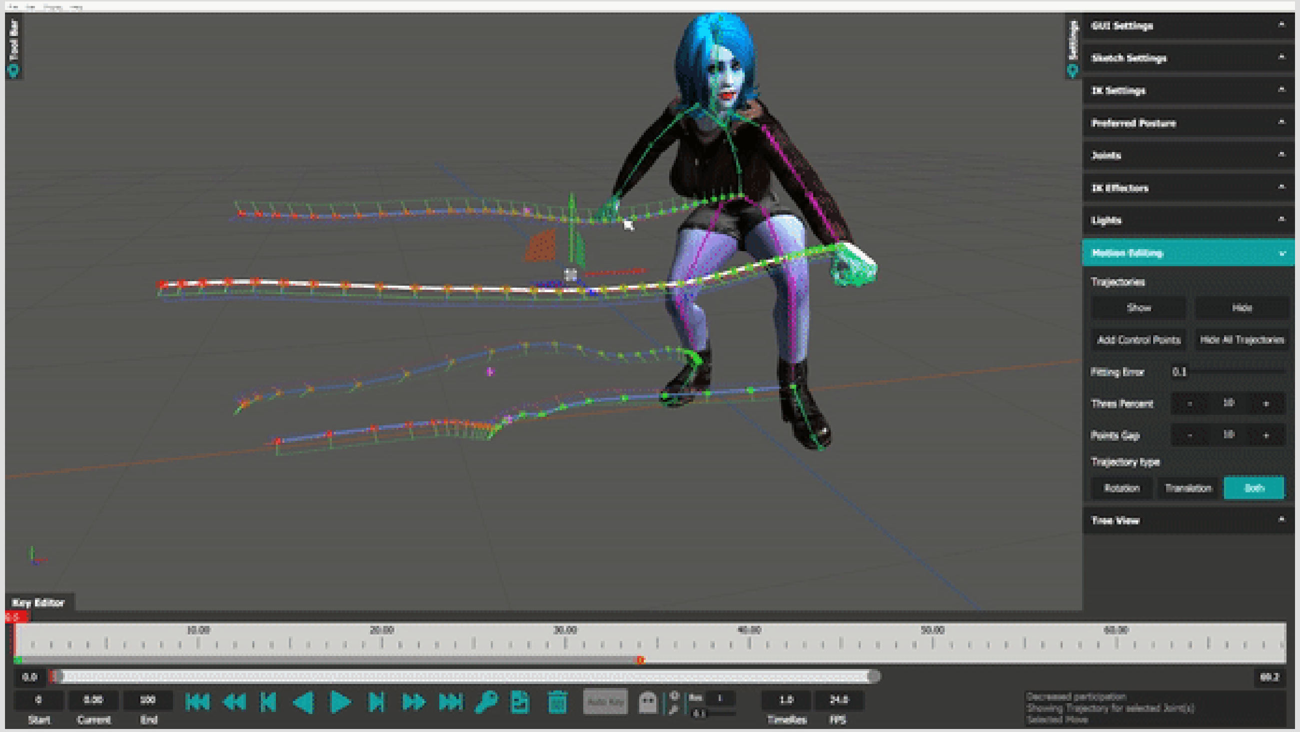
Motion Editing

- Getting the motion you ***want*** from the motion you ***have***

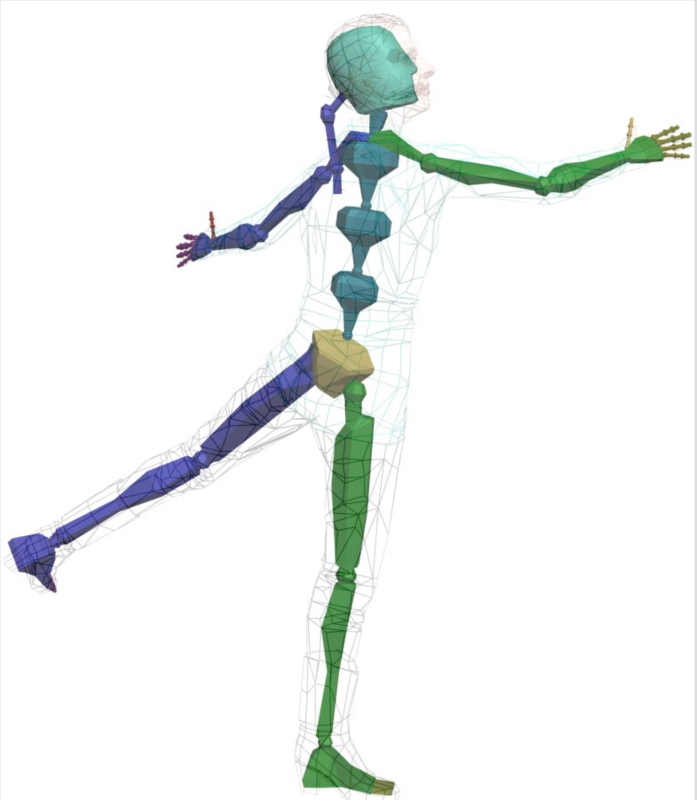
- General techniques
  - Warping
  - Splicing
  - Blending
  - Transplanting



Credit: Muni Animation

Overview

- Motion Editing
  - Warping
  - Splicing
  - Blending
  - Transplanting



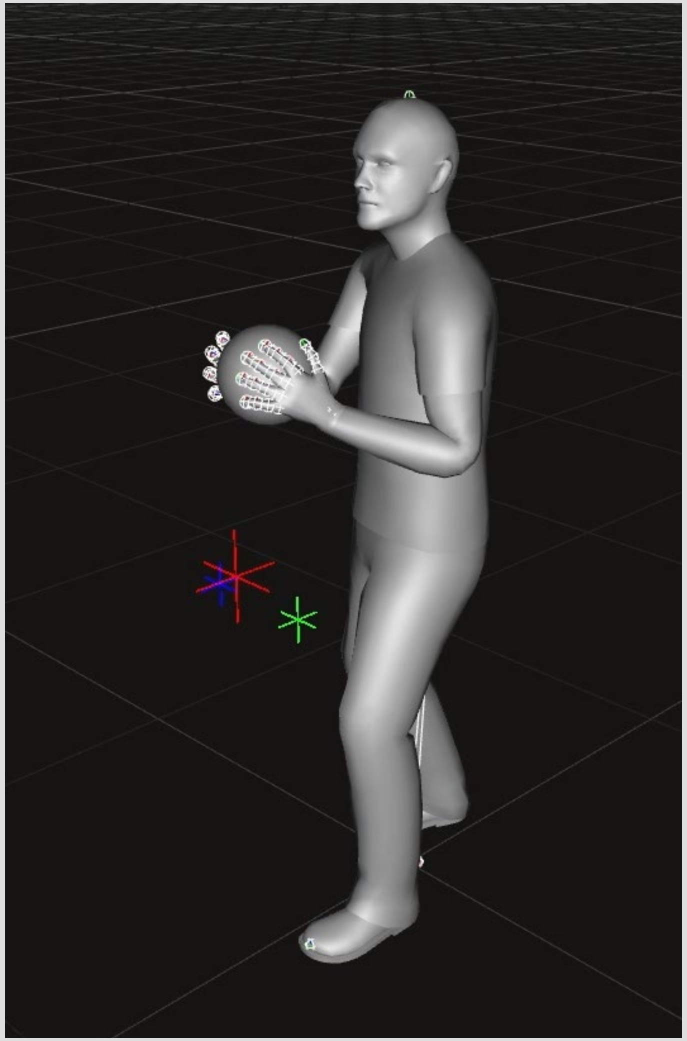
Next lecture:

- *State Machines*
- *Motion Graphs*
- *Neural State Machines*

Warping Motions

- Adapt a single motion
  - e.g., character needs to catch a ball
  - A catching motion is available
  - Problem: that motion catches where ball *isn't*

- Common solution:
  - Inverse kinematics
  - *Displacement splines*



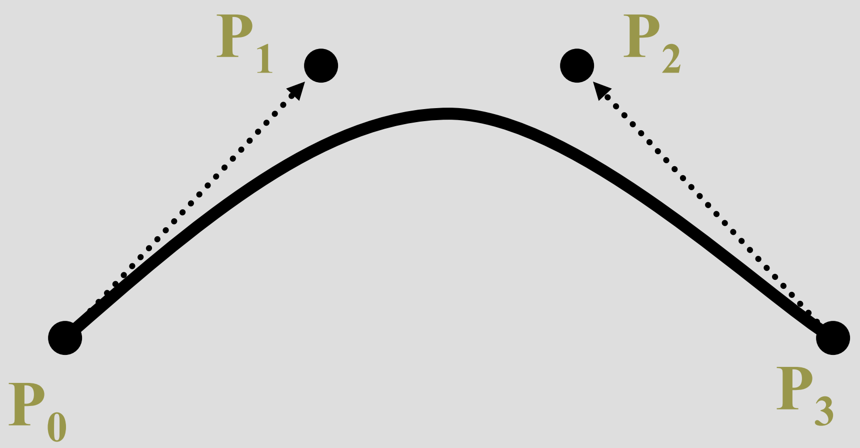
Displacement Splines

- Spline: smooth piecewise polynomial curve
- Displacement: distance away

- *Displacement spline:* smooth curve giving distance away from the original motion data
  - Smoothly moves animation away from original data to target point

Displacement Splines

- e.g., cubic Bezier curve
  - four control points P_i
  - $B(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t) P_2 + t^3 P_3$
  - $B(0) = P_0$
  - $B(1) = P_1$
  - $B'(0) = 3(P_1 - P_0)$
  - $B'(1) = 3(P_3 - P_2)$

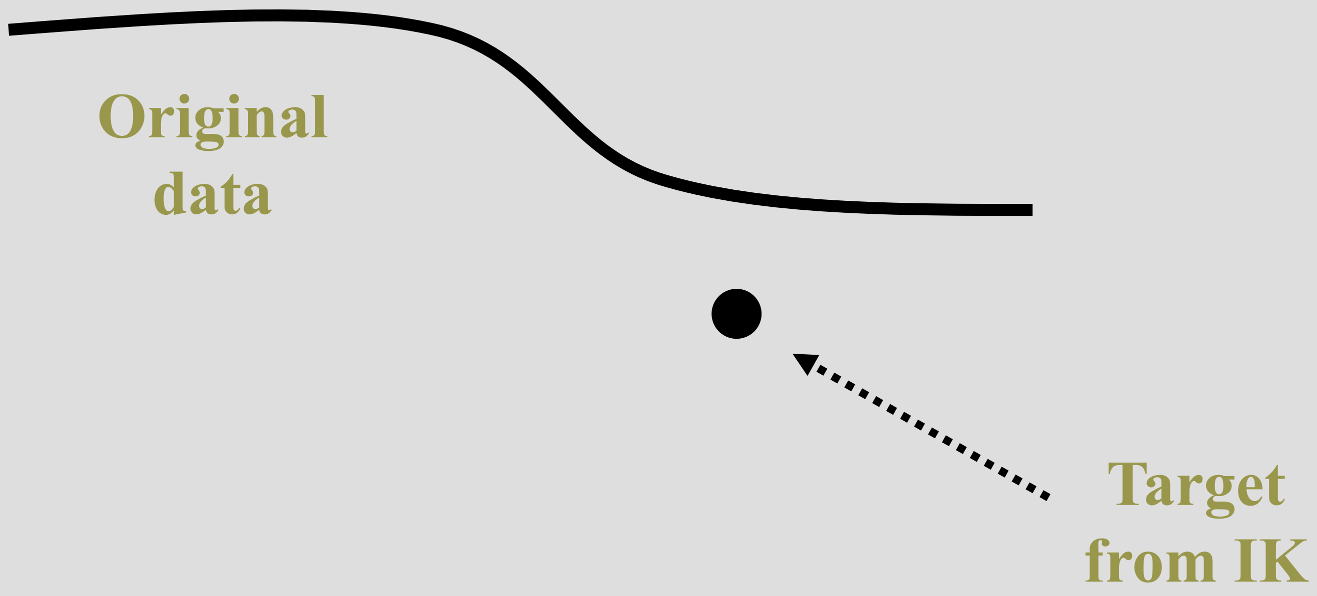


Displacement Splines

- e.g., cubic Bezier curve
  - Create longer curve via sequential cubics
  - Overlap first point of B_{i+1} with last point of B_i to make (C0) continuous curve
  - Overlap two points to make smooth C1 (velocity) continuous curve
  - Smoother curves require more advanced splines (e.g., cubic uniform B-splines)

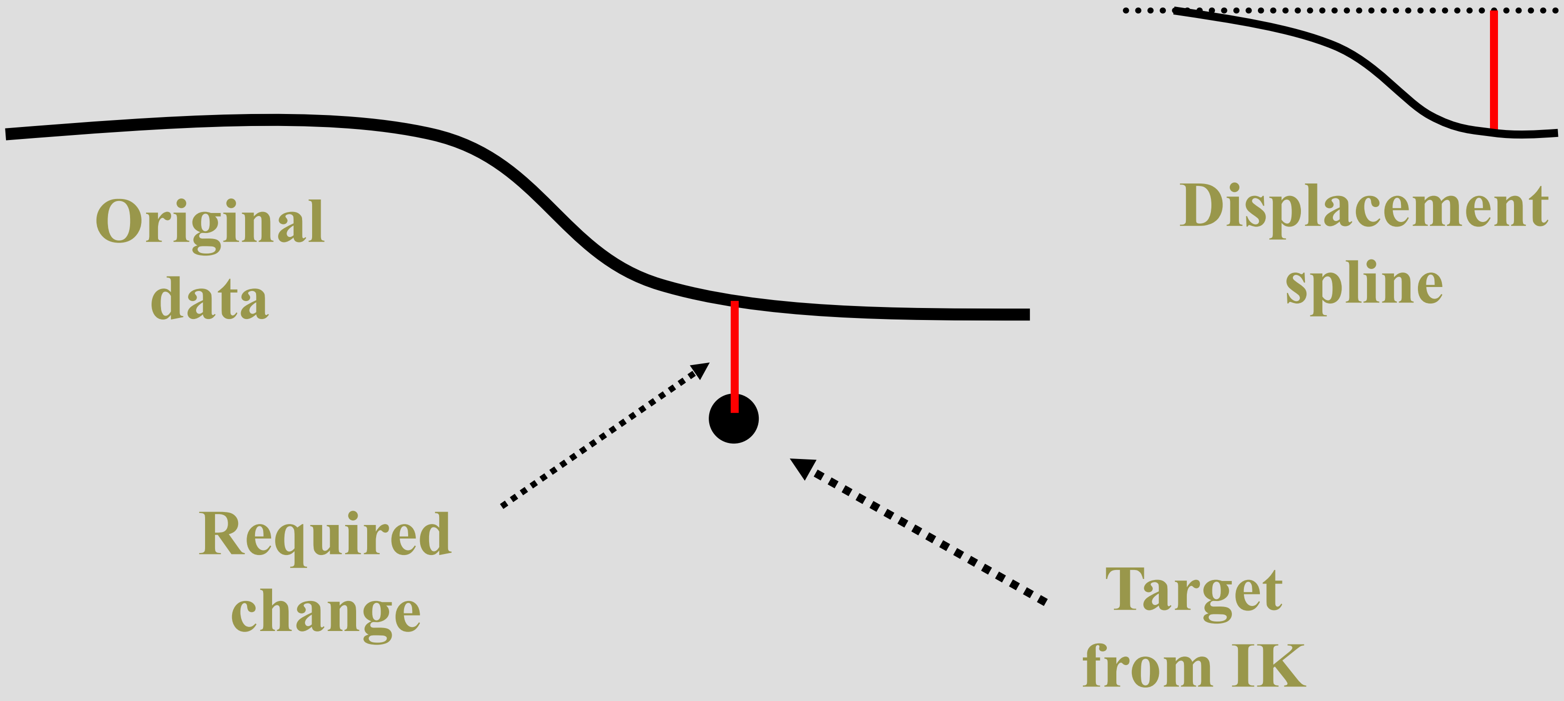
Warping Motions

- e.g., angle of elbow joint



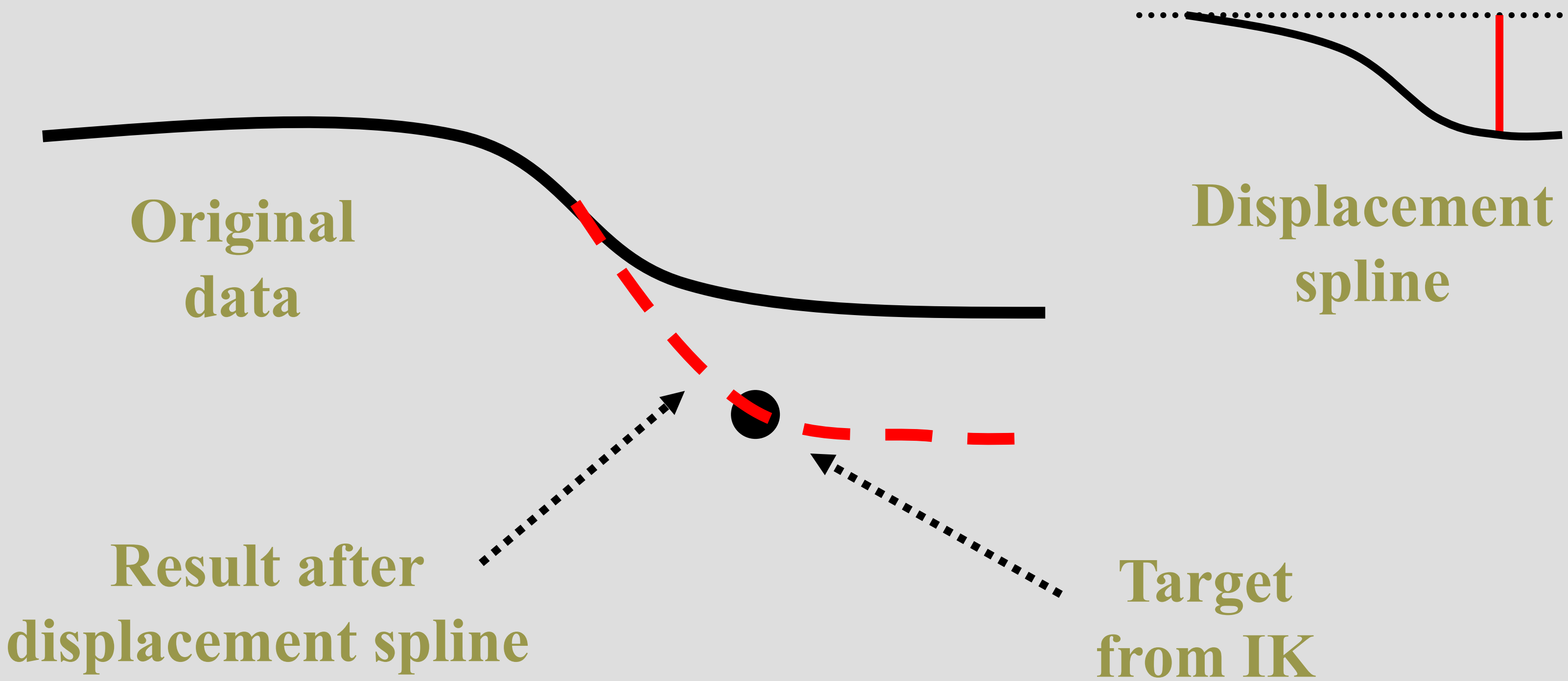
Warping Motions

- e.g., angle of elbow joint



Warping Motions

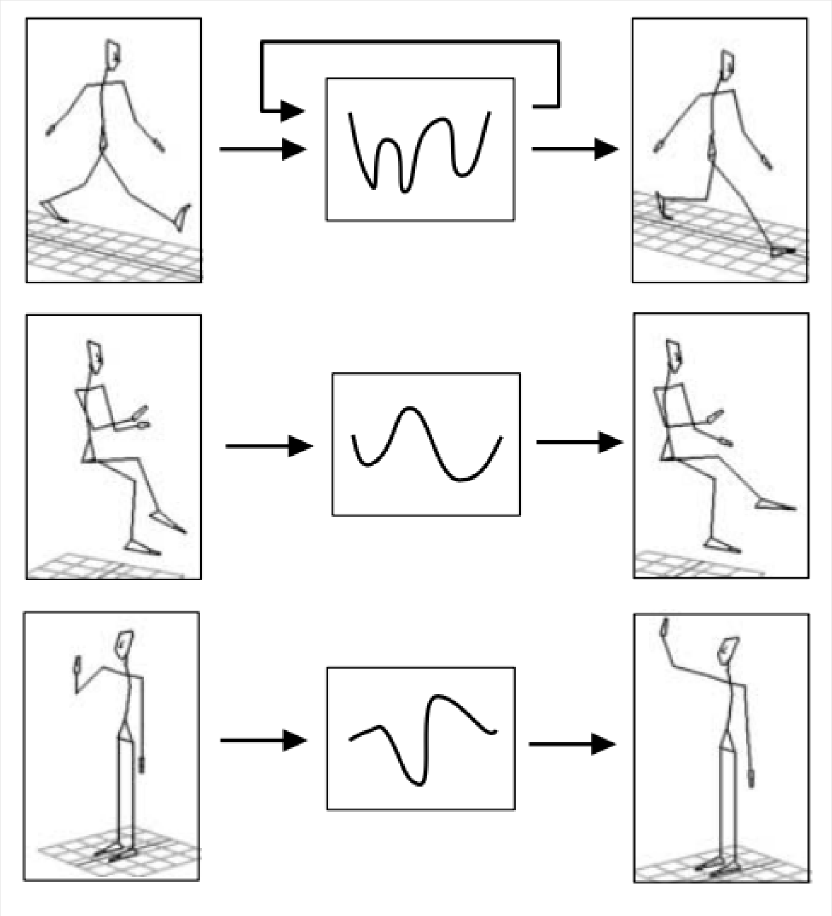
- e.g., angle of elbow joint



Warping Motions

- Also used to adjust locomotion
  - Longer steps
  - Higher jump
  - Proper turning angle
  - Duck under a beam

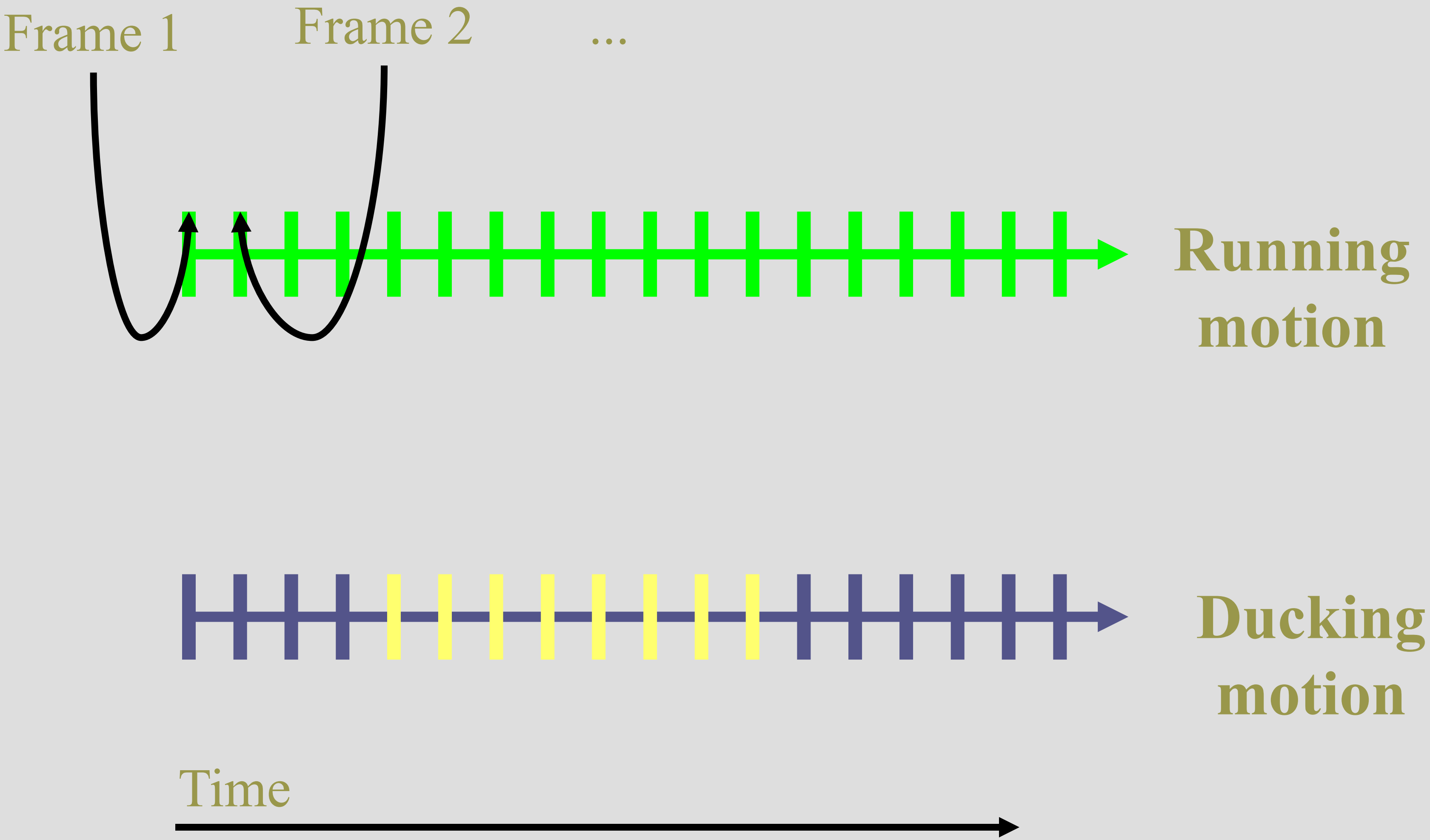
- General approach for adjusting or adding constraints to a single motion



Splicing Motions

- Have running motion
- Have ducking motion
- Want a motion where the character runs and then ducks

Example: Run + Duck



Approaches

1. Play running then ducking clips

Approaches

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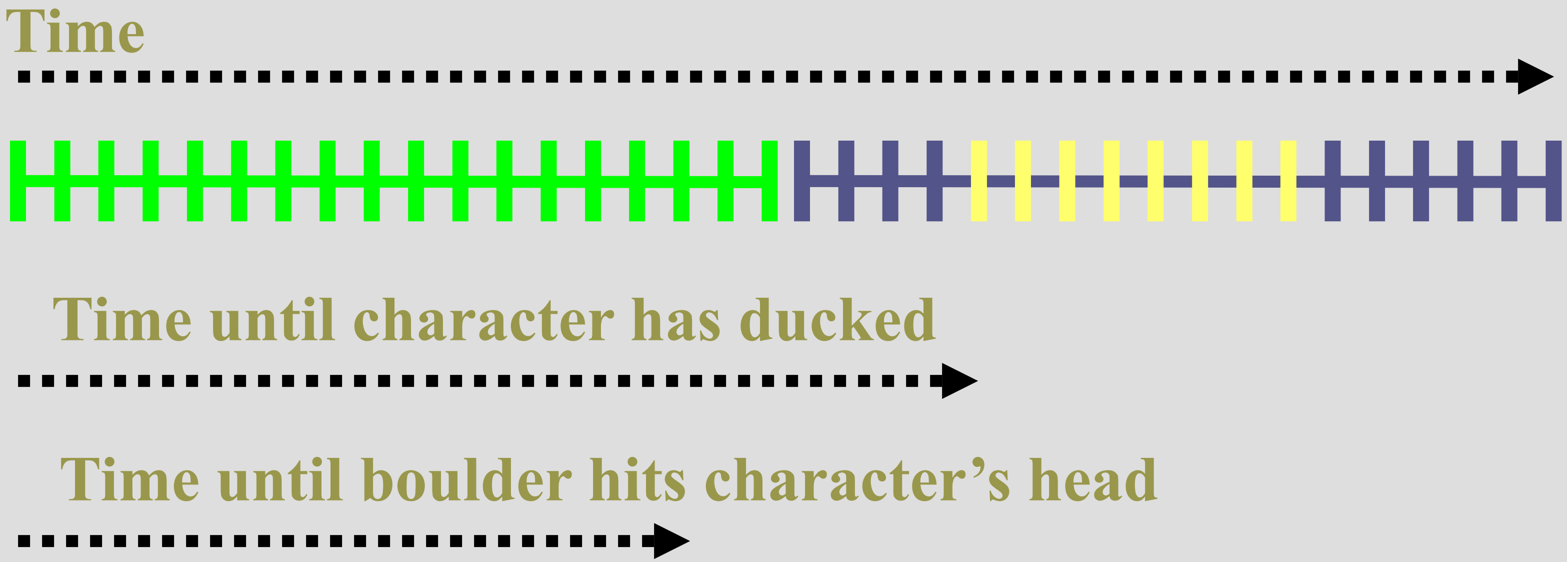
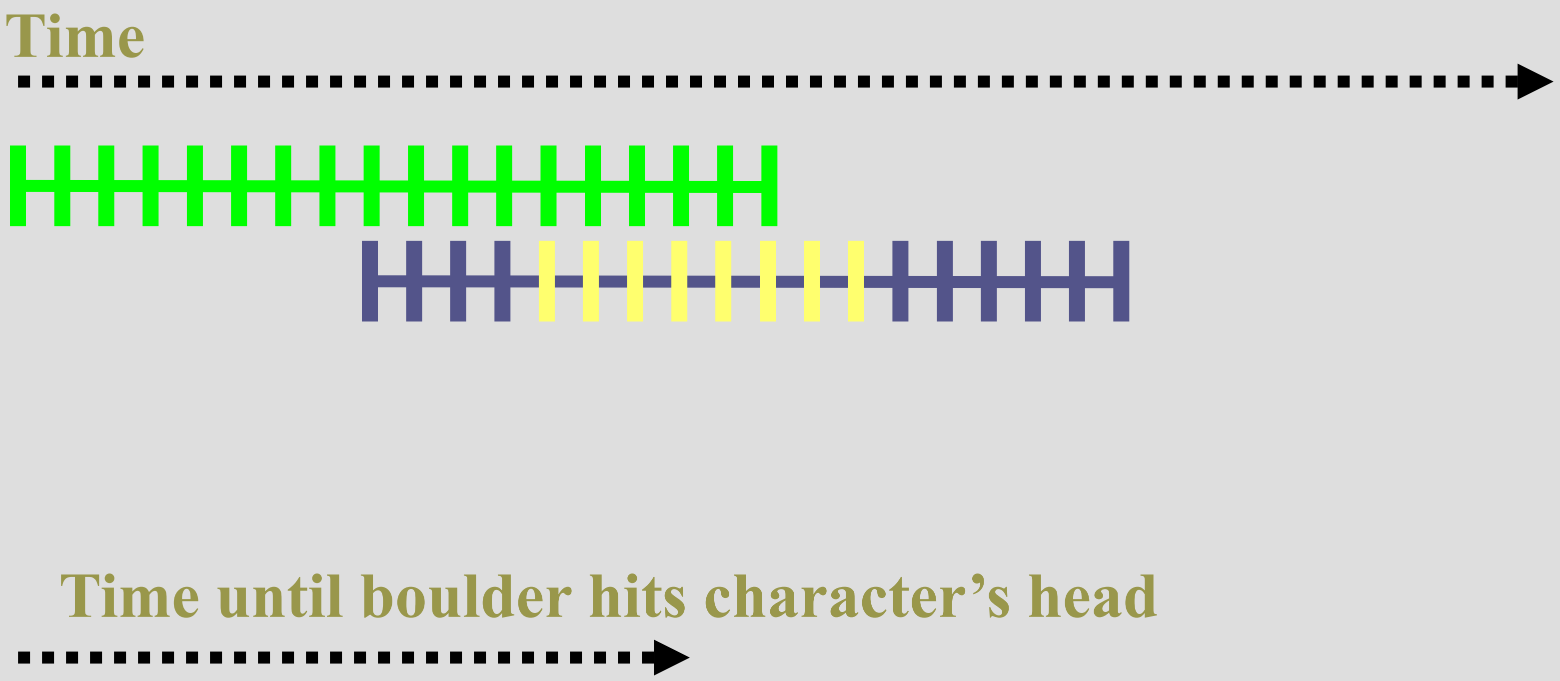


Approaches

1. Play running then ducking clips
    - Problem: no control over timing
2. Cut from running clip to ducking when needed

Approaches

1. Play running then ducking clips



Approaches

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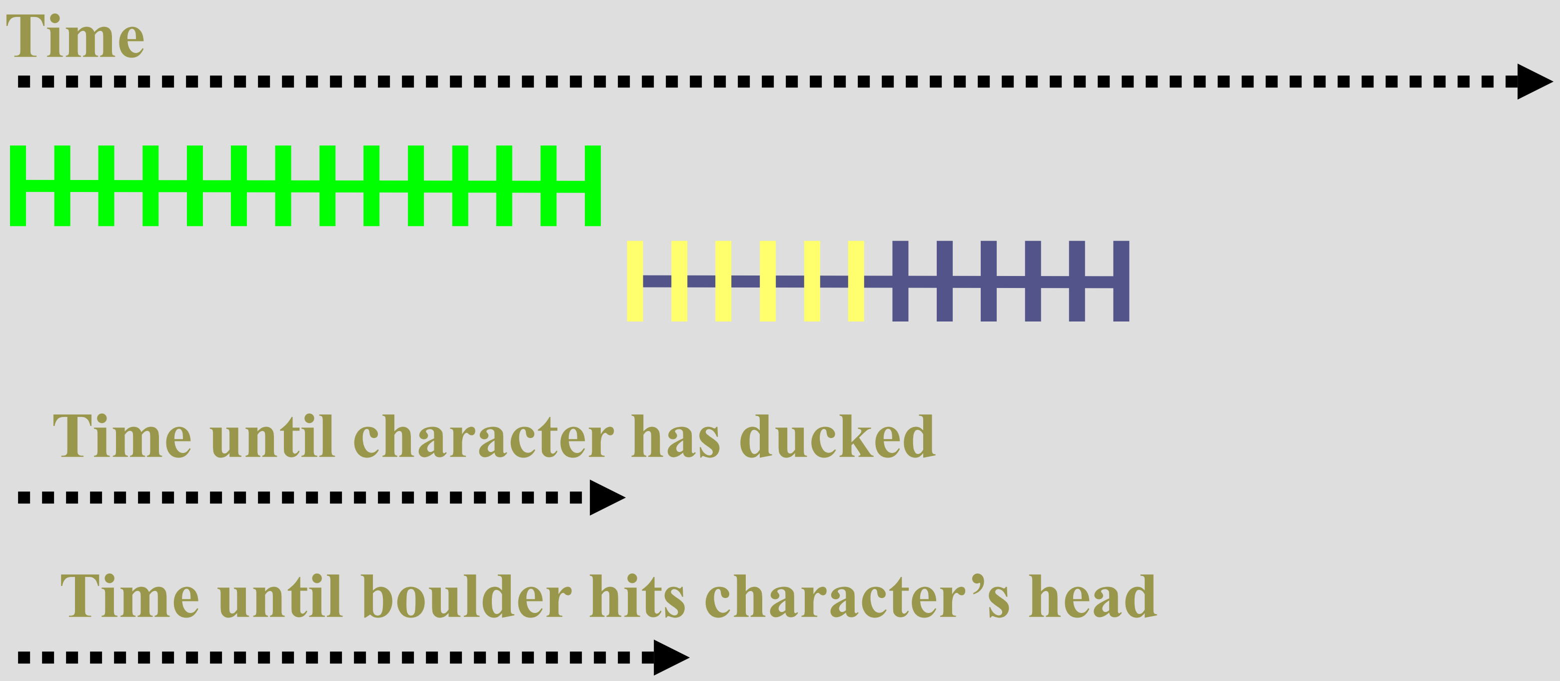

Approaches

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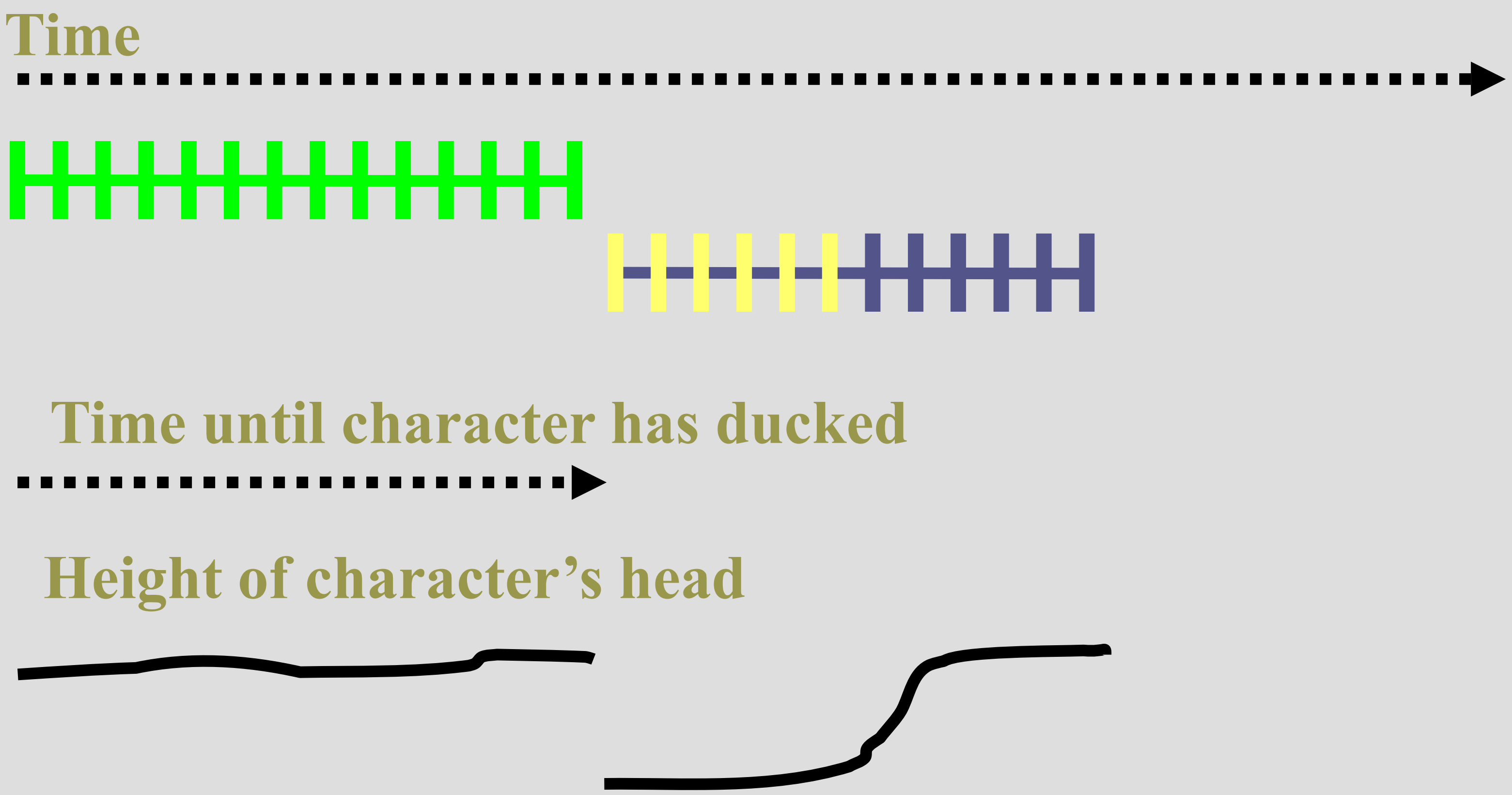


Approaches

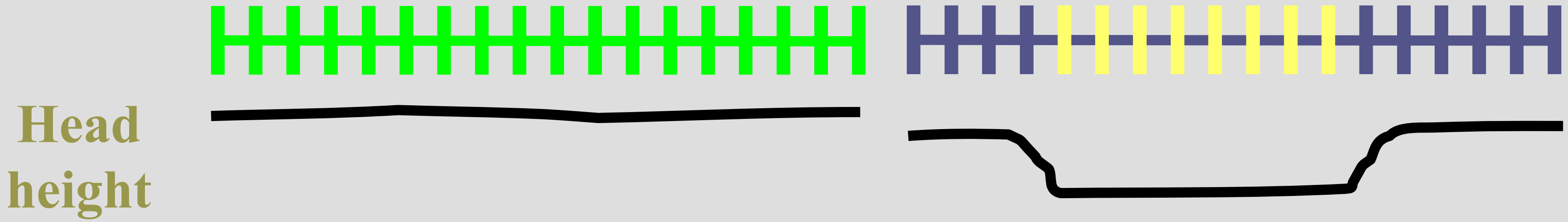
1. Play running then ducking clips
2. Cut from running clip to ducking when needed
    - Problem: bad transitions

Approaches

1. Play running then ducking clips
2. Cut from running clip to ducking when needed
   - Problem: bad transitions
   - *Aesthetic* problem (user preference)

Avoiding Bad Transitions

1. Capture the aesthetics
   - *Motion similarity metric*
   - Combine motions at highly similar points



Avoiding Bad Transitions

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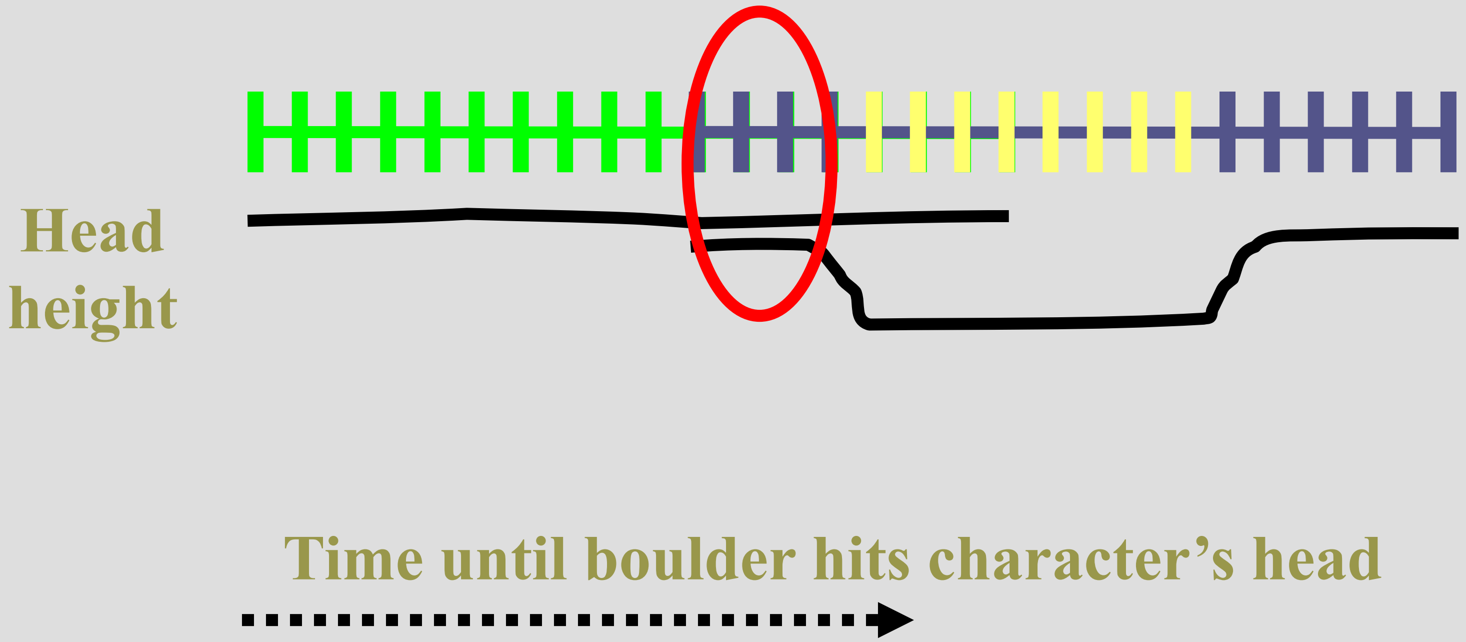
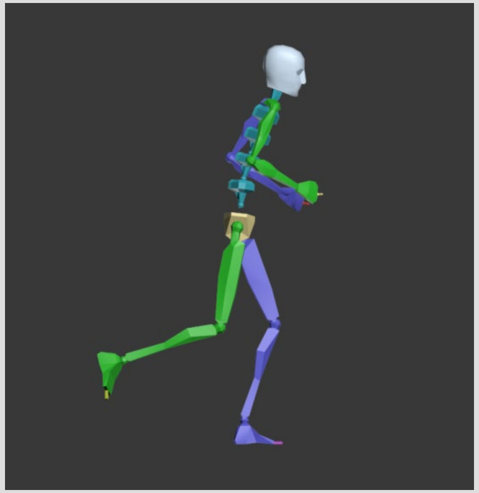
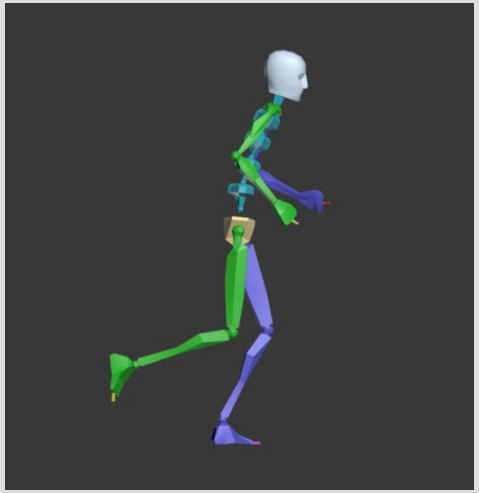
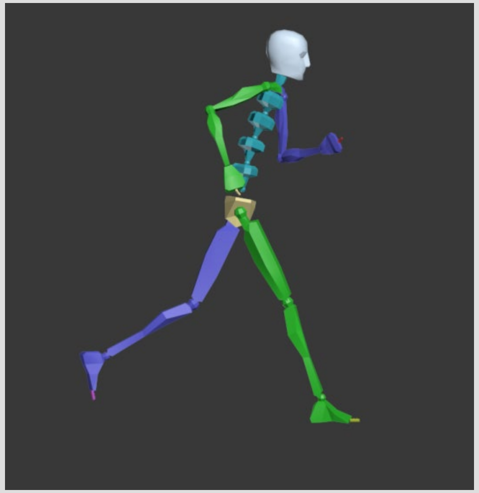


Avoiding Bad Transitions

1. Capture the aesthetics
   - *Motion similarity metric*
   - Combine motions at highly similar points
2. Smooth remaining gaps
   - *Motion smoothing algorithm*

Motion Similarity Metric

- Where are motions similar enough to move from one to the other with minimal disruption?
  - Pose similarity
  - Velocity similarity
  - Interaction similarity

Pose Similarity

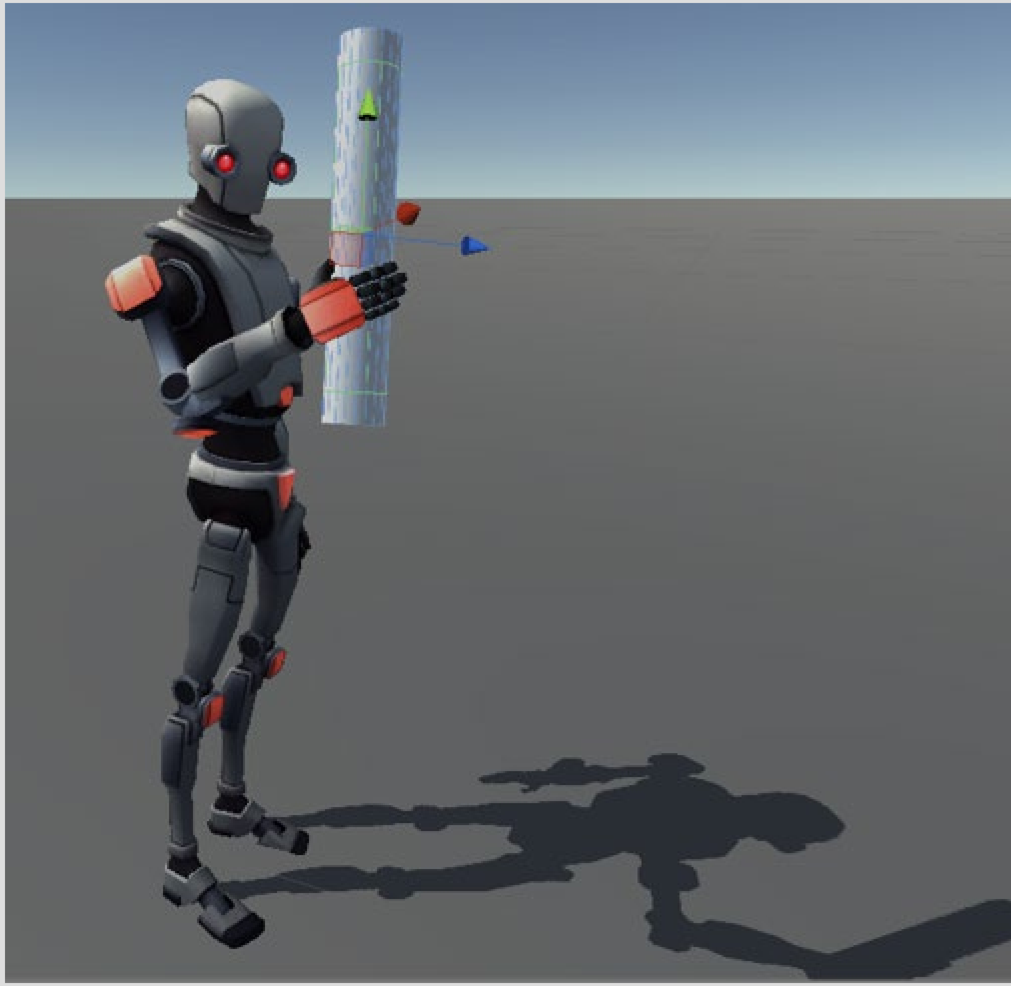
- Simplest: joint angle differences
  - Relative importance (shoulder vs. wrist)
  - e.g. $\boldsymbol{\Sigma}\ w(j)*(P(j_s) - P(j_t))^2$
- Alternatives
  - Alignment of virtual points on body
  - Visual difference of projection
  - Perceptual model (perception-based per-joint similarity weights)

Velocity Similarity

- To avoid splicing a touch and a punch
- Options:
  - Compute numerical derivative
    - $V(t) = P(t) - P(t-1)$
  - Match poses over time window

Interaction Similarity

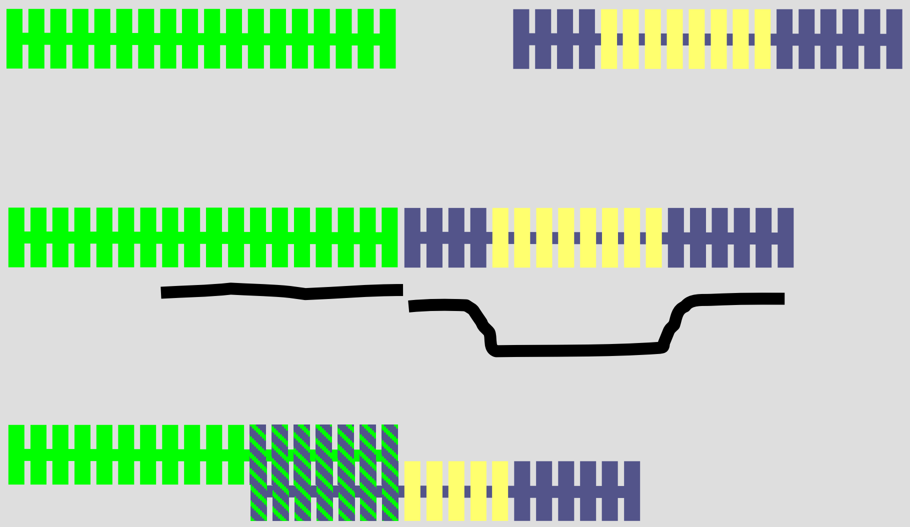
- Contact with the environment should remain crisp
  - Smoothing often loses this
  - e.g. feet sliding on/in ground
- Pose/velocity measures enforce this poorly
- May want to penalize score if motions differ in interaction with environment
  - e.g., setting foot down vs. standing still



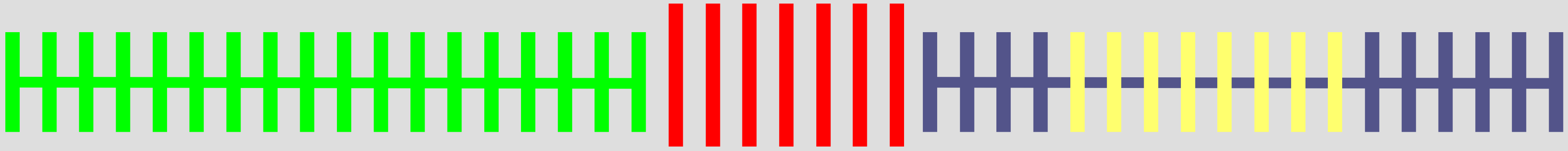
Motion Smoothing Algorithm

- Three basic choices

1. Connecting
2. Warping
3. Blending

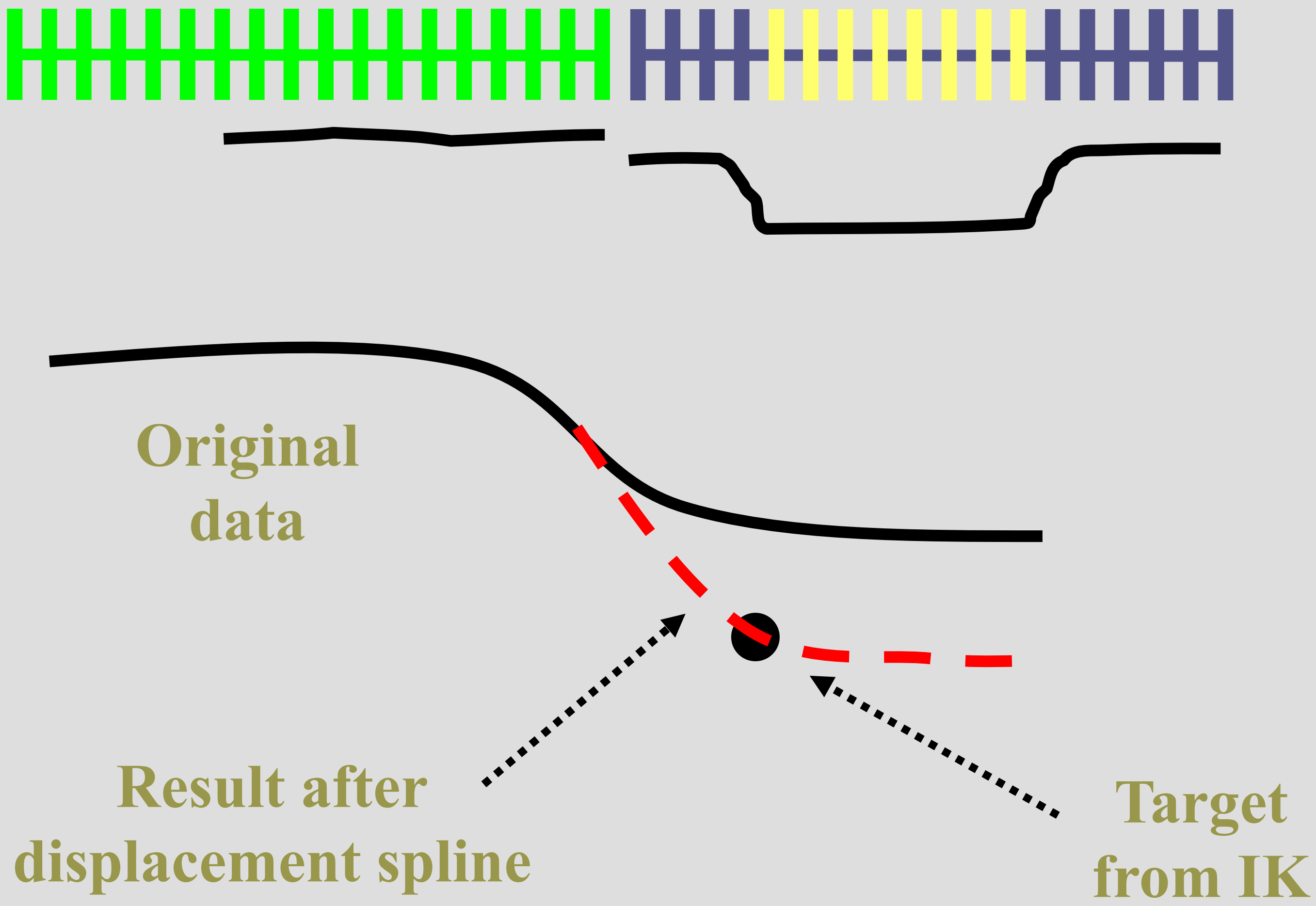


Connecting Motions



- Synthesize frames to fill the gap
  - Typically interpolate between poses
    - e.g., SLERP
  - Physics-based optimization also possible
    - Minimum-energy trajectory between poses

Warping Motions

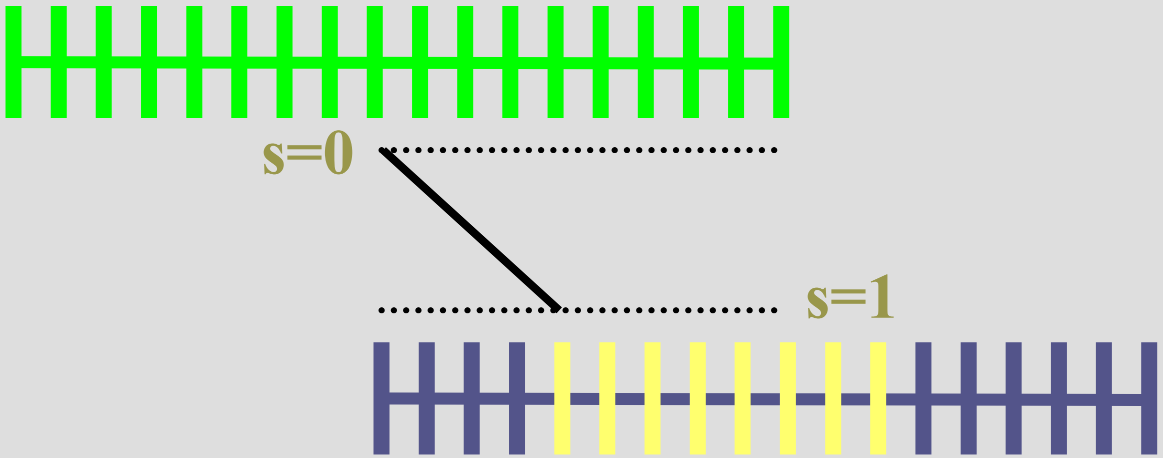


Blending Motions

- The term *animation blending* refers to any technique that allows more than one animation clip to contribute to the final pose of the character
- Combine 2 input poses to create an output pose
- Example
  - Injured walk animation
  - Regular walk animation
  - Can get various intermediate levels of injury

LERP Blending

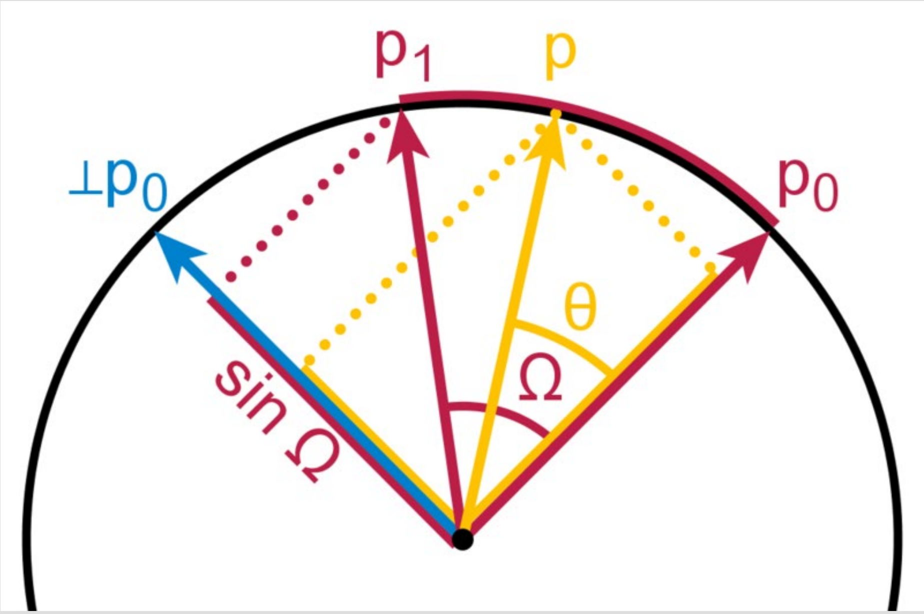
- Transition smoothly from motion A to motion B
  - Need blending algorithm, blending weights
  - $P(t) = (1-s)P_A(t) + sP_B(t)$, $0<=s<=1$



SLERP

- The linear interpolation of the rotation component is a quaternion LERP or SLERP (Spherical LERP)

$$\frac{\sin\big((1-\beta)\theta\big)}{\sin(\theta)}(q_A)_j + \frac{\sin(\beta\theta)}{\sin(\theta)}(q_B)_j$$



LERP

- The most natural looking intermediate poses are generally when each joint pose is interpolated <u>*independently*</u> of the others, in the space of that joint's immediate parent
- If we blended global poses, the results would look biomechanically <u>impossible</u>
  - **Pose blending** is generally performed on ***local poses***
- Since joints are blended independently of the interpolations of other joints
  - Interpolation can be performed in <u>parallel</u>

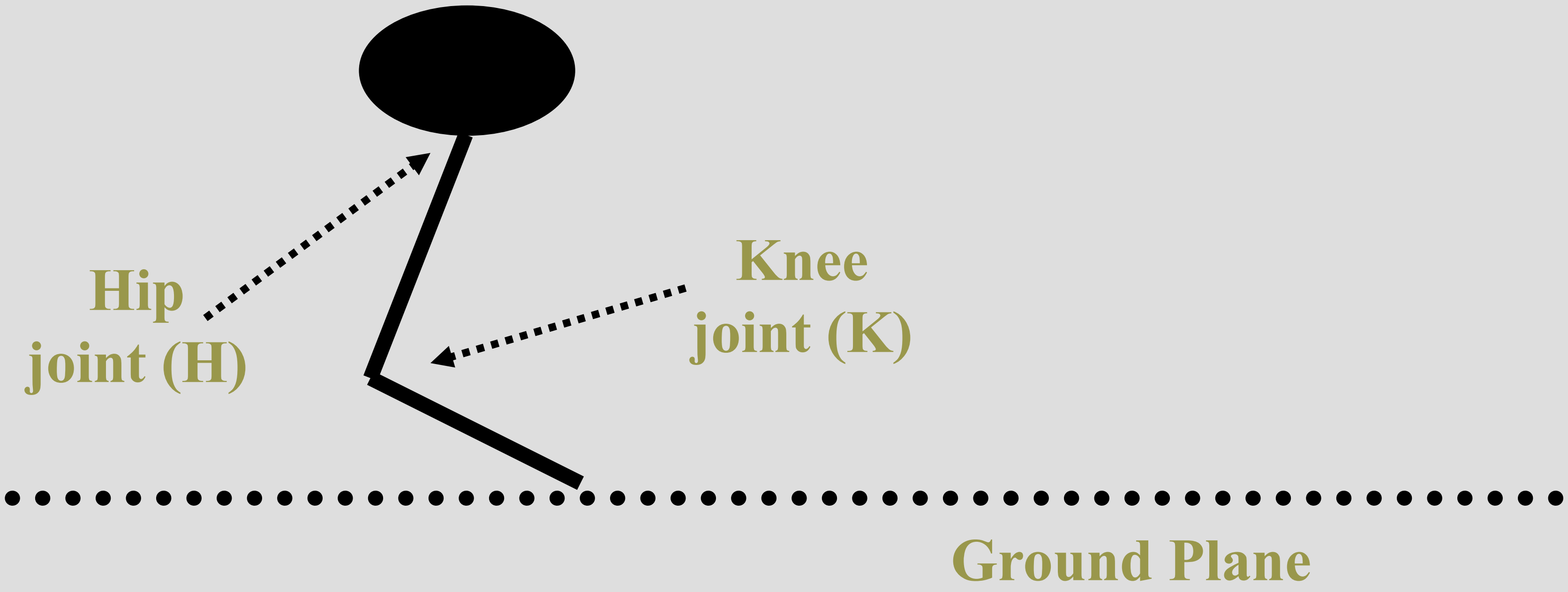
Blending Motions

- Not only for transitioning
- E.g.
  - Have a running motion
  - Have a walking motion
  - Want a ***jogging*** motion

- Problems with Blending Animation?
  - Bad environment contacts
  - Out-of-phase animation

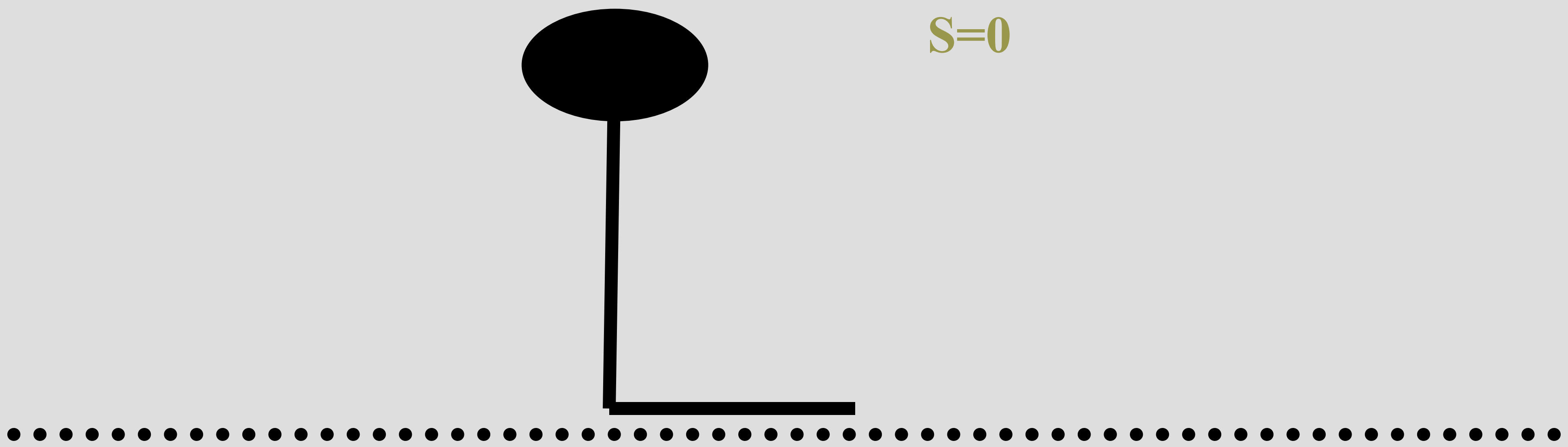
Blending Motions

1. Blend the joint angles



Blending Motions

1. Blend the joint angles



Blending Motions

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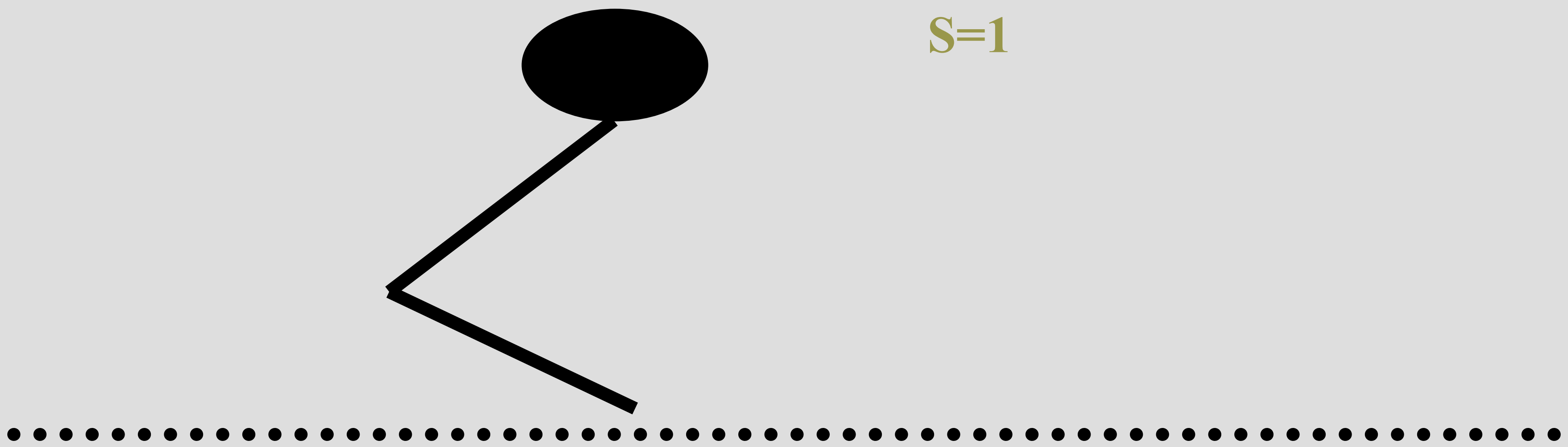
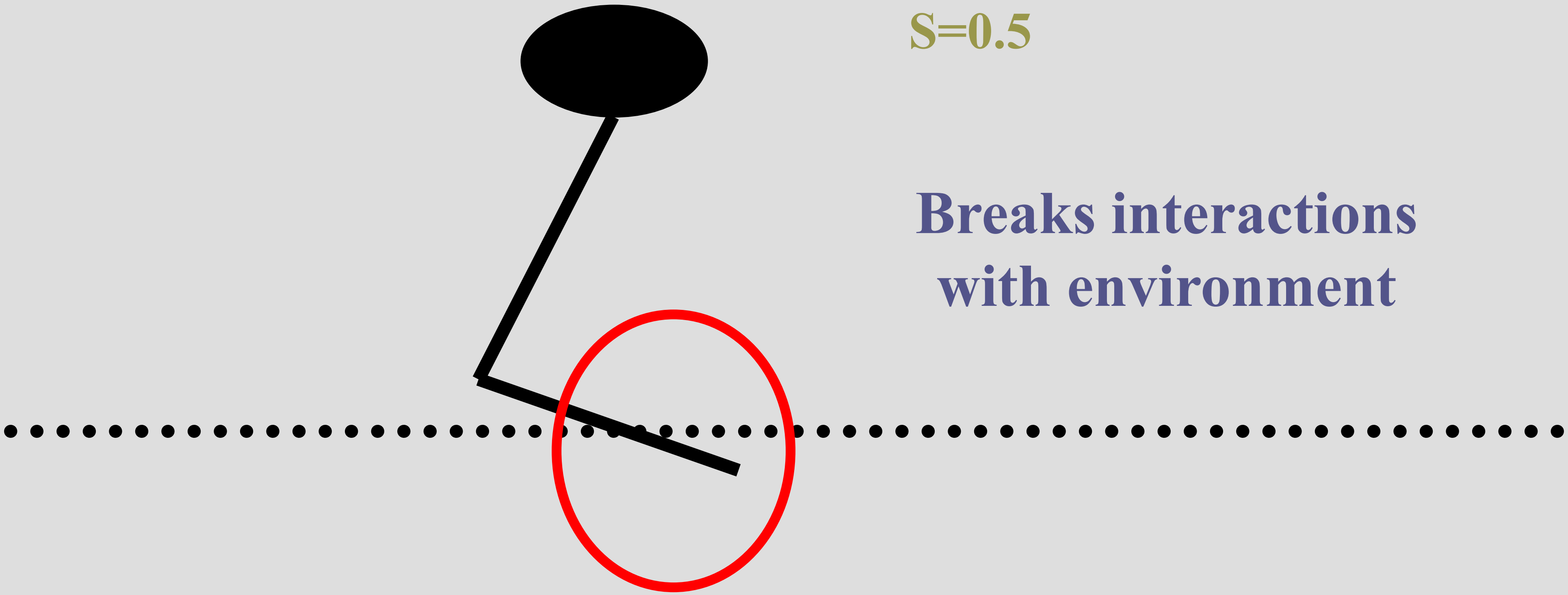


Blending Motions

1. Blend the joint angles
   - Problem:



S=0.5

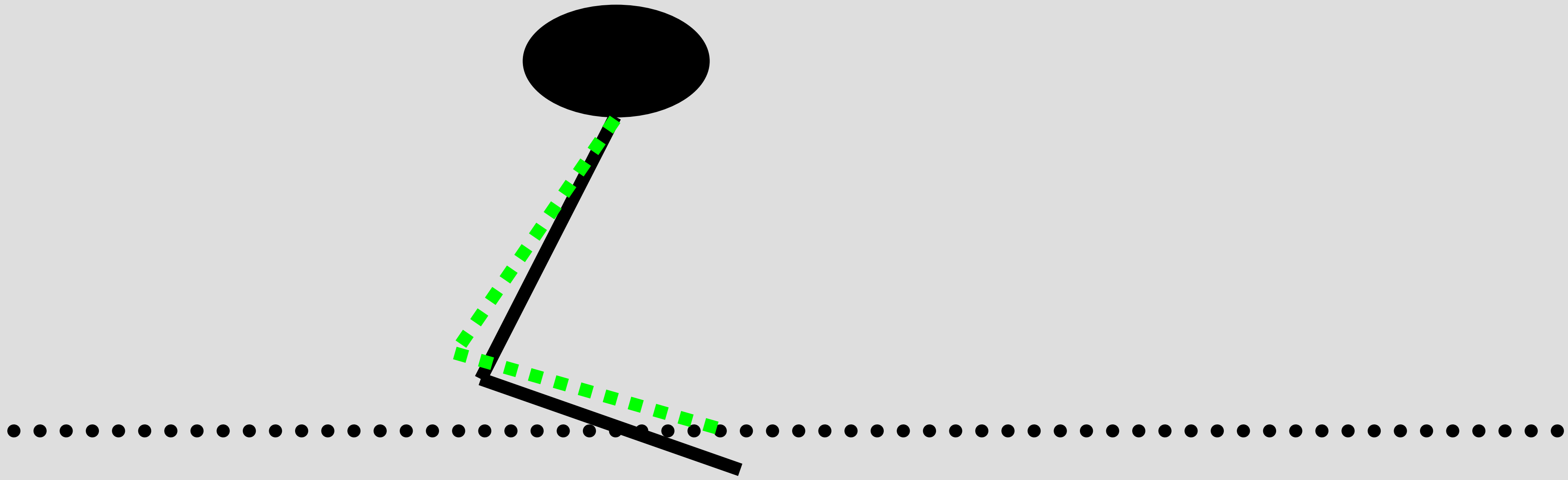
Breaks interactions with environment

Blending Motions

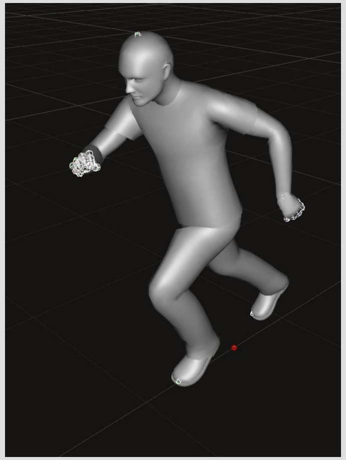
1. Blend the joint angles
   - Problem:
     - Breaks interactions with environment
     - Solution: *IK and motion warping*

Blending Motions

1. Blend the joint angles
   - Post-processing fix with IK



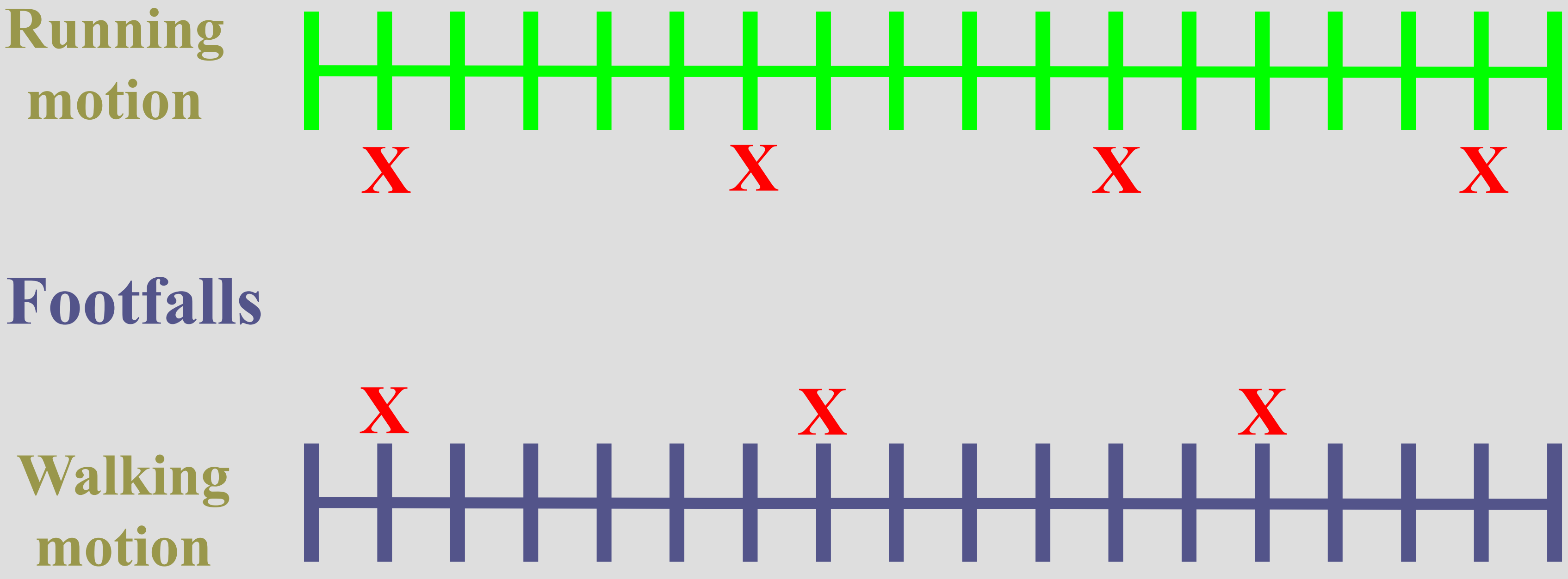
Blending Motions



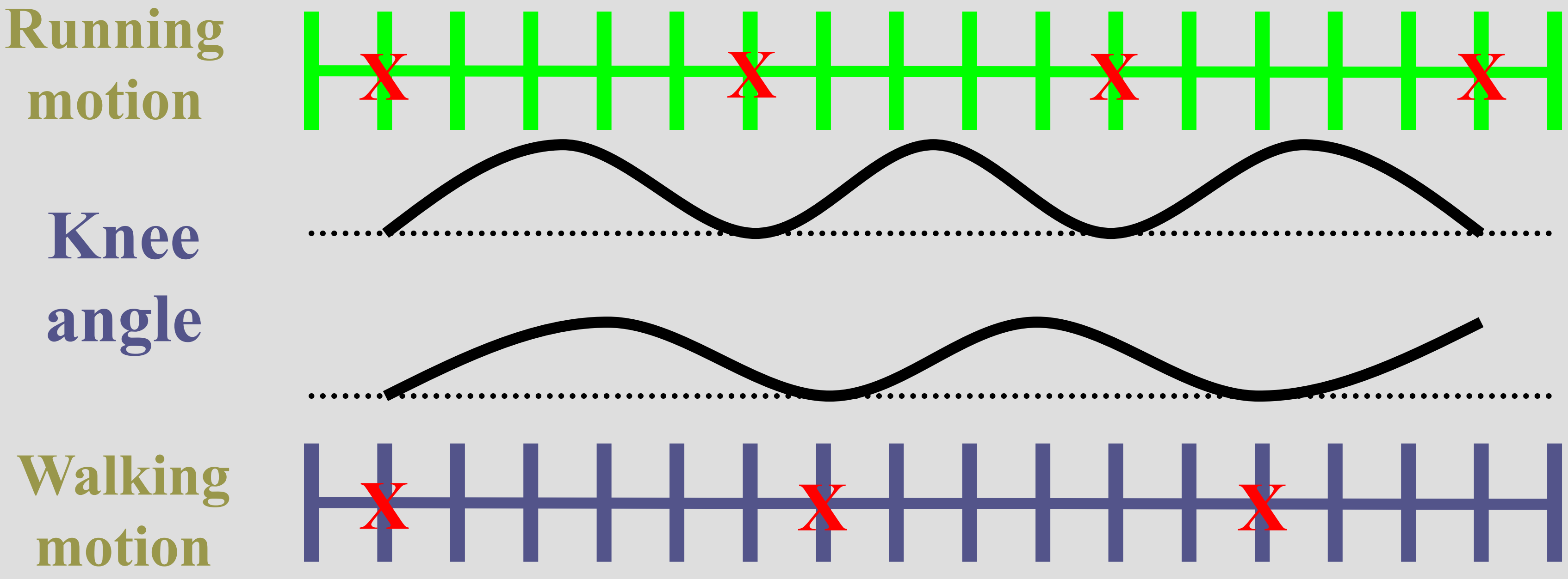
Running motion

Walking motion

Blending Motions



Blending Motions



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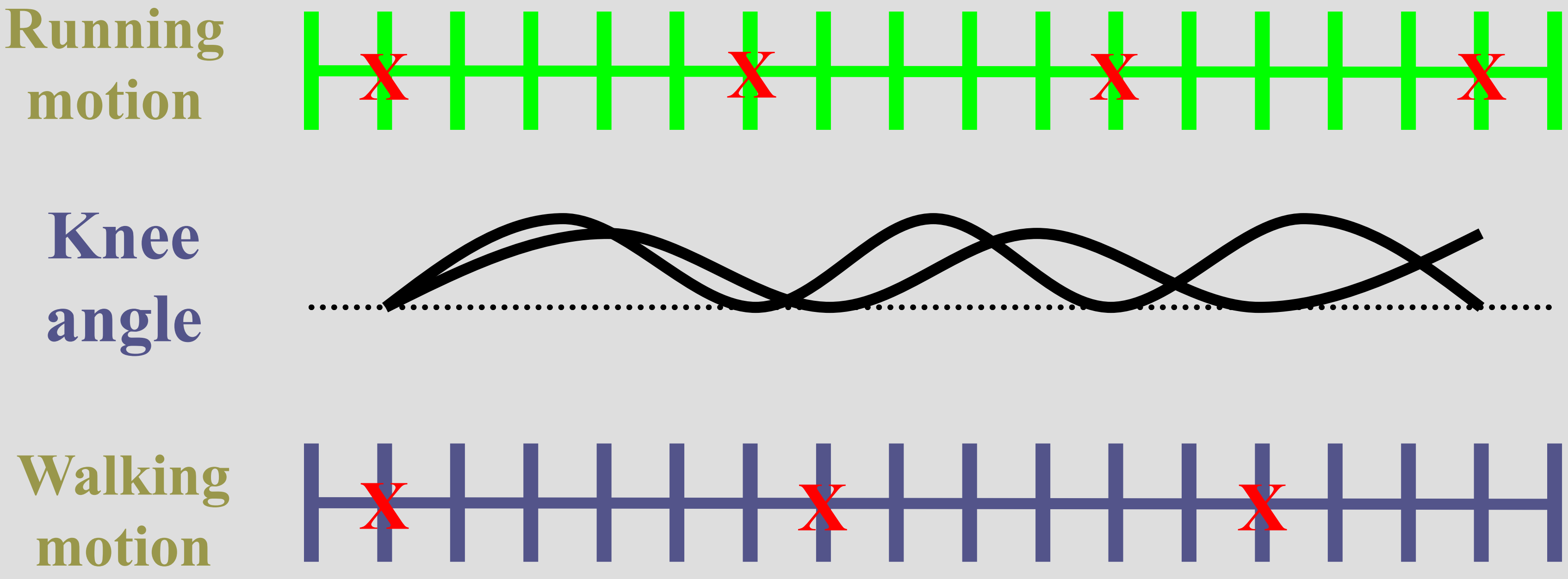
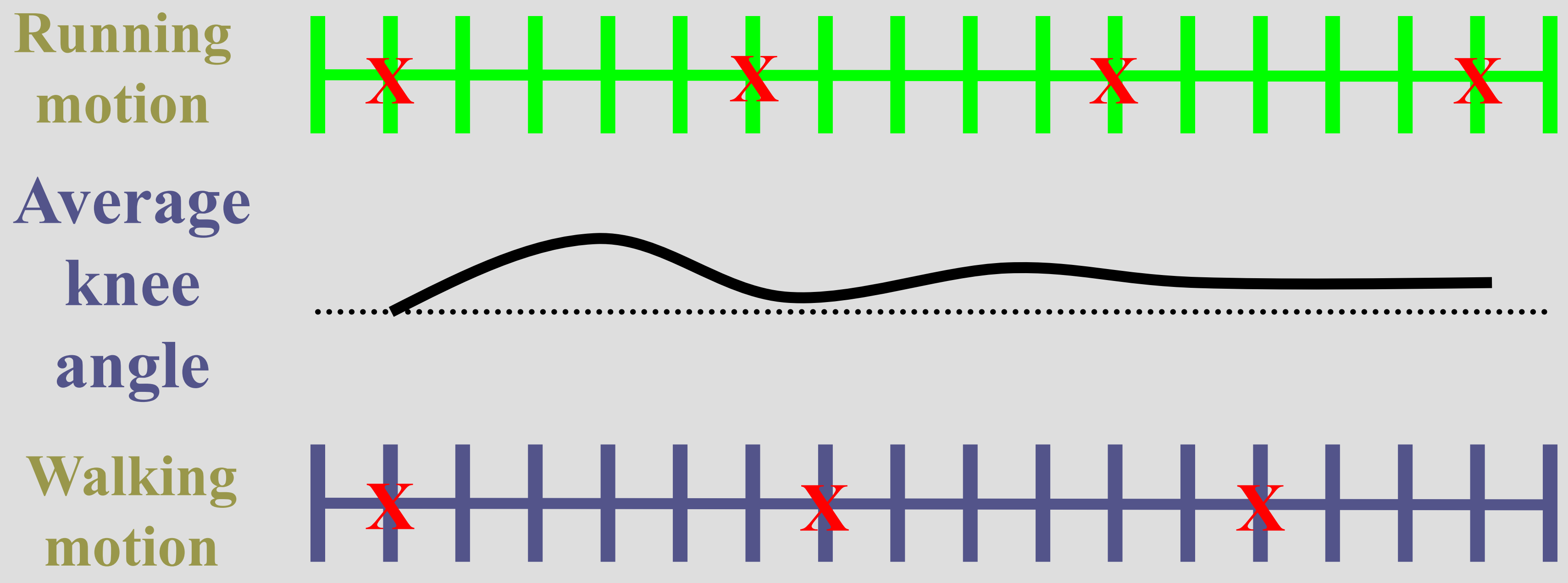


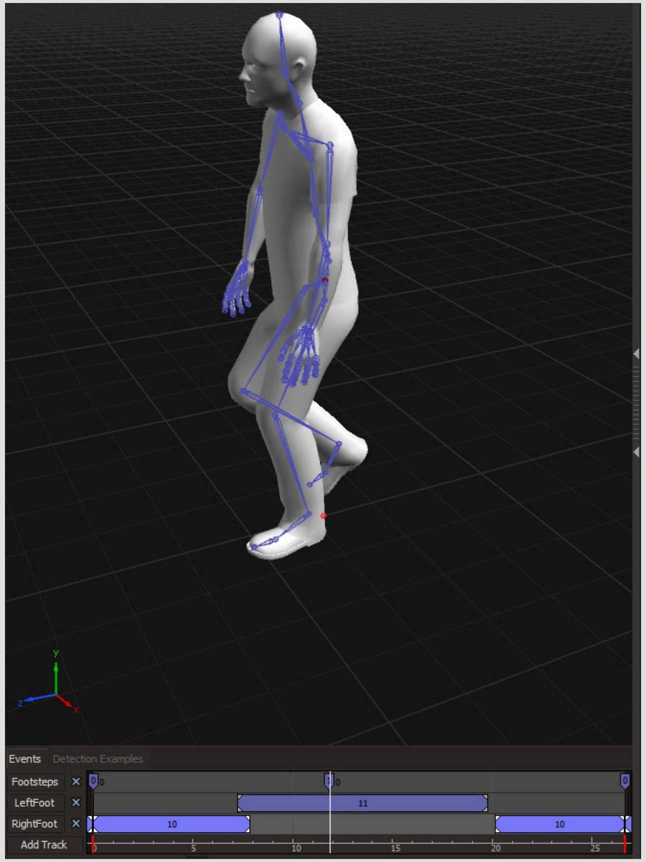
Blending Motions

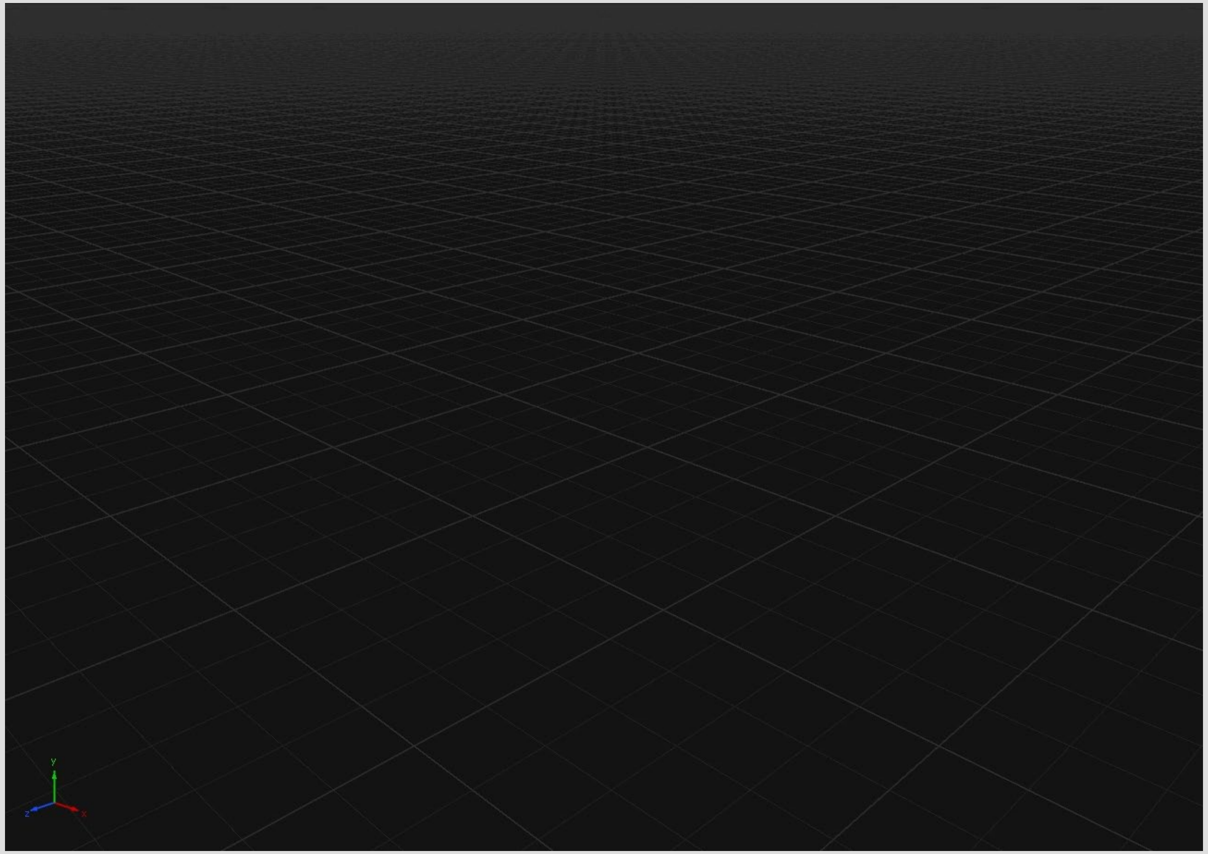


Blending Motions

1. Blend the joint angles
   - Problem: even similar motions get out of phase
   - *Time alignment algorithm*

Out of Phase Problem



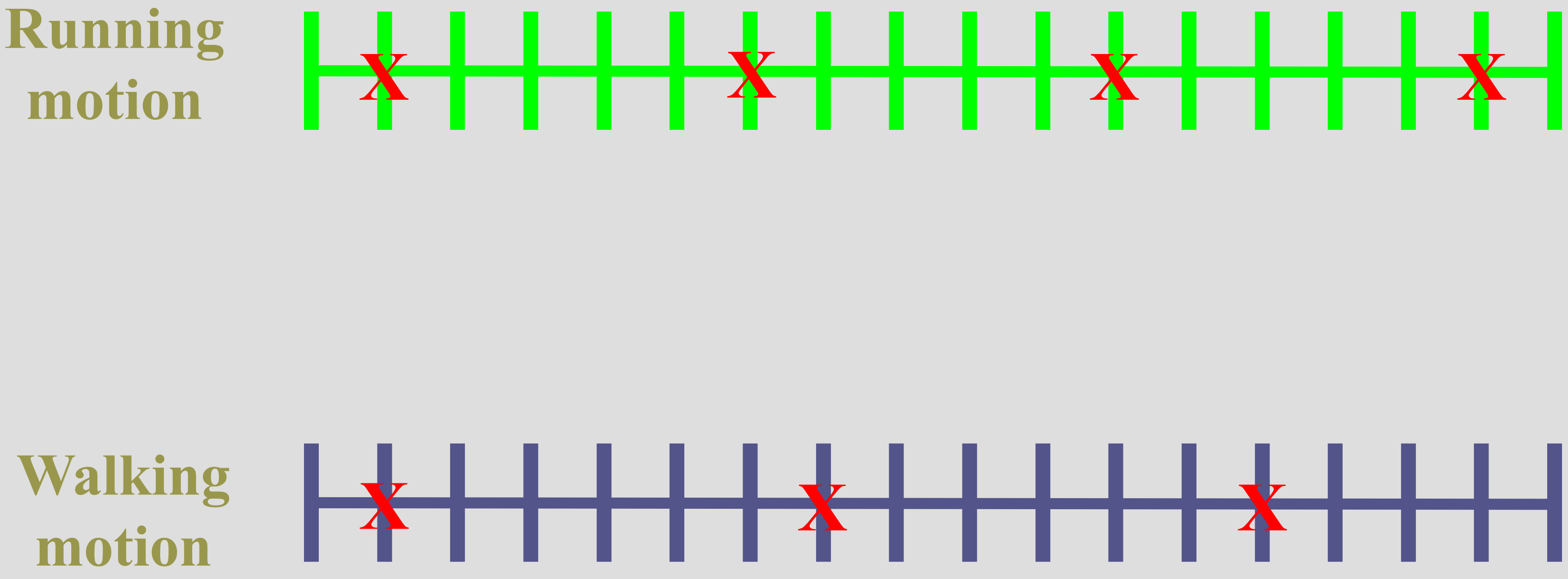


Time Alignment Algorithm

- Align logically similar parts of motion
  - e.g., footfalls with footfalls
  - Use *motion similarity metric (or do manually)*

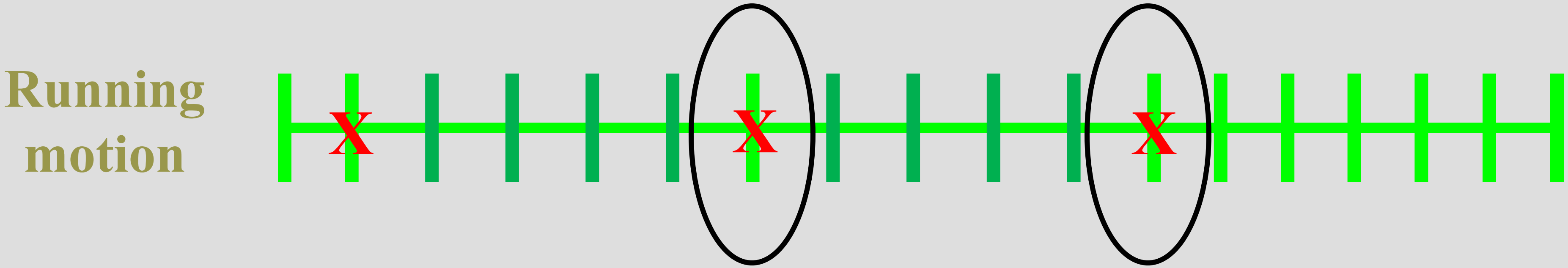
- Define mapping between frames of motions
  - Shorter motion **gets extended** to match longer motion
  - Perceptually: slowing down less noticeable than speeding-up

Aligning Motions

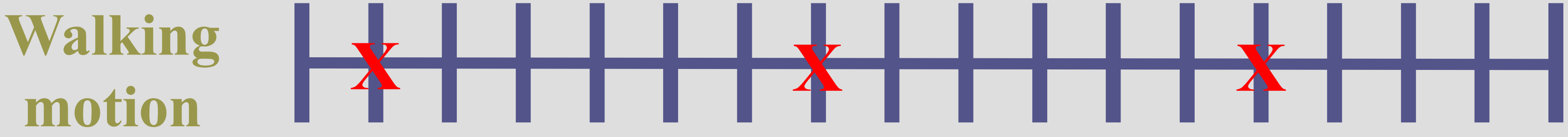


Aligning Motions

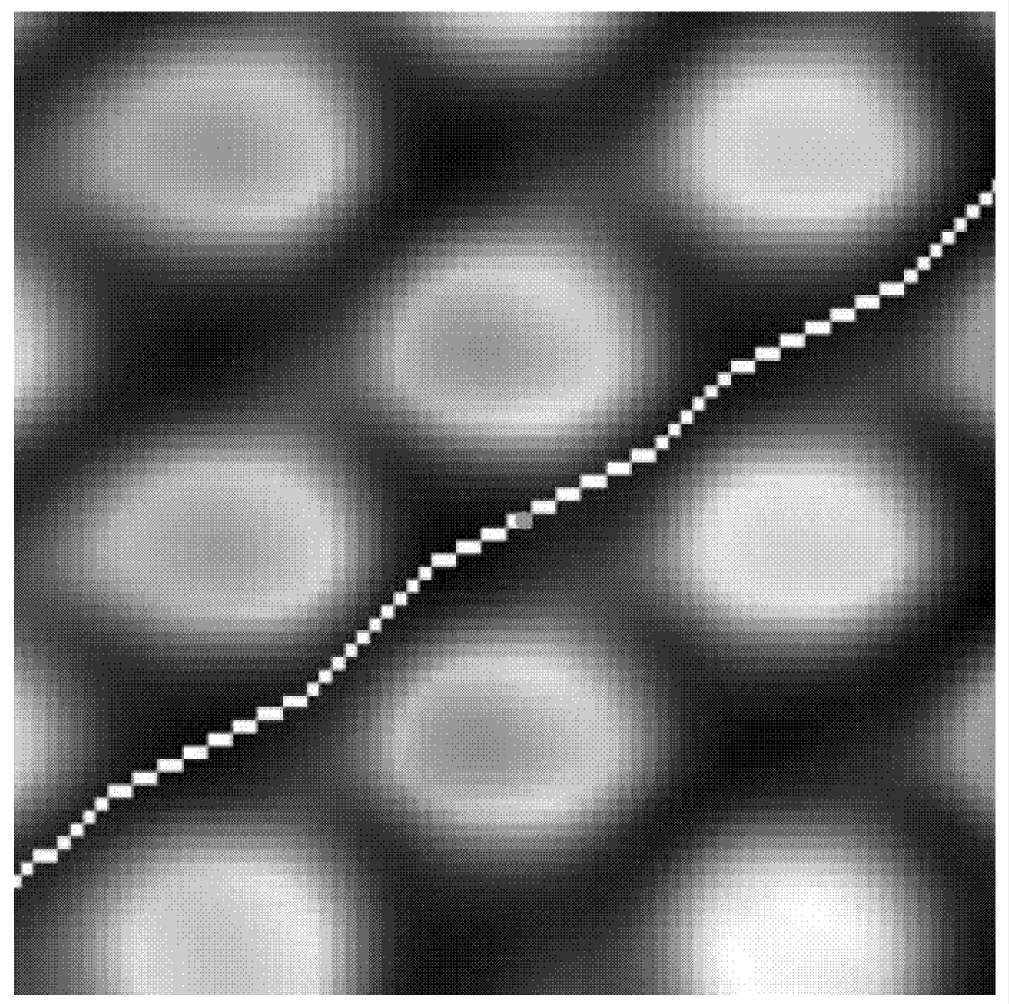
- Duplicate frames to fill gaps



- Extend motion to maximize similarity



Dynamic Timewarping



Frames of walking motion

Frames of running motion

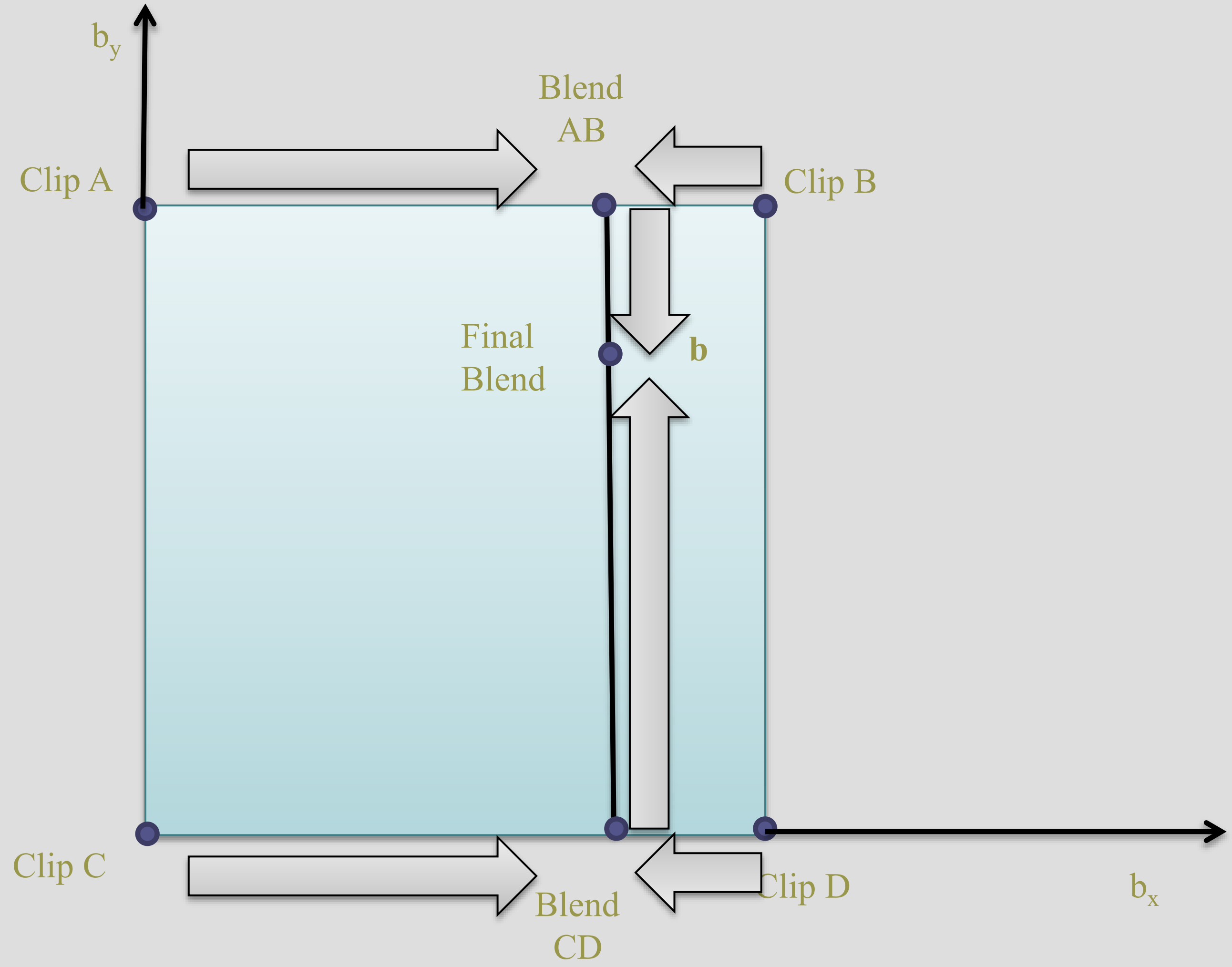
Matrix of frame-to-frame similarity (darker = more similar)

Two-Dimensional LERP Blending

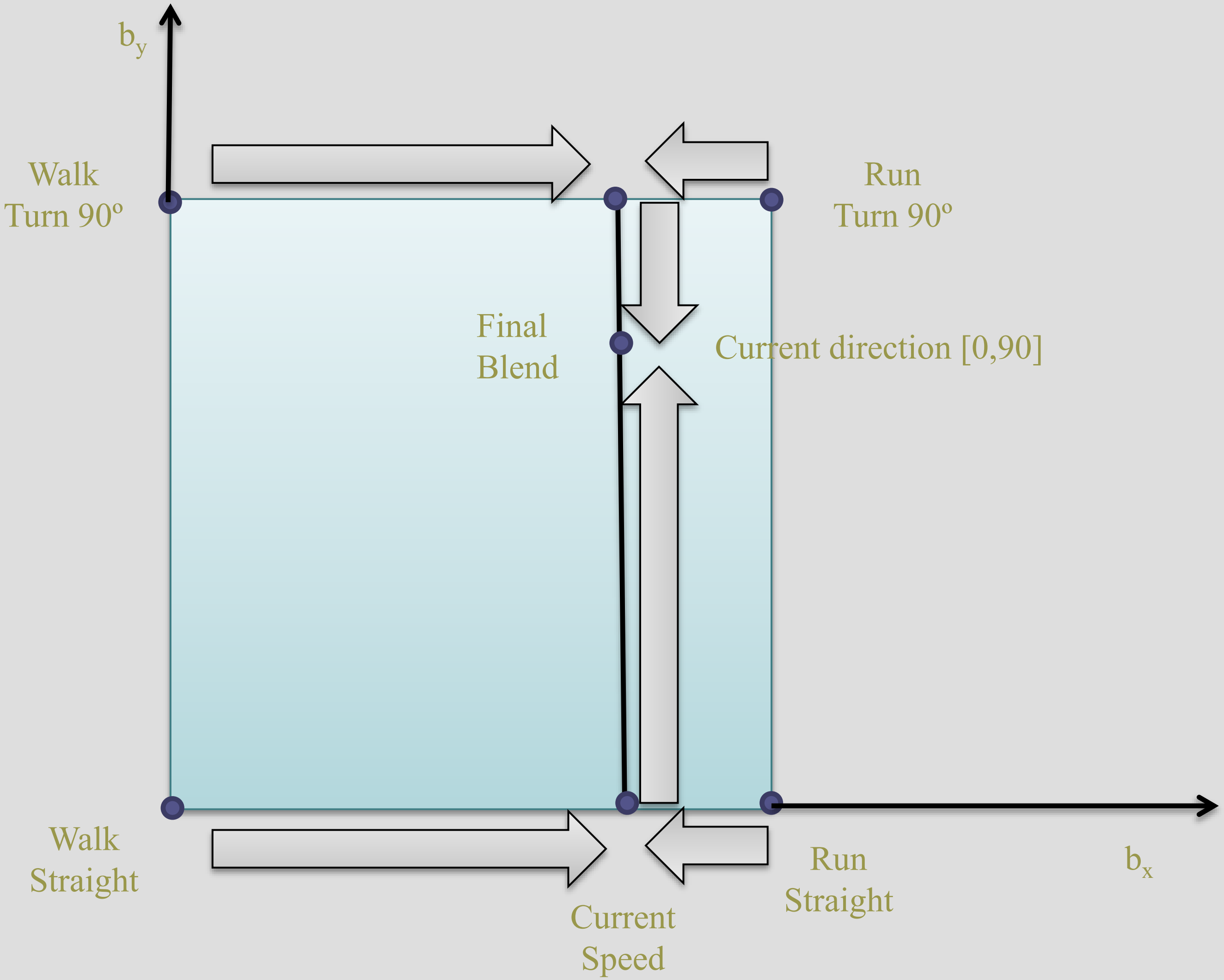
- Sometimes we would like to smoothly vary *two* aspects of a character's motion simultaneously
  - Vary pace and feet separation

- Extend 1-D LERP to 2-D in order to achieve these kinds of effects
  - Use two 1D blends
  - $\mathbf{b} = [b_x, b_y]$

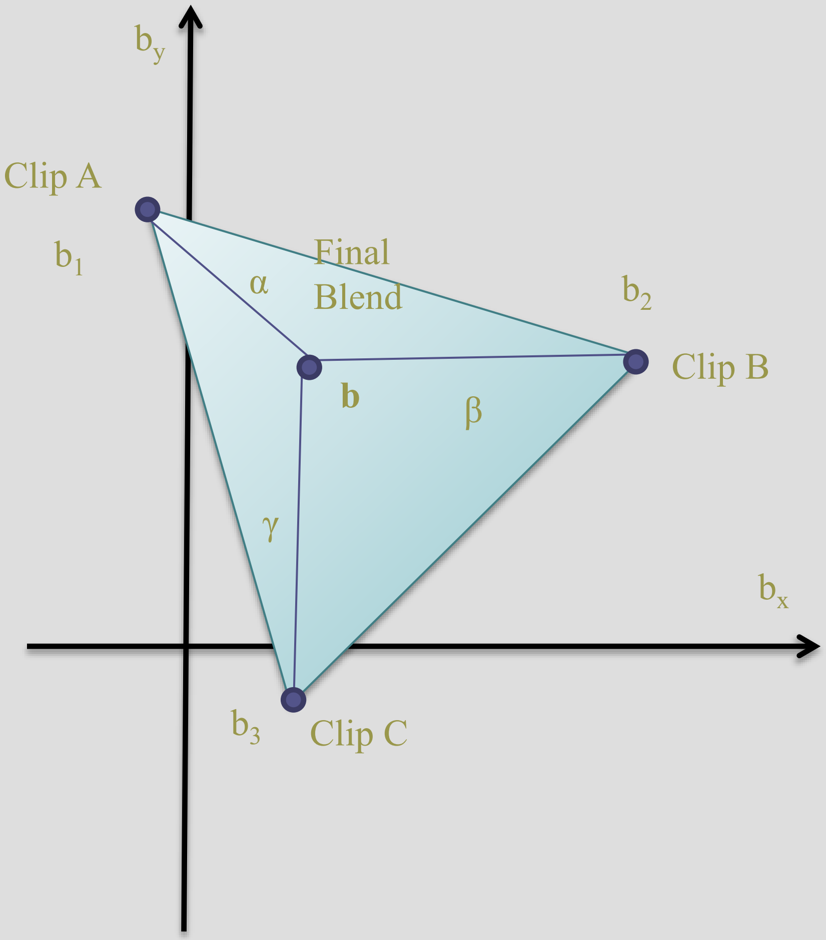
Two-Dimensional LERP Blending



Two-Dimensional LERP Blending



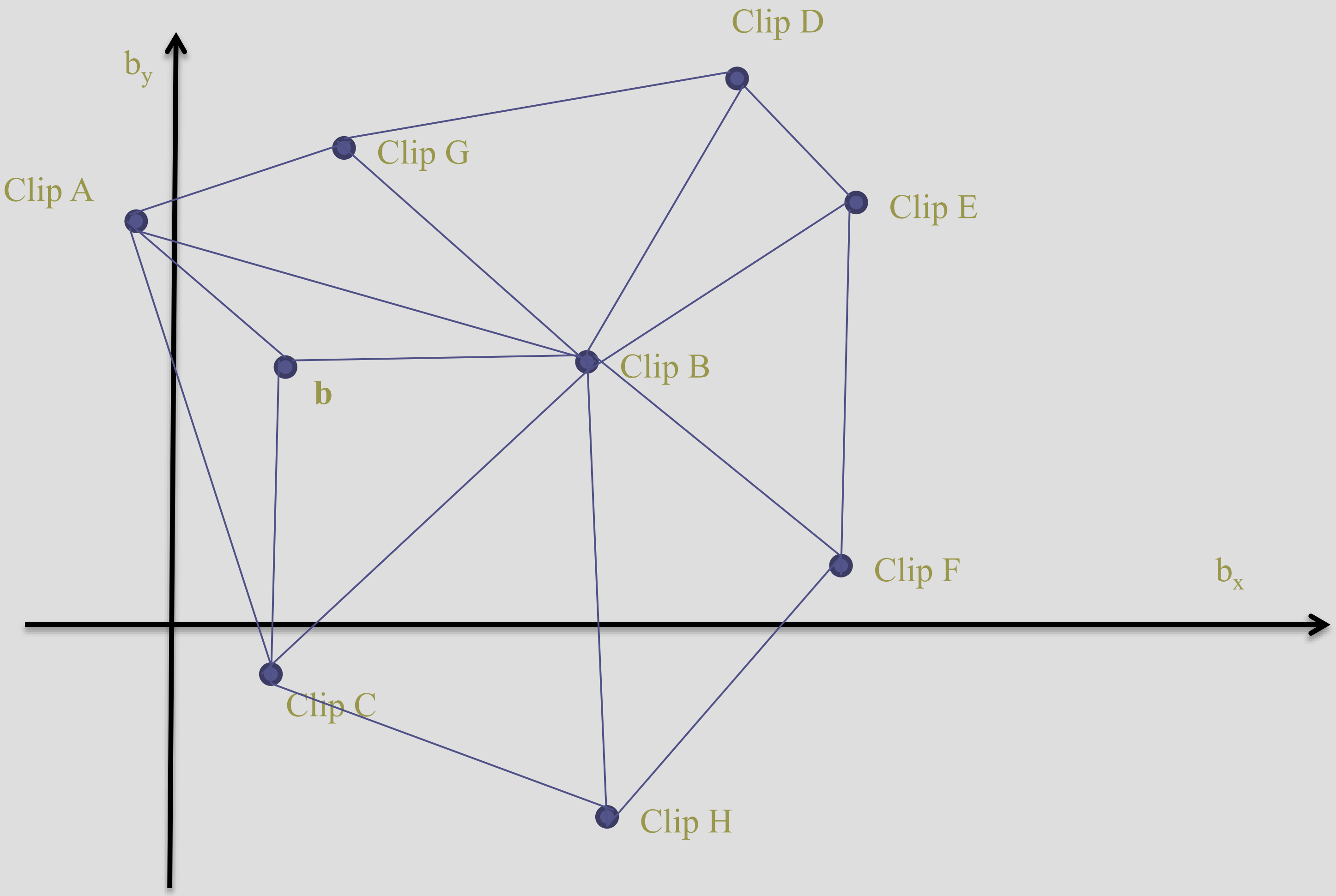
Barycentric Coordinates



- For 3-input LERP, we use 3 weights:
  - α, β, γ
  - With $\gamma = (1 - \alpha - \beta)$

$$b(t) = \alpha\, b_1(t) + \beta\, b_2(t) + (1 - \alpha - \beta)\, b_3(t)$$

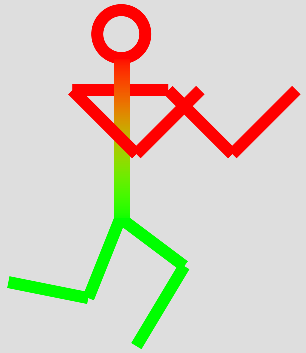
Generalized 2-D LERP



Delaunay Triangulation

Transplanting Body Parts

- A human being can control different parts of her body independently
  - Have a running motion
  - Have a catching motion
  - Want a catching-while-running motion



- Previously, we used the same blend percentage on every joint in the skeleton
  - Partial-Skeleton blending extends this idea by permitting the blend percentage to vary on a per-joint basis

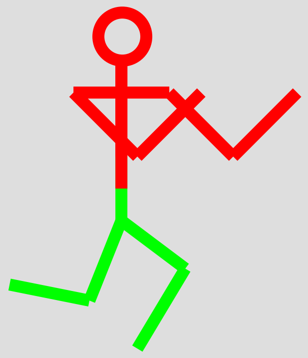
Blend Mask

- For each joint *j*, we define a separate blend percentage β_j
- The set of all blend percentages for the entire skeleton is called the *blend mask*
- It can be used to "mask" out certain joints by setting their blend percentages to zero

Transplanting Body Parts

- Have a running motion
- Have a catching motion
- Want a catching-while-running motion

- **Solution:** stick a catching torso on top of running legs



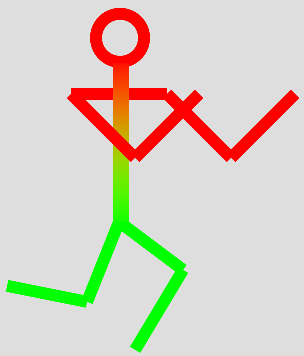
Transplant Example

Subtle example:
look at the fingers
opening and closing

Transplant Example 2

Unnatural Movement

- An abrupt change in the per-joint blend factors can cause the movements of one part of the body to appear disconnected from the rest
- Problem can be improved by **gradual blending**
  - Joints in legs get 100% of angles from running motion
  - Joints in arms get 100% of angles from catching motion
  - Joints in between blend both motions, with weights depending on whether closer to legs or arms



Unnatural Movement

- However, movements of a real human body are never totally independent
  - Persons wave while running vs. walking
  - More out of control and bouncy
- Use *additive blending*

Additive Blending

- Totally different approach
  - Use a “difference clip”

- Encodes the *changes* that need to be made to one pose in order to transform it into another pose
  - Difference from reference pose

- Input clips: source (S) and reference (R)
  - Difference (D) = S-R
  - Can be added to target clips (T): T+D

Additive Blending

- Example
  - R = character running
  - S = running in a tired manner
  - D = the changes necessary to make the character look tired
  - T = character walking
    - Add D to make the character walk while tired

Additive Blending

- We are dealing with joint poses, so we cannot simply subtract
  - Joint pose is a 4x4 matrix that transforms points from child's local space to parent space
- Matrix equivalent of subtraction is multiplication by inverse matrix
  - $D_j = S_j R_j^{-1}$
- "Adding" D to T is achieved by concatenating the difference transform and the target transform: $(S_j R_j^{-1}) T_j$

Additive vs. Partial Blending

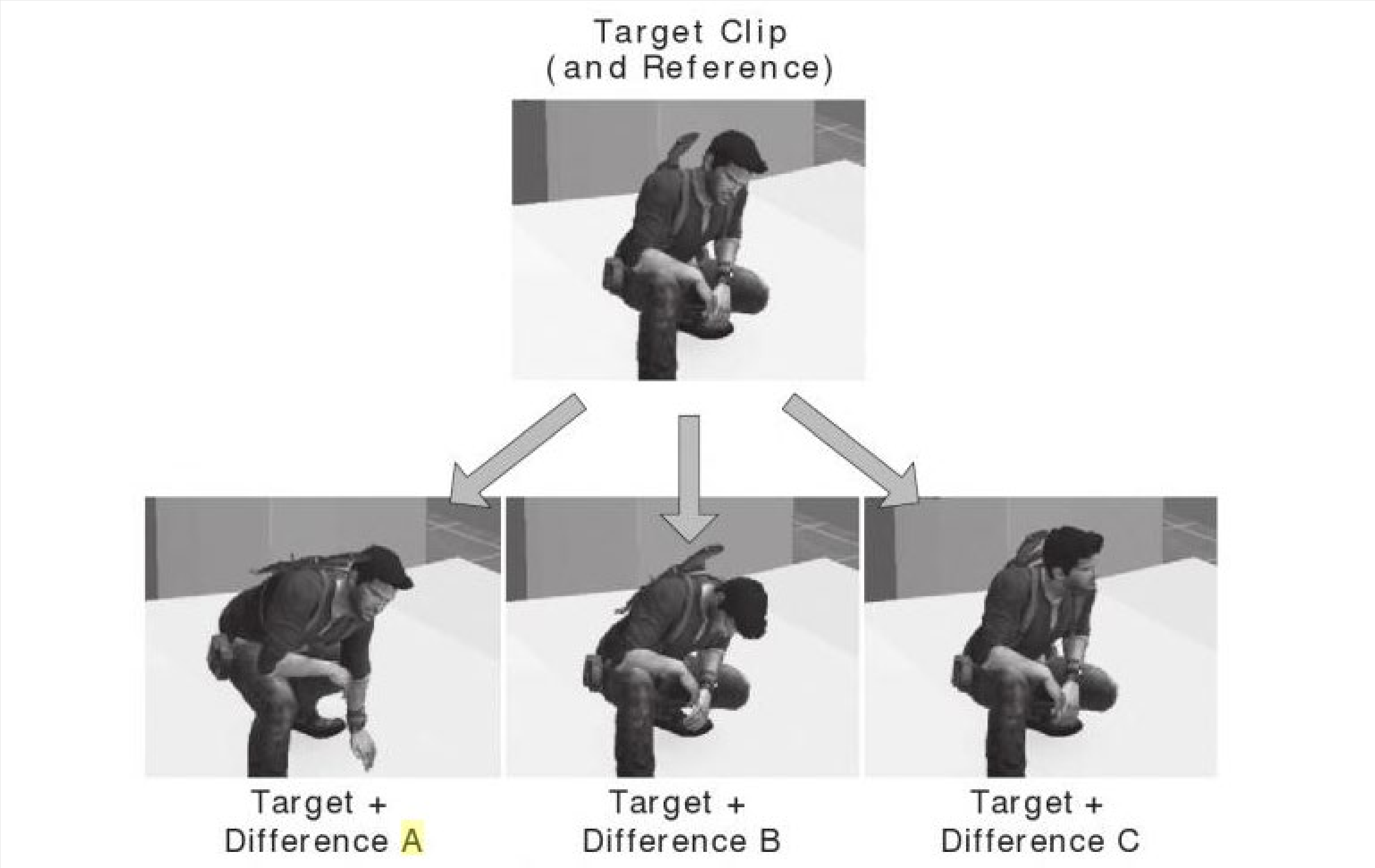
- Additive blends suffer less from the “disconnected” look of animations combined via partial blending
  - Because we are not replacing the animation for a subset of joints or interpolating 2 potentially unrelated poses
  - We are adding movement to original motion across the entire skeleton

Limitations

- Can have a tendency to over-rotate the joints in the skeleton

- Rules to avoid problems:
  - Keep hip rotations to minimum in R
  - Shoulder & elbow joints neutral in R
  - D animation for each core pose (standing, upright, crouched down, etc.)

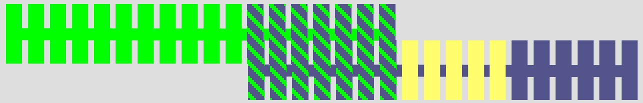
Layer Randomness to repetitive cycles



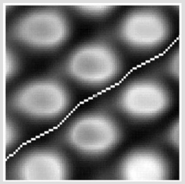
Motion Editing

- Warping

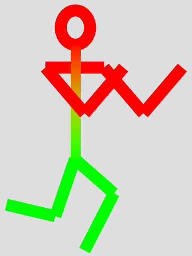
- Splicing



- Blending



- Transplanting



More Information

- Warping
  - “A hierarchical approach to interactive motion editing for human-like figures”, Lee and Shin, 1999
- Splicing
  - “Motion Graphs”, Kovar et al., 2002
- Blending
  - “Flexible Automatic Motion Blending with Registration Curves”, Kovar and Gleicher, 2003
- Transplanting
  - “Enriching a Motion Collection by Transplanting Limbs”, Ikemoto and Forsyth, 2004