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# CS-184: Computer Graphics

## Lecture #17: Motion Capture

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## Today

- Motion Capture

# Motion Capture

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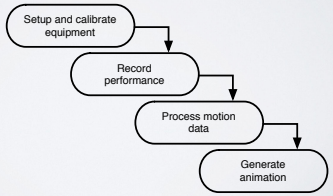
- Record motion from physical objects
- Use motion to animate virtual objects

Simplified Pipeline:






# Basic Pipeline

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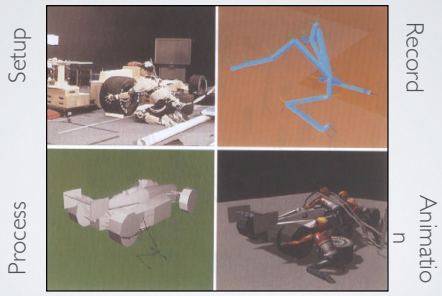


From Rose, *et al.*, 1998

## What types of objects?

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

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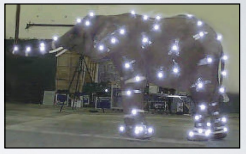
## Capture Equipment

6

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



Images from Motion Analysis

6

## Capture Equipment

7

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

Motion capture room for ShaqFu

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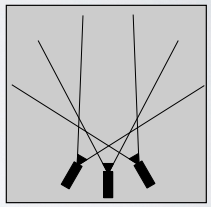
## Capture Equipment

8

- 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



8

## Capture Equipment

9

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## Capture Equipment

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- 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

10

## Capture Equipment

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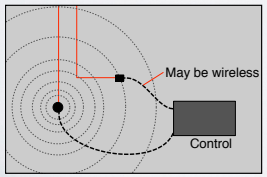
- Magnetic Trackers
  - Transmitter emits field
  - Trackers sense field
  - Trackers report position and orientation

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## Capture Equipment

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- 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

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## Capture Equipment

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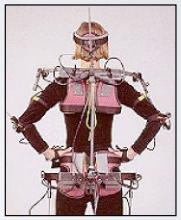
- Electromechanical



Analogus

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## Capture Equipment

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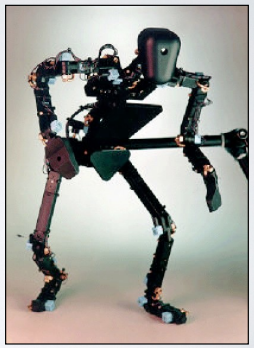
- Puppets



Digital Image Design

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## *Performance* Capture

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- 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

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

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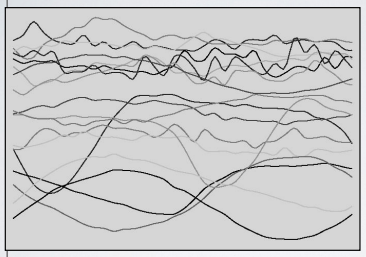
## Nature of Motion Data

17



Witkin and Popovic, 1995

Subset of motion curves from captured walking motion.

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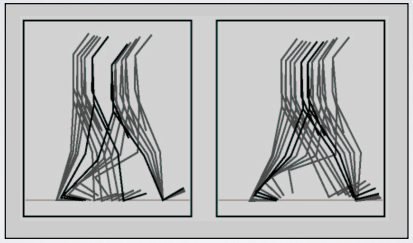
## Adjusting

18

- IK on single frames will not work



Gleicher, SIGGRAPH 98

18

## Adjusting

19

- Define desired motion function in parts

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

Adjustment

Inital sampled data

Result after adjustment

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## Adjusting

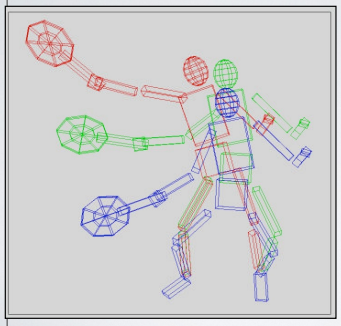
20

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

20

# Adjusting

21



IK uses control points of the B-spline now

Example:
position racket
fix right foot
fix left toes
balance

Witkin and Popovic SIGGRAPH 95

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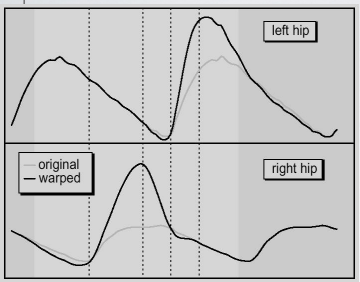
# Adjusting

22




Witkin and Popovic SIGGRAPH 95

What if adjustment periods overlap?

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## Blending

23

- 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

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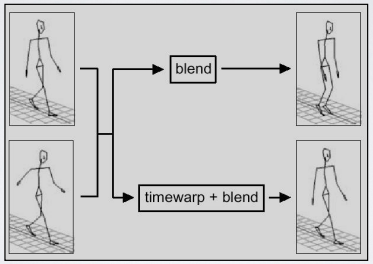
- Consider blending ***slow-walk*** and ***fast-walk***

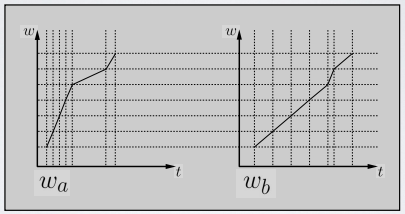



Bruderlin and Williams, SIGGRAPH 95

## Blending

25

- Define timewarp functions to align features in motion




Normalized time is $w$

25

## Blending

26

- Blend in normalized time

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

- Blend playback rate

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

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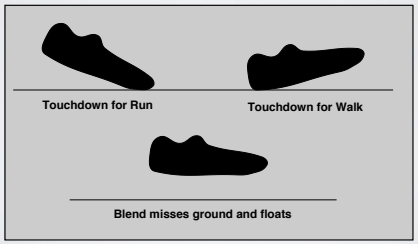
## Blending

27

- Blending may still break features in original motions




27

## Blending

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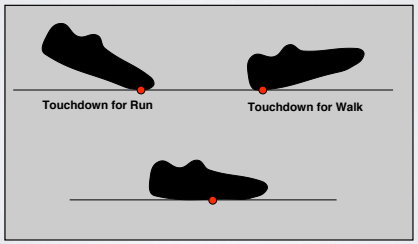
- Add explicit constrains to key points
  - Enforce with IK over time

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## Blending / Adjustment

29

- 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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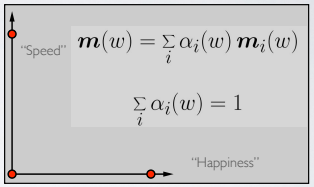
## Multivariate Blending

30

- Extend blending to multivariate interpolation

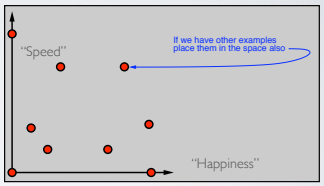



30

# Multivariate Blending

31

- Extend blending to multivariate interpolation




Use standard scattered-data interpolation methods

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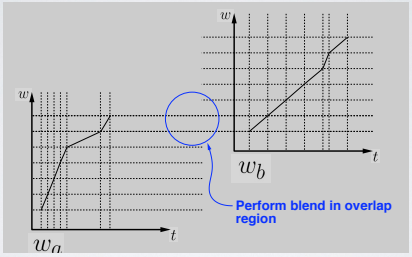
# Transitions

32

- Transition from one motion to another

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## Cyclification

33

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

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## Transition Graphs

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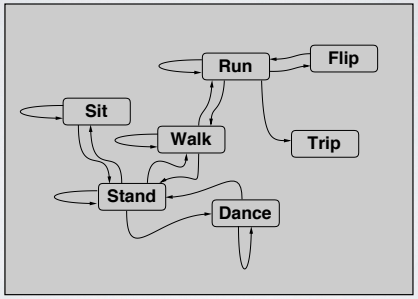


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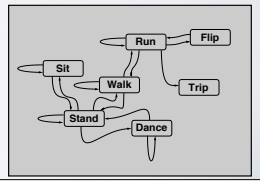
## Motion Graphs

35

- Hand build motion graphs often used in games
  - Significant amount of work required
  - Limited transitions by design
- Motion graphs can also be built automatically

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## Motion Graphs

36

- 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

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# Motion Graphs

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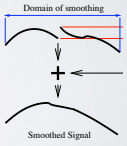
- Random walks
  - Start in some part of the graph and randomly make transitions
  - Avoid dead ends
  - Useful for "idling" behaviors
- Transitions
  - Use blending algorithm

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# Motion graphs

38

- 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

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## Typical Motion Graph

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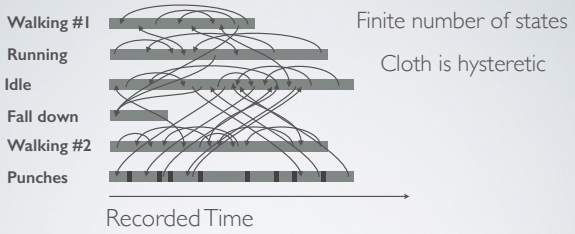


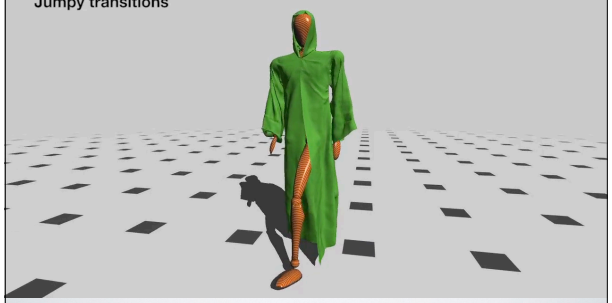

Finite number of states

Cloth is hysteretic

## Naïve Precomputation

40

Initially computed cloth motion
**Jumpy transitions**



## Graph Unrolling

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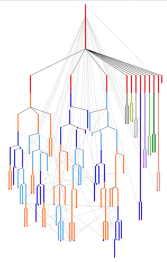
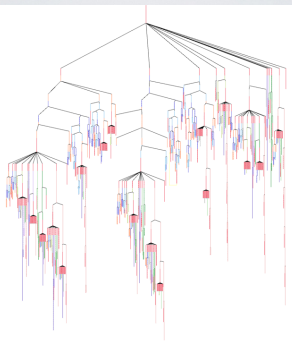


## Graph Unrolling

42



## Graph Unrolling

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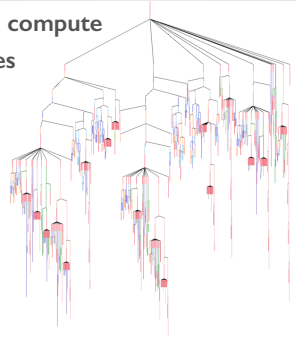
**5000 hours compute**
**100K frames**
**330 GB**



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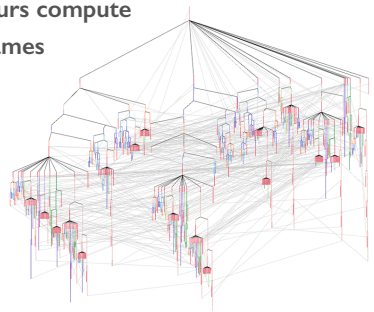

## Precomputed Cloth

45

72 MB Compressed
Laptop 60 fps
Low CPU load

## Precomputed Cloth

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## Precomputed Simulation

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- 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?

## Suggested Reading

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- 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.