CS 283
Advanced Computer Graphics

Motion Capture

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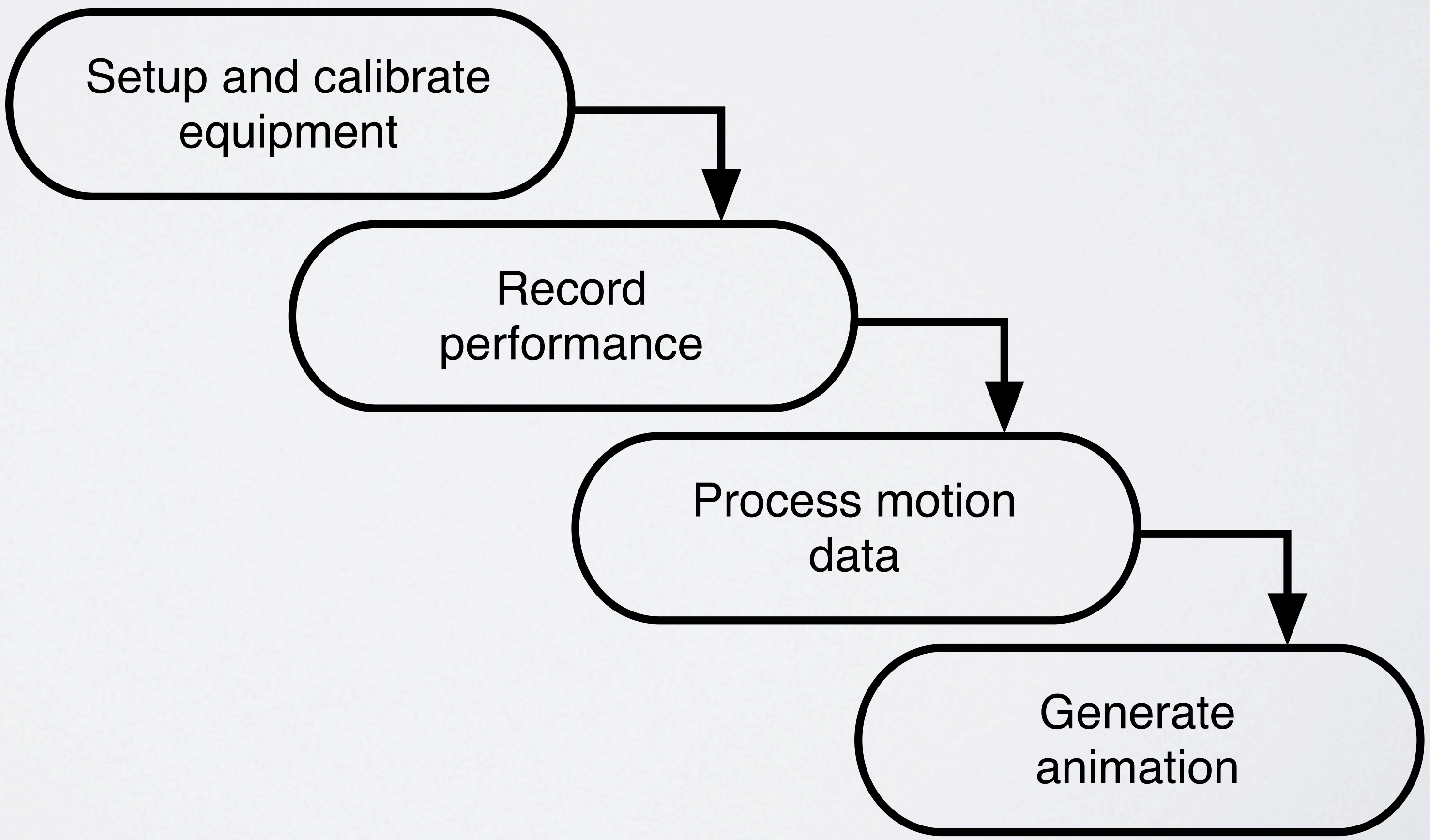
Motion Capture

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

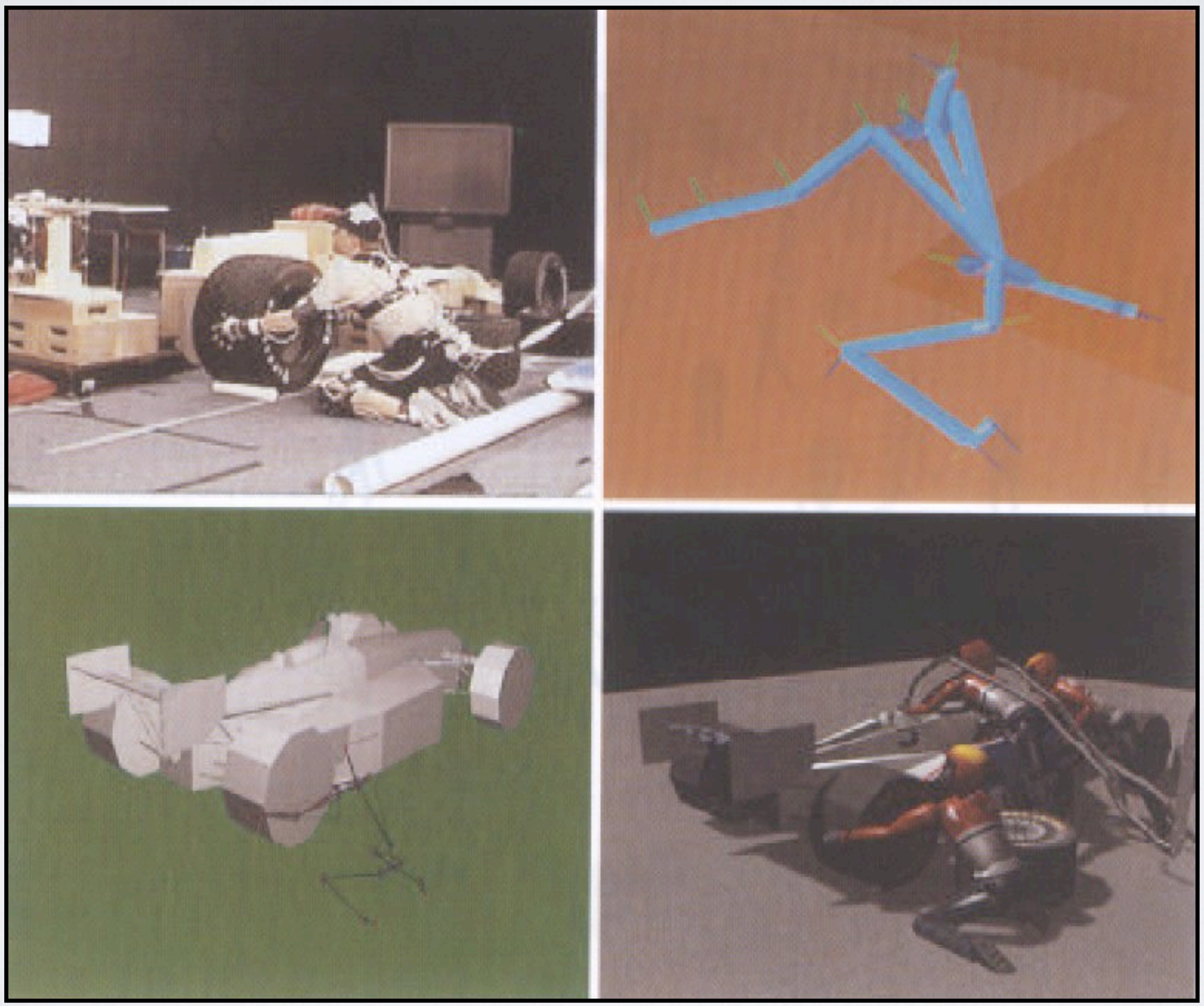
Simplified Pipeline:



Basic Pipeline

Setup

Record



Process

Animatio
n

From Rose, ***et al.,*** 1998

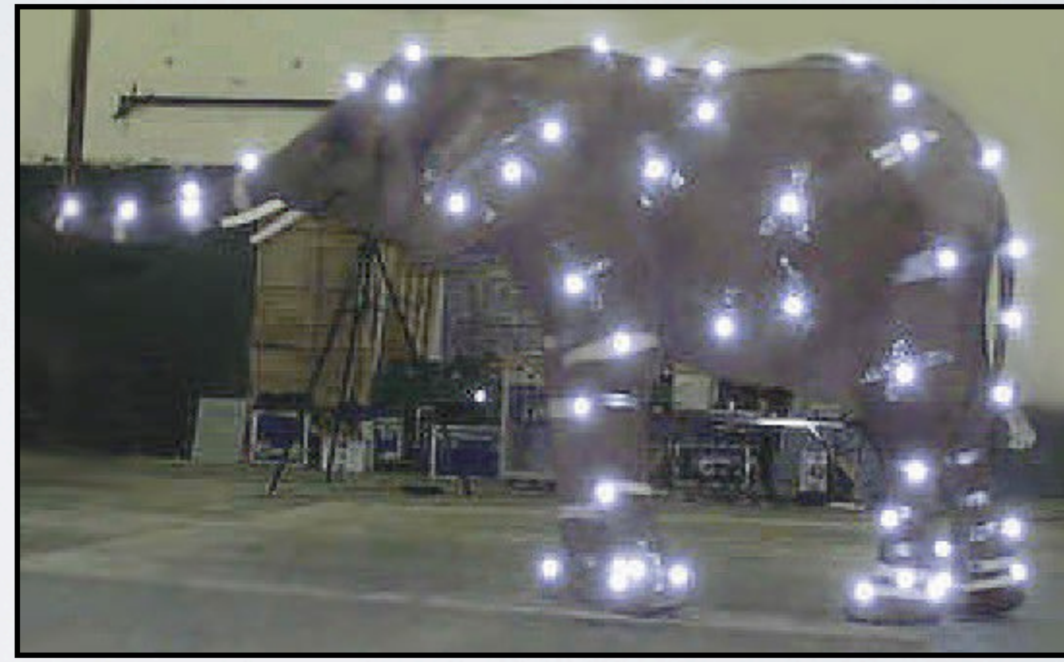
Captures "Signature" of Actor

What types of objects?

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

Capture Equipment

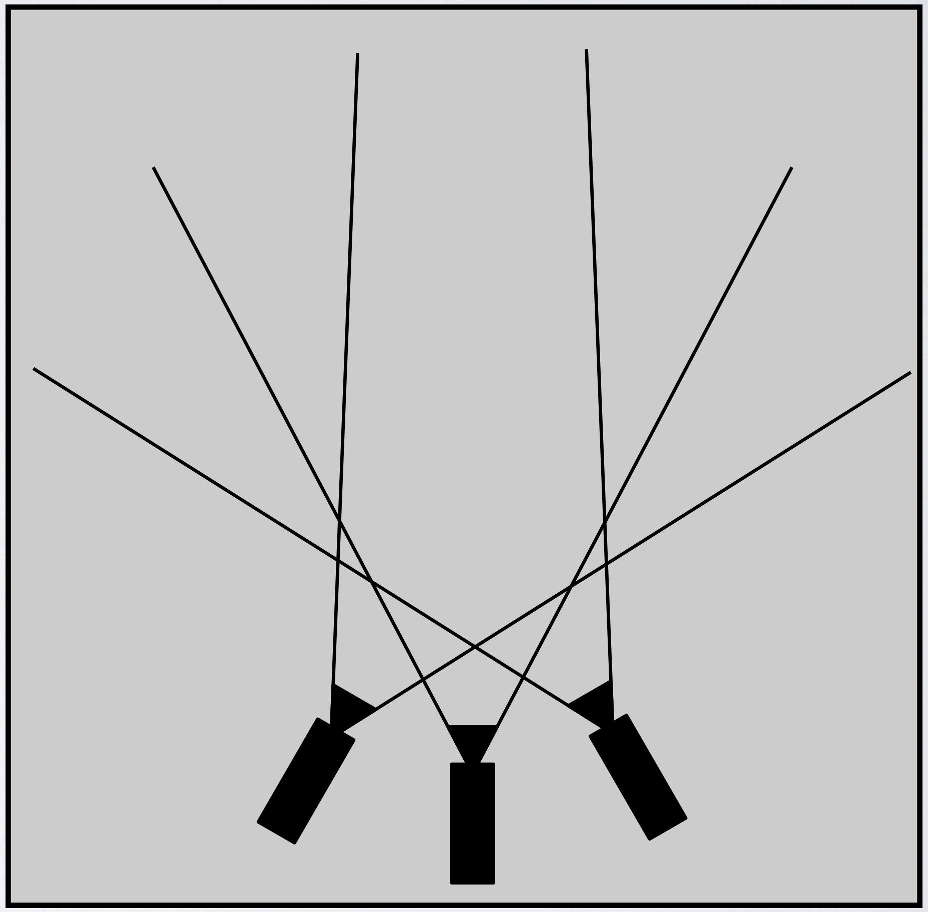
- Passive Optical
  - Reflective markers
  - IR (typically) illumination
  - Special cameras
    - Fast, high res., filters
  - Triangulate for positions



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

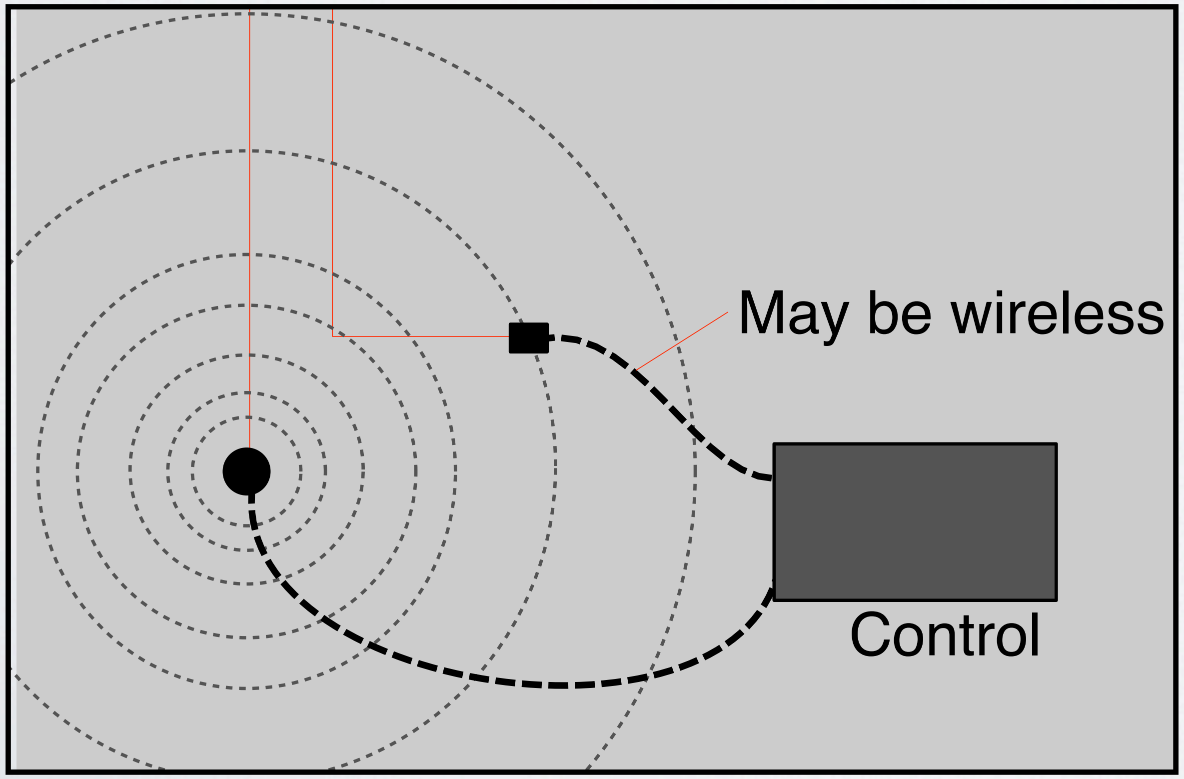
- Active Optical
  - Similar to passive but uses LEDs
  - Blink IDs, no marker swap
  - Number of markers trades off w/ frame rate

Phoenix Technology

Phase Space

Capture Equipment

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

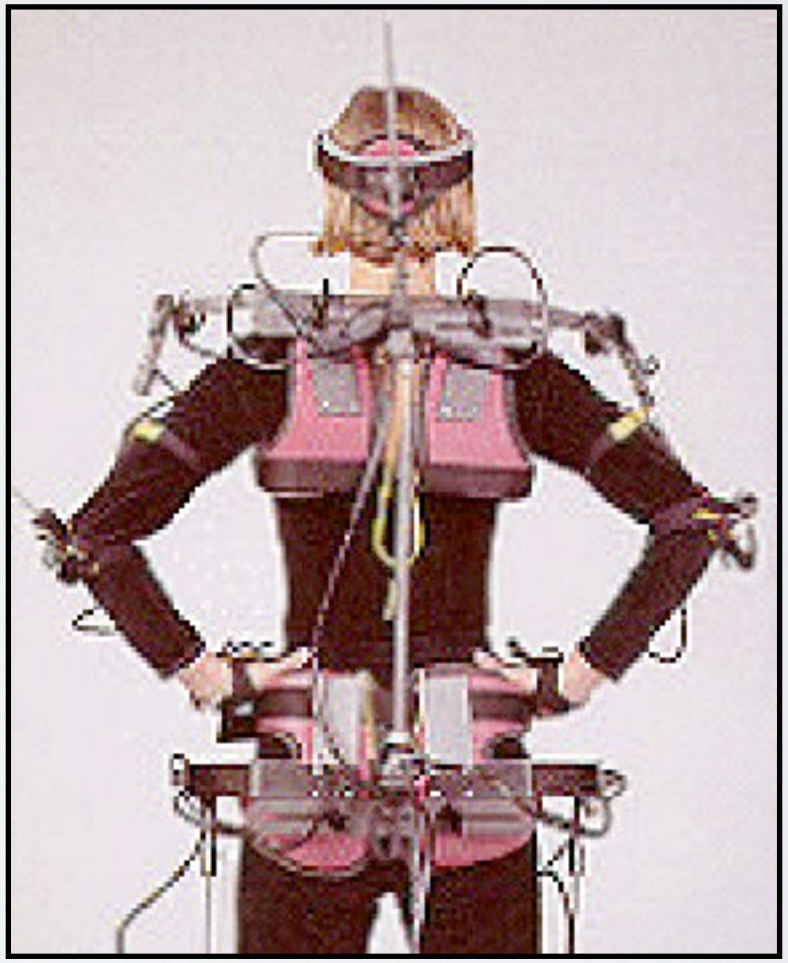


Capture Equipment

- 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

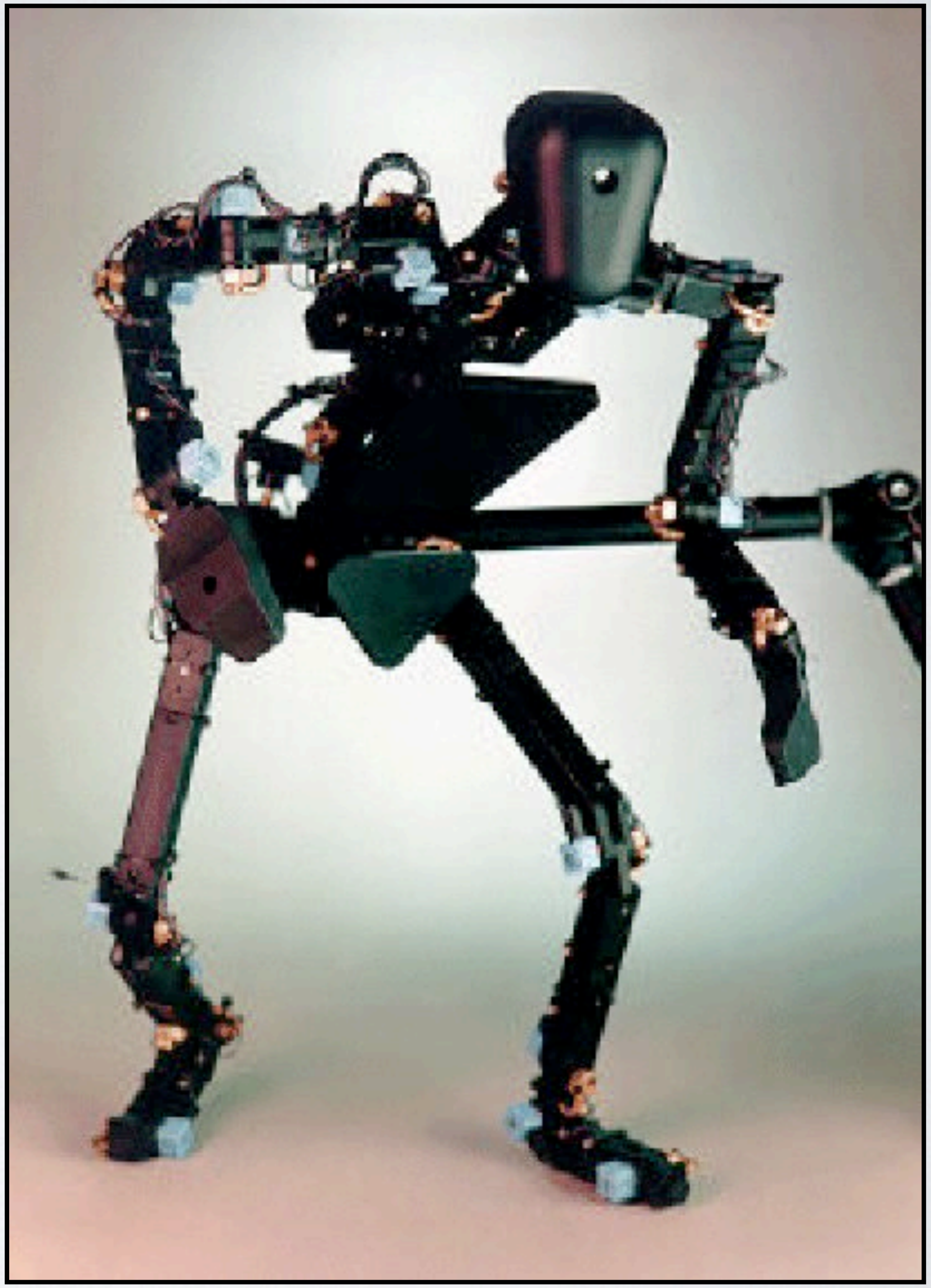
- Electromechanical



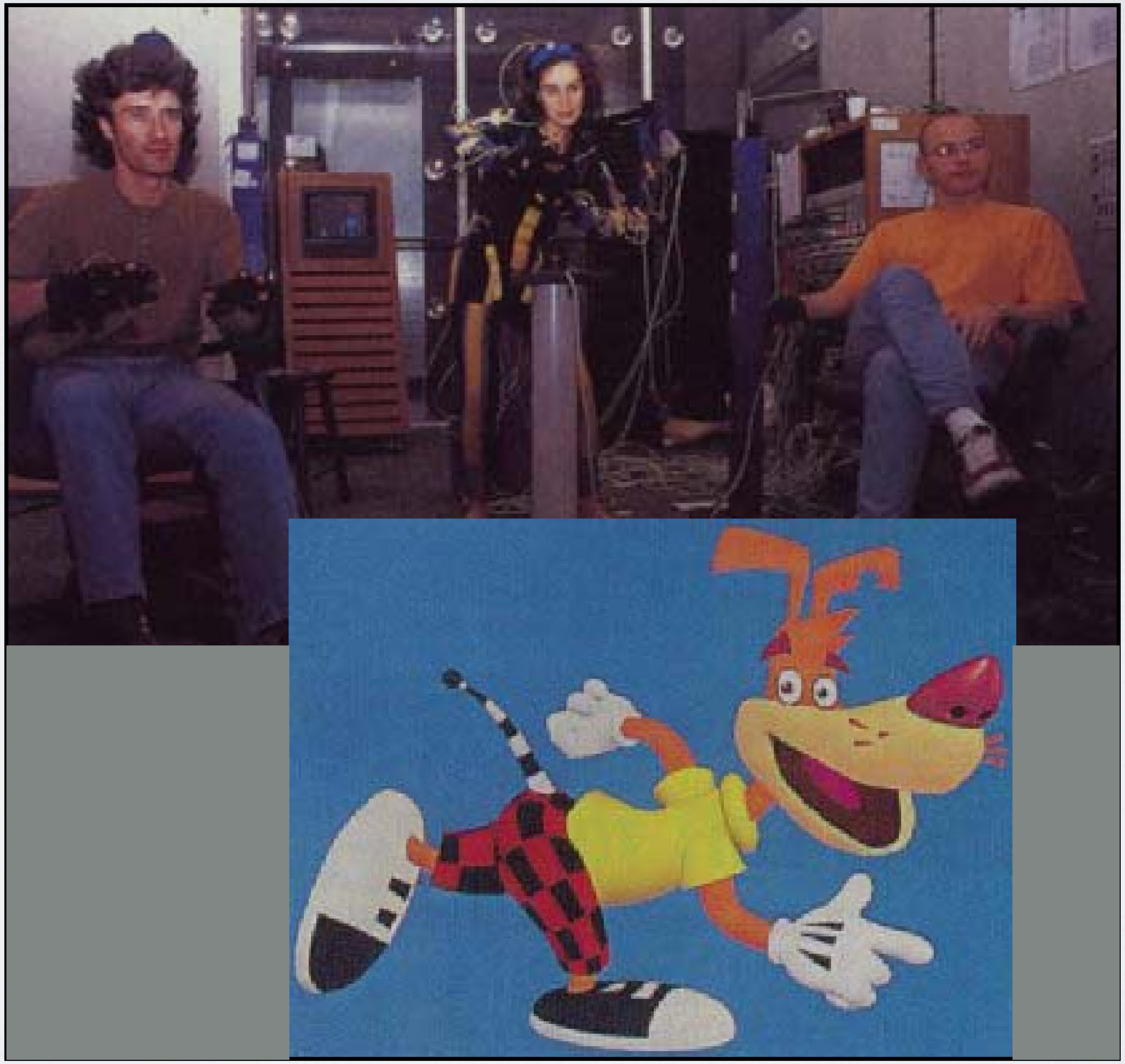
Analogus

Capture Equipment

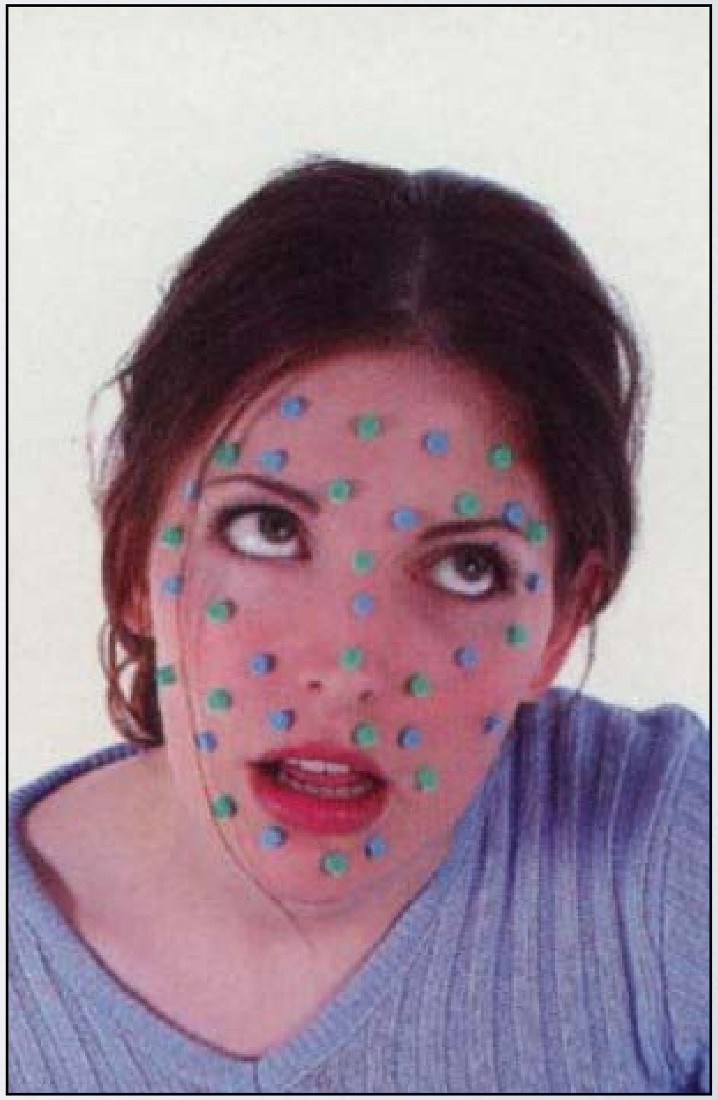
- Puppets



Realtime Systems



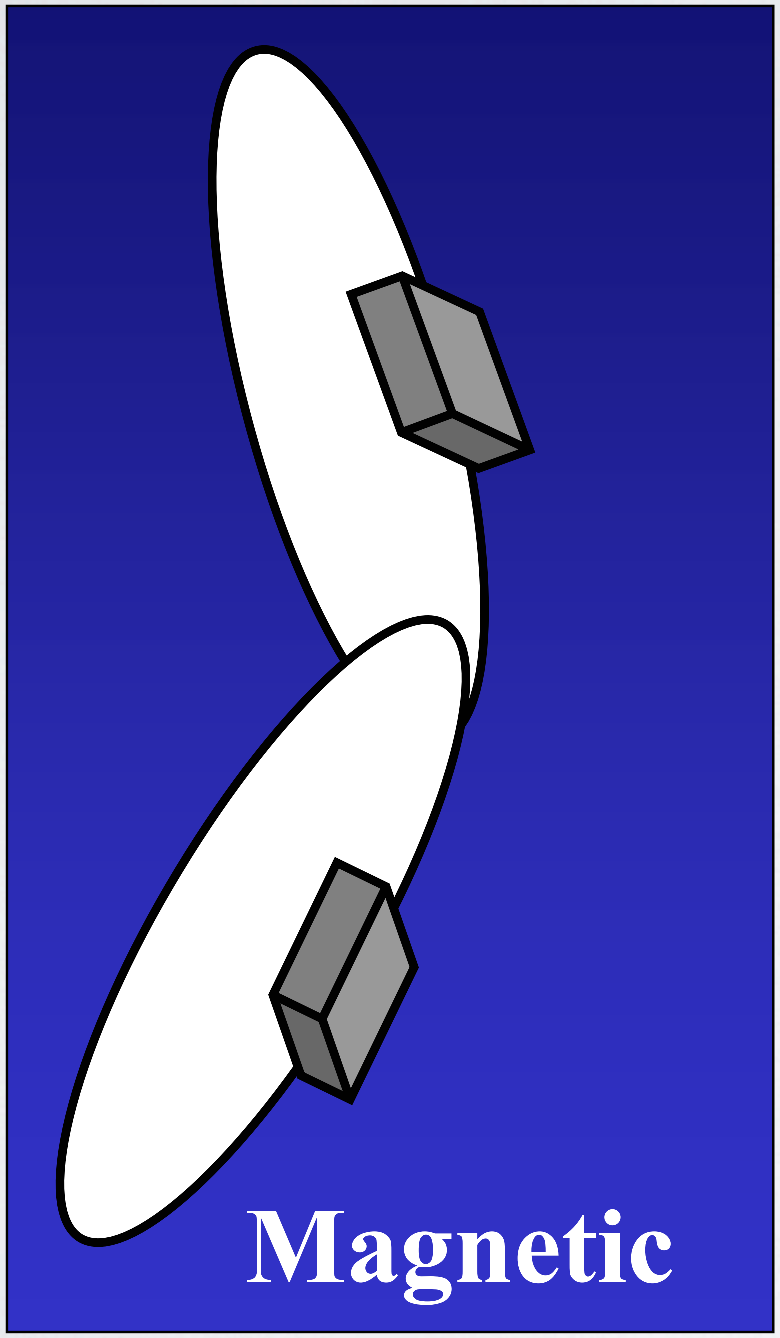
Facial Mocap

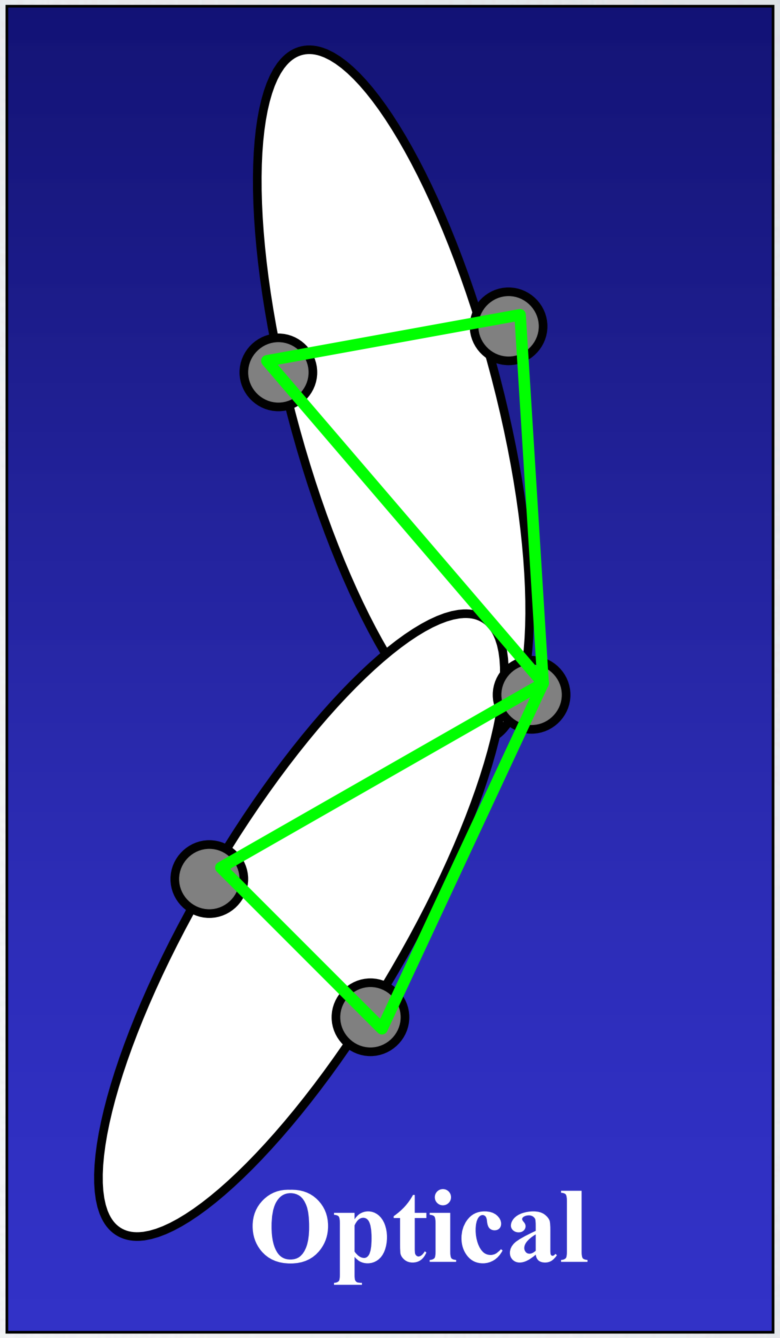


Performance Capture

- 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

Different Data

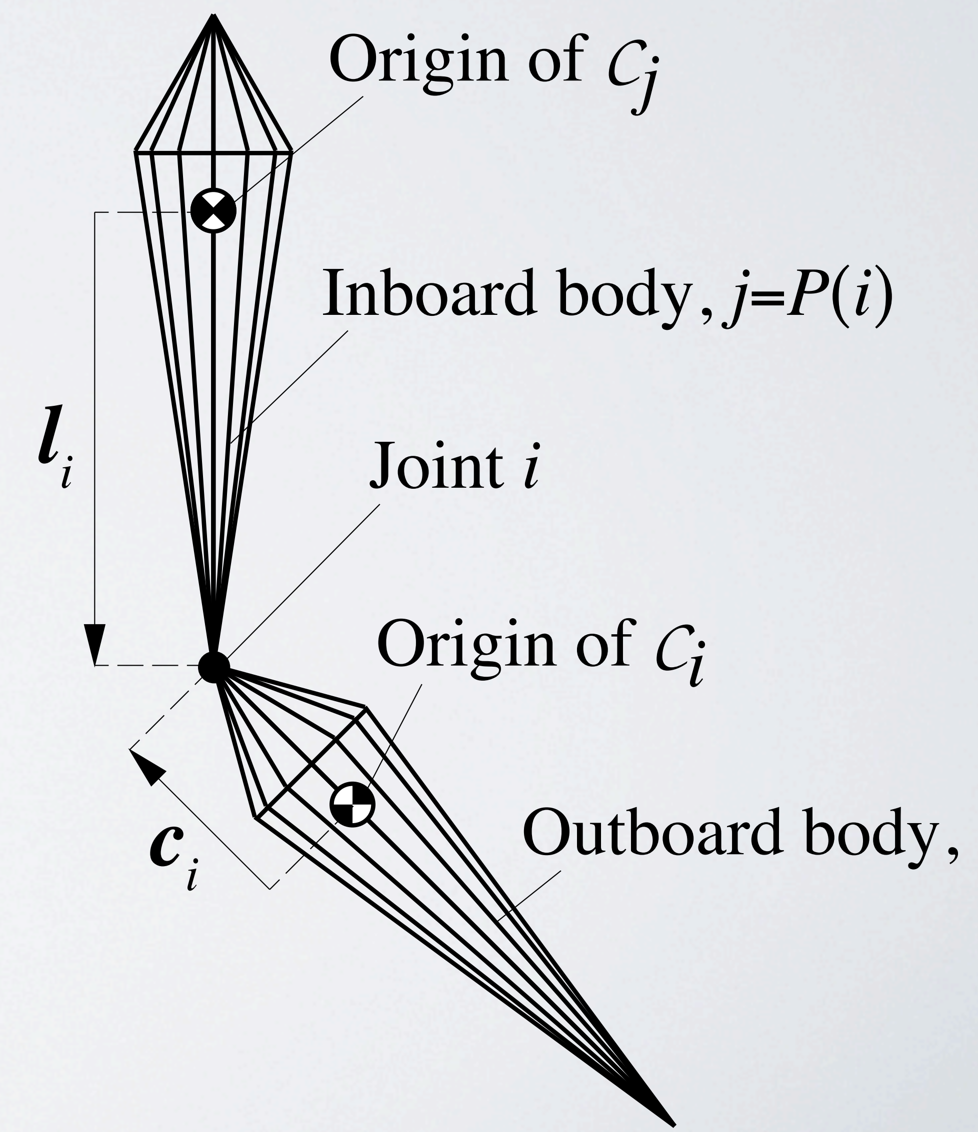




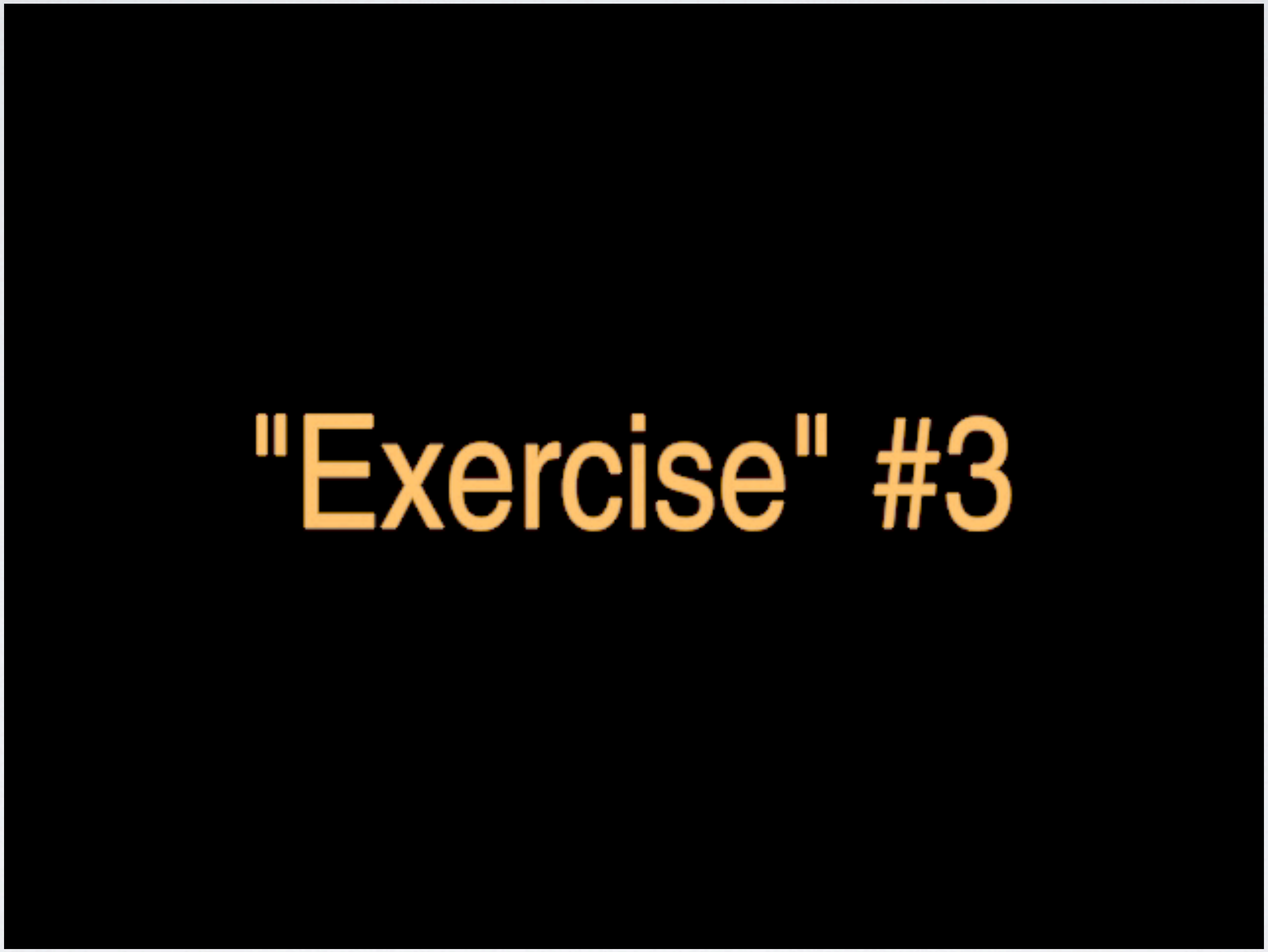
Auto Calibration

$$\mathbf{R}_k^{i\rightarrow\omega}\mathbf{c}_i + \mathbf{t}_k^{i\rightarrow\omega} = \mathbf{R}_k^{P(i)\rightarrow\omega}\mathbf{l}_i + \mathbf{t}_k^{P(i)\rightarrow\omega}$$

$$\begin{bmatrix} \mathbf{Q}_0^{i\rightarrow P(i)} \\ \vdots \\ \mathbf{Q}_k^{i\rightarrow P(i)} \\ \vdots \\ \mathbf{Q}_{n-1}^{i\rightarrow P(i)} \end{bmatrix} \begin{bmatrix} \mathbf{c}_i \\ \mathbf{l}_i \end{bmatrix} = \begin{bmatrix} \mathbf{d}_0^{i\rightarrow P(i)} \\ \vdots \\ \mathbf{d}_k^{i\rightarrow P(i)} \\ \vdots \\ \mathbf{d}_{n-1}^{i\rightarrow P(i)} \end{bmatrix}$$



Auto Calibration



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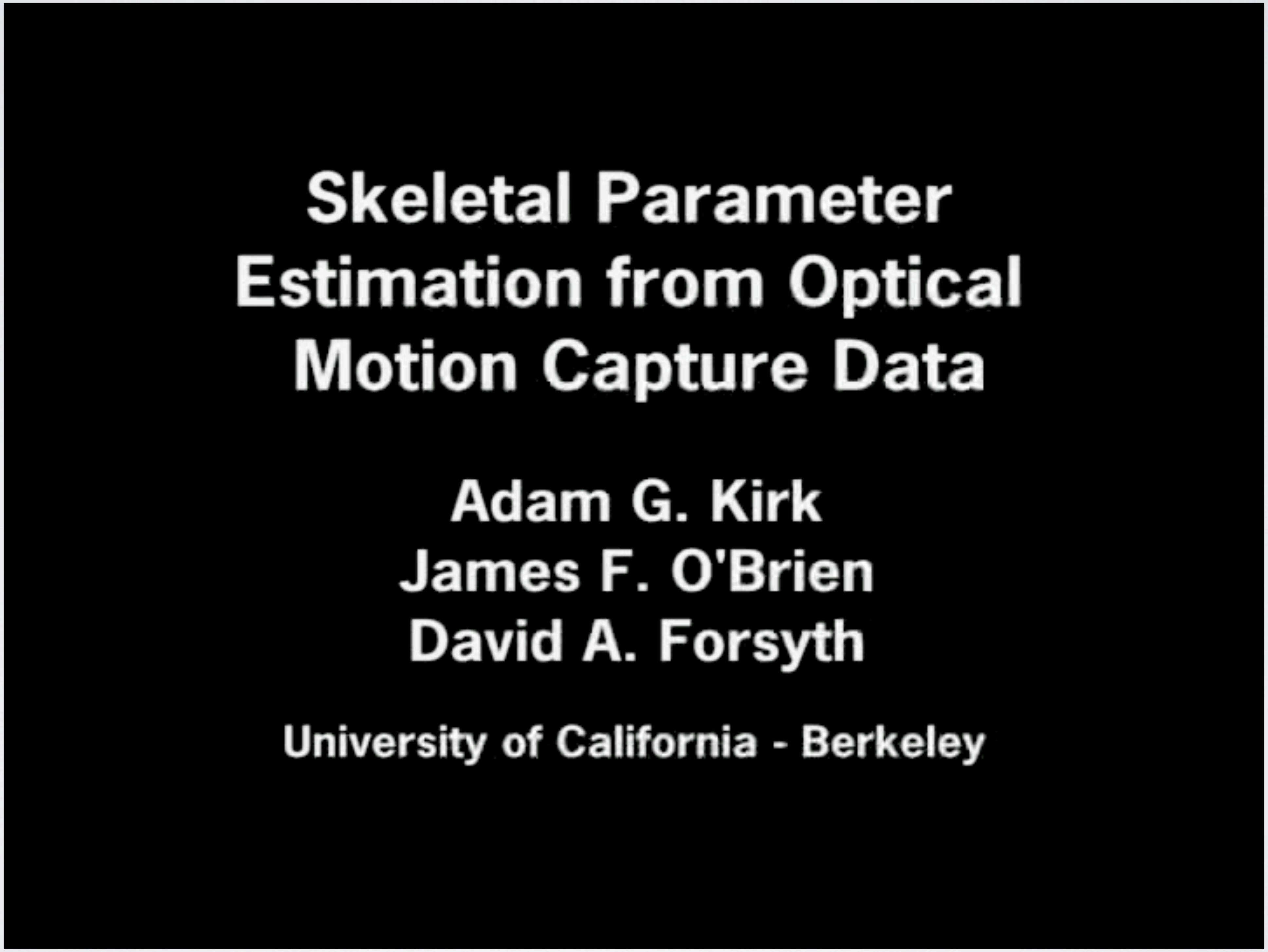
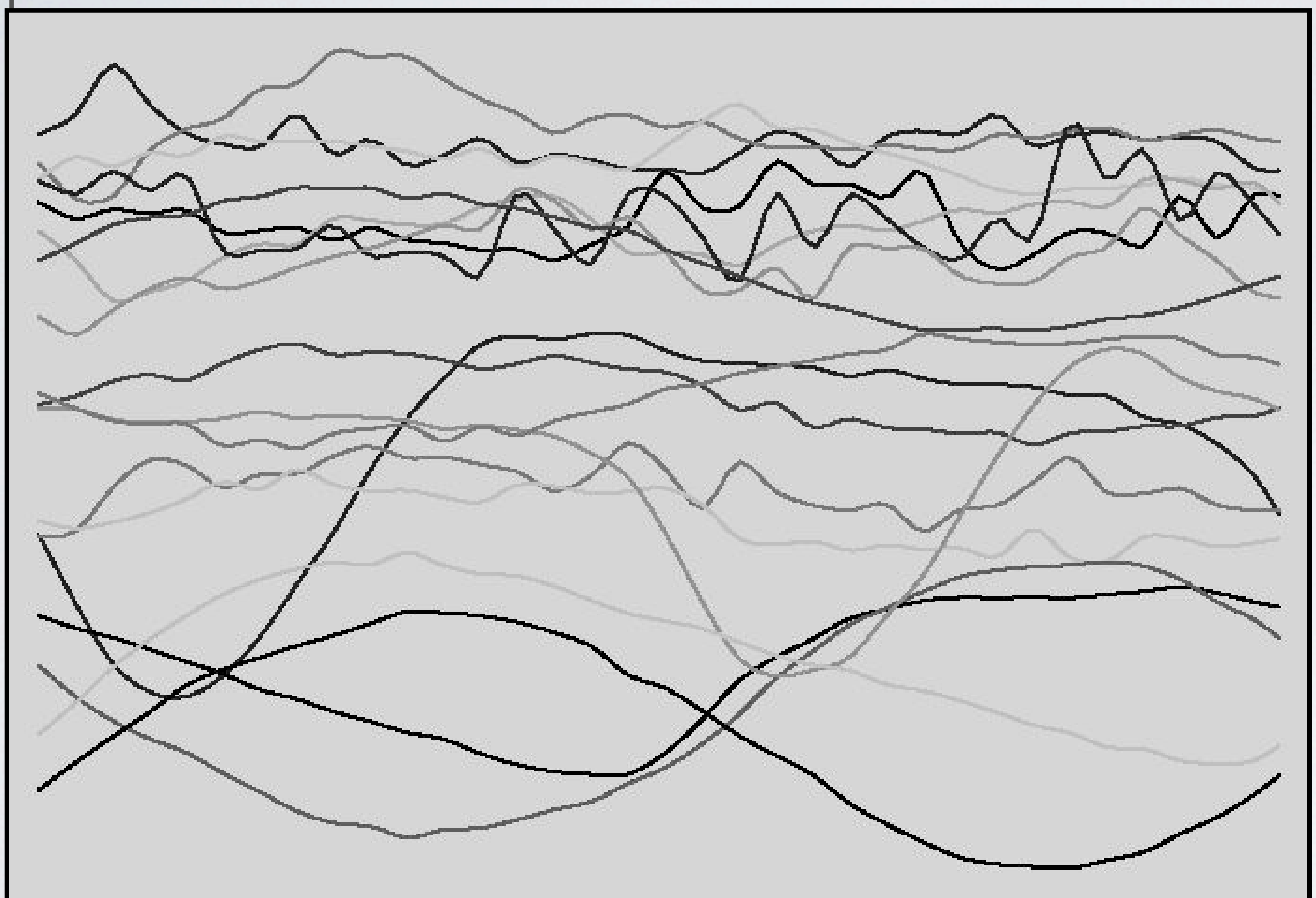


Manipulating Motion Data

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

Nature of Motion Data

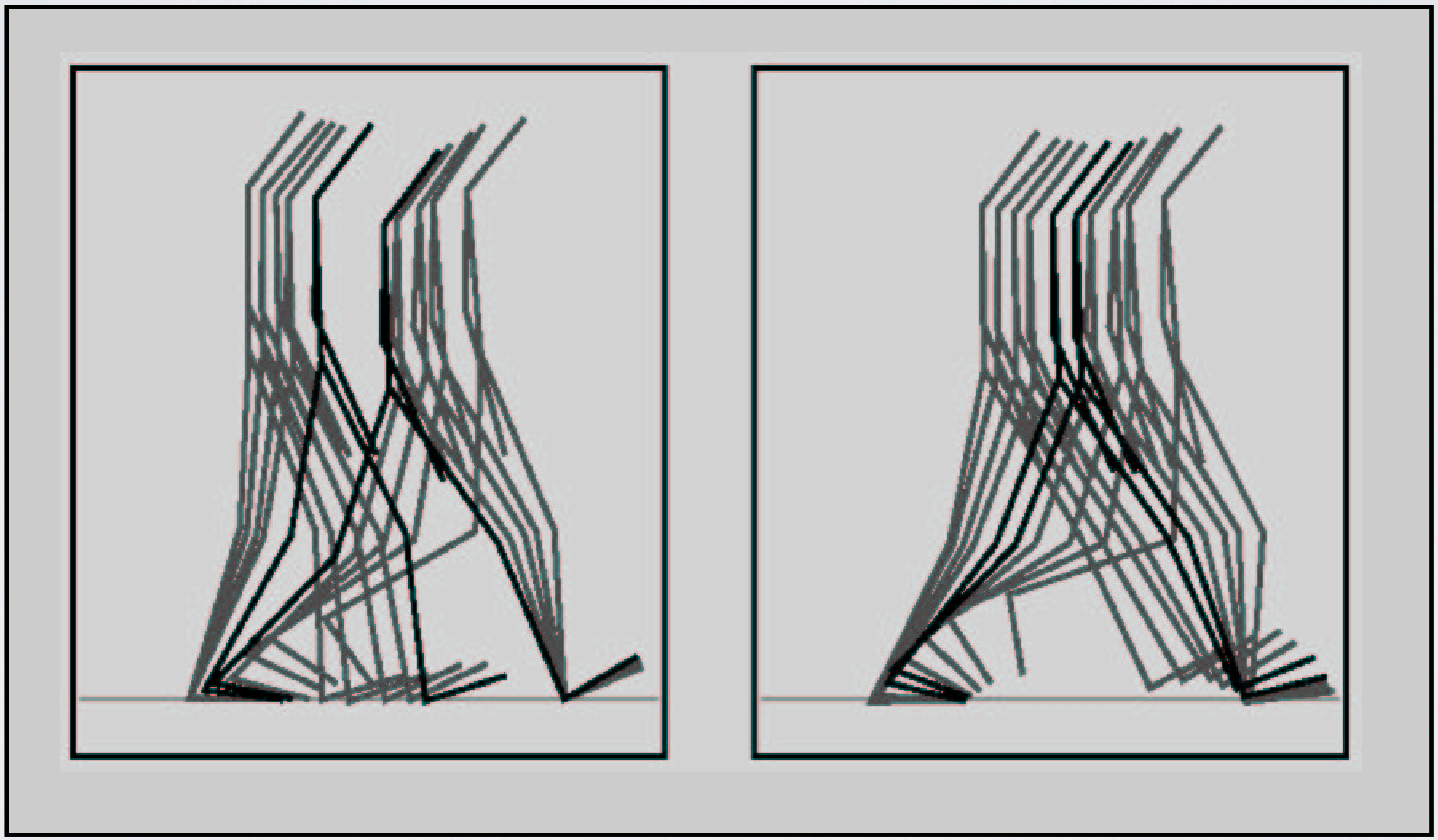


Witkin and Popovic, 1995

Subset of motion curves from captured walking motion.

Adjusting

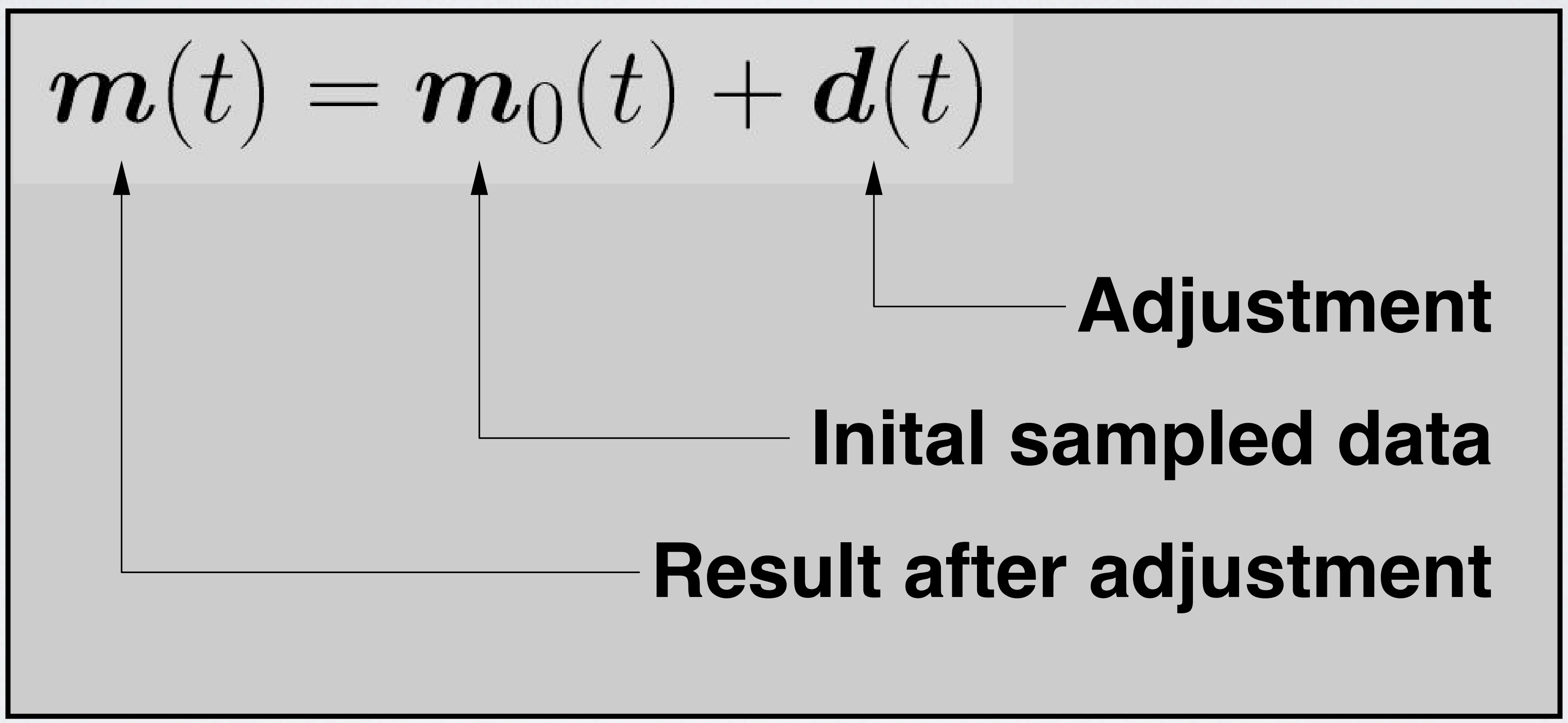
- IK on single frames will not work



Gleicher, SIGGRAPH 98

Adjusting

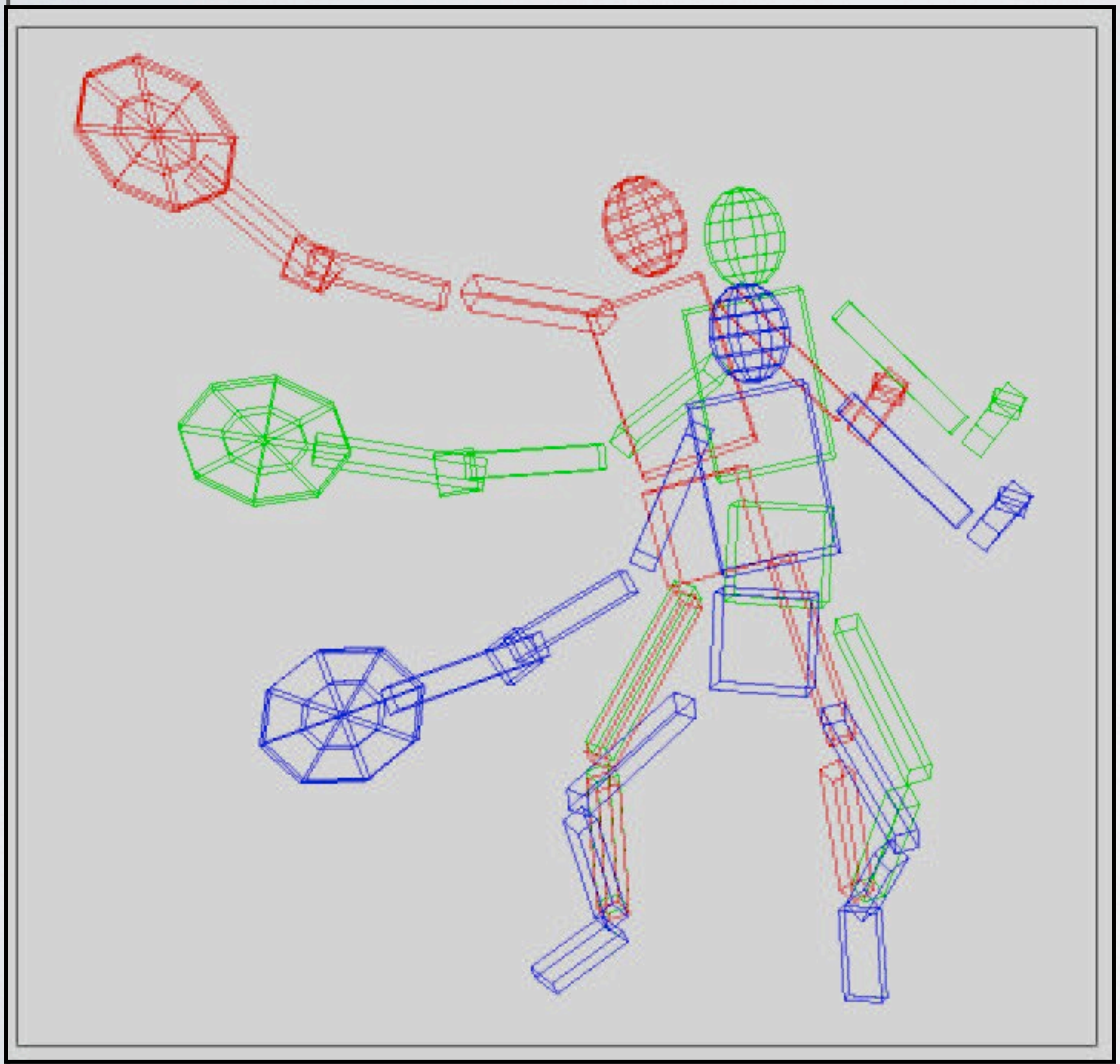
- Define desired motion function in parts



Adjusting

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

Adjusting



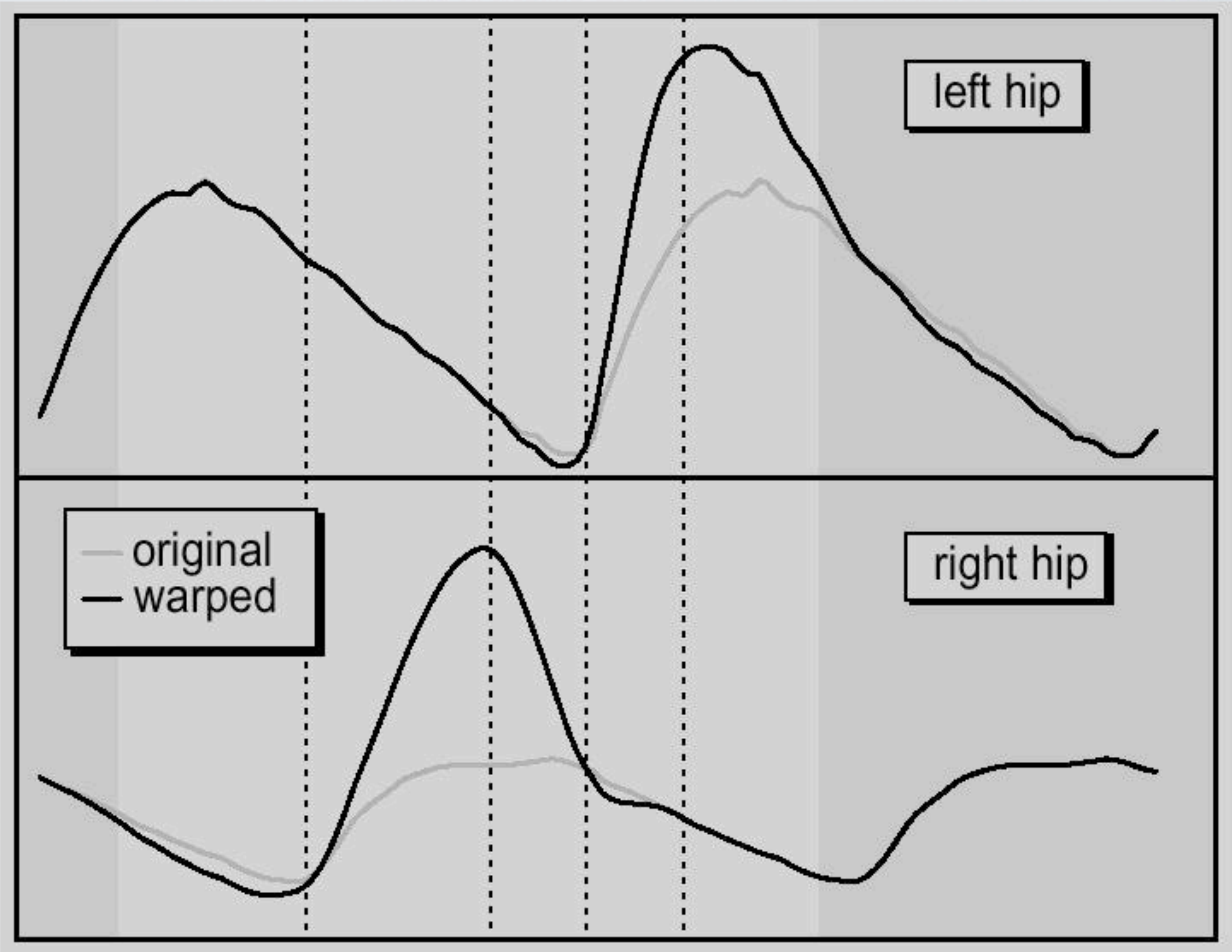
IK uses control points of the B-spline now

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

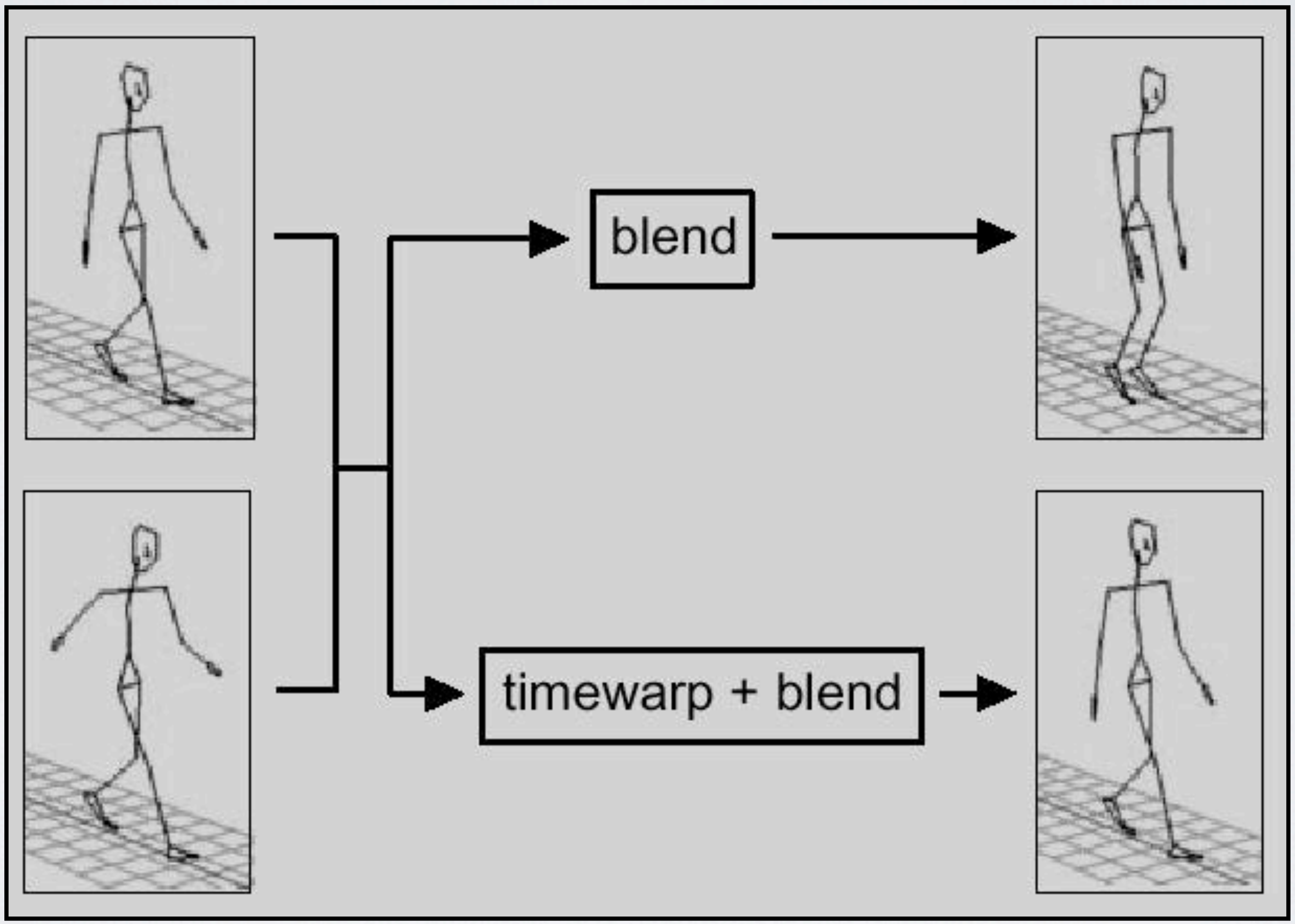
- Given two motions make a motion that combines qualities of both

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

- Assume same DOFs
- Assume same parameter mappings

Blending

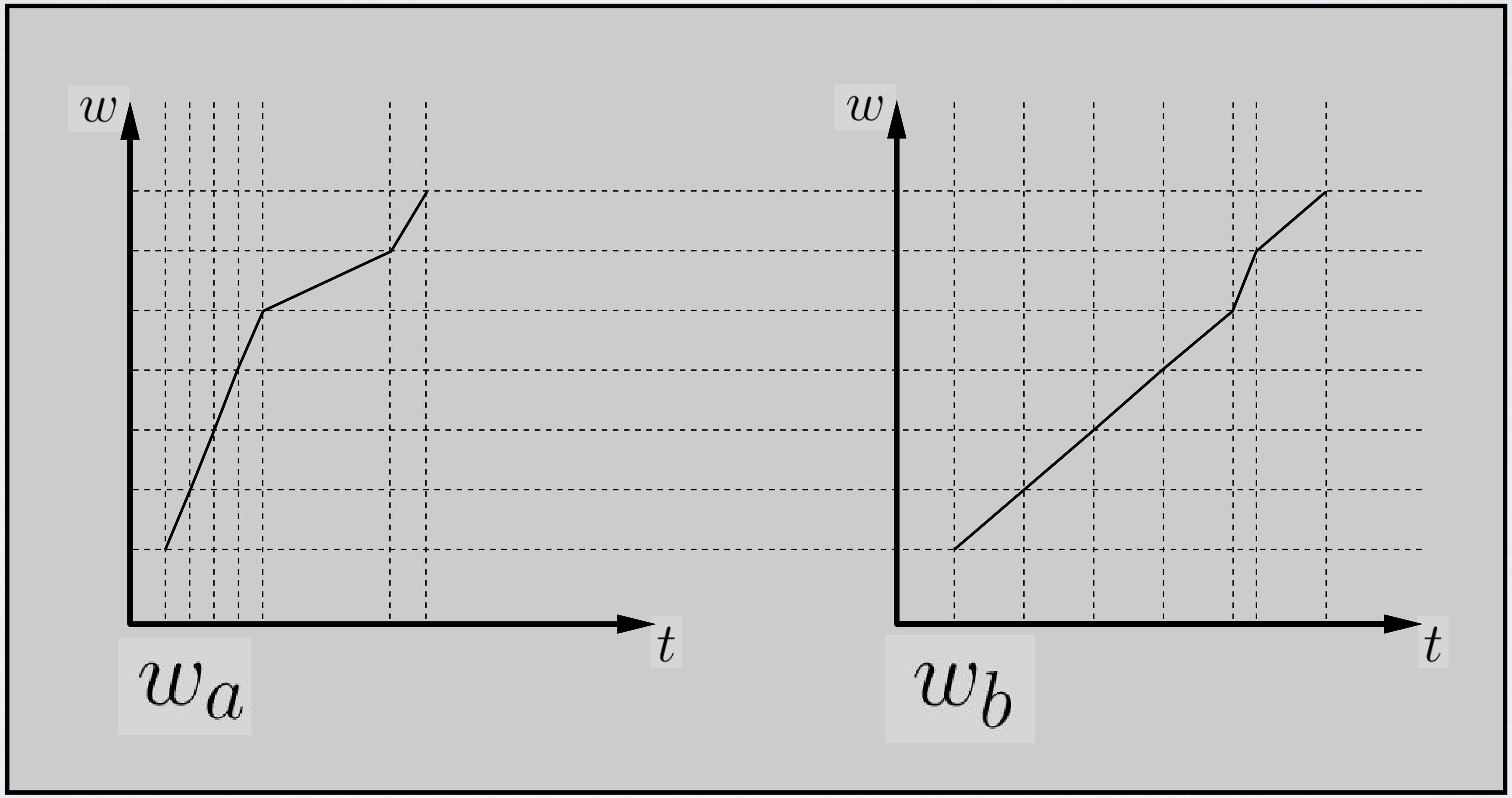
- Consider blending ***slow-walk*** and ***fast-walk***



Bruderlin and Williams, SIGGRAPH 95

Blending

- Define timewarp functions to align features in motion



Normalized time is *w*

Blending

- Blend in normalized time

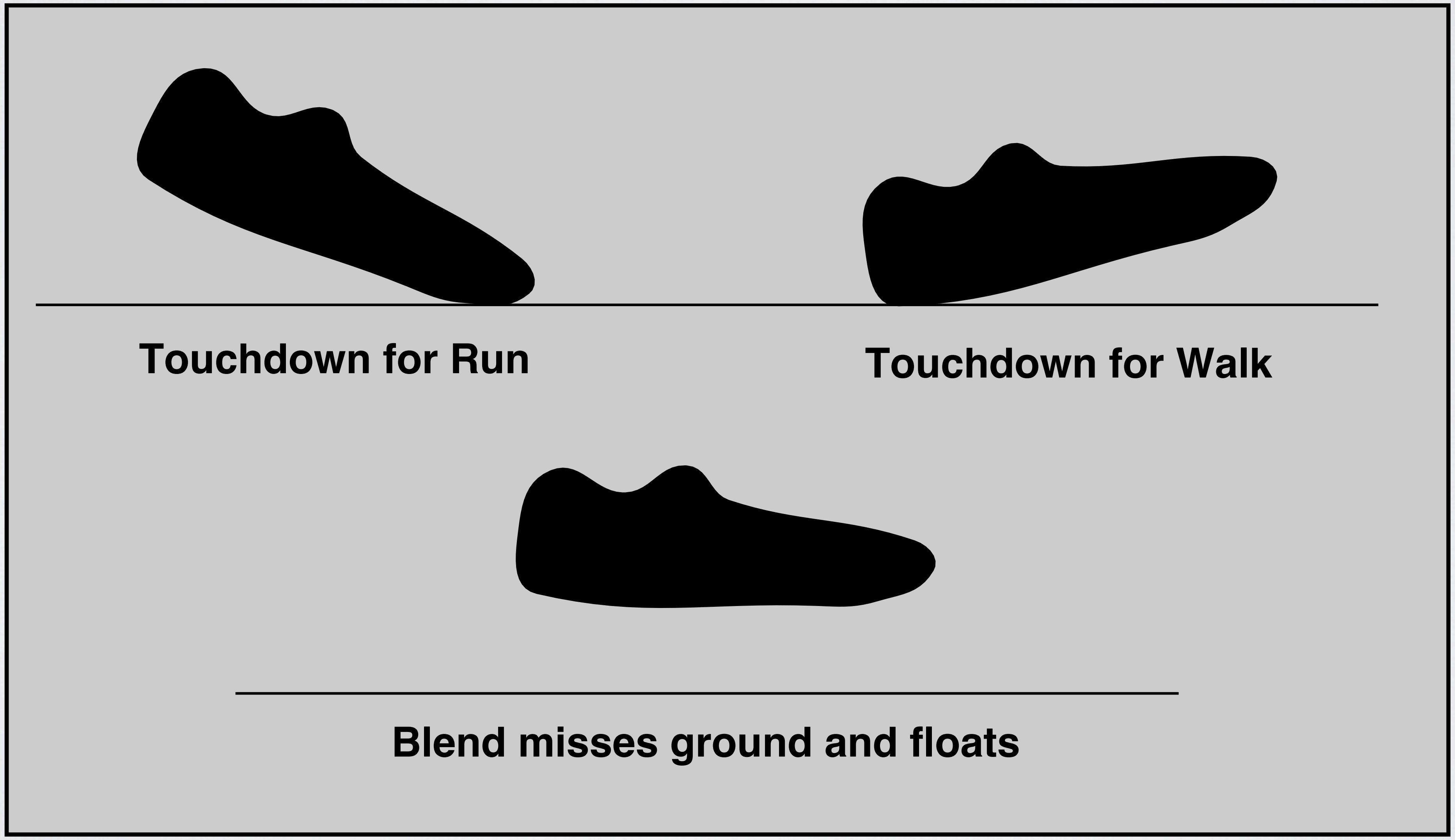
$$\boldsymbol{m}_\alpha(w) = \alpha \boldsymbol{m}_a(w_a) + (1-\alpha)\boldsymbol{m}_b(w_b)$$

- Blend playback rate

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

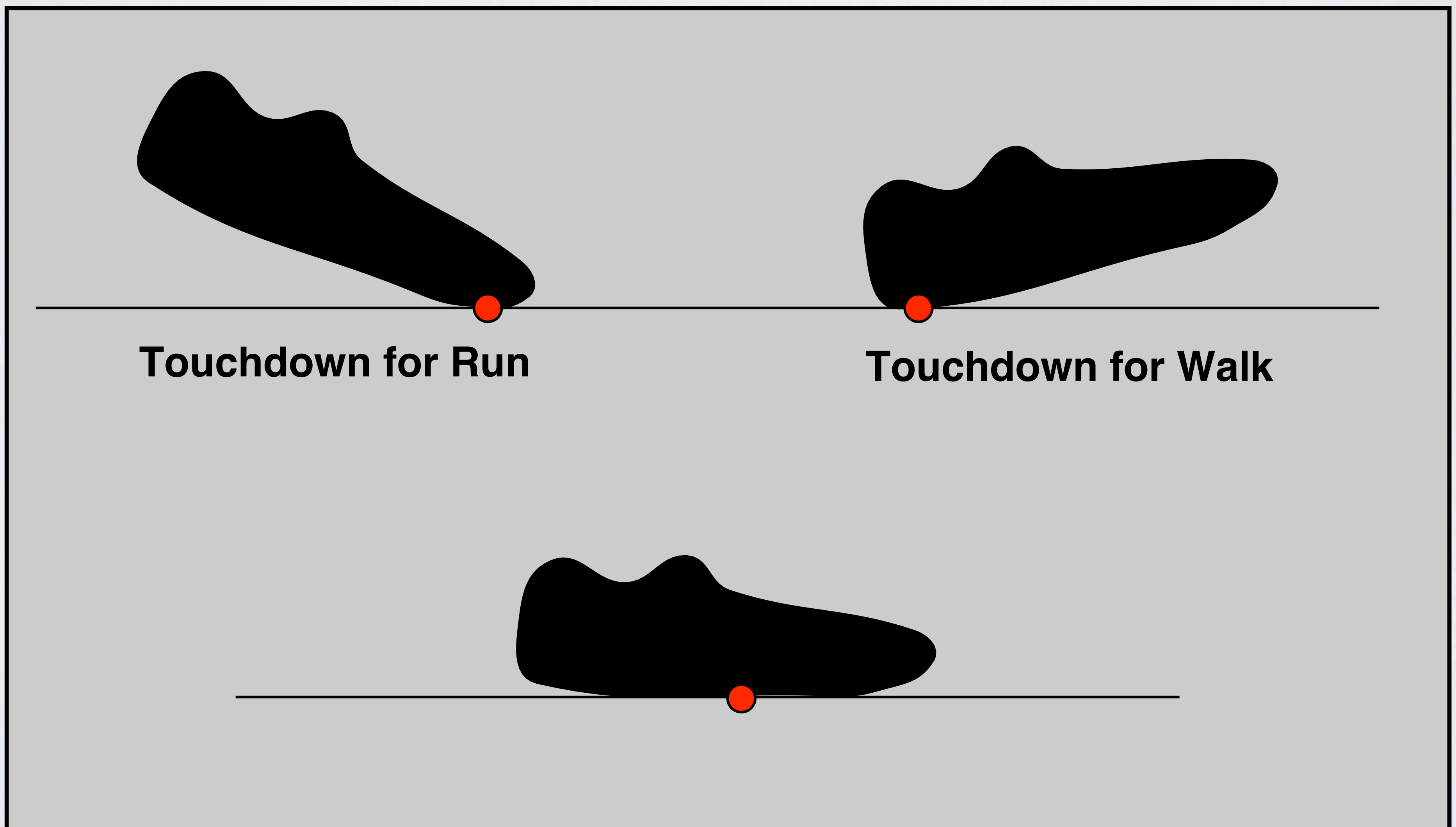
Blending

- Blending may still break features in original motions



Blending

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

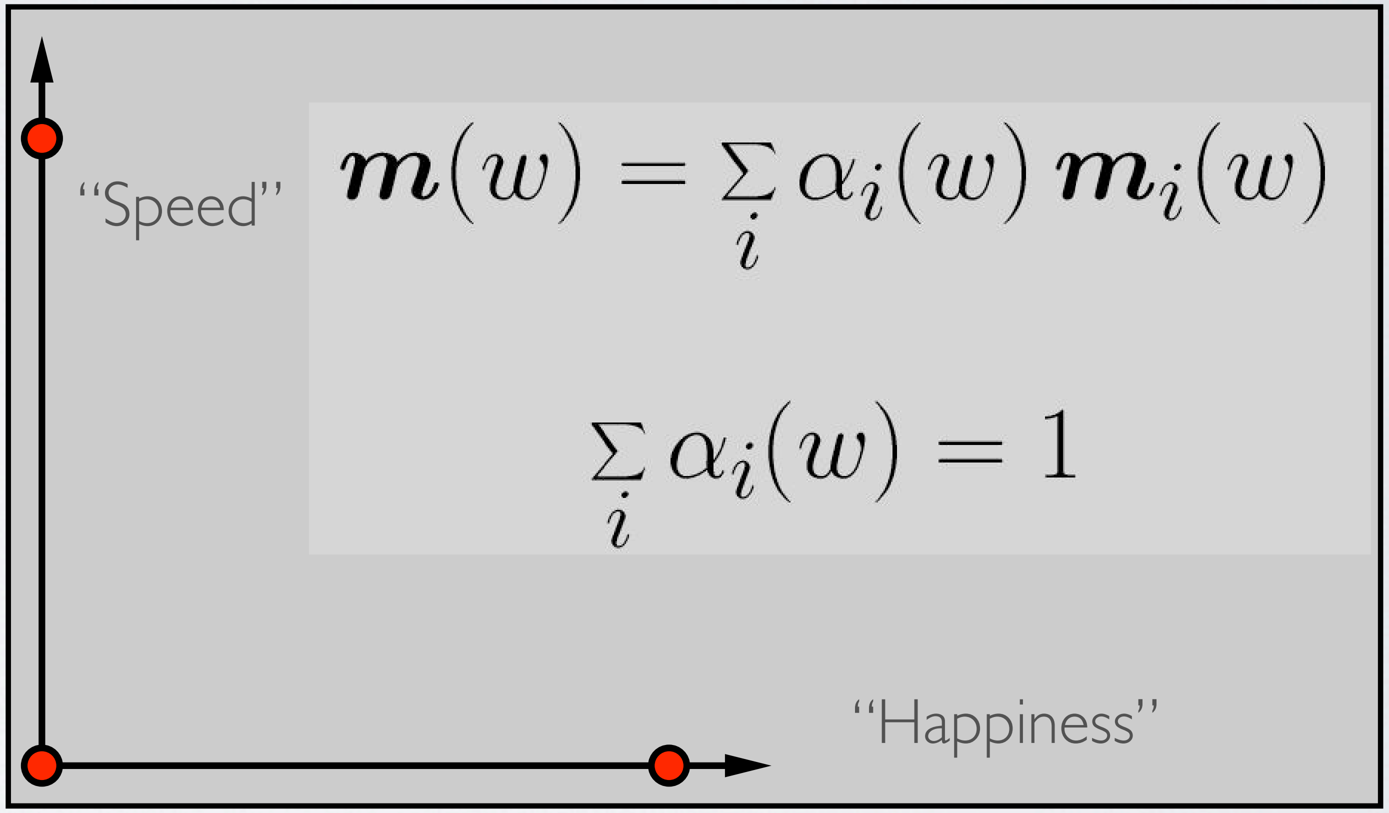


Blending / Adjustment

- 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

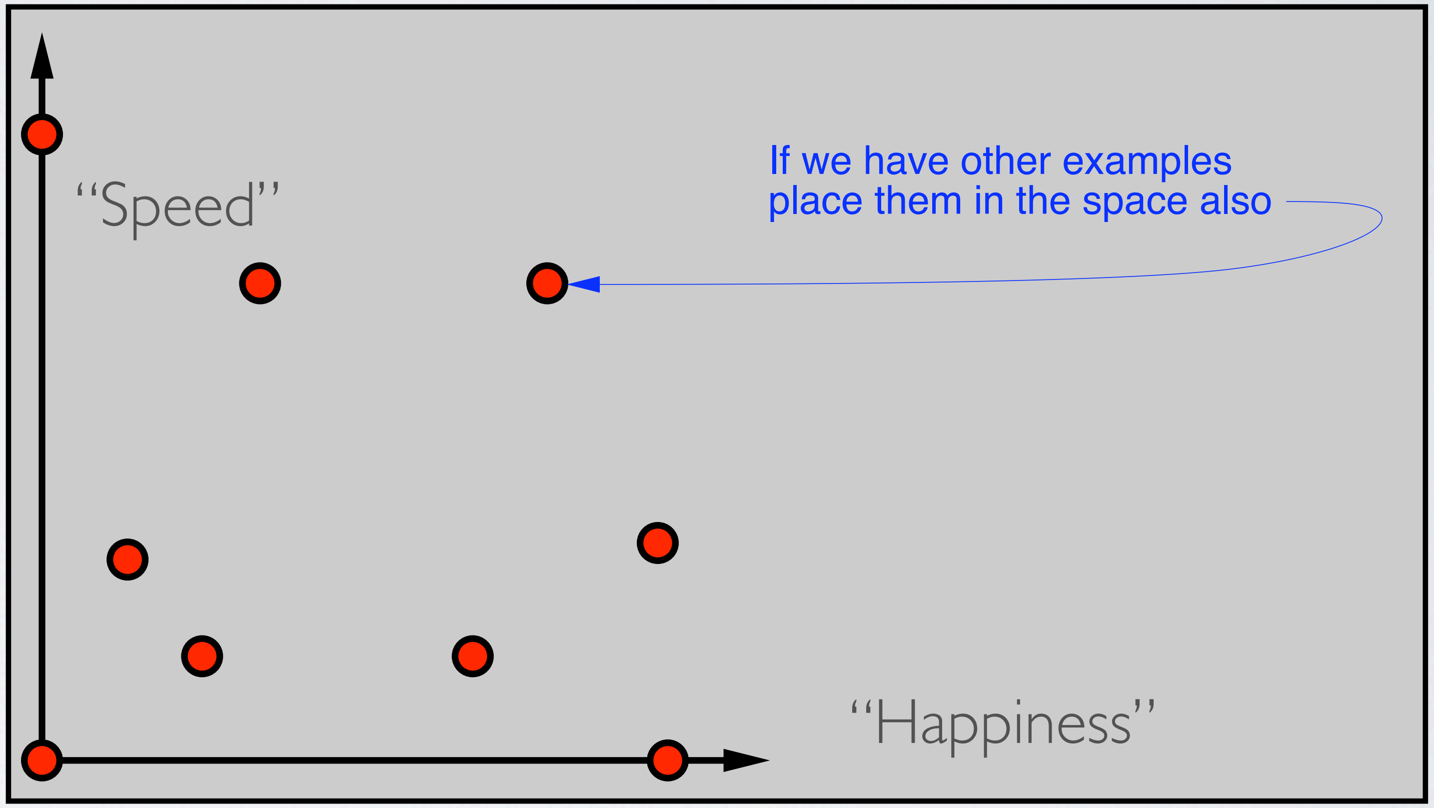


$$\boldsymbol{m}(w) = \sum_i \alpha_i(w)\, \boldsymbol{m}_i(w)$$

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

Multivariate Blending

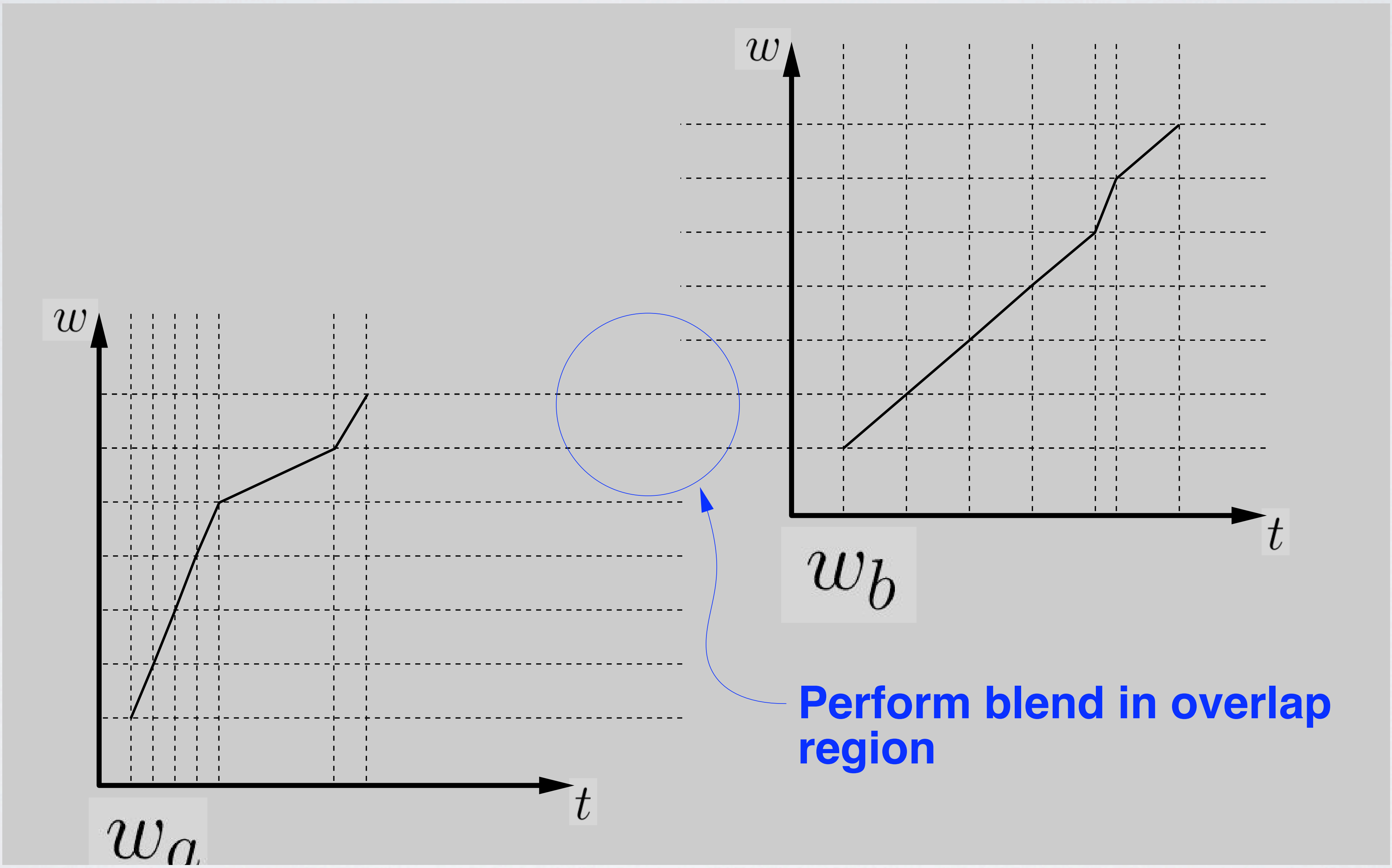
- Extend blending to multivariate interpolation



Use standard scattered-data interpolation methods

Transitions

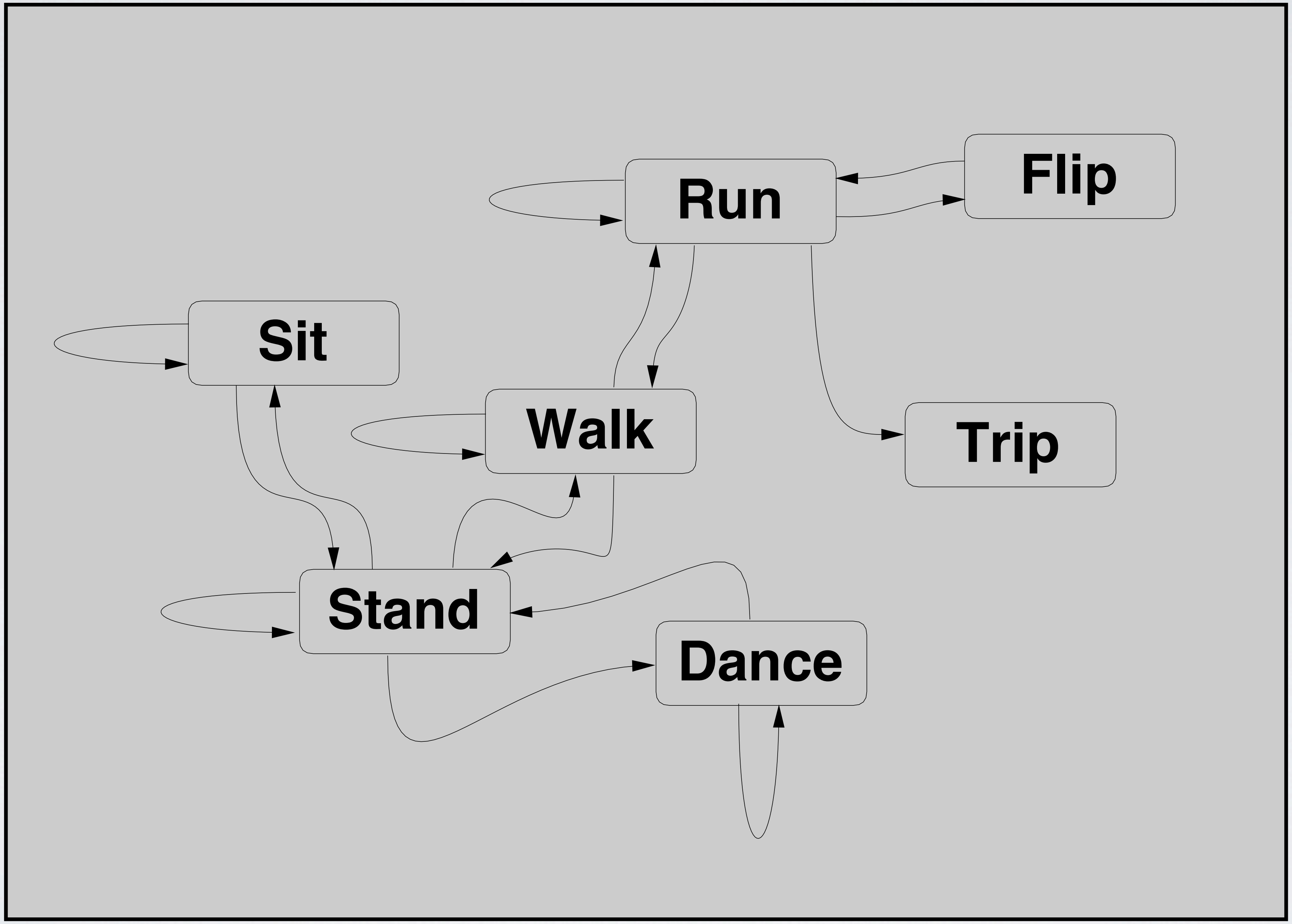
- Transition from one motion to another



Cyclification

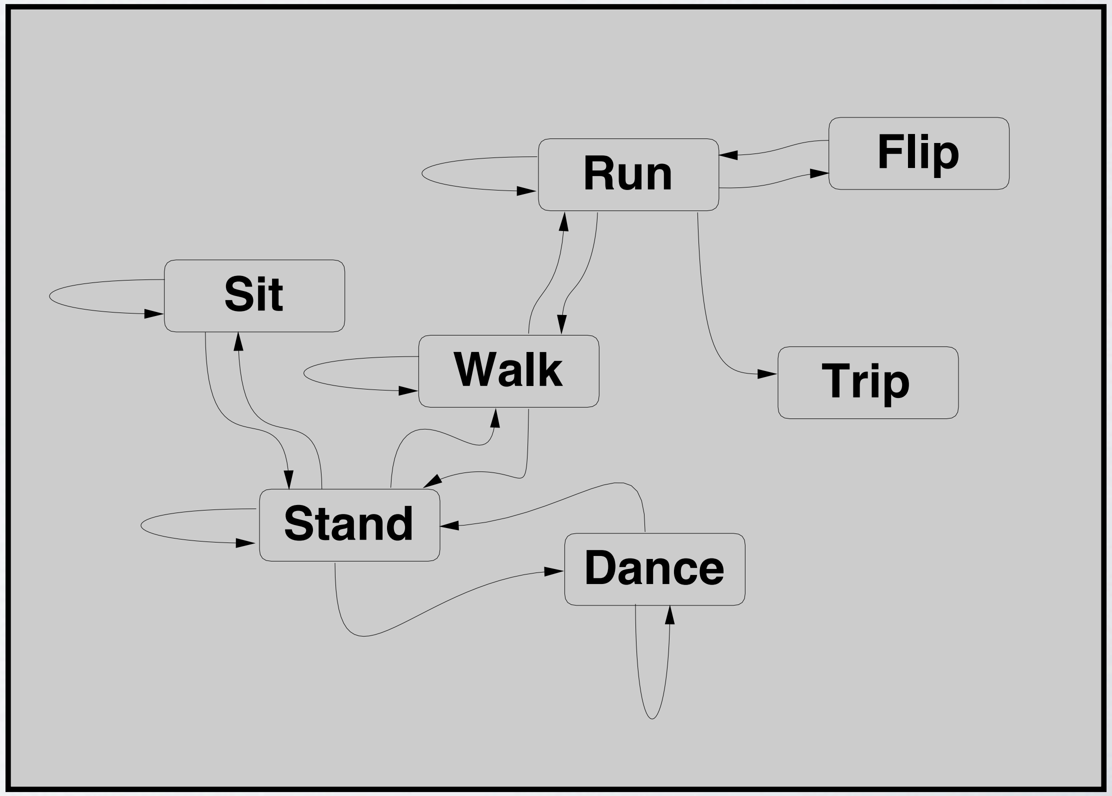
- Special case of transitioning
- Both motions are the same
- Need to modify beginning and end of a motion simultaneously

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

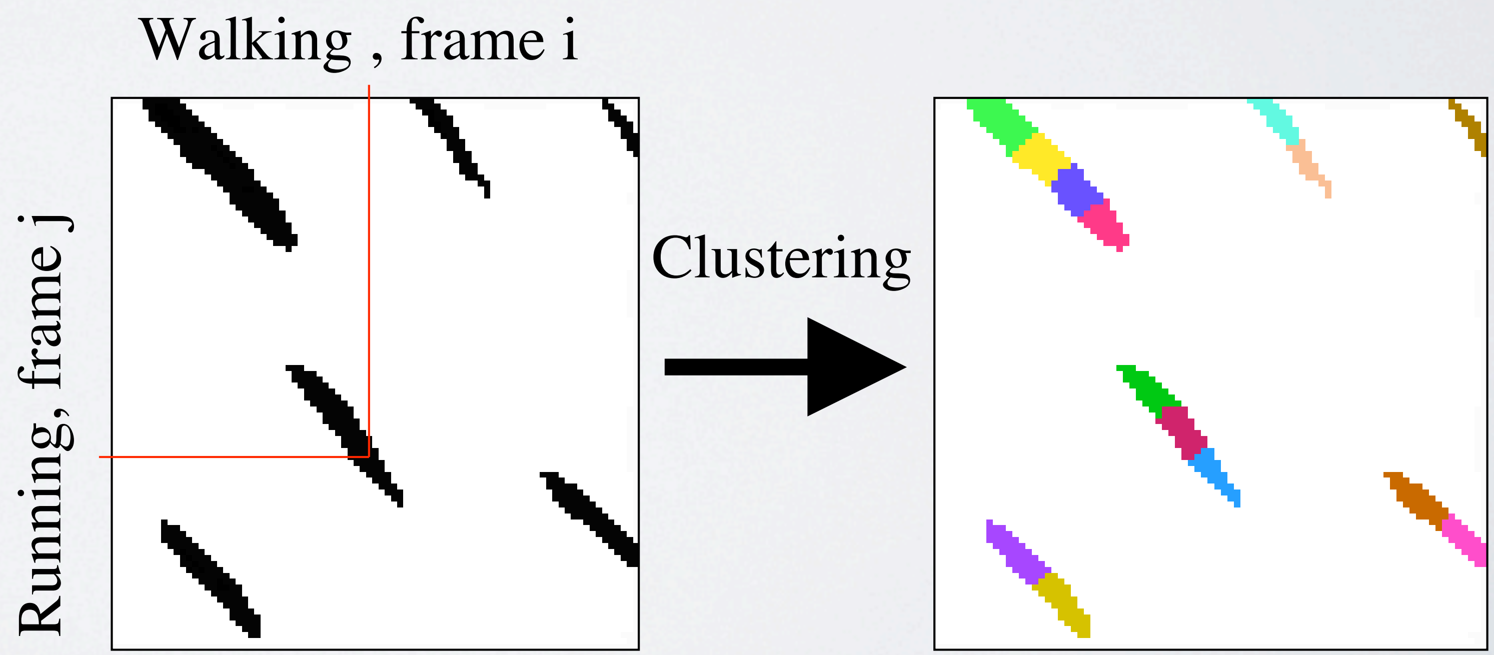


Motion Graphs

- 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

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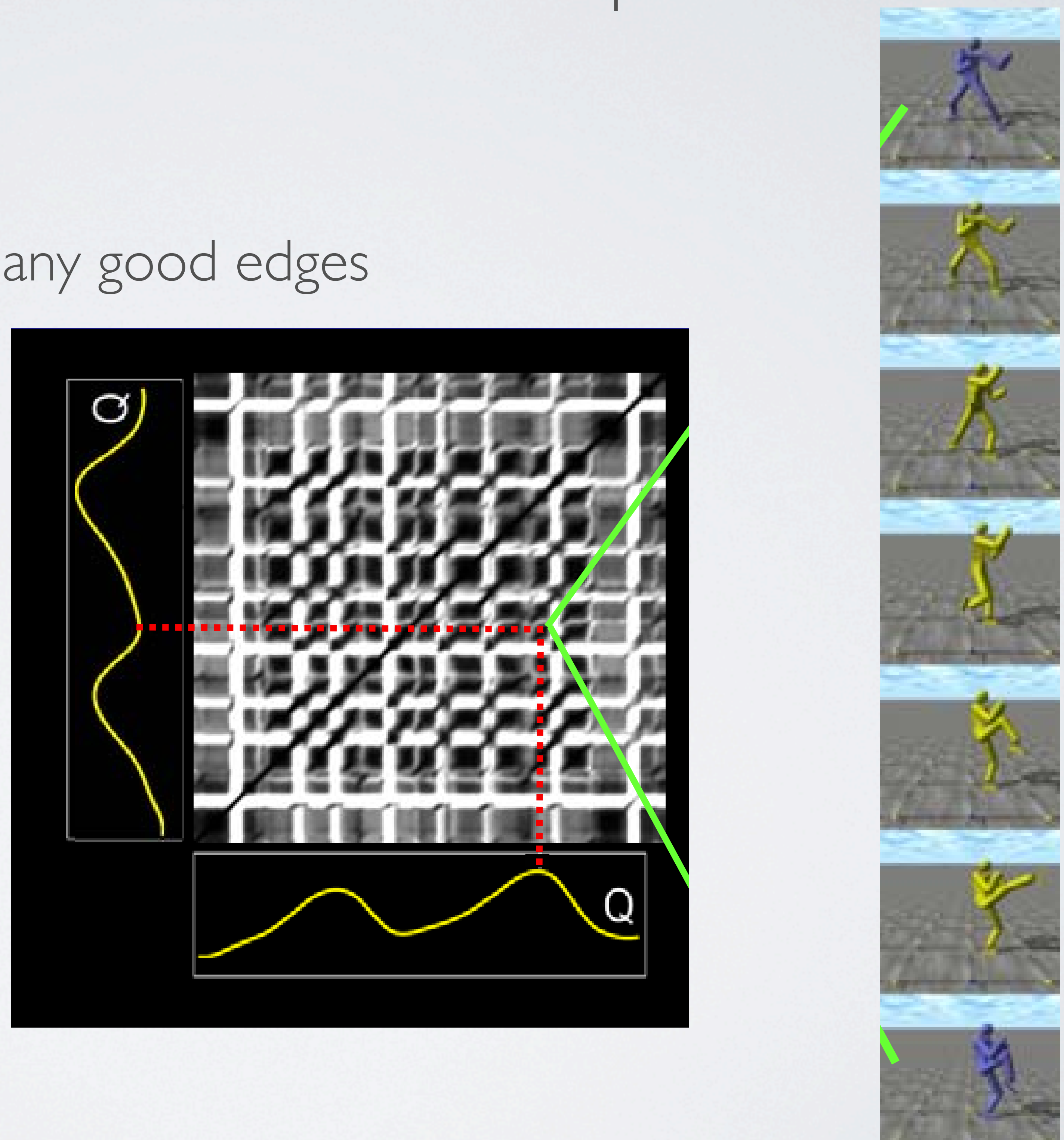
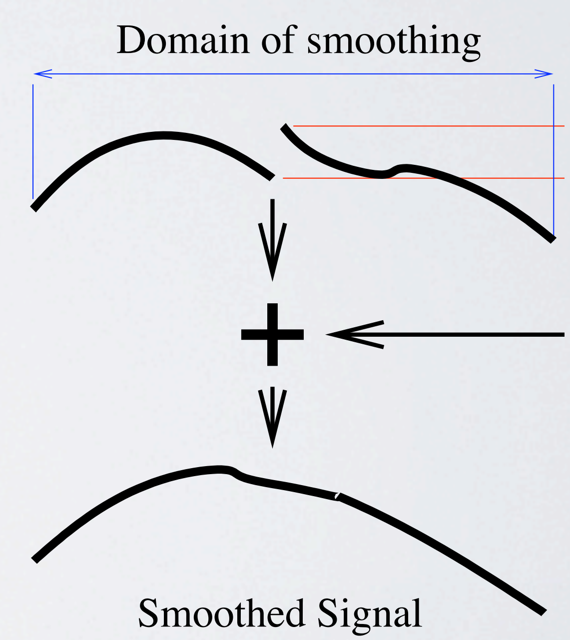


Motion Graphs

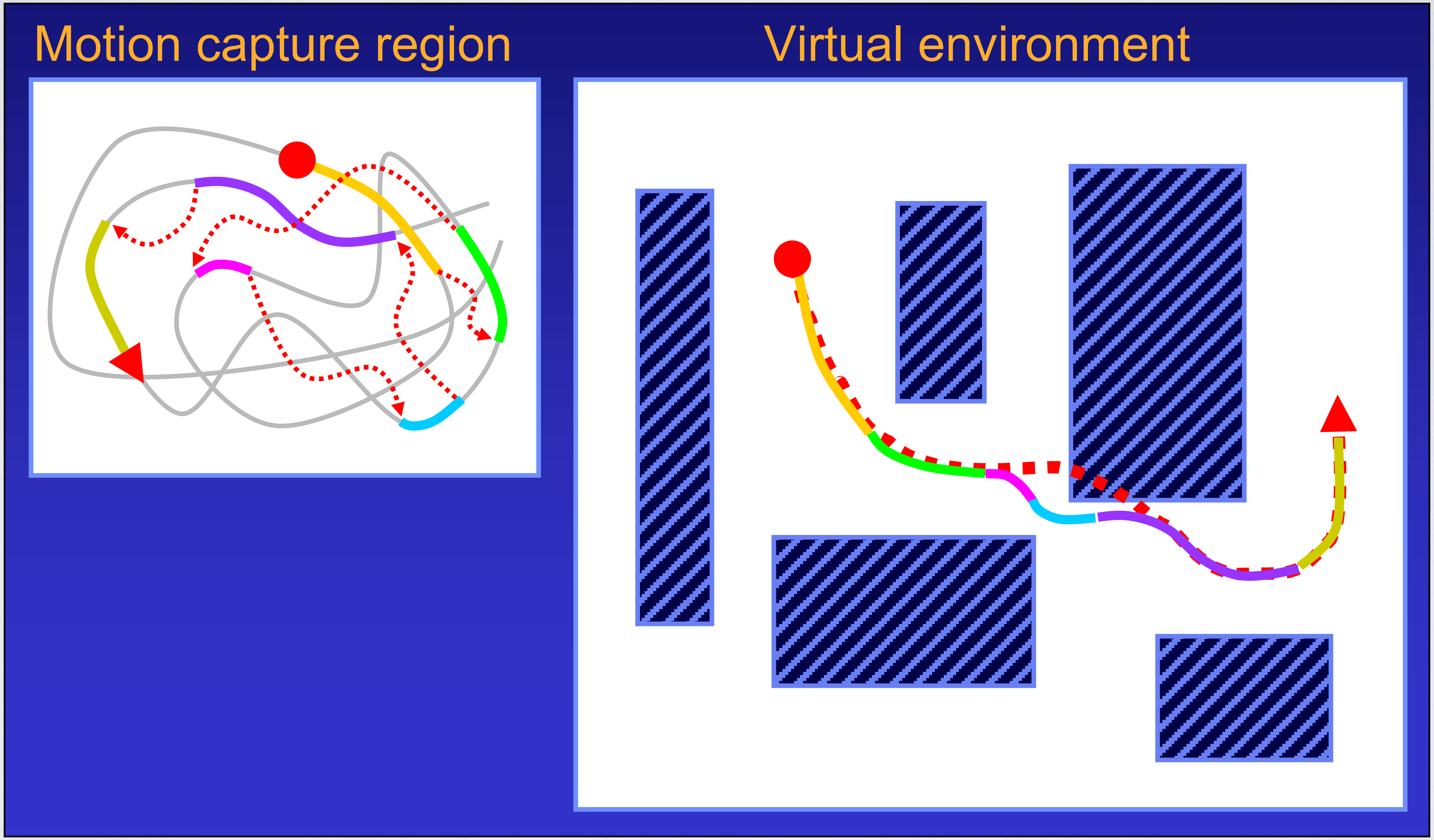
- Random walks
  - Start in some part of the graph and randomly make transitions
  - Avoid dead ends
  - Useful for "idling" behaviors
- Transitions
  - Use blending algorithm we discussed



Motion graphs

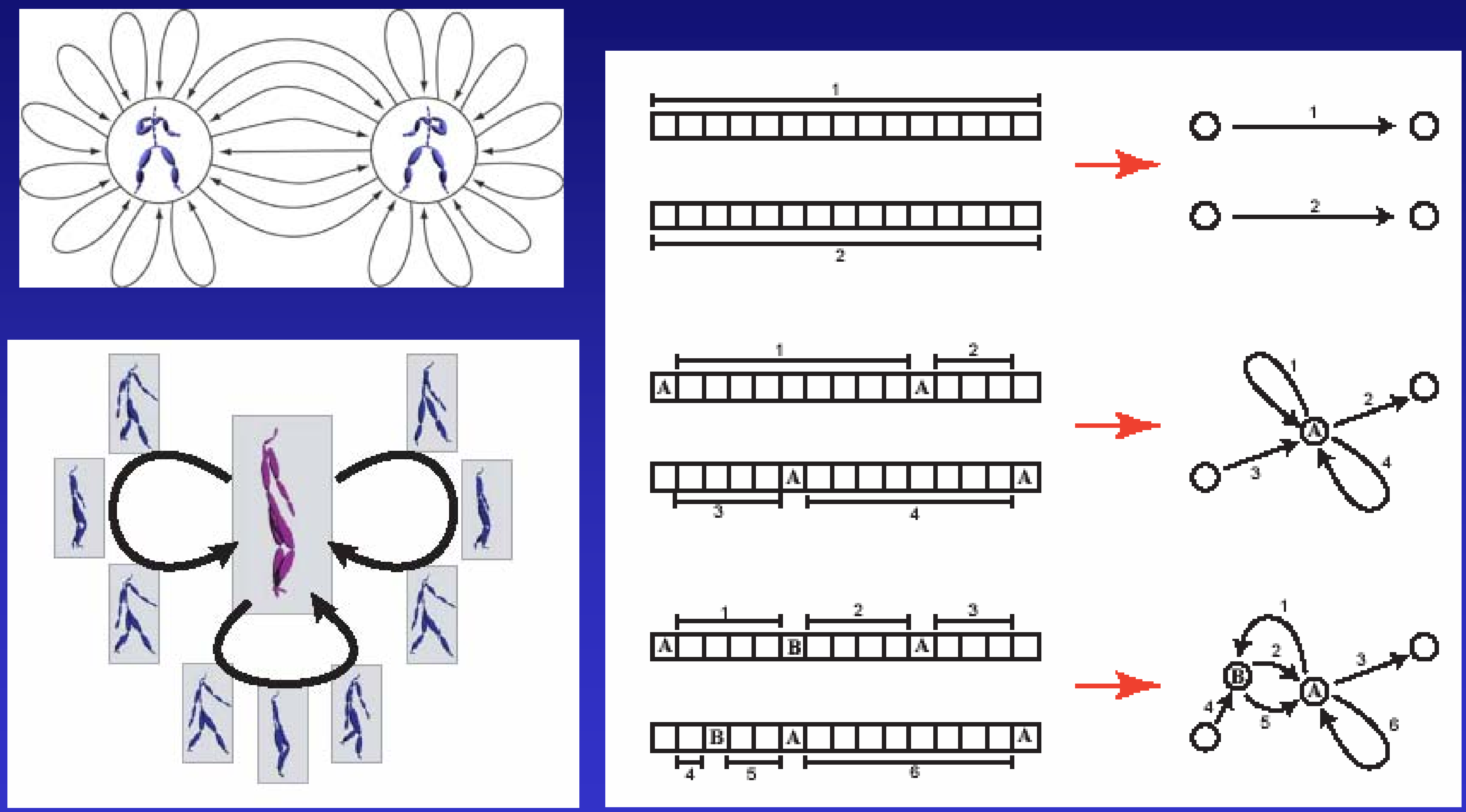
- Match imposed requirements
  - Start at a particular location
  - End at a particular location
  - Pass through particular pose
  - Can be solved using ***dynamic programing***
  - Efficiency issues may require approximate solution
  - Notion of "goodness" of a solution

Reordering



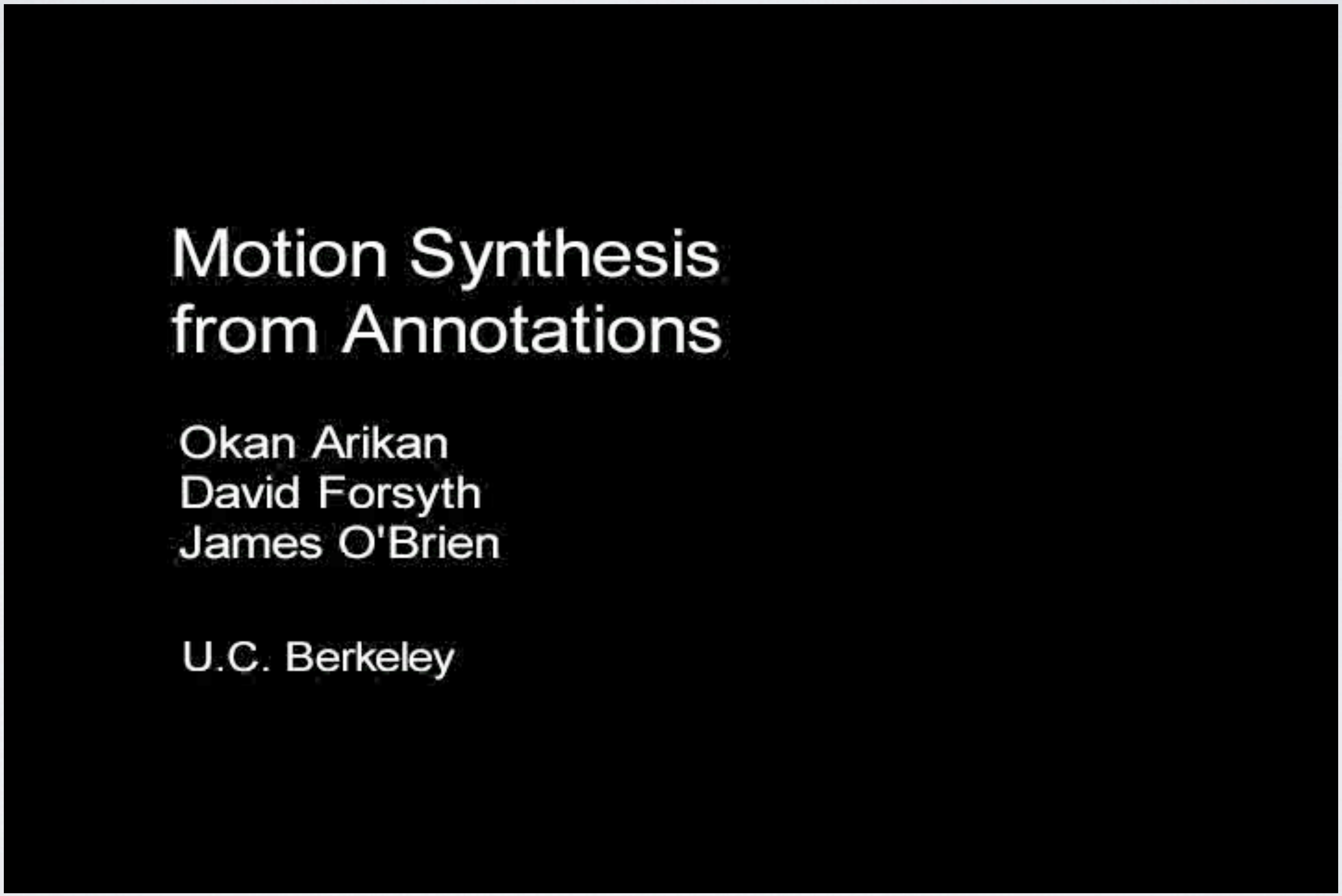
Slide from Victor Zordan

Gleicher et al - "Snap together motion"



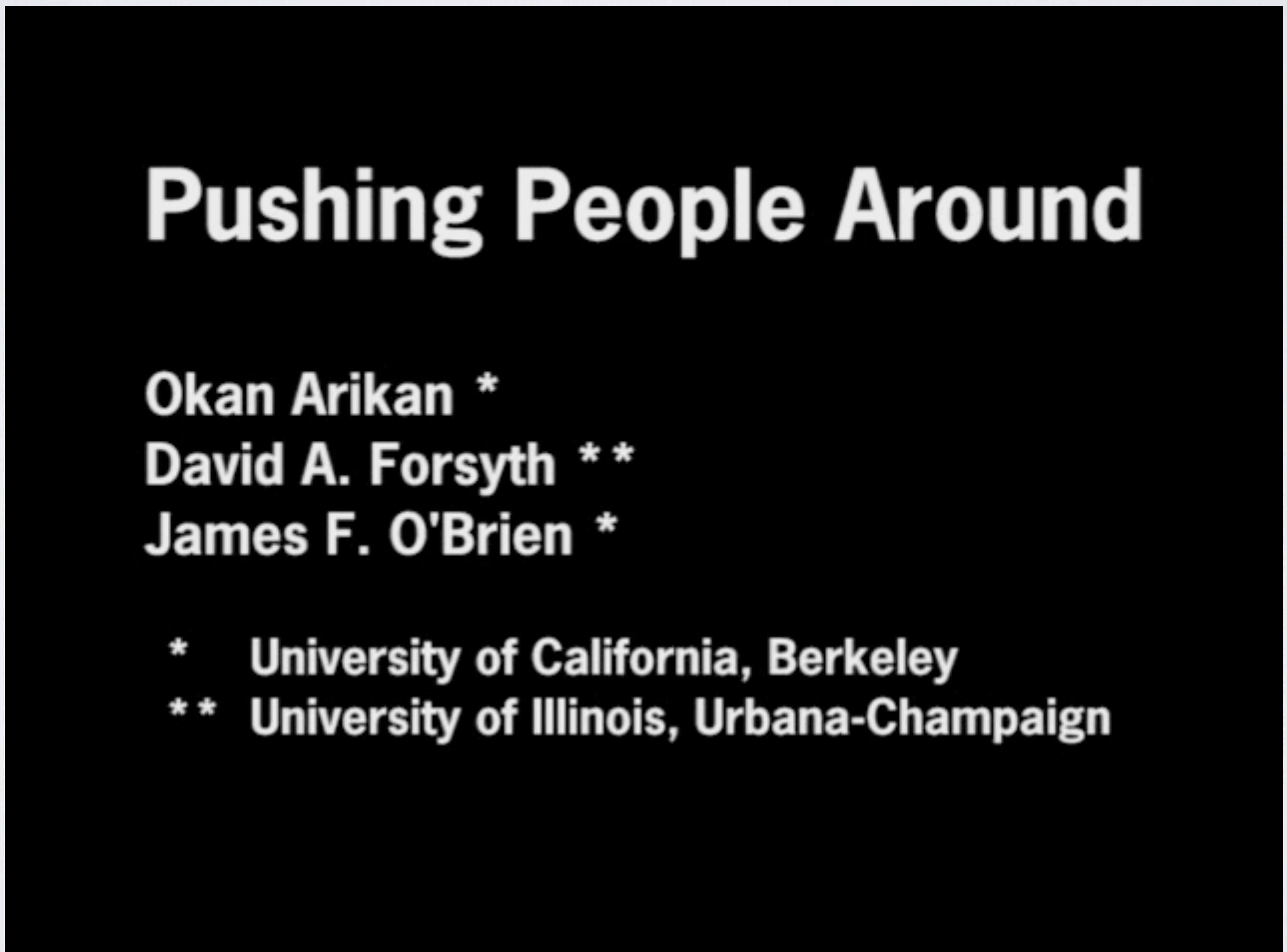
Slide from Victor Zordan

Content Tags



Integrating Physics

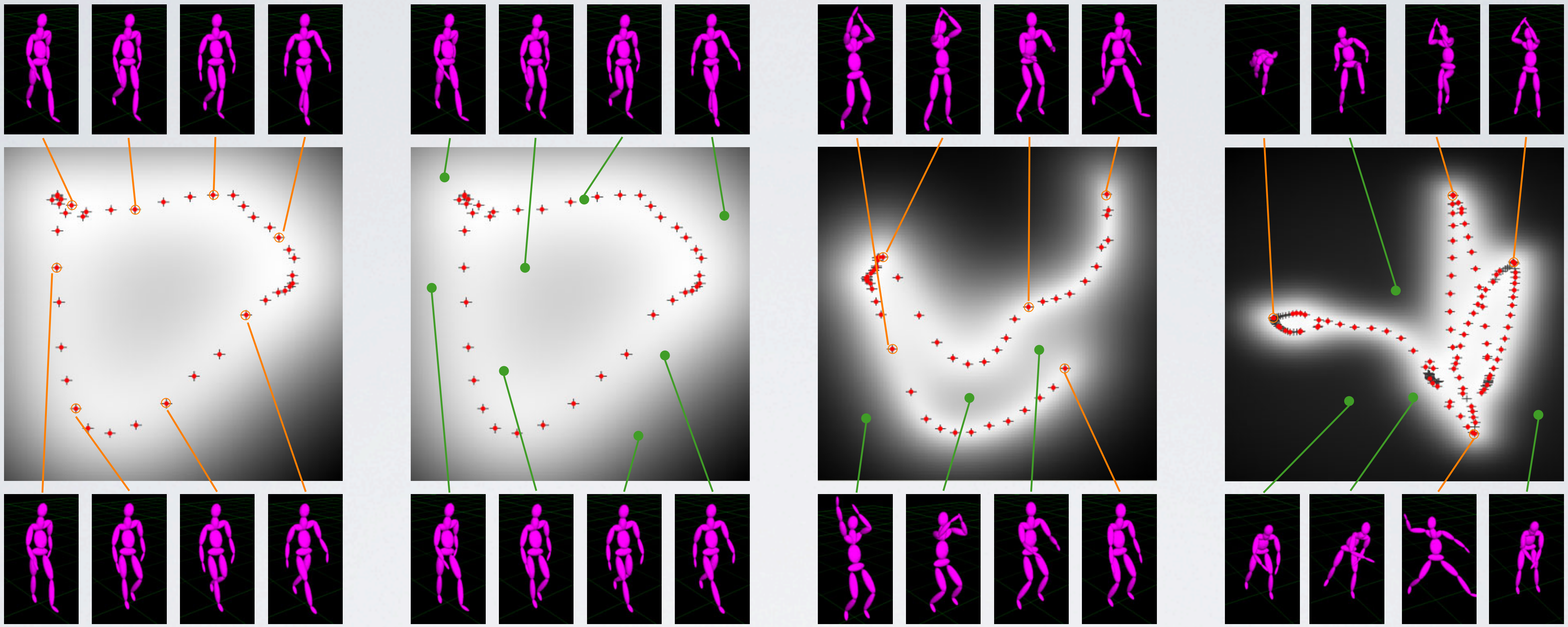
- Simulation added to base motion
- Inverse dynamics for matching
- Oracle to assess results

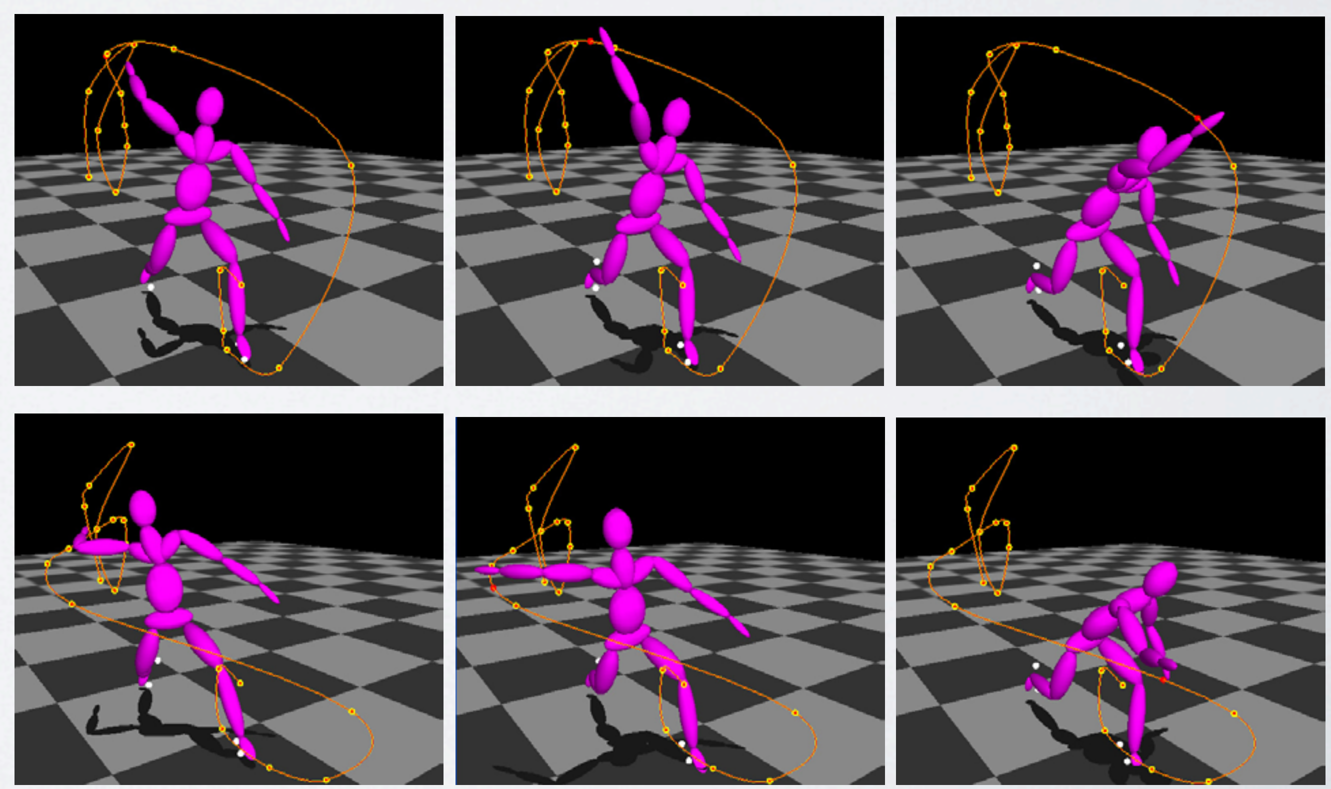


Integrating Physics

Dynamic Response for Motion Capture Animation
Zordan, V. B., Majkowska, A., Chiu, B., Fast, M.
ACM SIGGRAPH 2005

Prior on "good" configurations





Style-Based Inverse Kinematics
Grochow, Martin, Hertzmann, Popović

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.