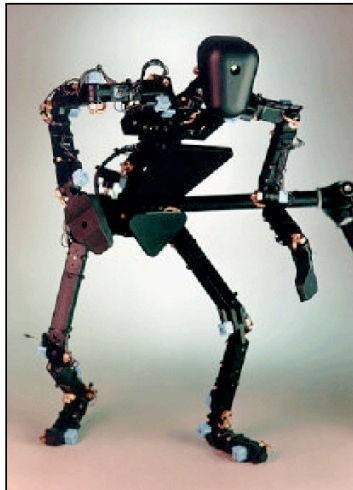 - Limited number of trackers

Capture Equipment

• Electromechanical

Analogus

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# Capture Equipment

• Puppets

Digital Image Design

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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

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Manipulating Motion Data

- Basic tasks
  - Adjusting
  - Blending
  - Transitioning
  - Retargeting
- Building graphs

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Nature of Motion Data

Why is this task not trivial?
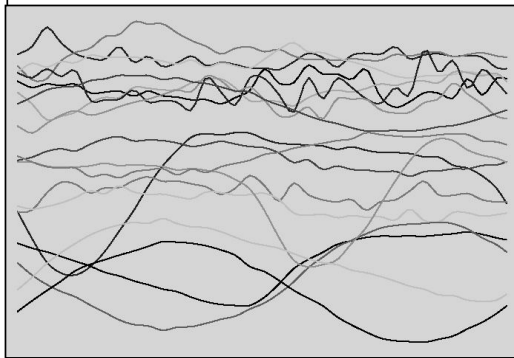
Witkin and Popovic, 1995

Subset of motion curves from
captured walking motion From Witkin and Popovic, SIGGRAPH 95

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Adjusting

IK on single frames will not work
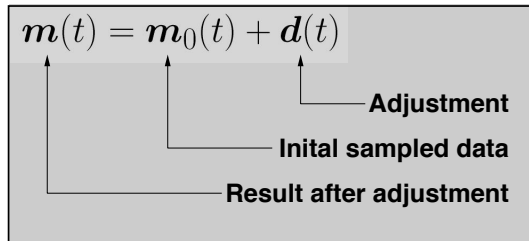
• IK on single frames will not work

Gleicher, SIGGRAPH 98
From Gleicher, SIGGRAPH 98

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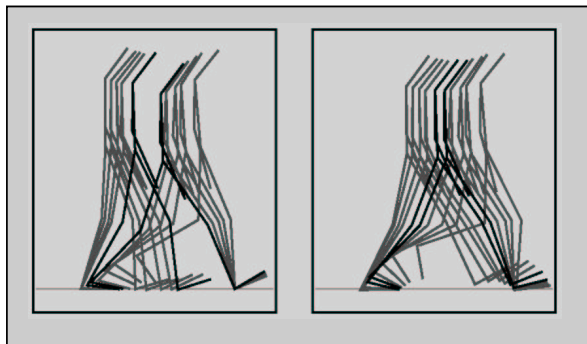
Adjusting

- Define desired motion function in parts

Define desired function with

$$m(t) = m_0(t) + d(t)$$

- Adjustment
- Inital sampled data
- Result after adjustment

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Adjusting

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

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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

left hip

original
warped

right hip

Witkin and Popovic SIGGRAPH 95

What if adjustment periods overlap?

Blending

- Given two motions make a motion that combines qualities of both
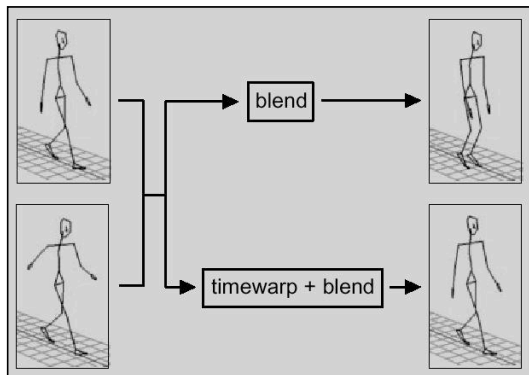
$$\boldsymbol{m}_\alpha(t) = \alpha\boldsymbol{m}_a(t) + (1-\alpha)\boldsymbol{m}_b(t)$$

- Assume same DOFs

- Assume same parameter mappings

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Blending

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

Bruderlin and Williams, SIGGRAPH 95

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Blending

- Define timewarp functions to align features in motion

Define timewarp functions

w_a w_b
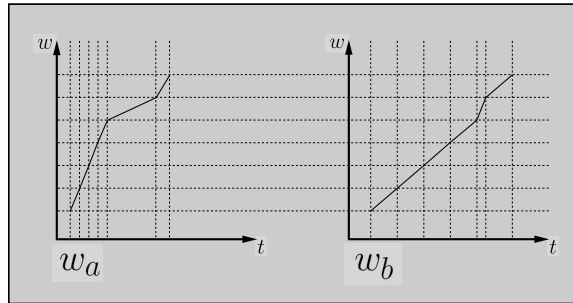
Normalized time is w

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Blending

- Blend in normalized time

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

- Blend playback rate

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

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Blending

- Blending may still break features in original motions

Blending may still break "features" in original motions

Touchdown for Run

Touchdown for Walk

Blend misses ground and floats

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Blending

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

Add explicit constraints to key points
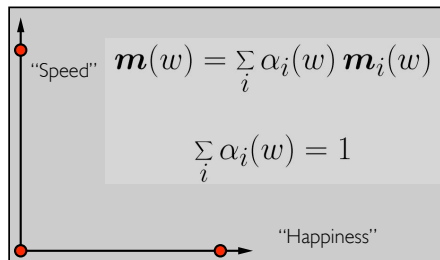
Touchdown for Run

Touchdown for Walk

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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
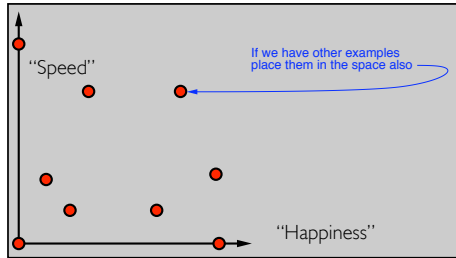 - Explicit smoothness constraints
  - Other criteria...

Multivariate Blending

Blending
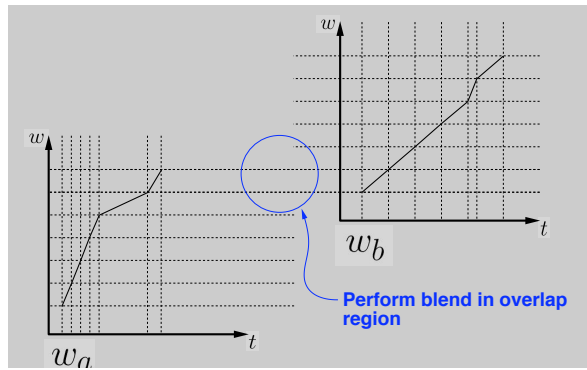
- Extend blending to multivariate interpolation

Extend to multivariate interpolation

"Speed"
$$m(w) = \sum_i \alpha_i(w)\, m_i(w)$$

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

"Happiness"

Weights are now barycentric coordiantes

Multivariate Blending

Blending

- Extend blending to multivariate interpolation

Extend to multivariate interpolation

"Speed"

If we have other examples place them in the space also

"Happiness"

Becomes standard interpolation problem...

Use standard scattered-data interpolation methods

Transitions

Transitioning

- Transition from one motion to another

Transition from motion A to motion B

w

w

w_b

t

w_a

t

Perform blend in overlap region

Cyclification

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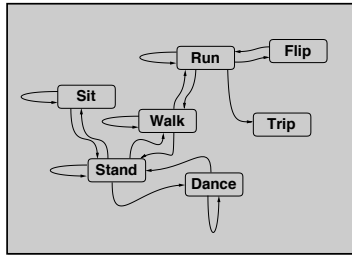- Need to modify beginning and end of a motion simultaneously

Transition Graphs

Transition Graphs

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
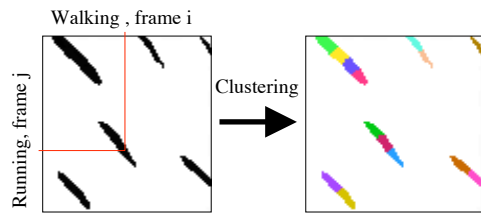
Transition Graphs

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
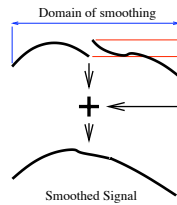
Running, frame j

Clustering

Arikan and Forsyth, 2002

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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

Domain of smoothing

+

Smoothed Signal

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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.