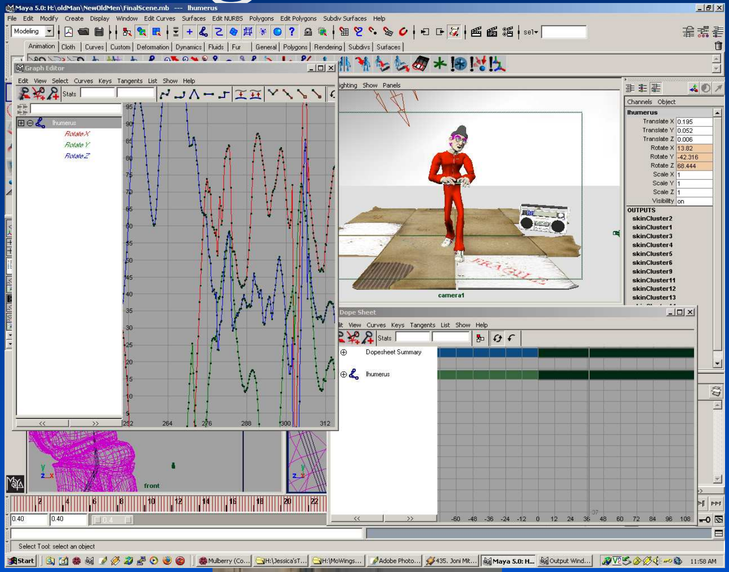
Announcements

- Next class: games (James Kuffner)
- Last class: image based rendering + demos of other graphics classes

Character Animation

Advantages & Disadvantages



Key Framing

- Low level control
- A lot of manual labor
- Experienced user

Motion Capture

- Realistic human performance
- Hard to modify and generalize

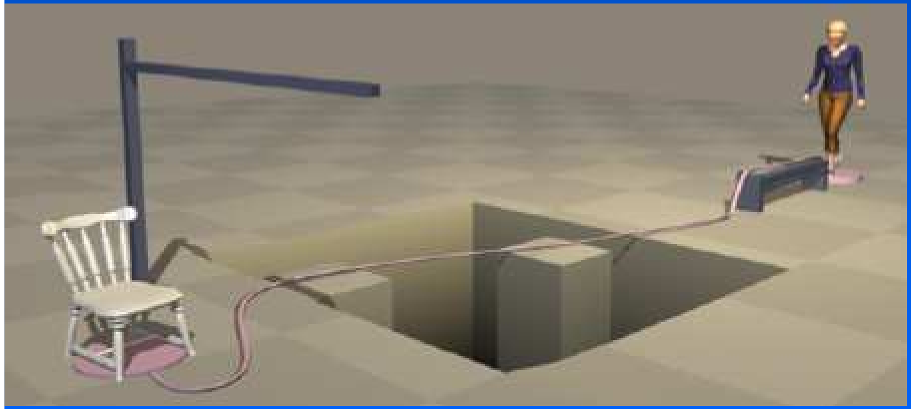
Constrained Optimization

- High level control
- Little manual labor
- Easy for a naive user

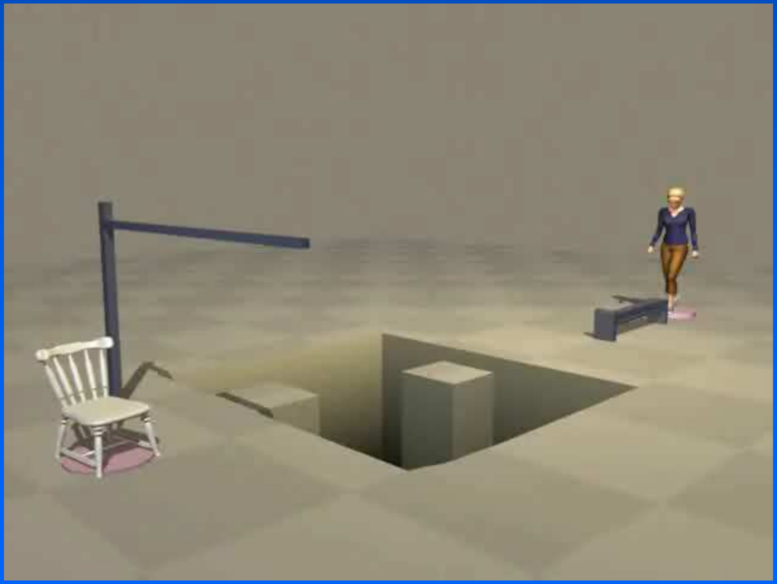
Create animation from simple input

- User provides only a small amount of information
- We synthesize a physically valid motion to match the sketch

Sketch of the path



Synthesized motion



Applications

Allow game players create rich set of motions

Currently:
Limited set of predefined carefully hand-picked motions

Applications

http://www.magickeys.com/books/

Allow children to tell stories

Applications

Firefighters training environment, ETC, CMU

Allow novice users to create effective training scenarios

Talk Overview

- Video Textures and Character Animation from Video
- Move Graphs and Motion Graphs
- Interpolation
- Optimization

Animation From Video

Problem Definition

given video clip

generate an infinite amount of similarly looking video

Pictures, Videos, Video Texture

Picture

static

Video

dynamic but finite

Pictures, Videos, Video Texture

Video Texture

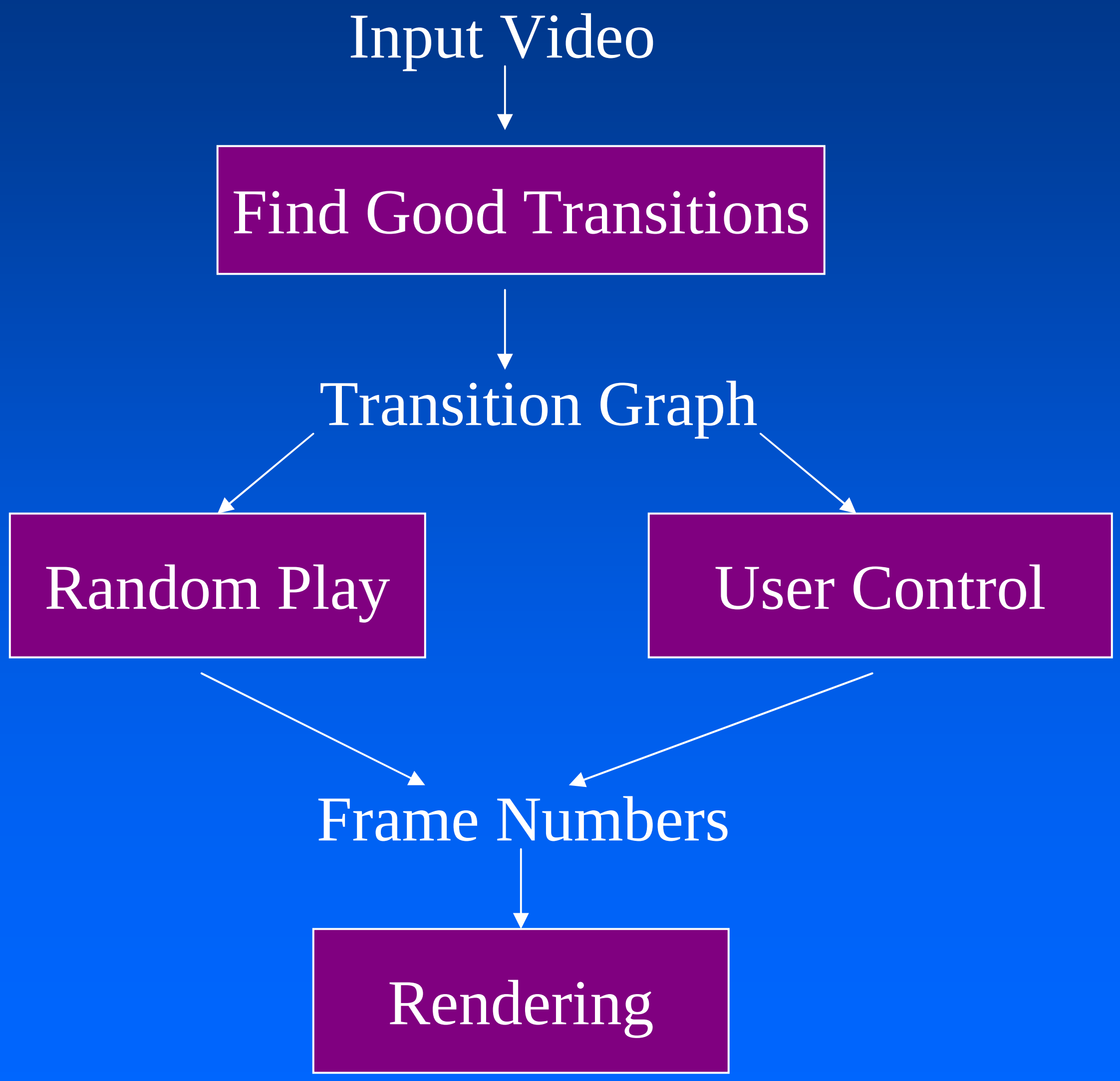
infinite and dynamic

Application

- Instead of static photo on a computer screen

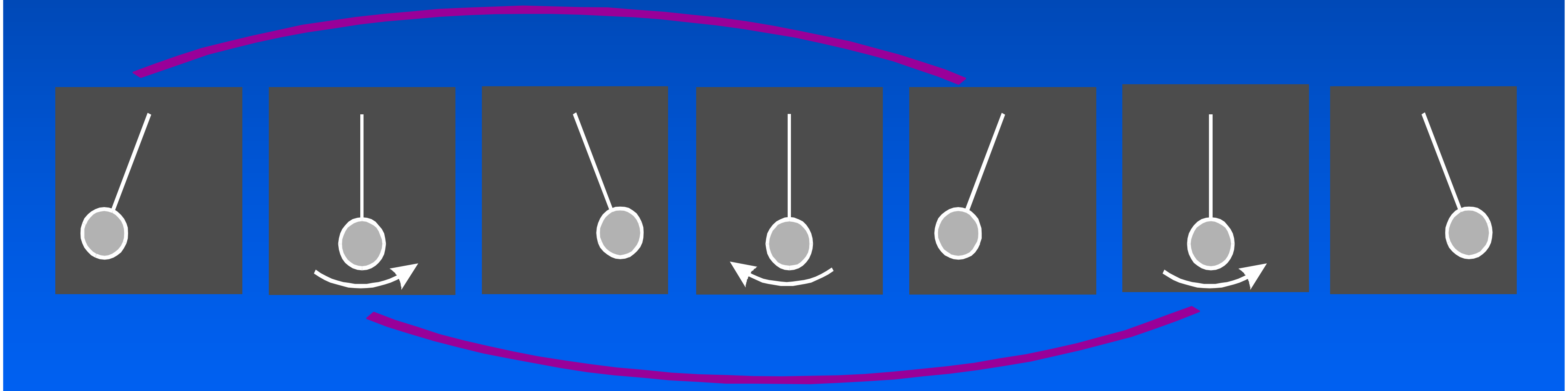
- Advertising - beach with palm trees blowing
- Games - dynamic backdrops
- Video Based Animation

Algorithm Overview



Finding Good Transitions

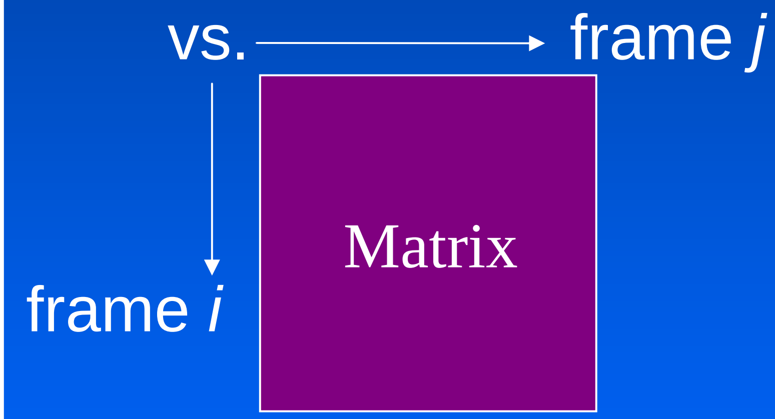
Similar frames make good transitions



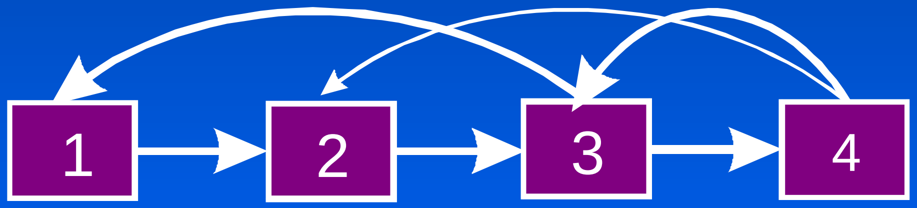
Can use L_2 distance to compare two images

Finding Good Transitions (contd.)

Compute L_2 distance $D_{i,j}$ between all images



Transition Matrix



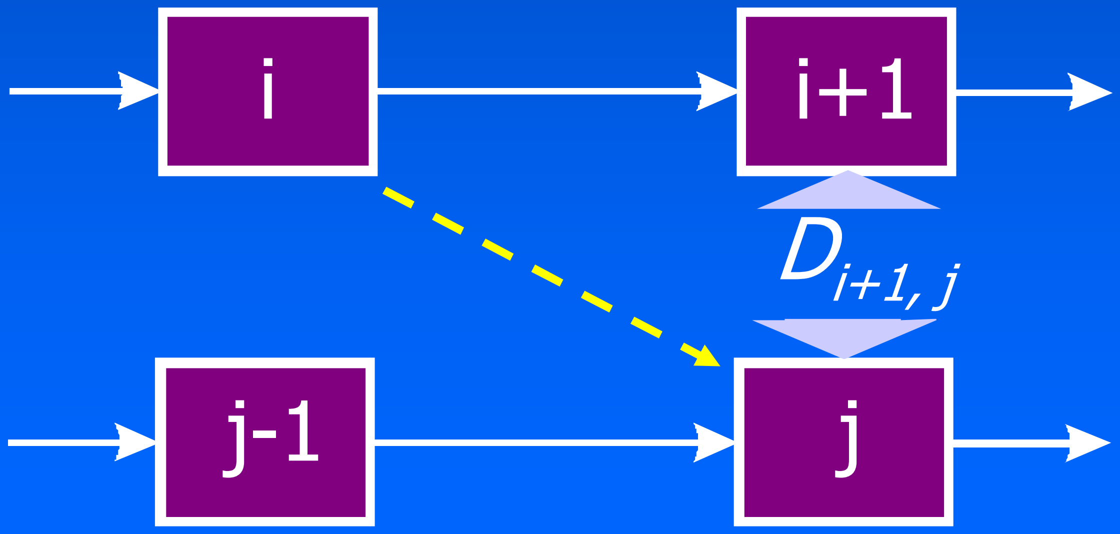
Transition Graph

Making Transition

During Video Texture Synthesis

Transition from i to j if successor of i is similar to j

$D_{i+1,\,j}$ is small



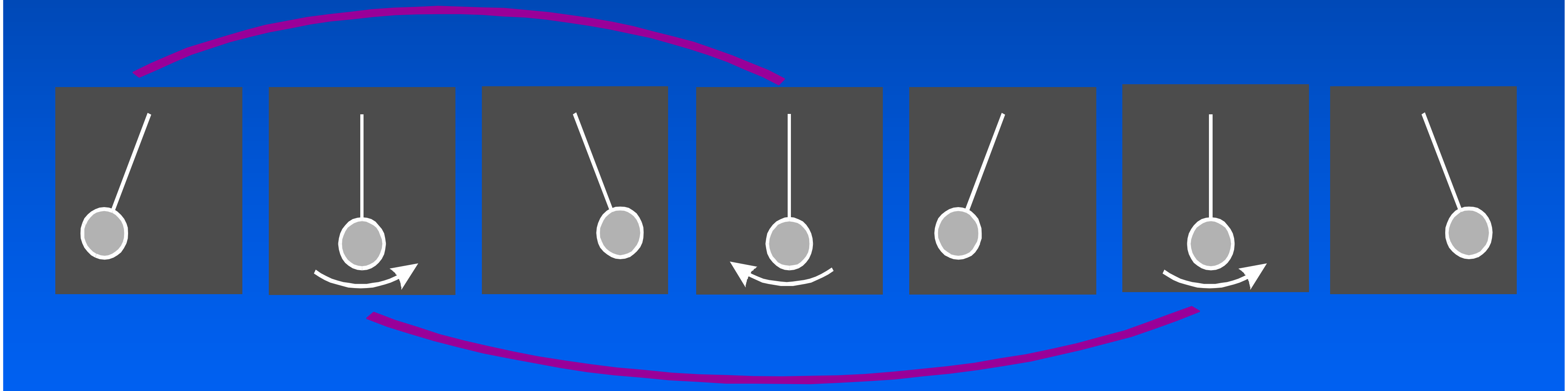
Threshold

high σ low σ

Preserving dynamics

Finding Good Transitions

Similar frames make good transitions

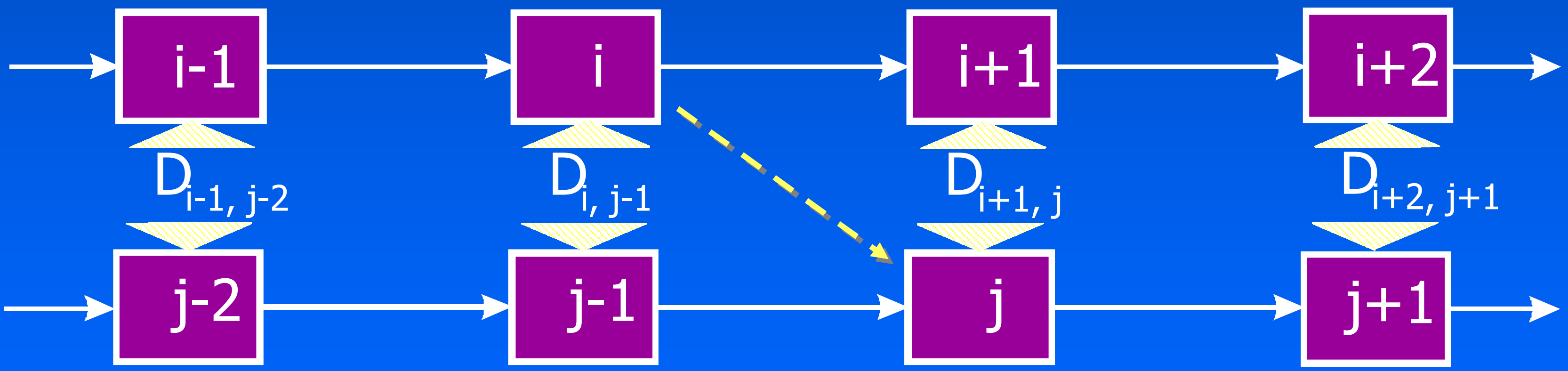


Can use L_2 distance to compare two images

Preserving dynamics

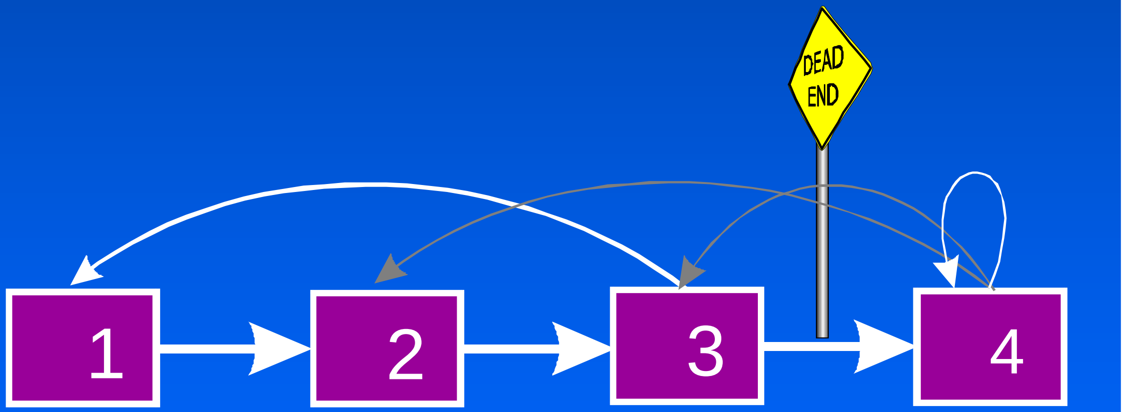
Cost for transition *i*→*j*

$$C_{i\to j} = \sum_{k=-N}^{N-1} w_k D_{i+k+1,\, j+k}$$



Dead ends

No good transition at the end of sequence



No Dead Ends

Synthesis - Random Play

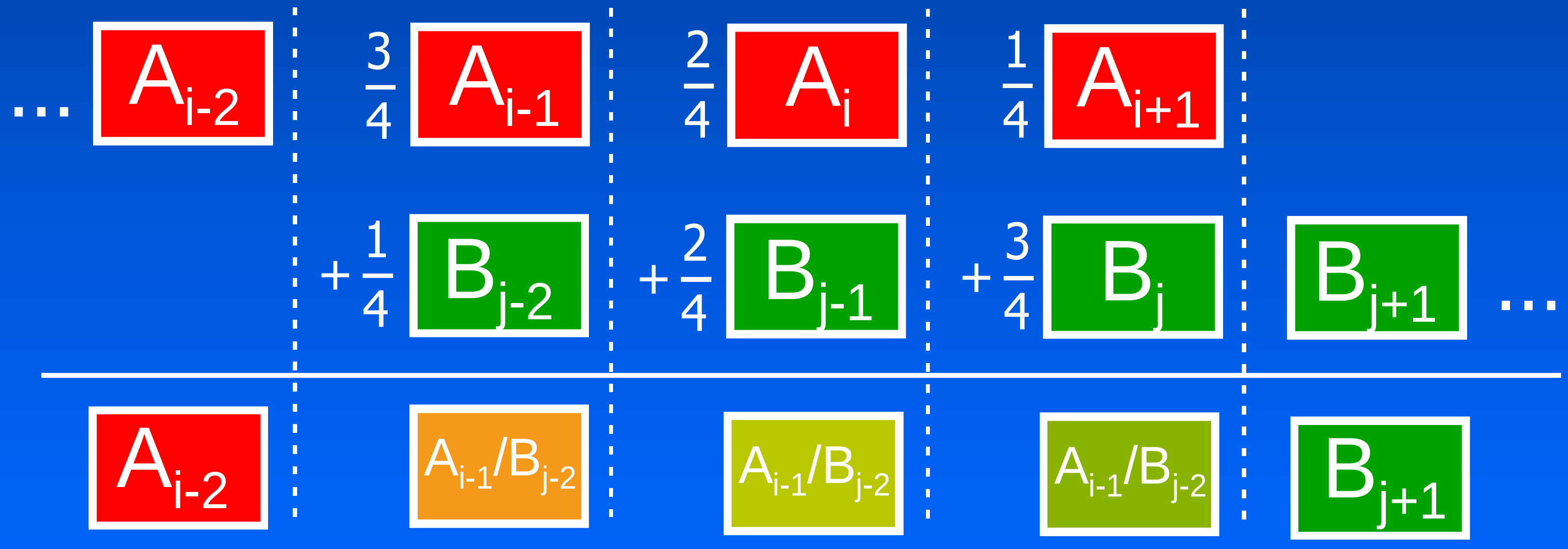
- Begin at some frame i
- Select next frame probabilistically based on P_{ij}, for $j = 0 \ldots n$

Rendering

- Problem: Visible “Jumps”

Rendering (contd..)

- Solution 1: Crossfade from one sequence to the other.



… A_{i-2} $\frac{3}{4} A_{i-1}$ $\frac{2}{4} A_i$ $\frac{1}{4} A_{i+1}$

$+\frac{1}{4} B_{j-2}$ $+\frac{2}{4} B_{j-1}$ $+\frac{3}{4} B_j$ B_{j+1} …

A_{i-2} A_{i-1}/B_{j-2} A_{i-1}/B_{j-2} A_{i-1}/B_{j-2} B_{j+1}

Results (contd..)

- Waterfall (cross fading)

Results (contd..)

- Waterfall (frequent jumps & cross fading)

Results (contd..)

- Video Portrait (random play, with fading)

Useful for web pages

Results (contd..)

- Campfire (single loop, with fading)

Results (contd..)

- Blowing grass (with fading)

Region-based analysis

- Divide video up into regions (by hand)

- Generate a video texture for each region

Region-based analysis (contd..)

- Divide video up into regions (by hand)

- Generate a video texture for each region

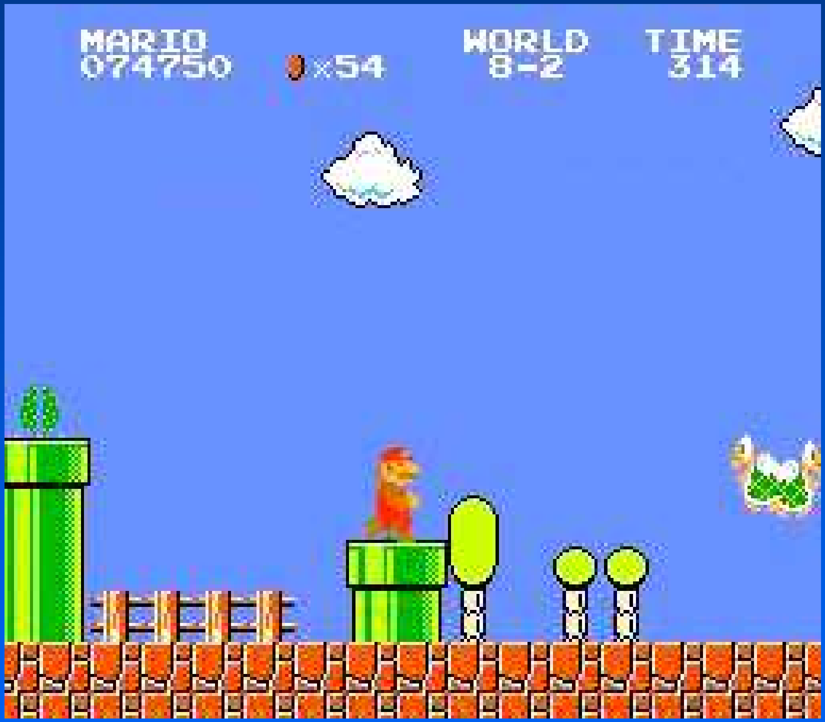
Region-based analysis (contd..)

- Divide video up into regions (automatically)

- Generate a video texture for each region

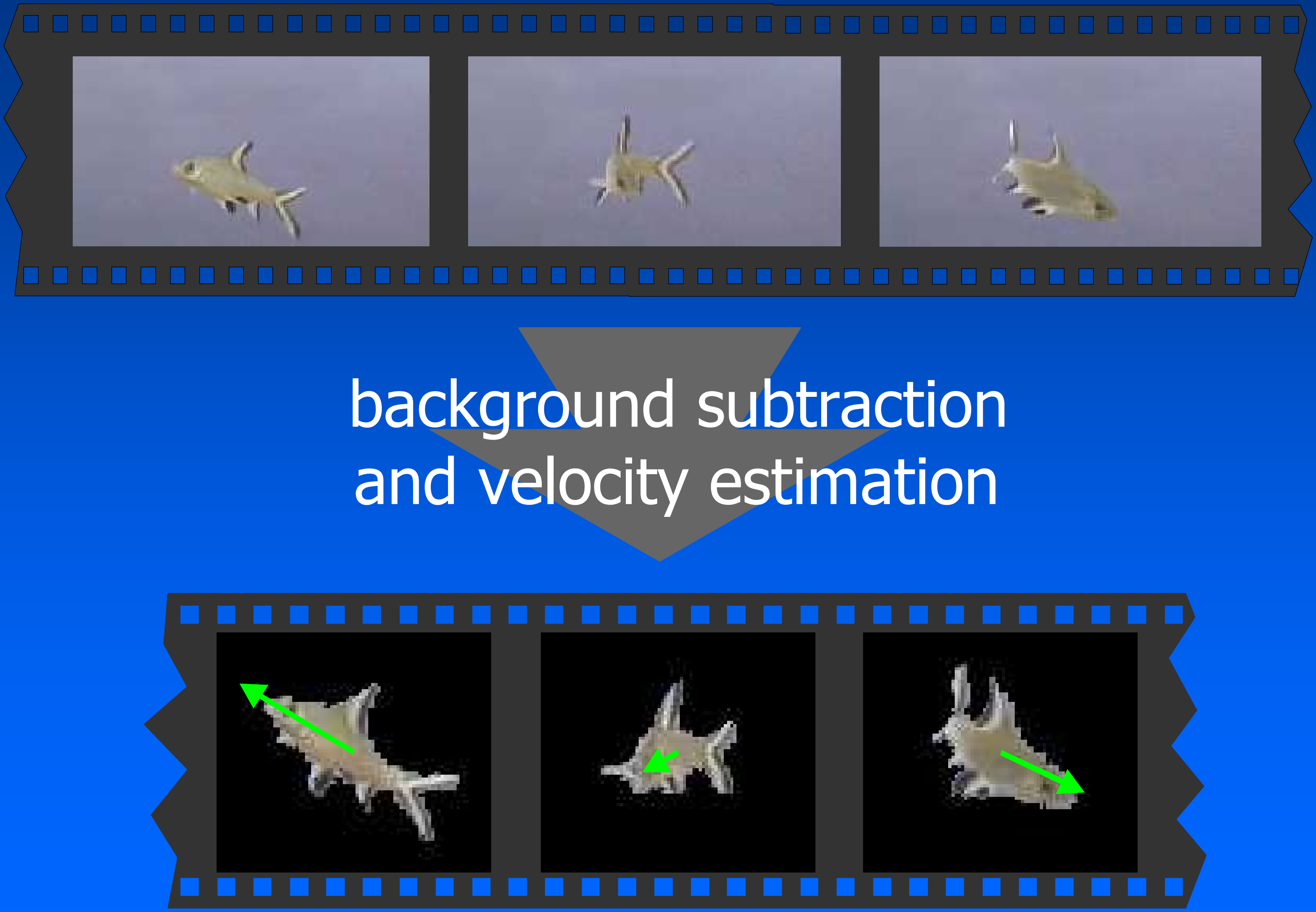
Video-based animation

- Like sprites computer games
- Extract sprites from real video
- Interactively control desired motion



©1985 Nintendo of America Inc.

Video sprite extraction



background subtraction
and velocity estimation

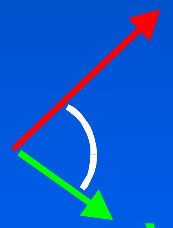
Video sprite result

Video sprite control

- Augmented transition cost:

$$C_{i\to j} = D_{i+1,j}$$

$$C^{\text{Animation}}_{i\to j} = \underbrace{\alpha\, C_{i\to j}}_{\text{Similarity term}} + \underbrace{\beta\ \text{angle}}_{\text{Control term}}$$



vector to mouse pointer

velocity vector

Interactive fish

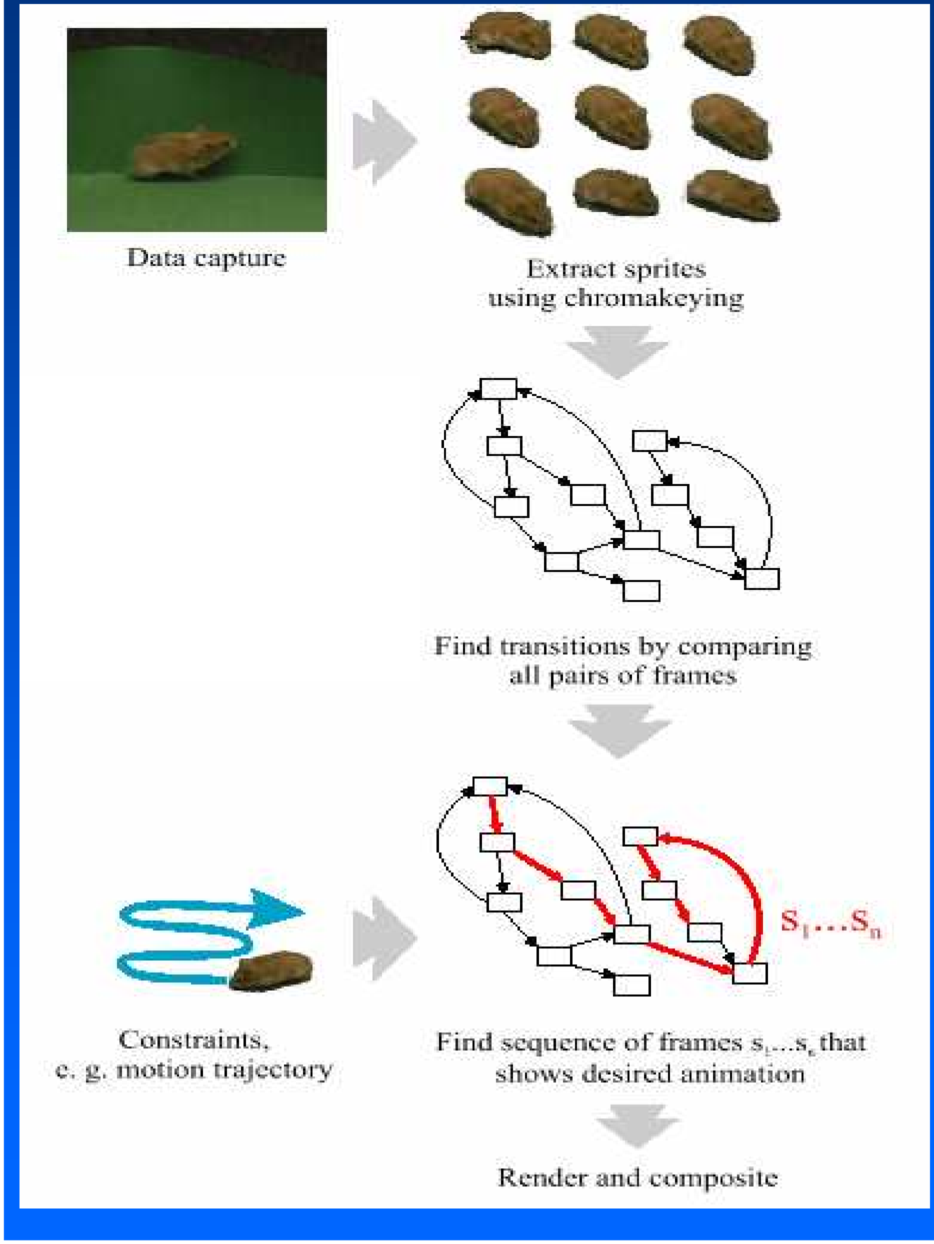
Video sprite example

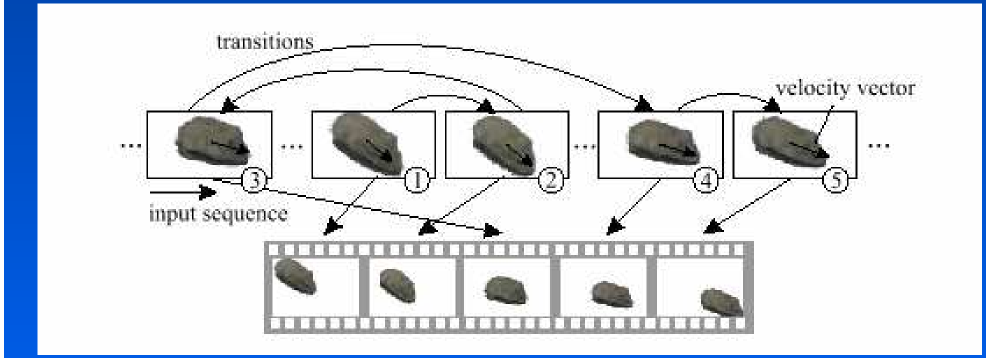
Character Animation From Video

Arno Schodl and Irfan Essa

- Animation Of Real Animals
  - animals are difficult to train & animate
- Animator imposes constraints to control the motion of sprite
- Find frame sequence that minimize the cost function describing desired animation

Character Animation From Video


Data capture
Extract sprites using chromakeying
Find transitions by comparing all pairs of frames
$S_1 \ldots S_n$
Constraints, e. g. motion trajectory
Find sequence of frames $s_1 \ldots s_n$ that shows desired animation
Render and composite

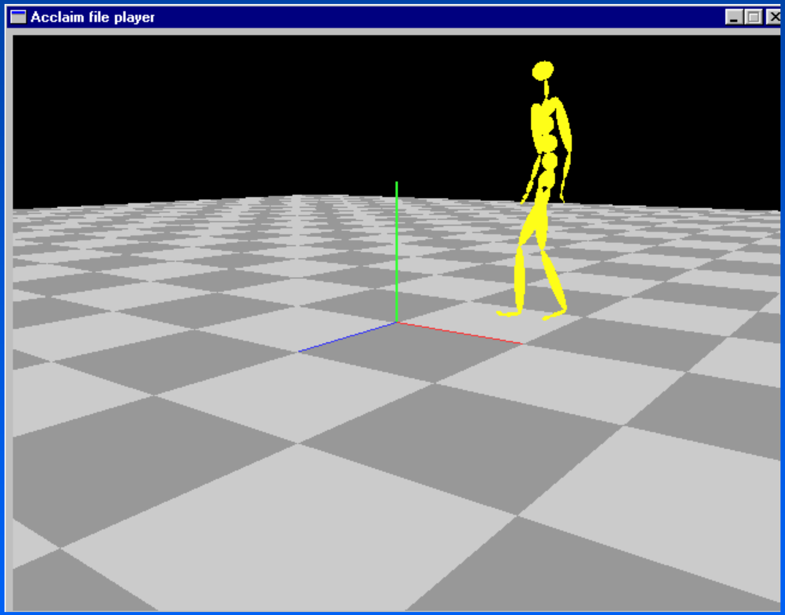


Results

Results

Motion Graphs
Video Textures for Motion Capture

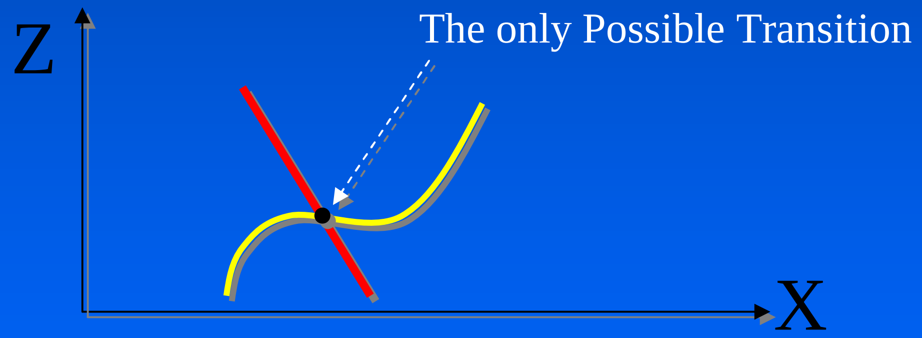
- Each frame is a character Pose
- Find Good Transitions



- Pose:
  - root position & orientation
  - joint angles

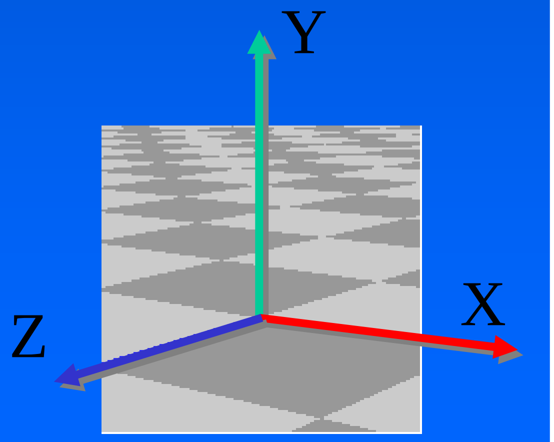
Finding Transitions Between Poses

- Find good metric for
  - D_{ij} = difference$(Pi\ ,\ Pj)$
- Include root position into metric

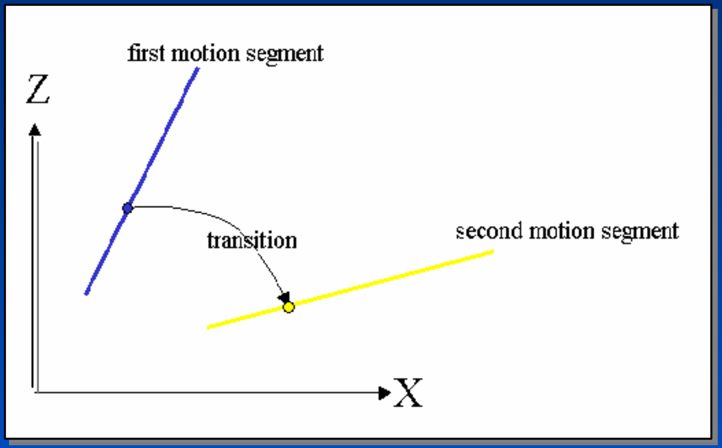


The only Possible Transition

- Do not include into metric:
  - character X and Z root position
  - character orientation around Y axis



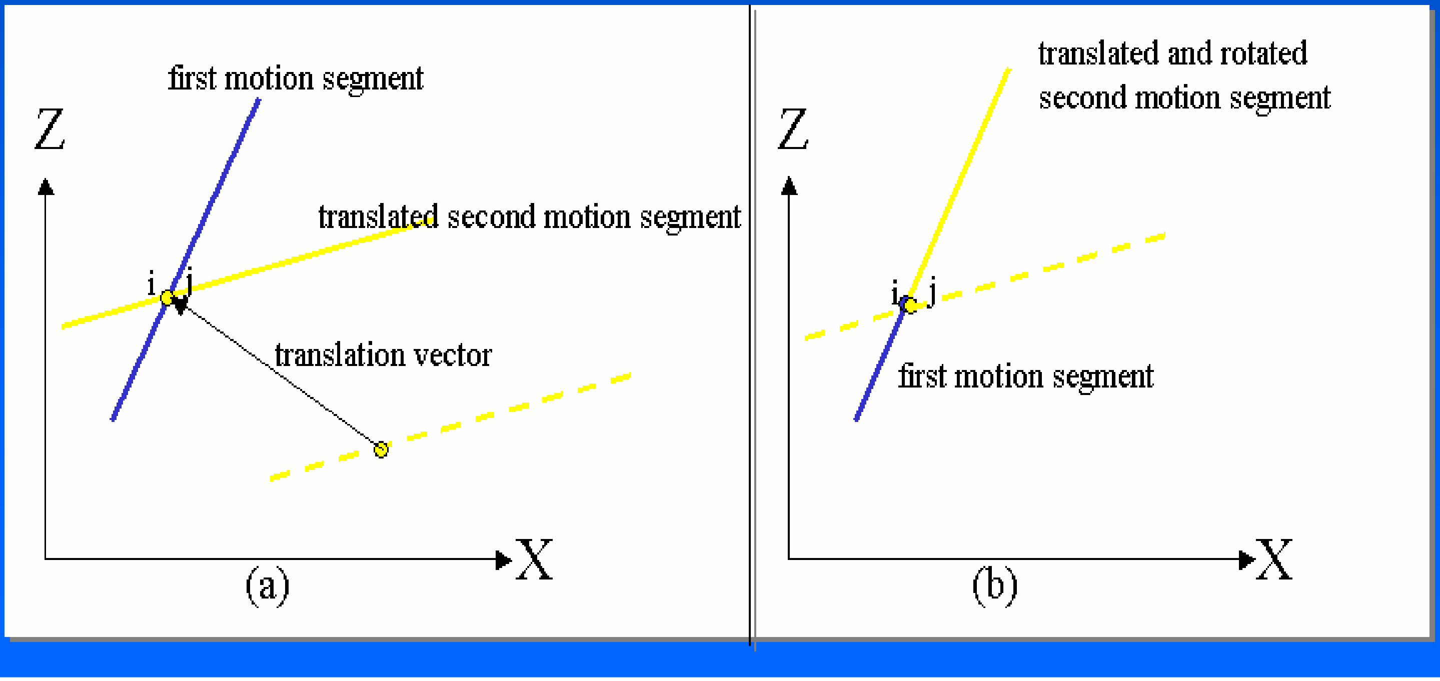
Finding Good Transitions (Contd..)



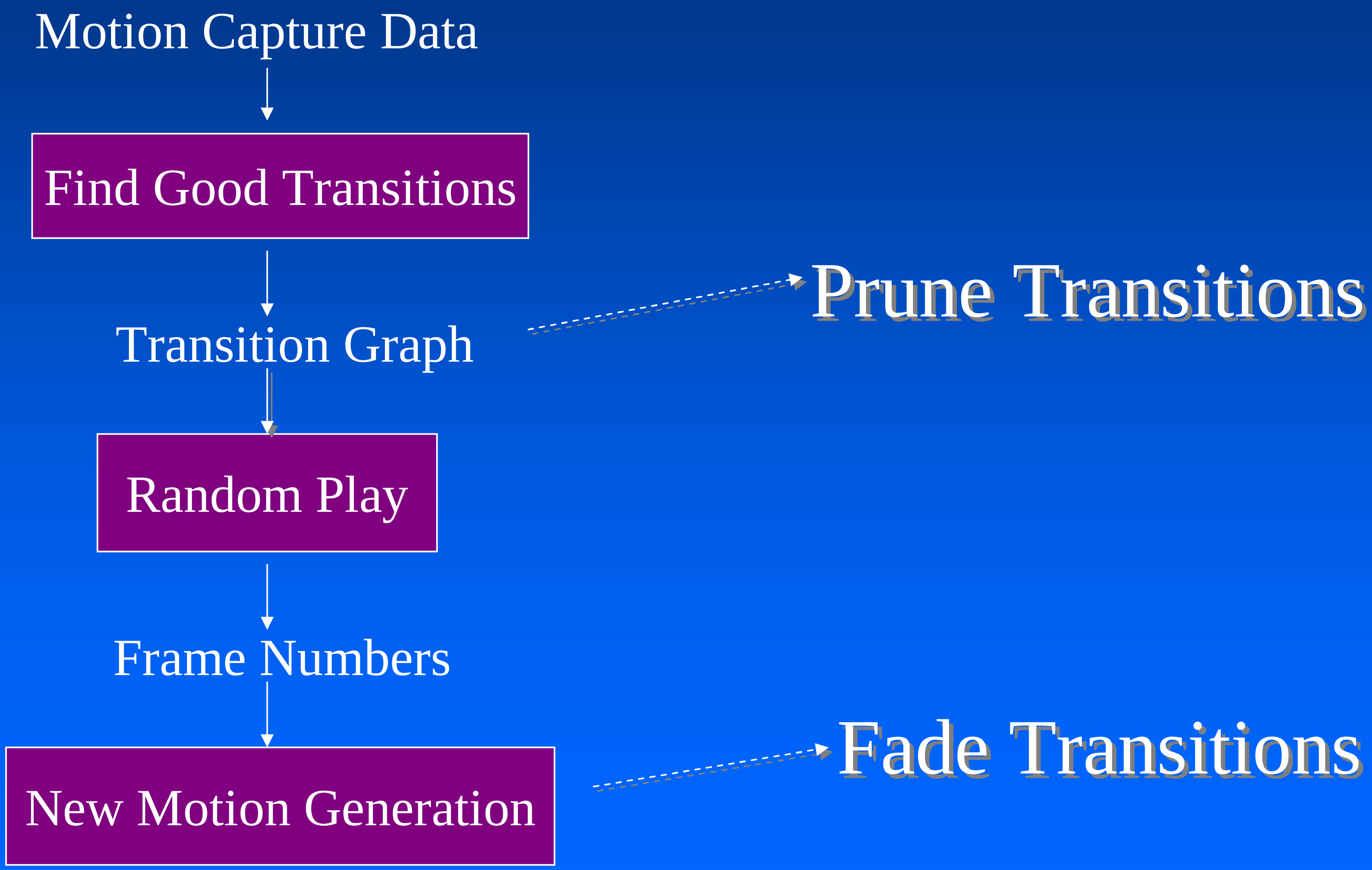
Possible Transition

Translated Motion

Rotated Motion



Generating Motion



Motion Capture Data

Find Good Transitions

Transition Graph

Random Play

Frame Numbers

New Motion Generation

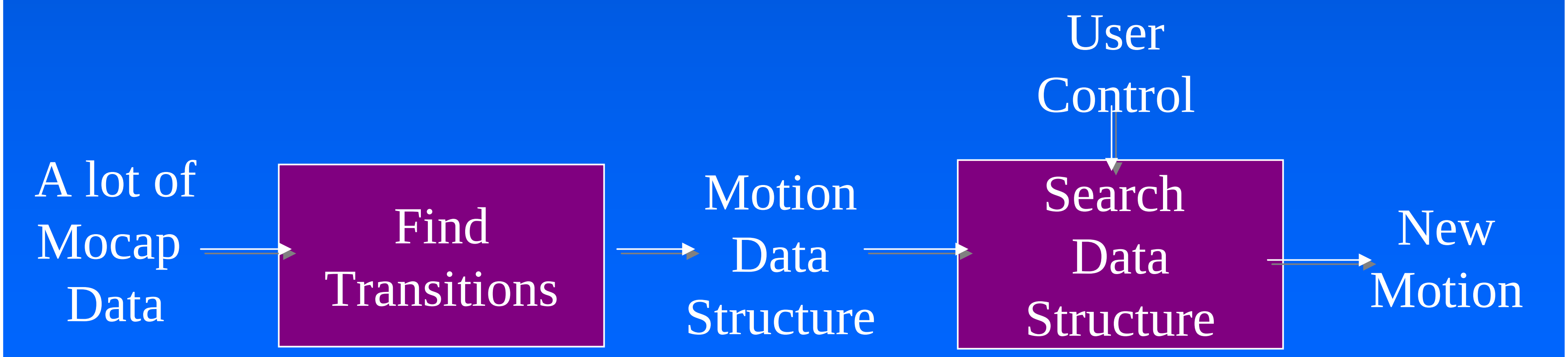
Prune Transitions

Fade Transitions

Interactive Control of Avatars with Human Motion Data

J. Lee, J. Chai, P. S.A. Reitsma, J.K. Hodgins, N. S. Pollard

- Motion Textures
- Controlling avatar
  - Games & Virtual Environments



User Control

A lot of Mocap Data

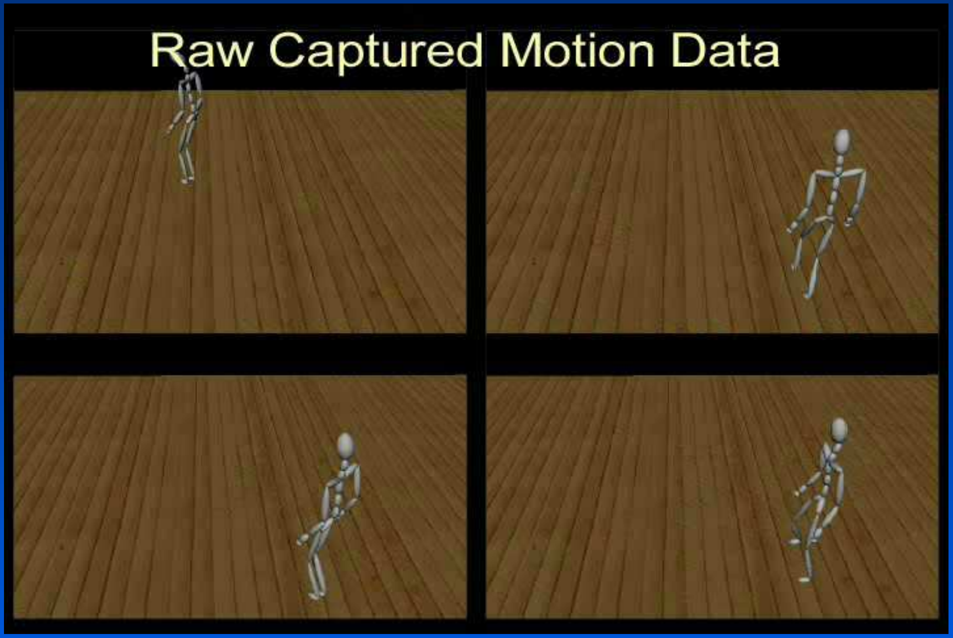
Find Transitions

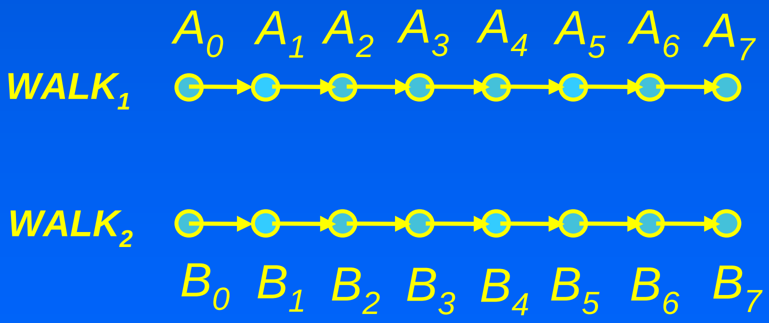
Motion Data Structure

Search Data Structure

New Motion

Motion Graphs





A_0 A_1 A_2 A_3 A_4 A_5 A_6 A_7

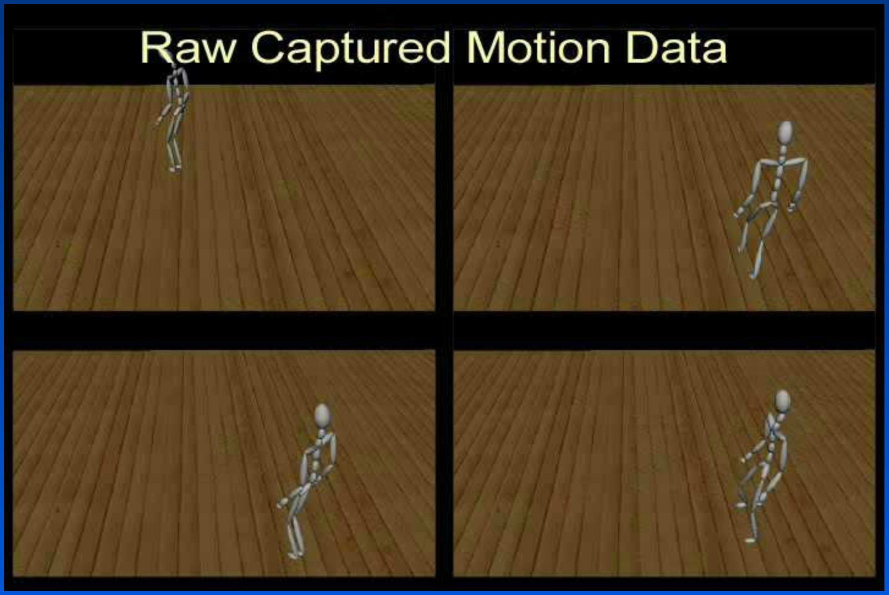
$WALK_1$

$WALK_2$

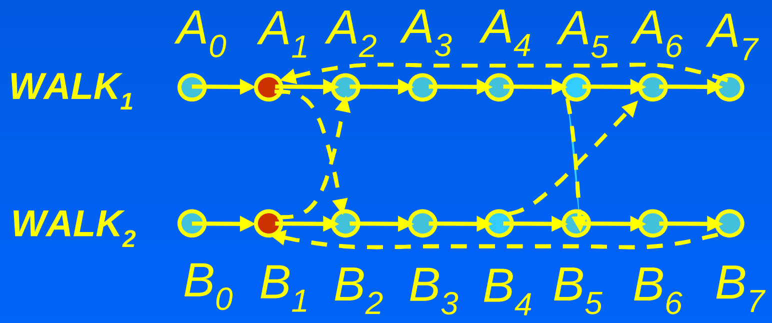
B_0 B_1 B_2 B_3 B_4 B_5 B_6 B_7

Store: pose and change in root position from previous frame

Motion Graphs



Raw Captured Motion Data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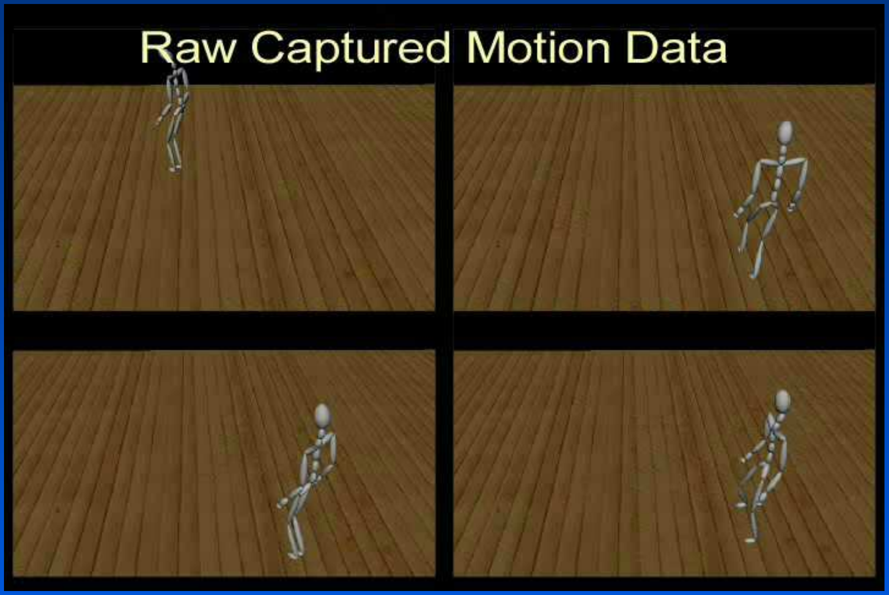
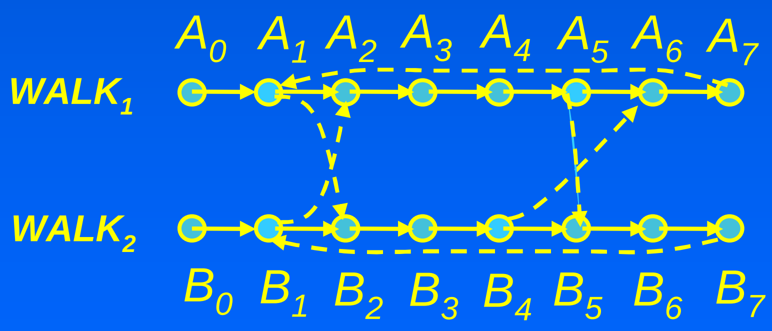
$WALK_1$
$WALK_2$
B_0 B_1 B_2 B_3 B_4 B_5 B_6 B_7

Motion Graphs

Jehee Lee et al. SIGGRAPH 2002

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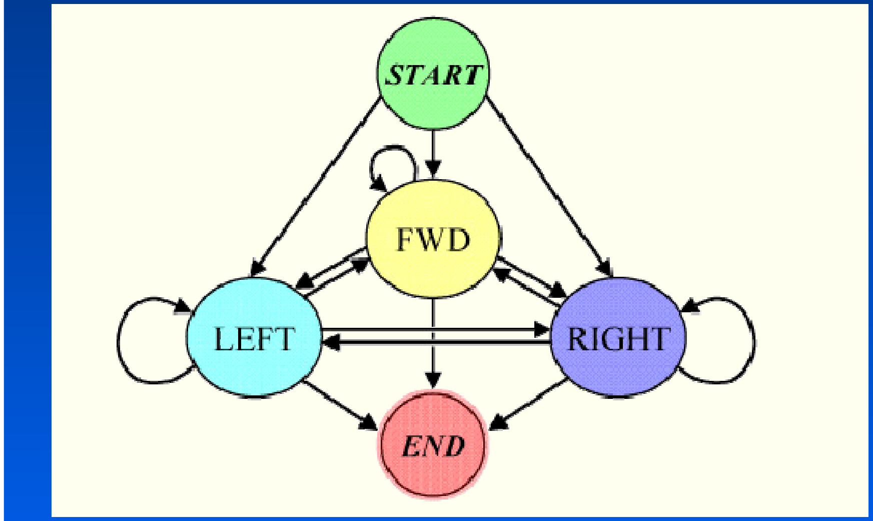
Behavior Based Graphs

Behavior Planning for Character Animation
M. Lau & J. Kuffner



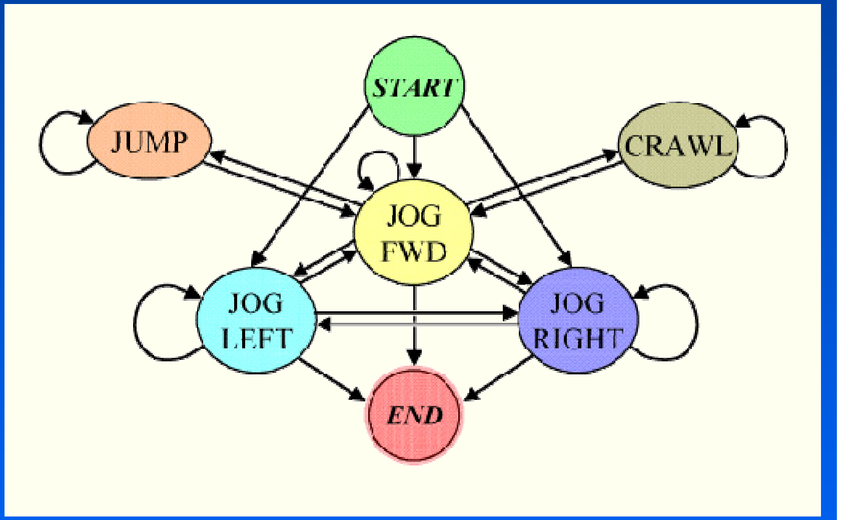
Motions abstracted as **high-level behaviors** and organized into a finite state machine (FSM).

(in contrast to connections of individual poses)

Behavior Based Graphs

Behavior Planning for Character Animation
M. Lau & J. Kuffner

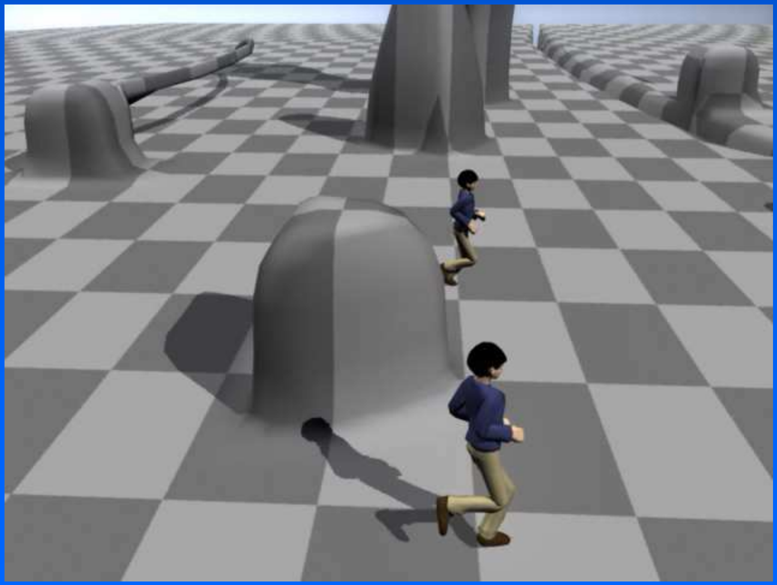
Manually-Constructed Behavior FSM



+ Search Efficiency
+ Memory Usage
+ Intuitive Structure

– Requires segmented motion data
– Requires FSM with appropriate transitions

Examples



Motion Graphs: Summary

- Build on the idea that natural human motion contains many similar poses – transitions can be found easily

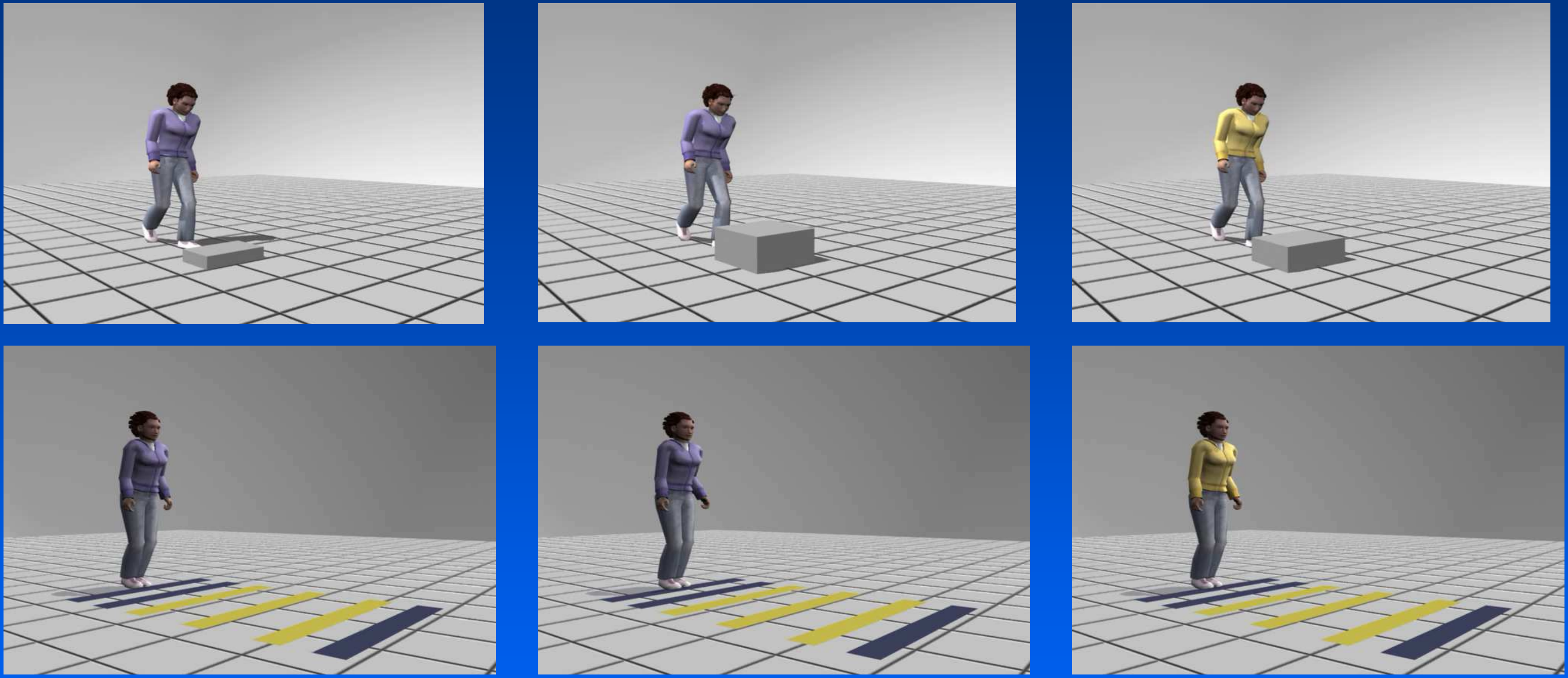
- Can synthesize long multi-behavior motions

- Restricted to motions in the database – can not synthesize variations

Motion Graphs: Summary

- Build on the idea that natural human motion contains many similar poses – transitions can be found easily
- Can synthesize long multi-behavior motions
- Restricted to motions in the database – can not synthesize variations

Motion Interpolation (introduced in 1995)



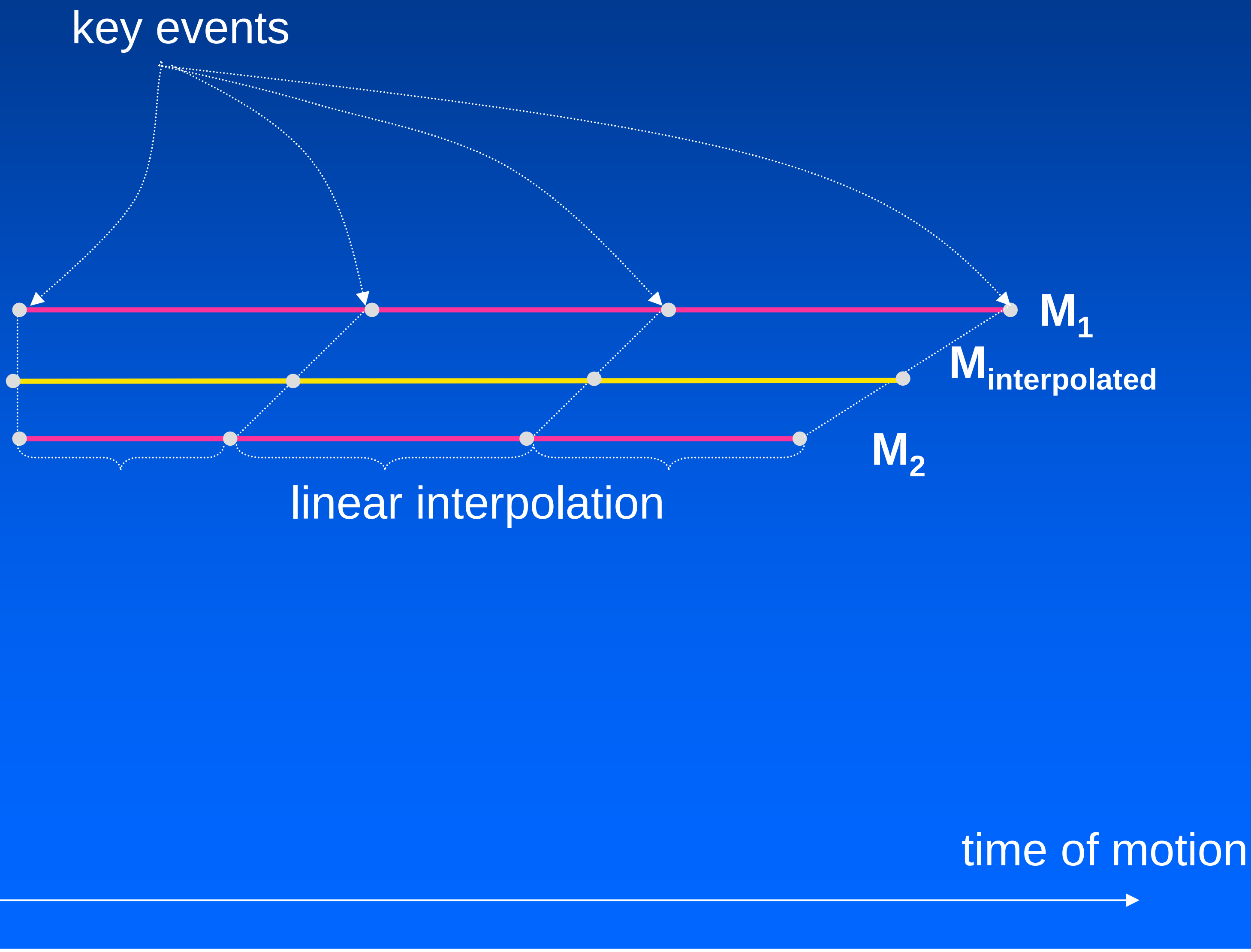
motion capture

interpolated motion

Resulting motion is natural

Close to physically correct in many cases

How do we compute interpolated motion?



key events

M_1

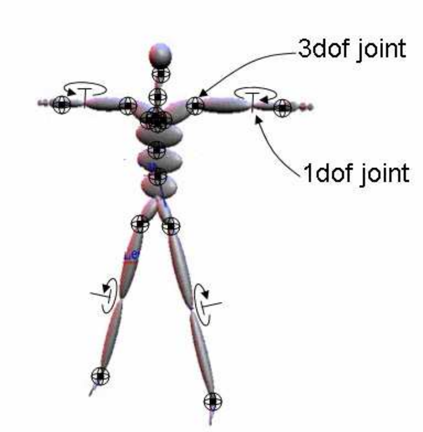
$M_{interpolated}$

M_2

linear interpolation

time of motion

How do we compute interpolated motion?



joint angles
root position

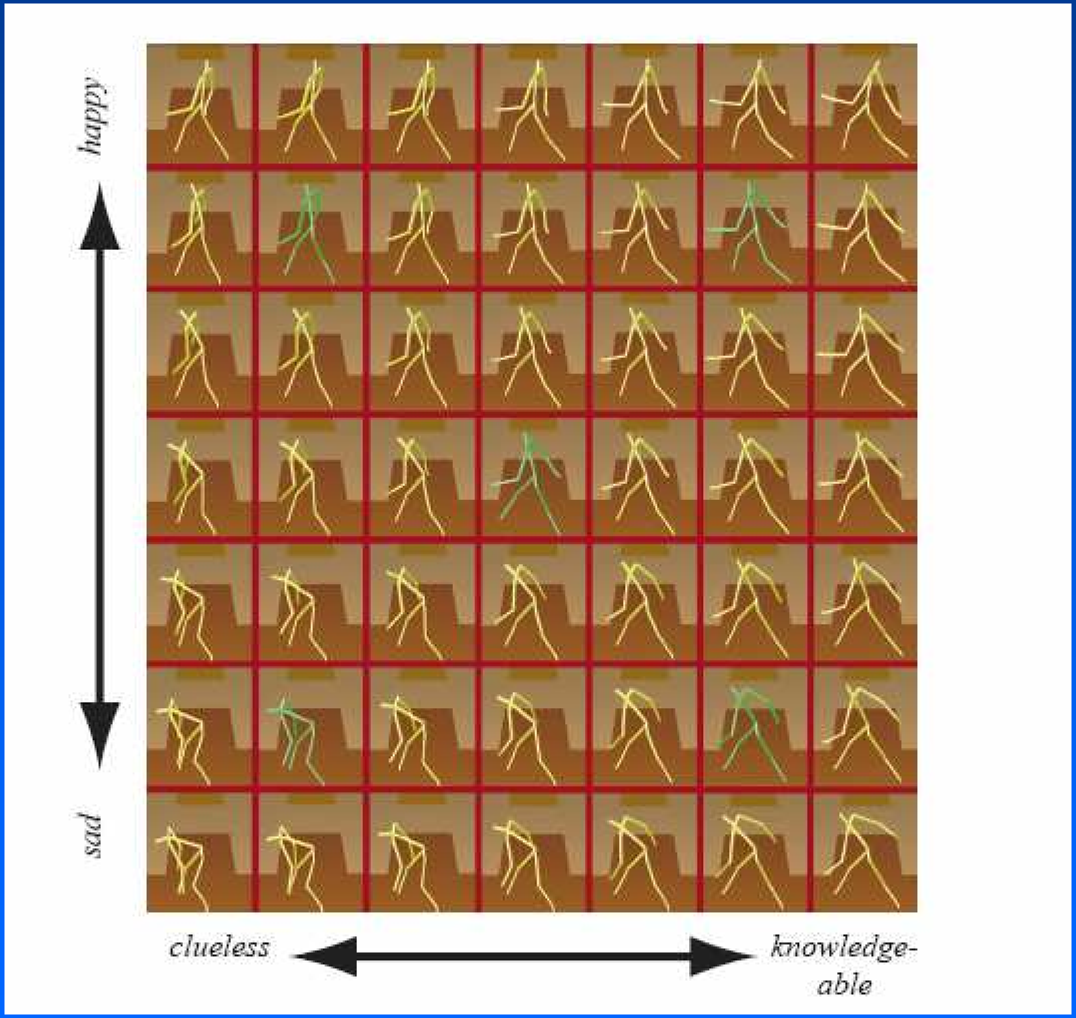
Contact Phase of Motion:

$$M(t) = \begin{cases} P(t)\text{: root position over time} \\ Q(t) = q_1(t) \ldots q_{60}(t)\text{: all joint angles over time} \end{cases}$$

Linear interpolation:

$$M(t,w) = \begin{cases} P(t) = wP_1(t_1) + (1-w)P_2(t_2) & \textbf{root position} \\ q_i(t) = wq_{1i}(t_1) + (1-w)q_{2i}(t_2) & \textbf{joint angles} \end{cases}$$

Verbs and Adverbs: Multidimensional Motion Interpolation
Charles Rose, Michael Cohen and Bobby Bodenheimer



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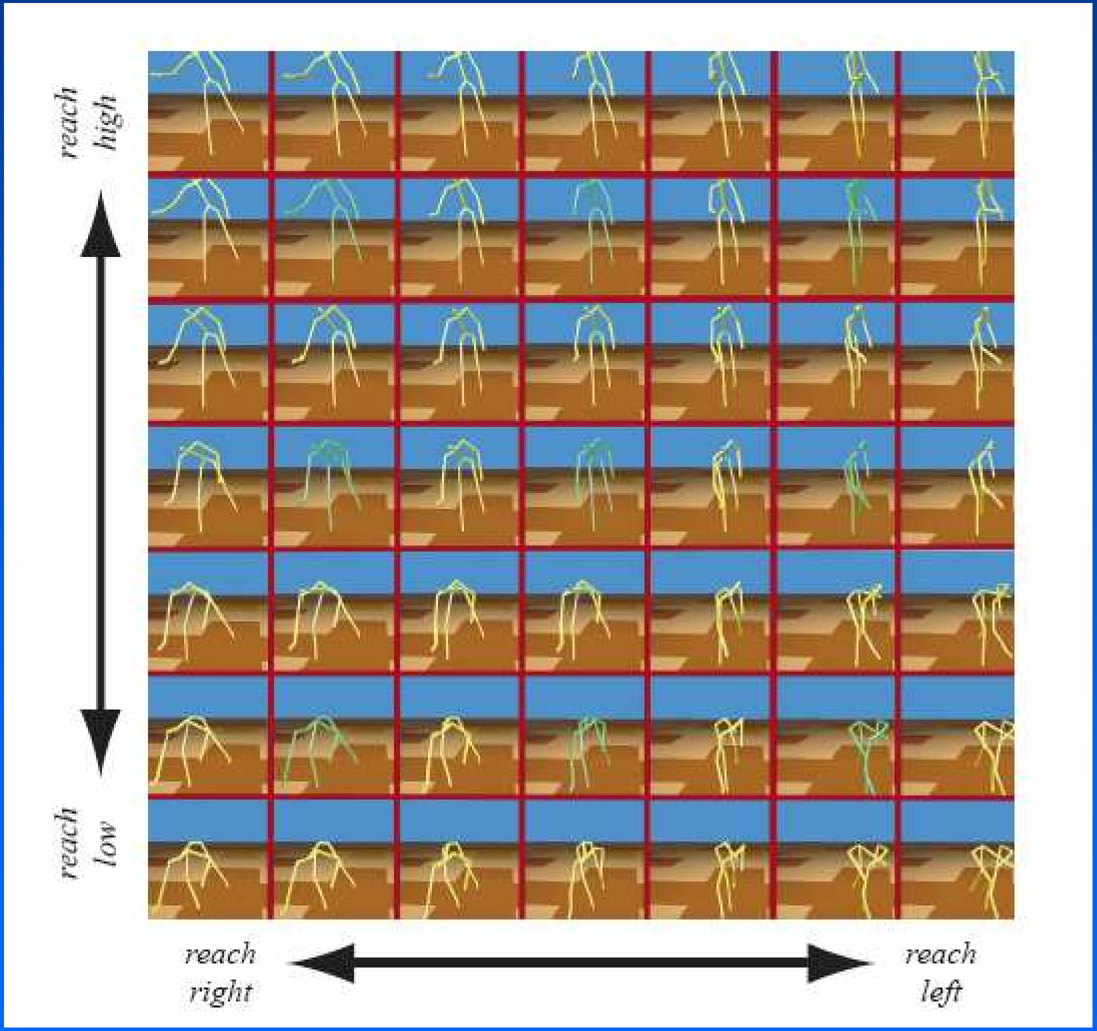

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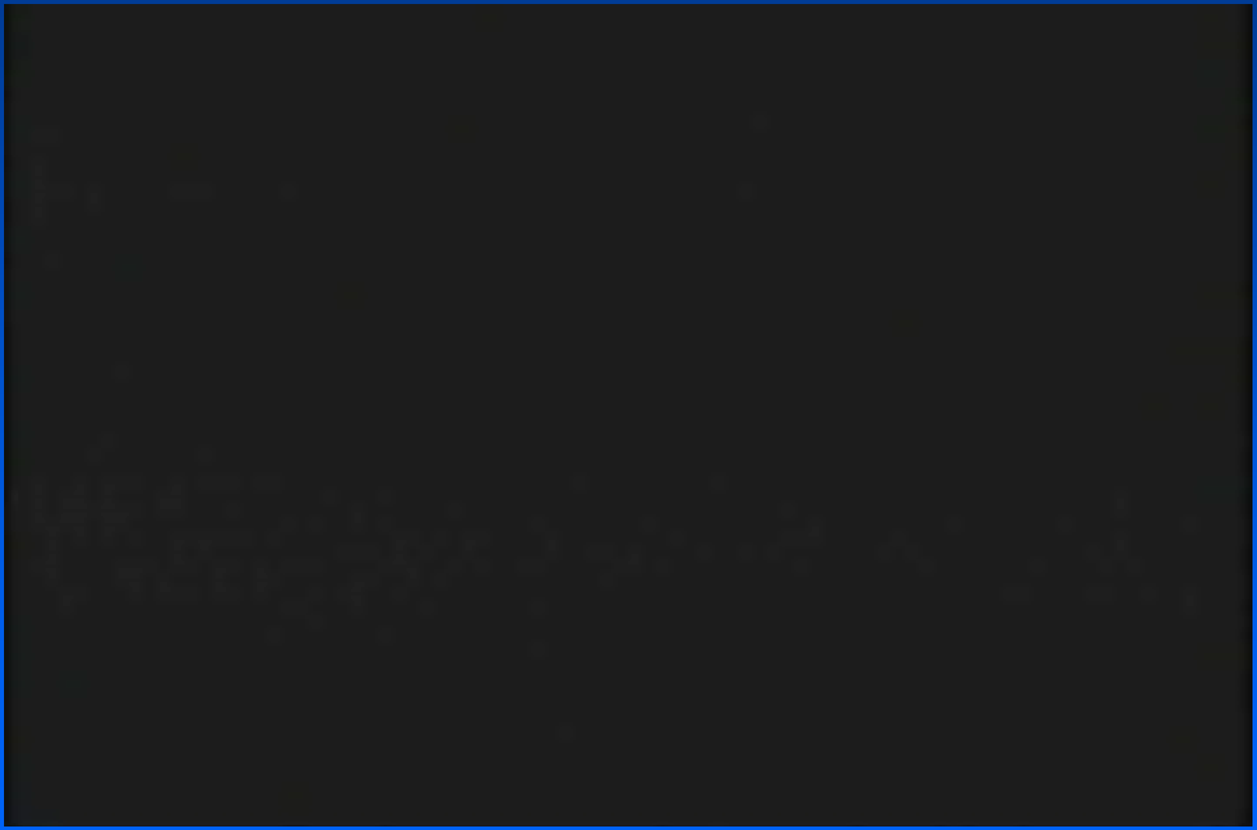


Interpolation: Summary

- Interpolation produces surprisingly natural motion
- Motion is often close to physically correct
- Sequences must be properly aligned and of a single behavior

Interpolated Motion Graphs

Safonova and Hodgins

Each pose is represented by interpolation of existing poses

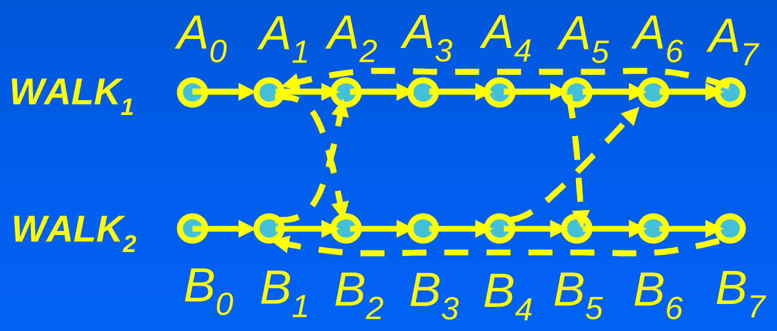
$$P_{new}(t) = P_1(t)w + P_2(t)(1-w)$$

$P_i(t)$ path through the motion graph

Path Through Motion Graph

$P_{new}(t) = P_1(t)w + P_2(t)(1-w)$

$P_i(t)$ path through the motion graph


A_0 A_1 A_2 A_3 A_4 A_5 A_6 A_7
$WALK_1$
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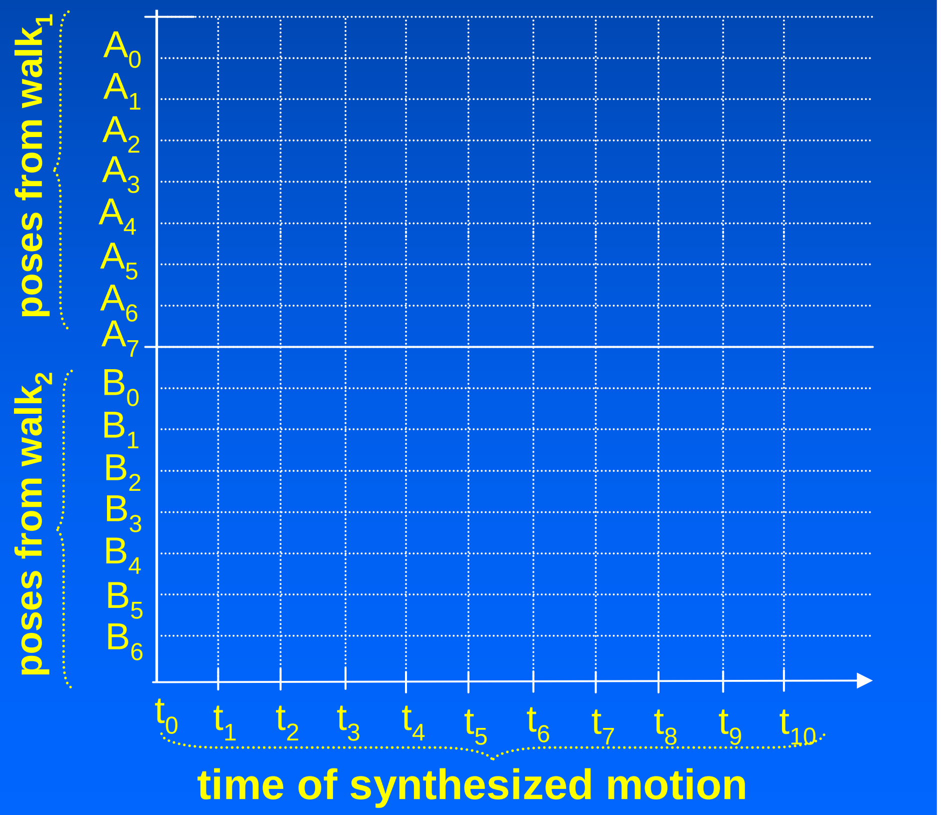
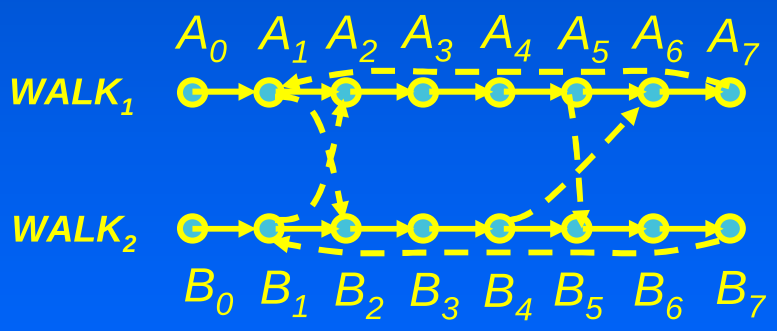


Path Through Motion Graph

$P_{new}(t) = P_1(t)w + P_2(t)(1\text{-}w)$

$P_i(t)$ path through the motion graph



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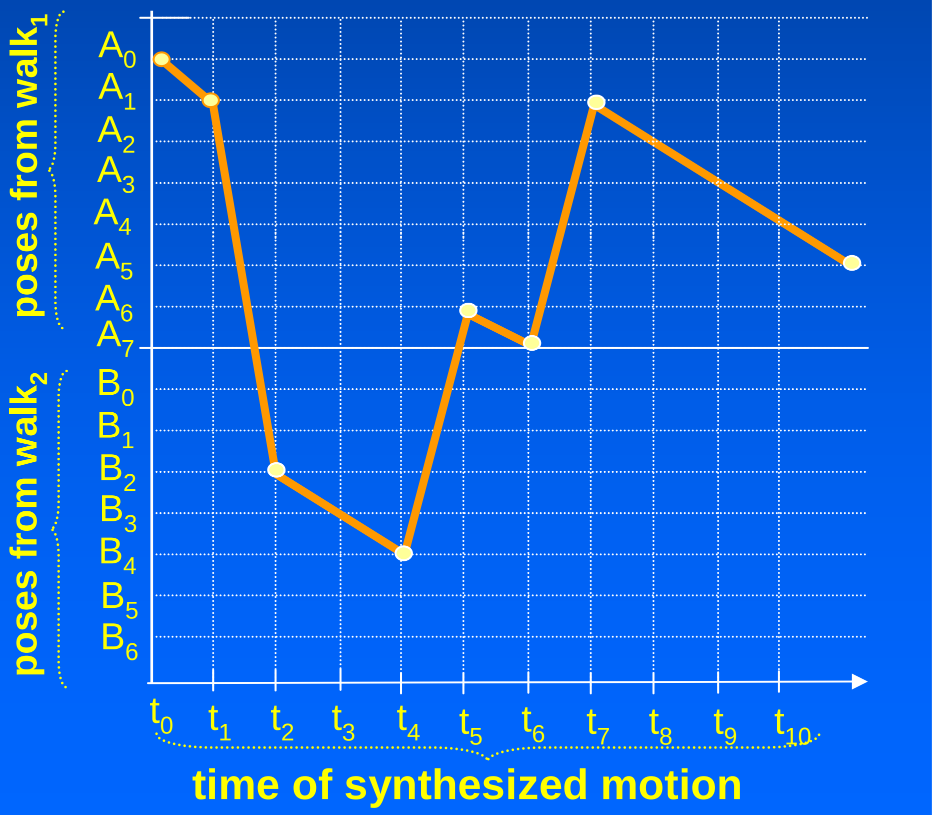
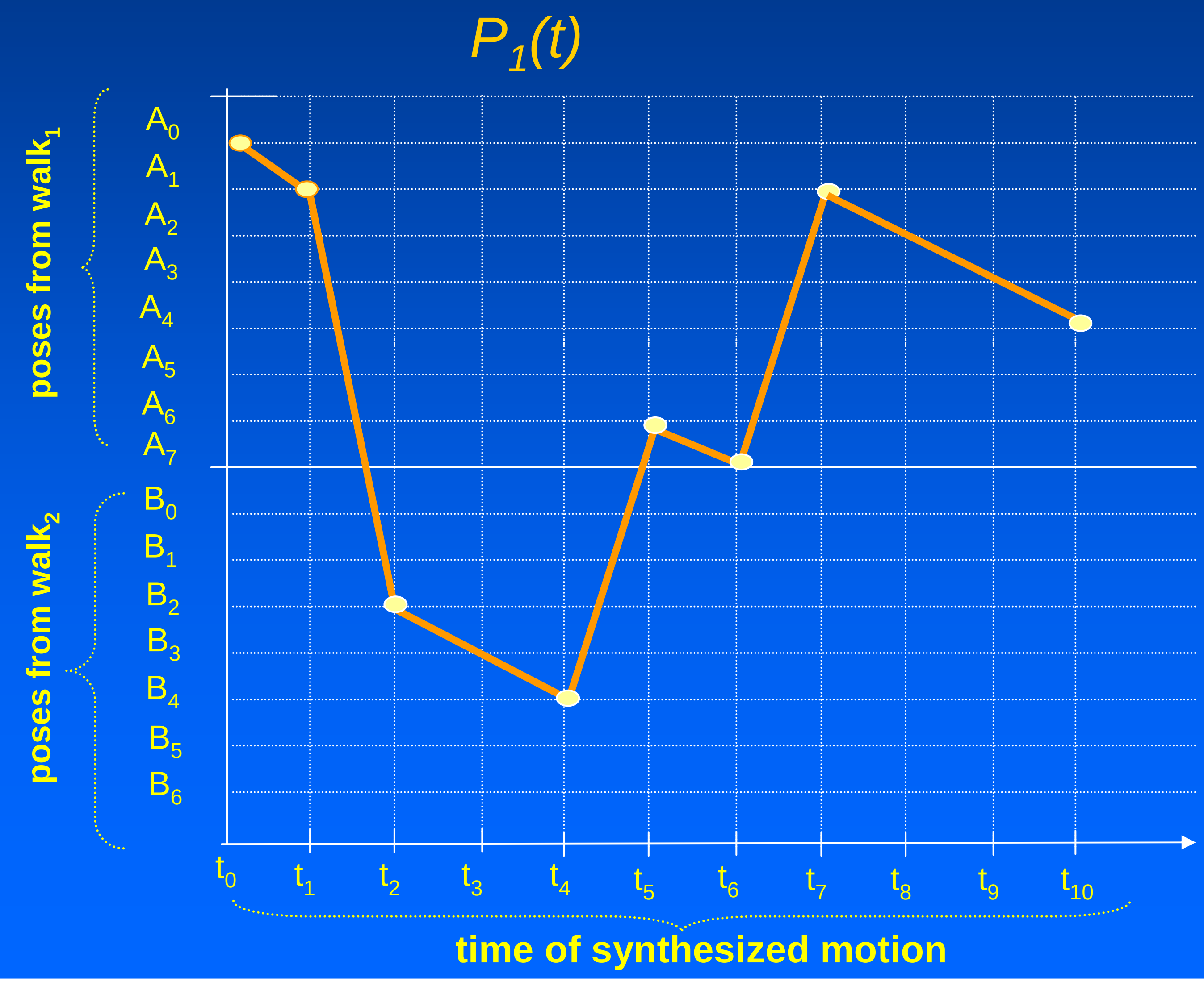
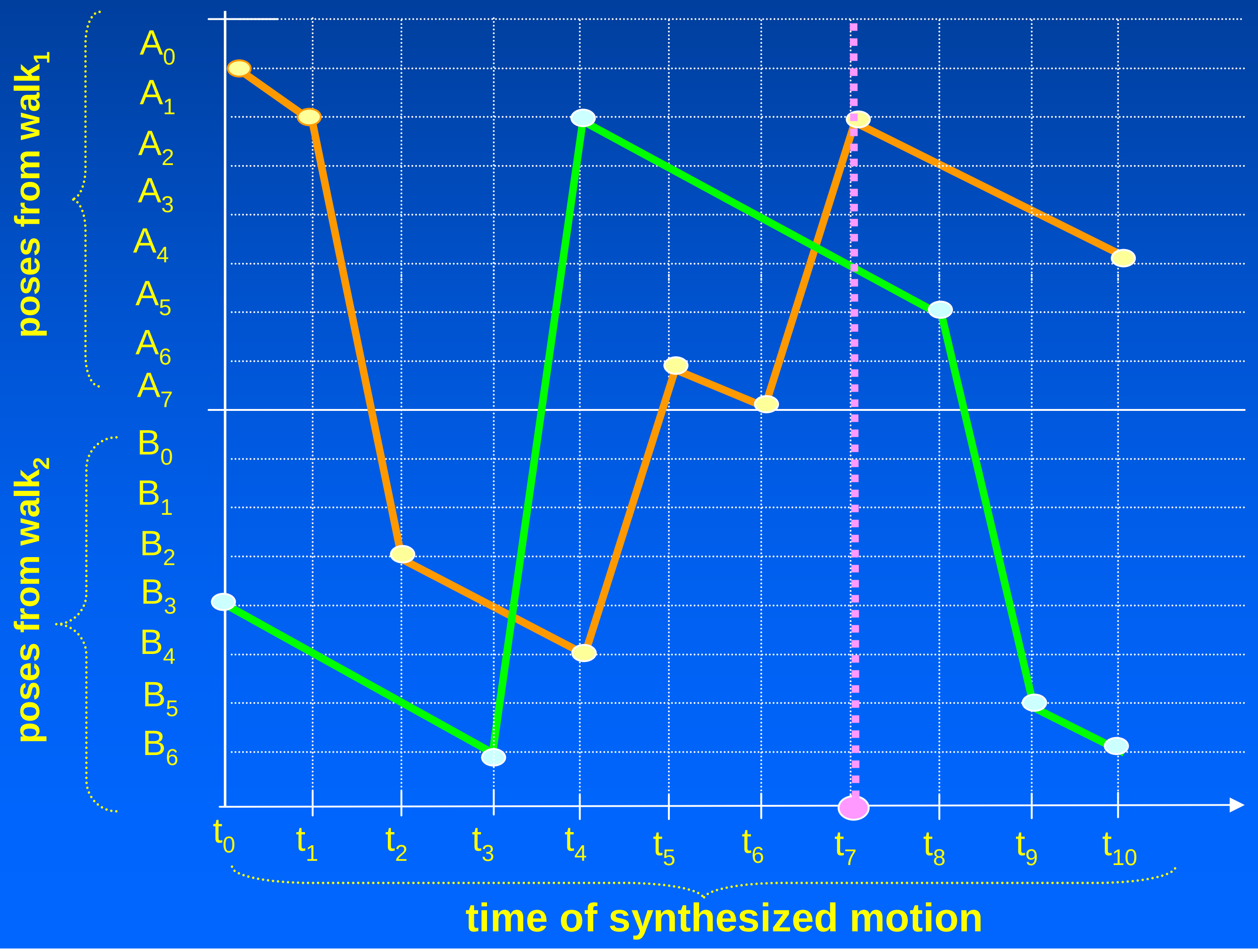


Interpolated Motion Graph



Interpolated Motion Graph

$$P_{new}(t) = P_1(t)w + P_2(t)(1-w)$$



Interpolating paths through motion graph

Why good representation?

$$P_{new}(t) = P_1(t)w + P_2(t)(1-w)$$

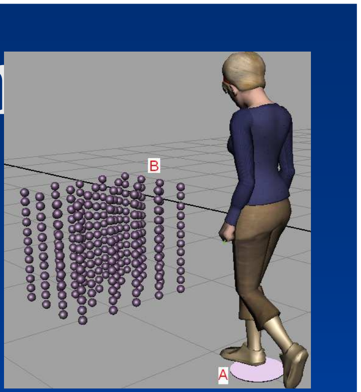
$P_i\,(t)$ path through the motion graph

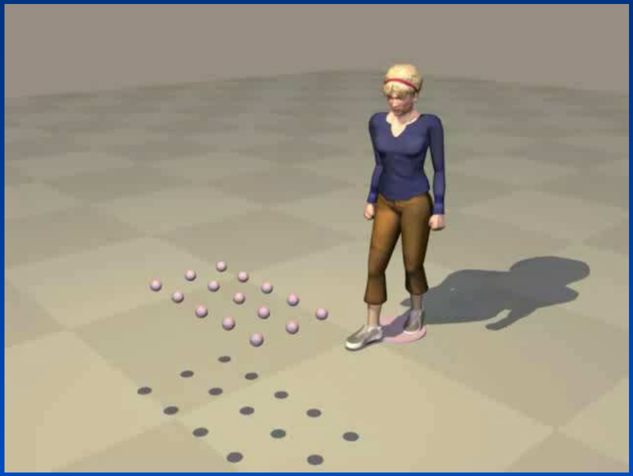
Unlike motion graph:
Can generate variations of motions in mocap database

Unlike interpolation:
Can optimize for complex longer motions
Do not need to pre-process motions into similar segments by hand

Retains naturalness and physical realism
Retains natural transitions of motion graphs

The benefit of interpolation



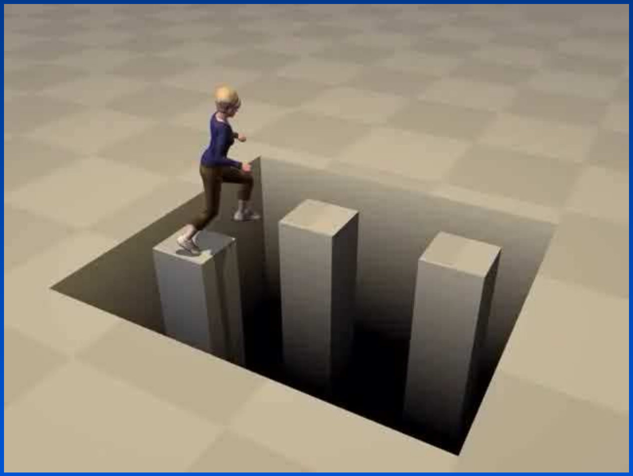


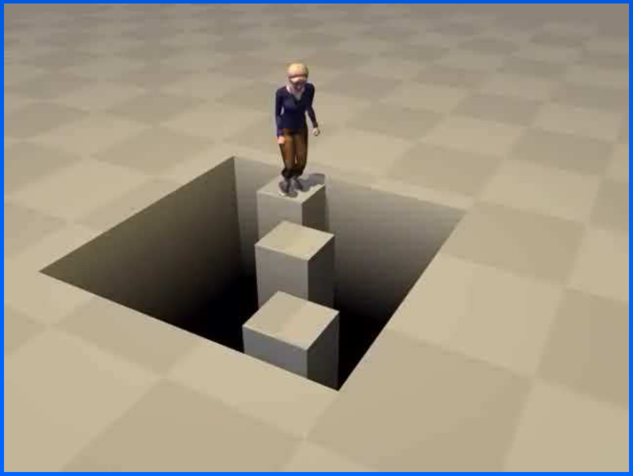
270 sample points

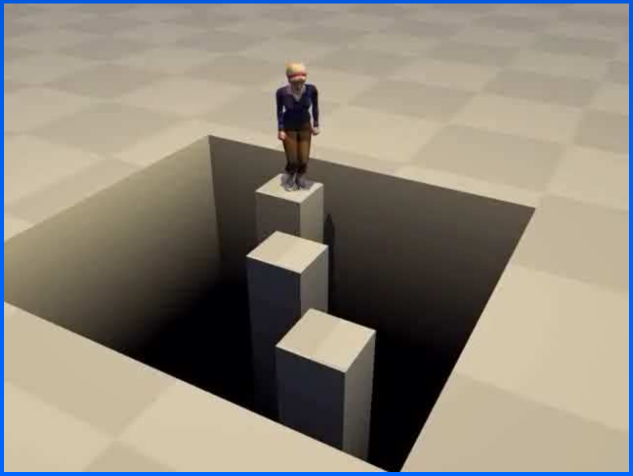
31% success with no interpolation

99% success with interpolation

Examples of motions – jumping across stones

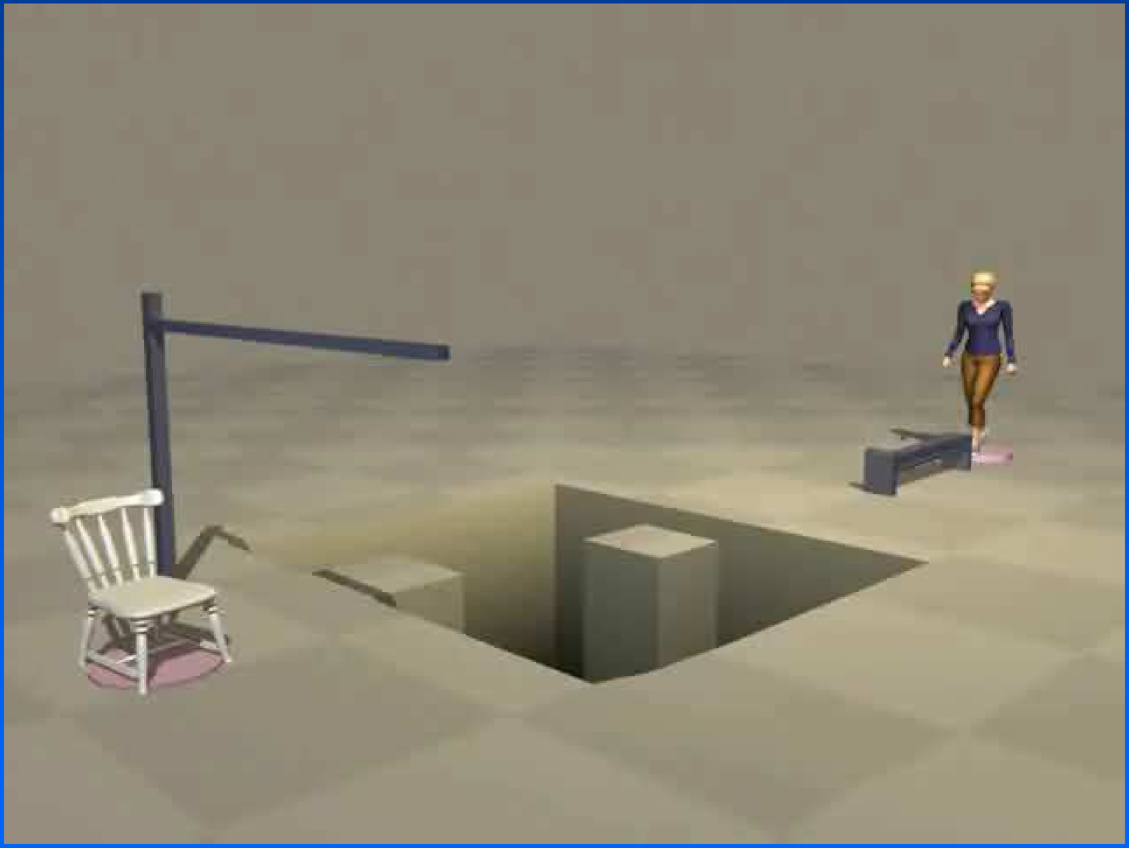






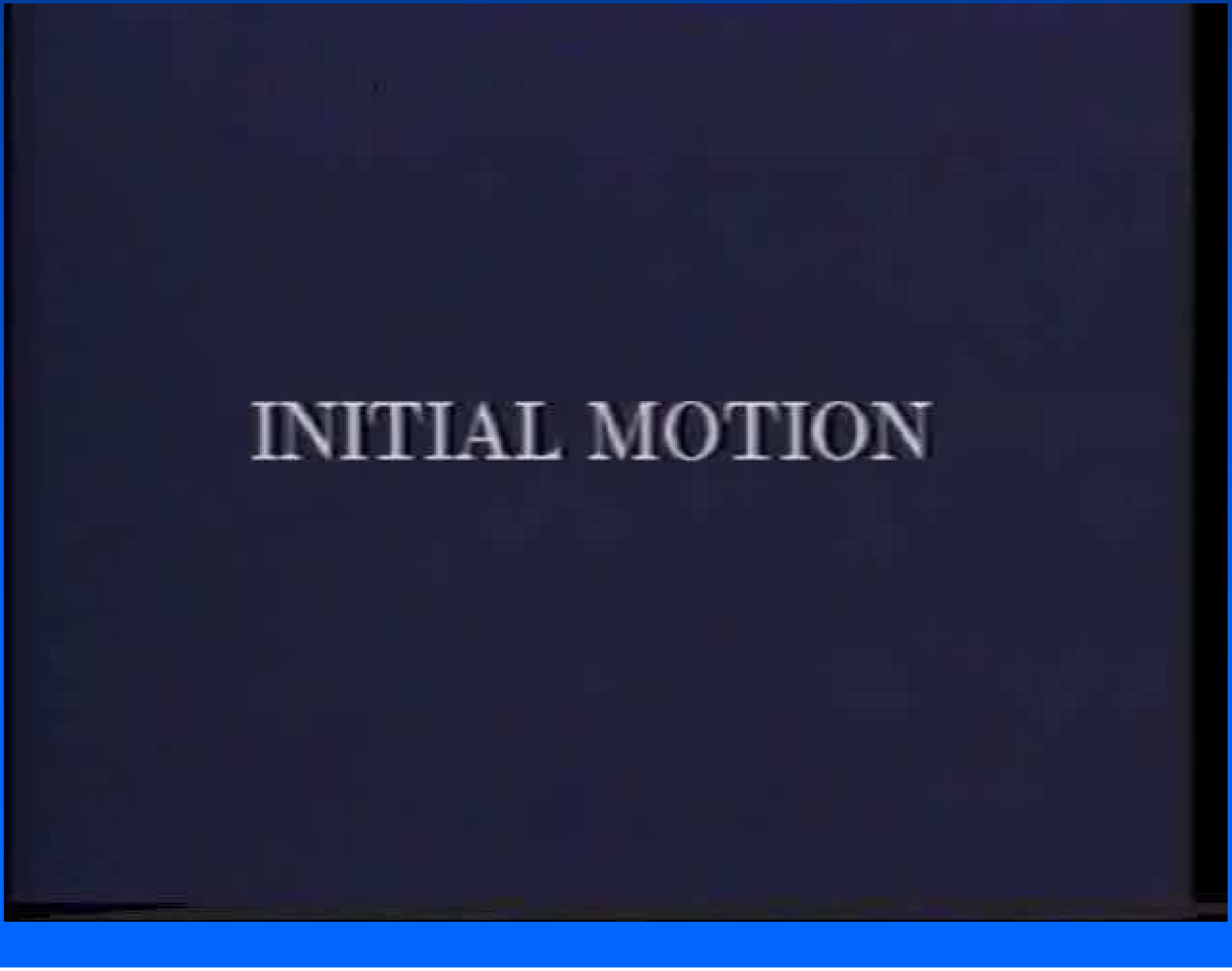
Examples of motions – obstacle course

Examples of motions – obstacle course



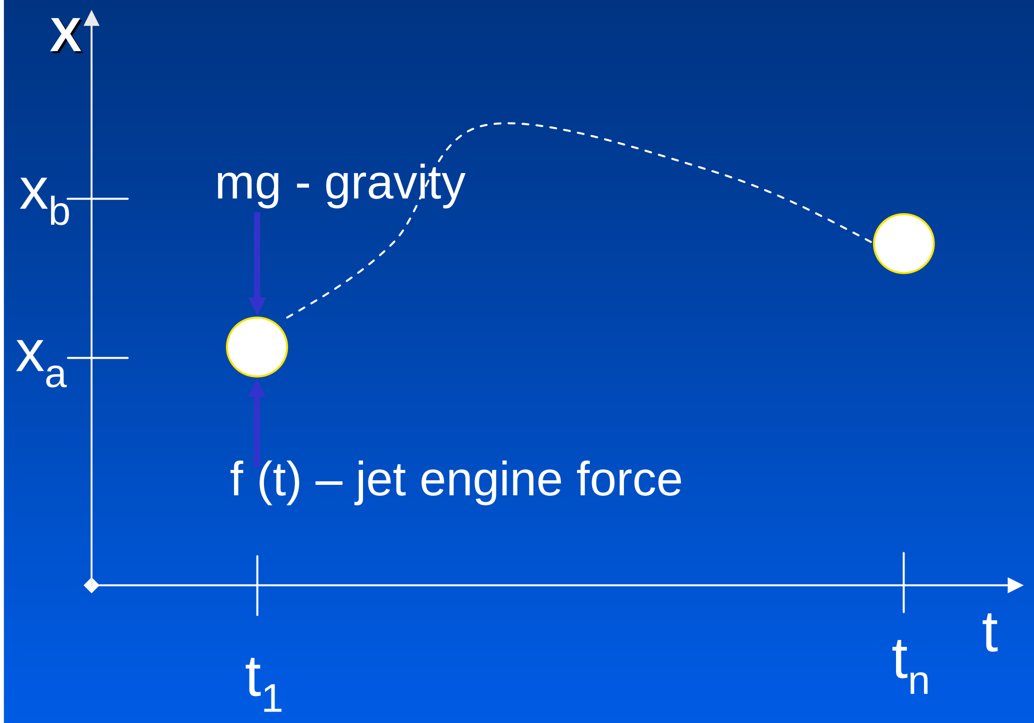
Constrained Optimization

Luxo Lamp (Spacetime Constraints, Witkin and Kass, SIGGRAPH 88)



INITIAL MOTION

Optimization Problem Setup



Given:

- Particle is at point X_a at time t_1
- Particle is at point X_b at time t_n

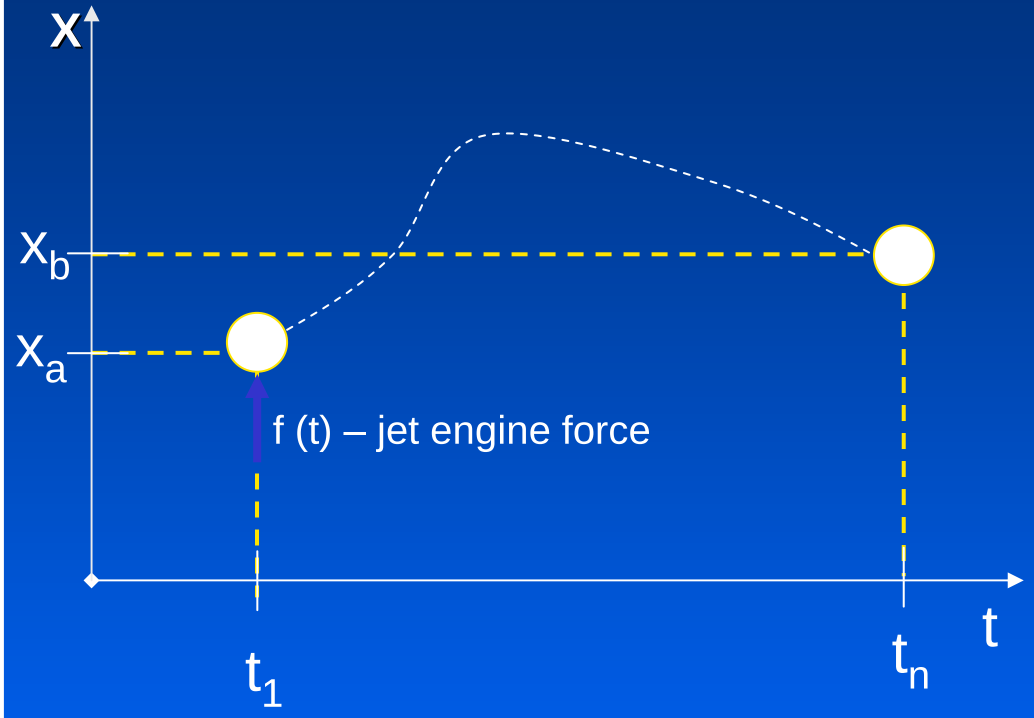
Find:

- Trajectory of the particle that minimizes fuel consumption

$$\sum forces = m\ddot{x}$$

$$f - mg = m\ddot{x}$$

Optimization Problem Setup



Optimization Problem:

- unknowns

  $x(t_1), x(t_2)\dots x(t_n)$

- constraints

  $$x(t_1) = x_a$$

  $$x(t_n) = x_b$$

  $$F_{\min} \le f(t) \le F_{\max}$$

- minimize

  $$R = \sum_{i=1}^{n} \left| f(t_i) \right|^2$$

Optimization Problem Setup

Optimization Problem:

- unknowns

  $x(t_1), x(t_2)\ldots x(t_n)$

- constraints

$$x(t_1) = x_a$$

$$x(t_n) = x_b$$

$$F_{\min} \le f(t) \le F_{\max}$$

- minimize

$$R = \sum_{i=1}^{n} \left| f(t_i) \right|^2$$

Optimization Problem Setup

Optimization Problem:

- unknowns

$x(t_1), x(t_2) \ldots x(t_n)$

number of unknowns ?

n

- constraints

$$x(t_1) = x_a$$

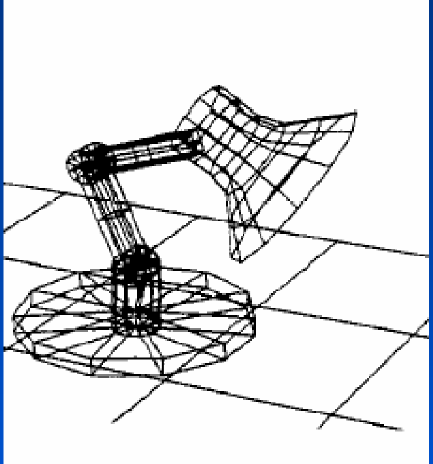
$$x(t_n) = x_b$$

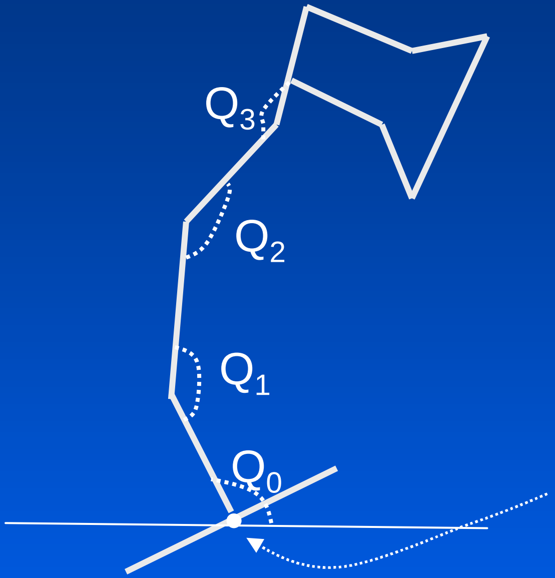
$$F_{\min} \le f(t) \le F_{\max}$$

- minimize

$$R = \sum_{i=1}^{n} \left| f(t_i) \right|^2$$

Luxo in Plane





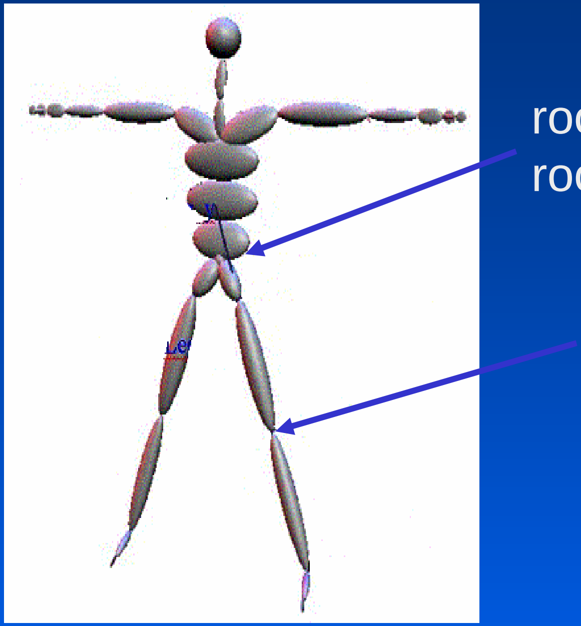
(P_x, P_y) root position

unknowns:

P_x at time t_1 … t_n
P_y at time t_1 … t_n
Q_0 at time t_1 … t_n
Q_1 at time t_1 … t_n
Q_2 at time t_1 … t_n
Q_3 at time t_1 … t_n

→ **6n unknowns**

Human in 3D space



root position
root orientation

joint angles

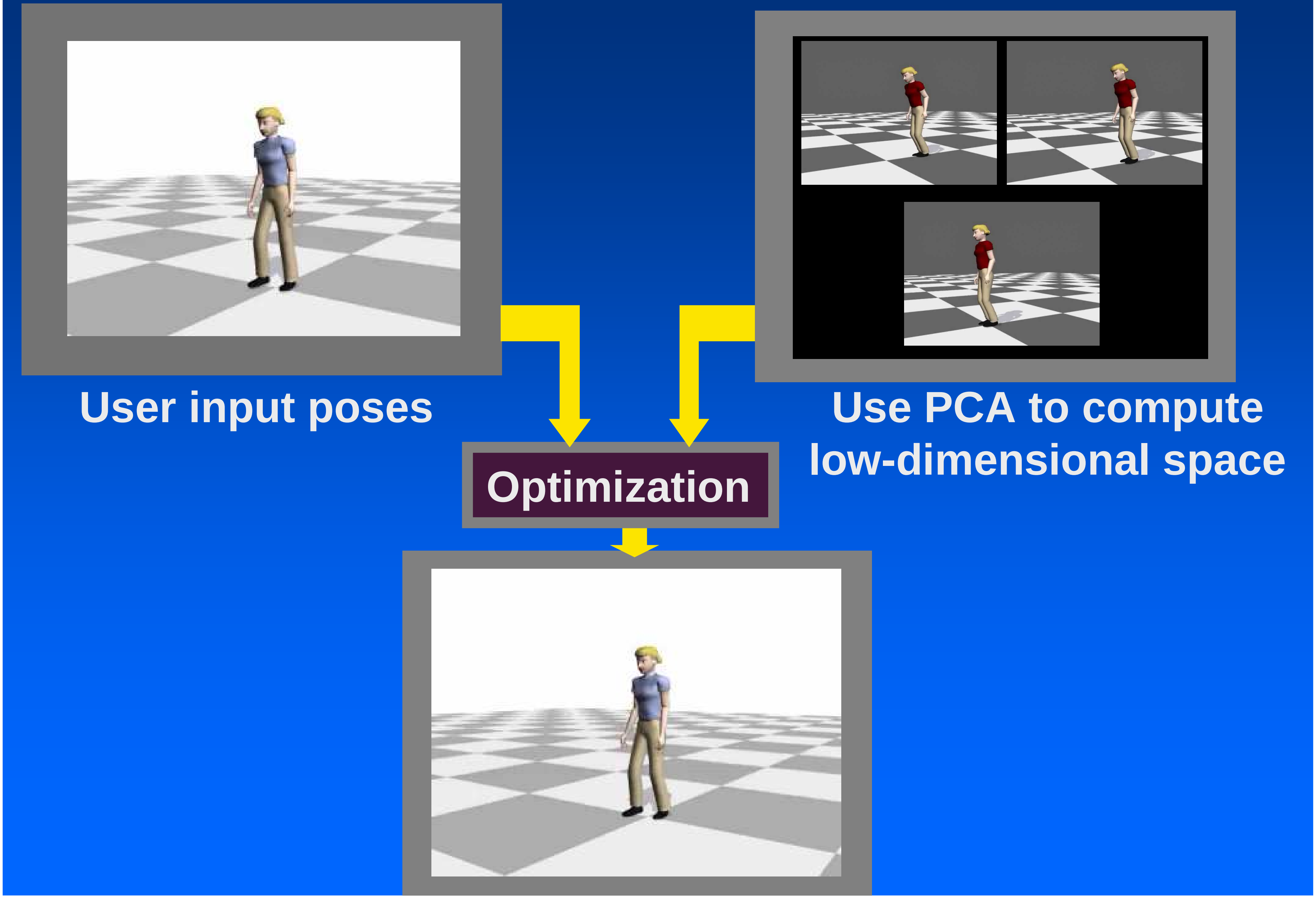
50 parameters (degrees of freedom)

50n unknowns

nonlinear optimization function
nonlinear constraints

50 degrees of freedom

Optimization in low-d space



User input poses

Use PCA to compute low-dimensional space

Optimization

Announcements

- Course Evaluation is now open
- Until Monday, May 7th
- Please complete the evaluation

- We read it and listen to what you say