Character Animation

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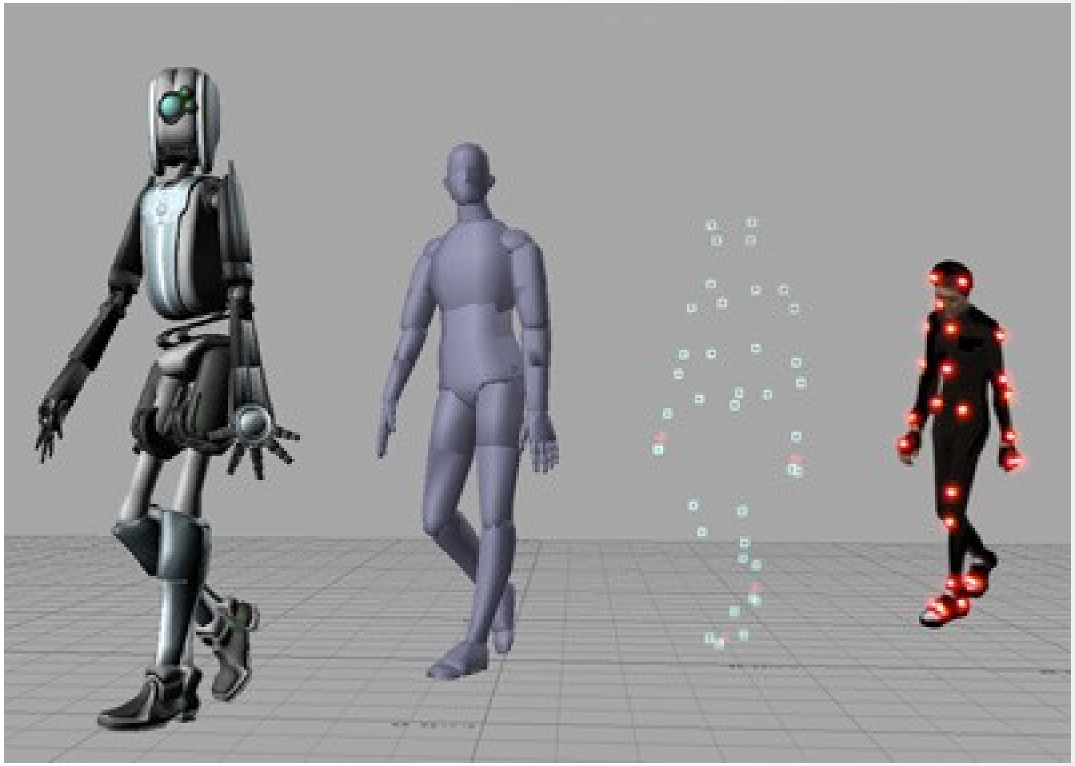
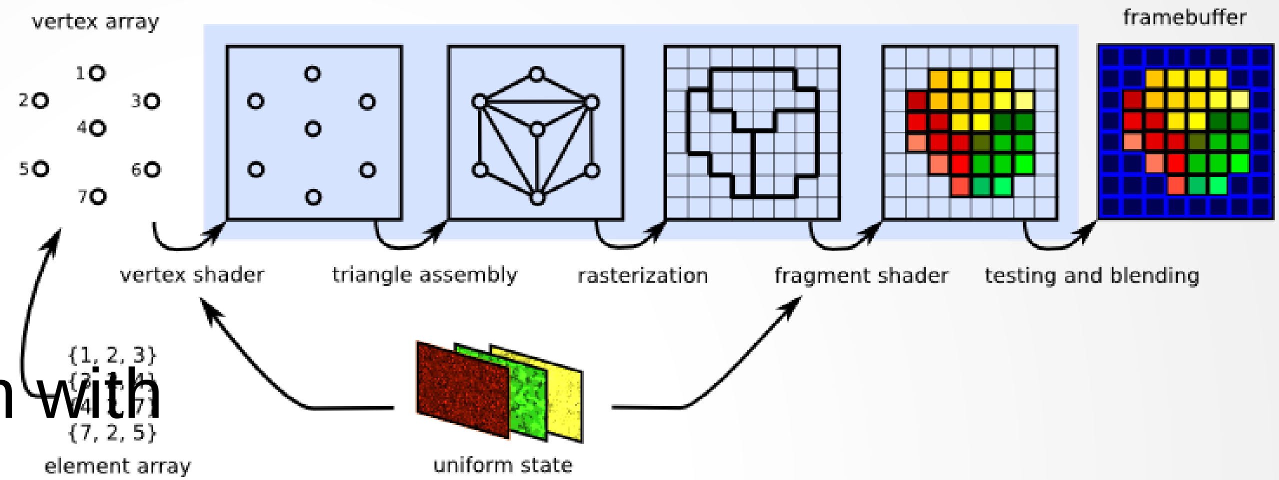
March 9, 2017

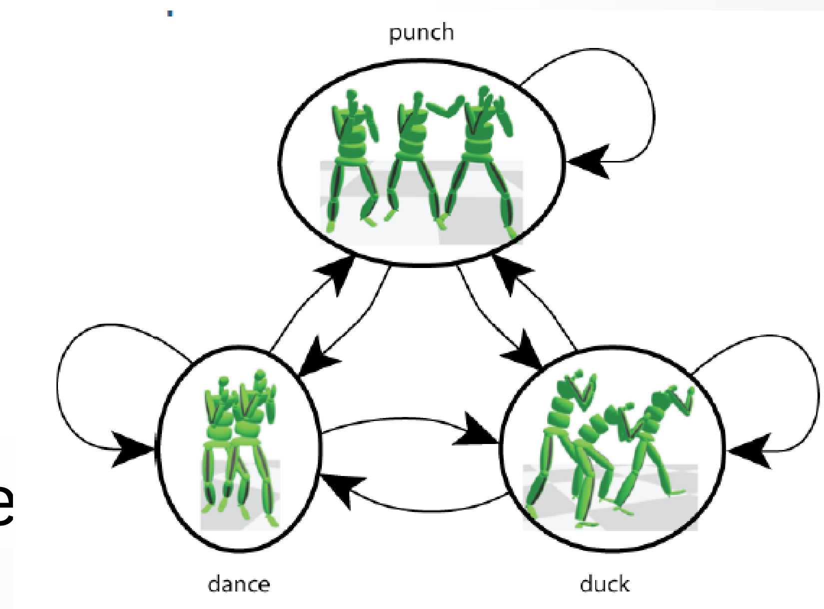


Outline

- **Intordduction**
  - Skeletal Animation
  - Motion Capture
  - Controllable motion with constraints



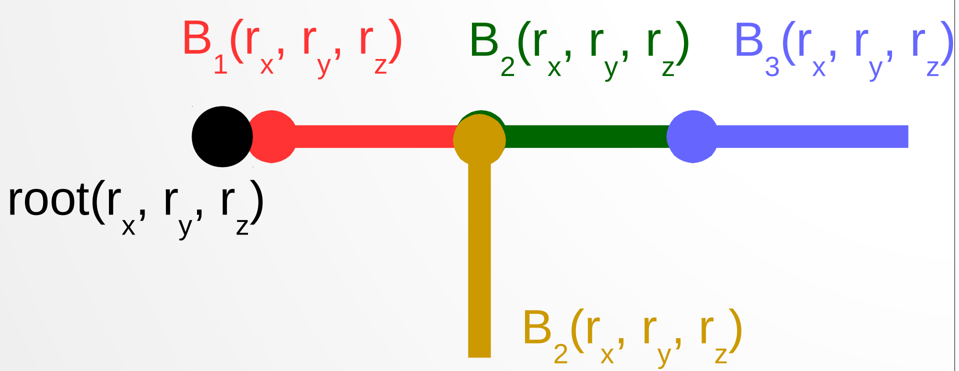
- **Motion Graphs**
  - What is a motion graph?
  - Creating Transitions
  - Motion graph construction
  - What can motion graphs be used for



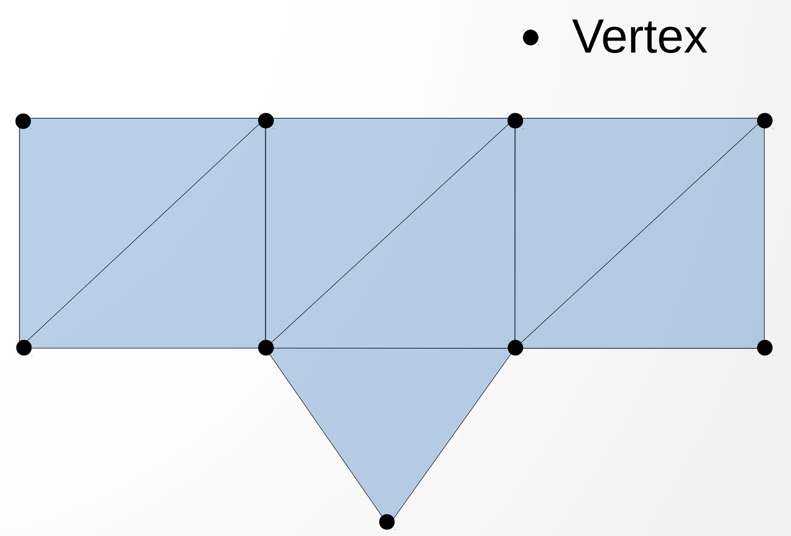
Introduction - Skeletal Animation

- An animated character consists of:
  - An invisible bone hierarchy called a ***skeleton***.
  - A visible polygon mesh enclosing the skeleton called a ***skin***.

Skeleton

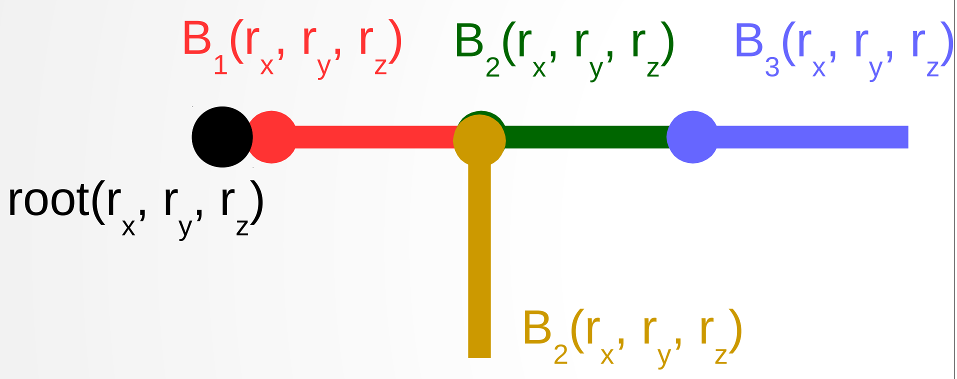


Skin

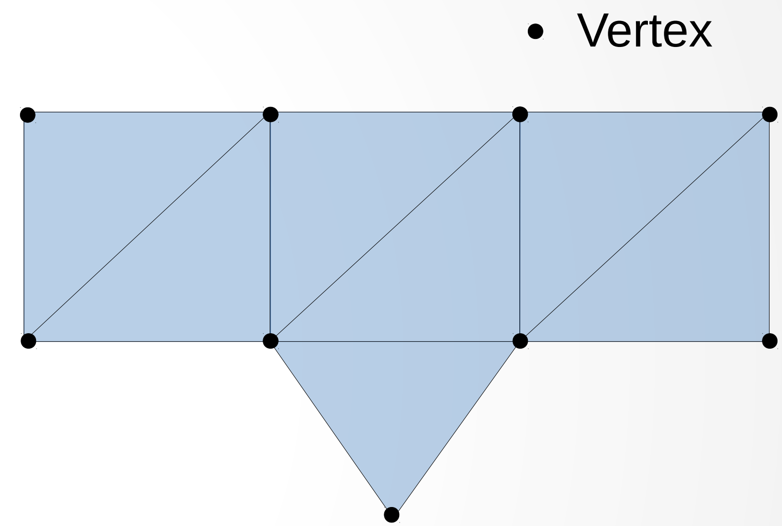


Introduction - Skeletal Animation

Skeleton



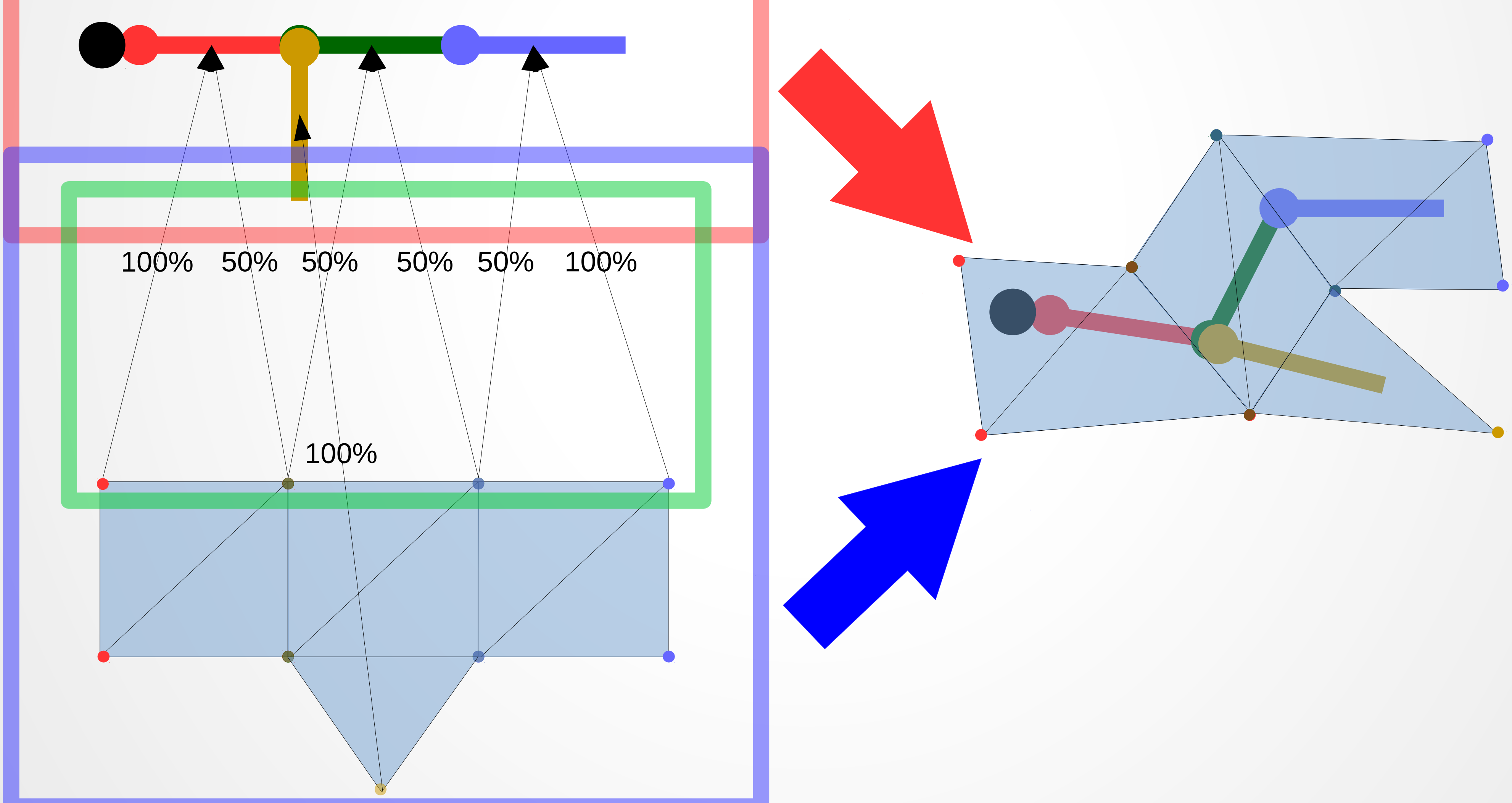
Skin



- A ***pose*** is defined as a vector of rotation values.
  $P = \{ \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\} \}$
- ***Bind Pose*** is the pose at the time the association between bones and skin vertices is made.

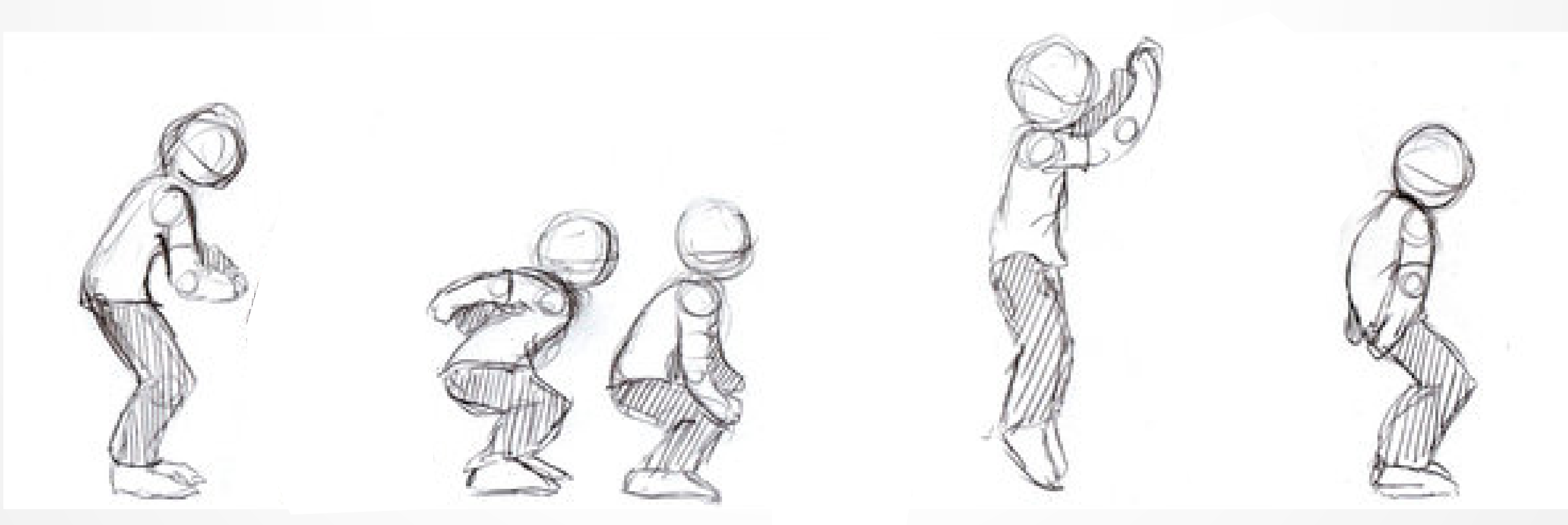
Introduction - Skeletal Animation

$P(t) = \{ \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\}, \{r_x, r_y, r_z\} \}$



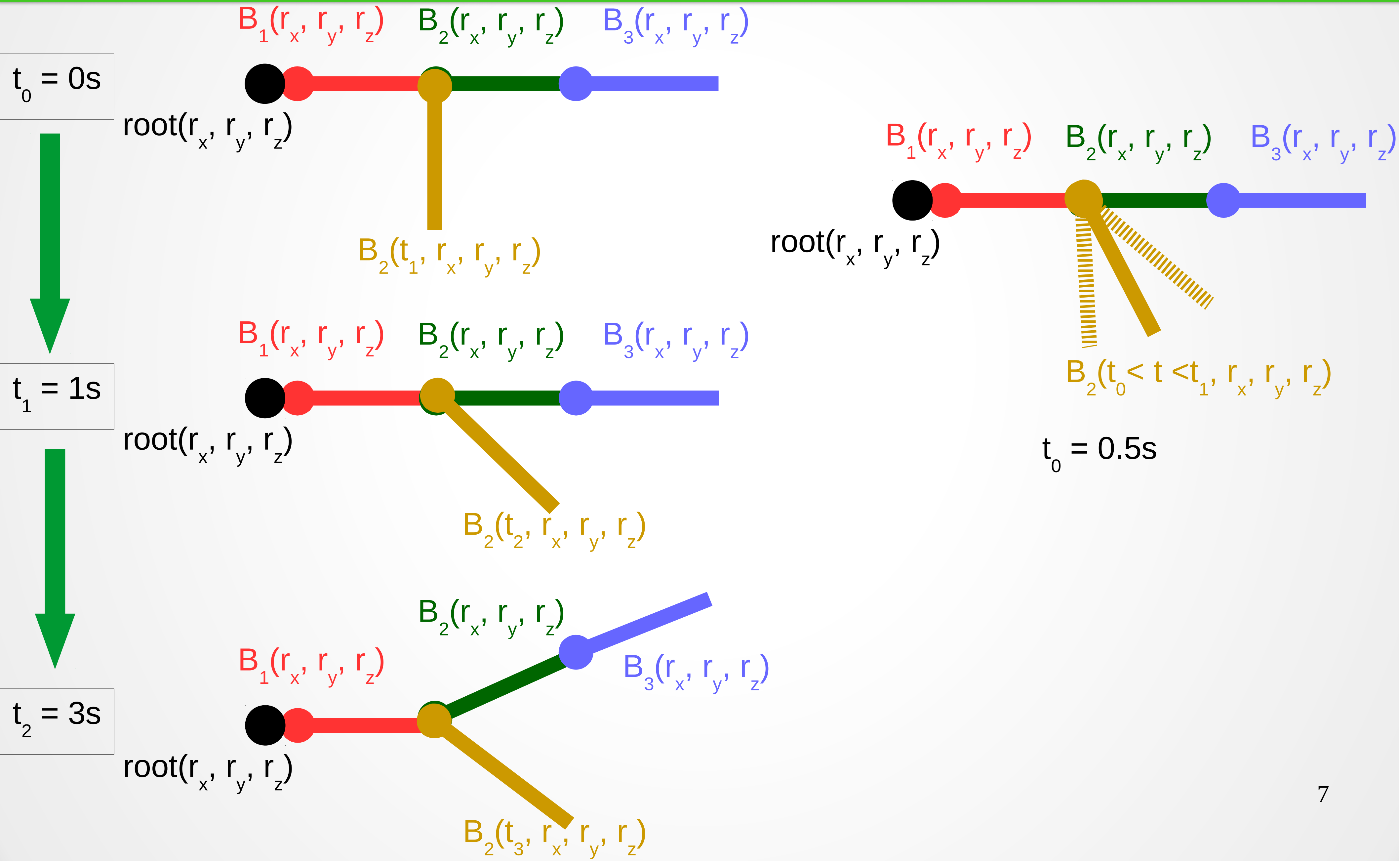
Introduction - Key Framing

- ***Key framing:*** Define a skeleton pose at specified time points. Assume that motion in between these time points is smooth.

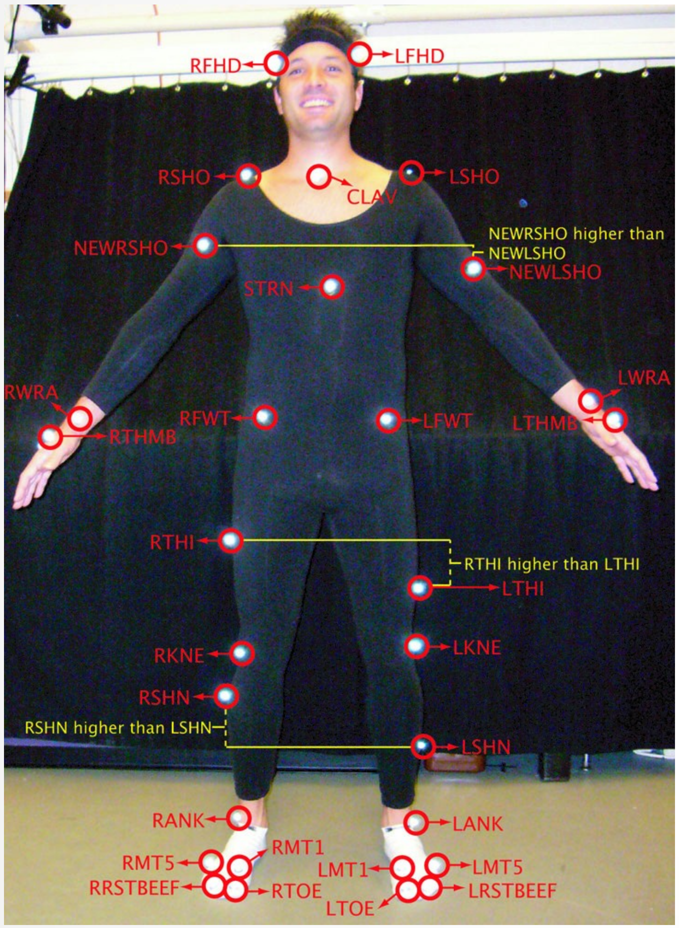


Key Frame : 0 1 2 3 4 5 6 7
Time (s): 0.0 0.1 0.3 0.7 0.8 0.9 0.95 1.0

Introduction – Key Framing



Introduction – Motion Capture



- Recorded images of an actor performing different movements while wearing special equipment are analyzed from various angles in order to extract bone rotation angles.
- Rotation angles and skeleton information are saved usually in text files.
- The rotation angles can then be transferred to a virtual character.

Introduction – Motion Capture

- Yields high detail keyframe data.
- Bone speed and acceleration is captured naturally.
- Data can be noisy and needs post processing.
- Huge amount of data (60 to 120 fps).
- A ***motion clip*** consists of a a sequence of poses parameterized by time (or frame number).

Introduction – Motion Capture

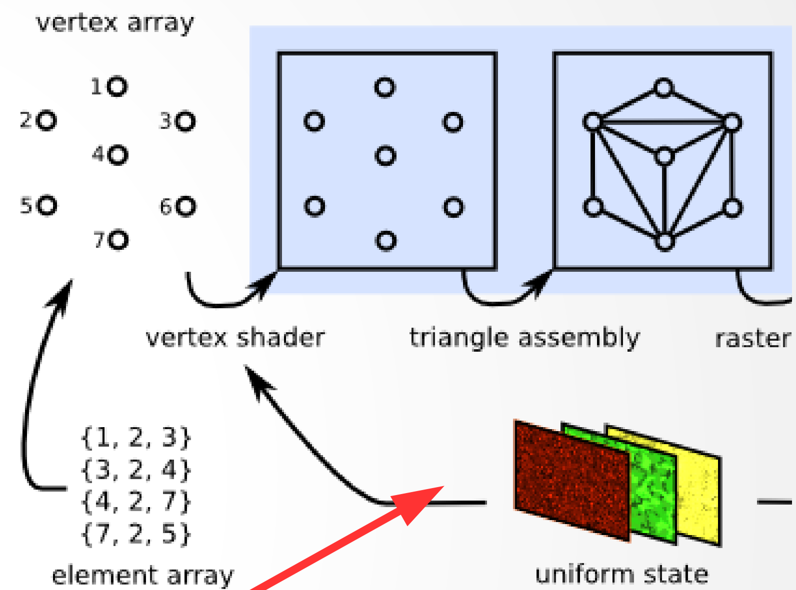
Motion Clip Demo

Introduction – Motivation

- Reuse existing motion clips to create new motions.
- Contol character motion at interactive rates suitable for real time applications.
- Synthesize motion to satisfy logical, spatial, temporal constraints.

Animation Engine – Skinning

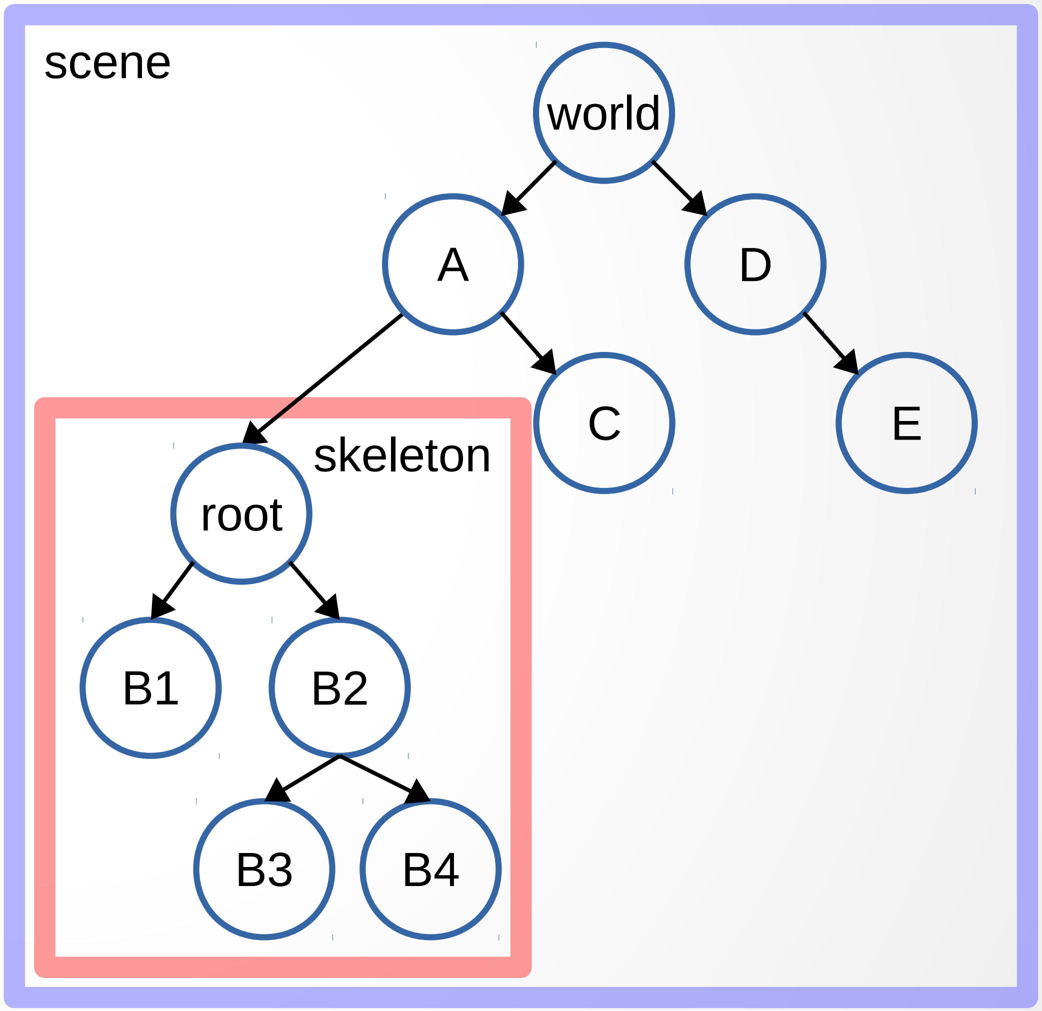
- ***Skinning*** is the process of computing a mesh configuration based on a pose and a rig.
- Skinning is done on the GPU
  - Vertex shader input:
    - position coordinates (p).
    - bone indices affecting each vertex (I).
    - weights affecting each vertex (W).
  - Uniform State:
    - bind pose inverse matrices one for each bone (BPInv).
    - current pose matrices one for each bone (M).



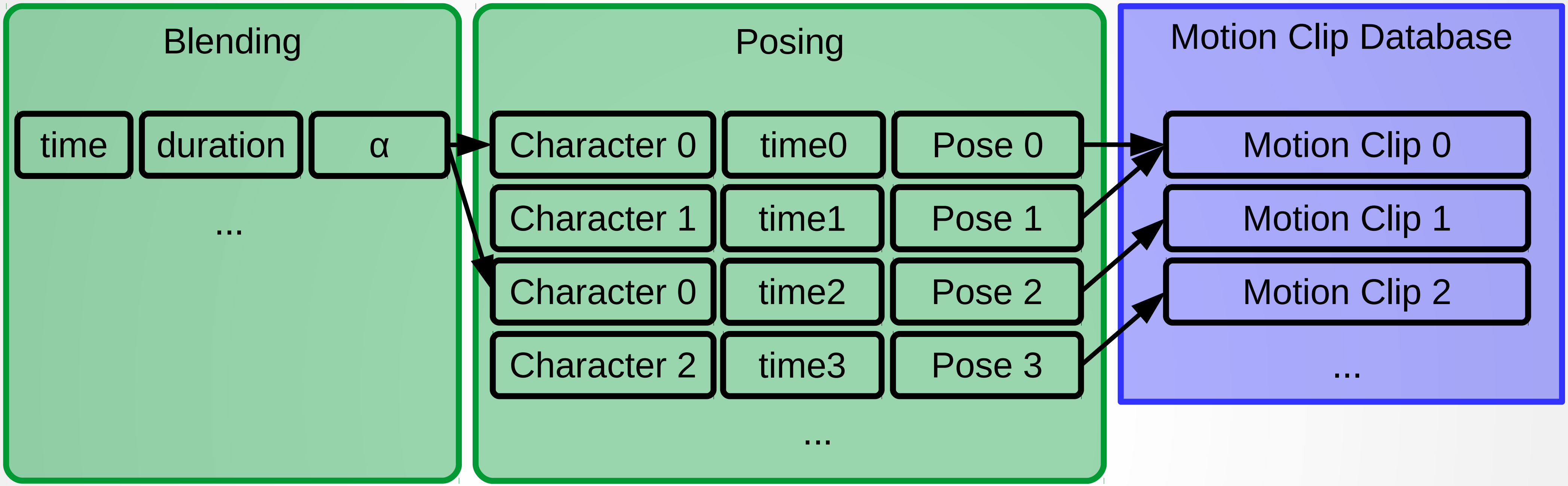
$$p'[i] = W[i] * M[I[i]] * BPInv[I[i]] * p[i]$$

Animation Engine – Scene Graph

- The spatial dependency of the objects in a scene is represented as a rooted tree.
- The position and orientation of each node is relative to the coordinate system of its parent node.
- Animated skeletons are trees themselves and therefore they are parts of the scene tree.



Animation Engine – Blending

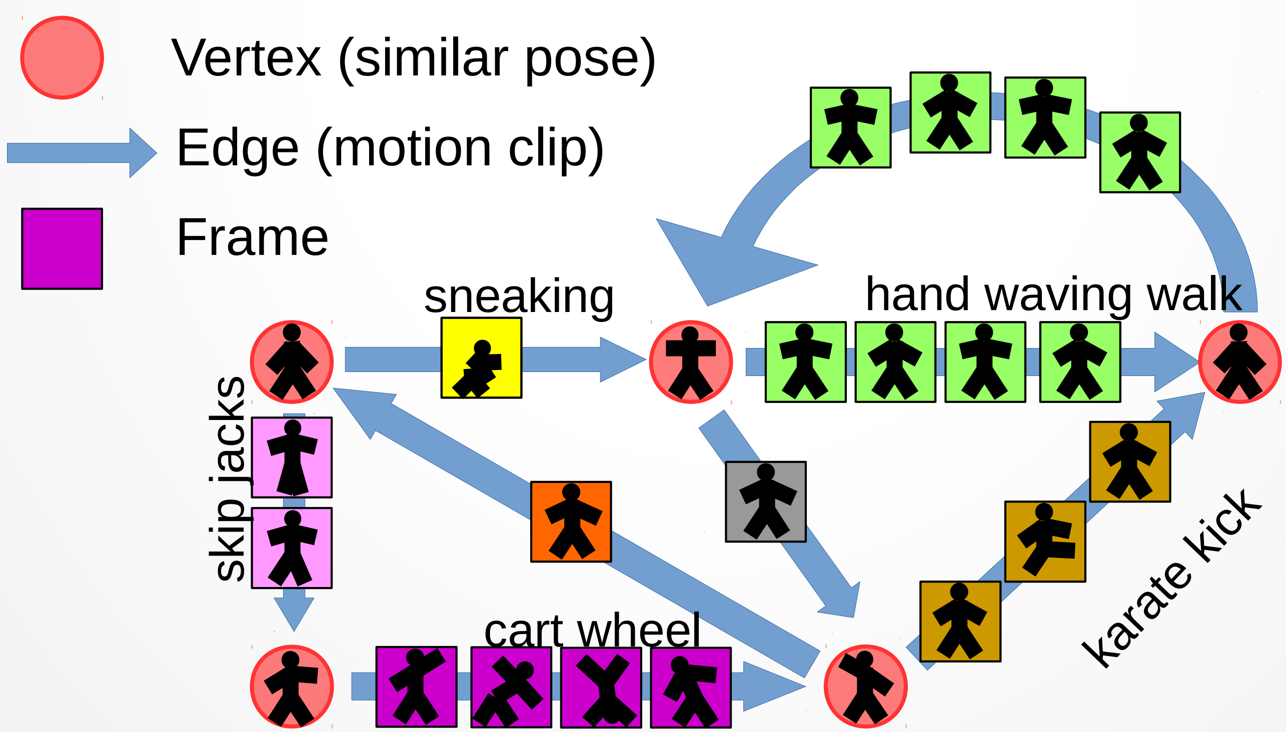


- Blend entries are kept in an array.
- time is relative to the beginning of the blend.
- duration is the total time required to complete the blend.
- α is the blend factor $\alpha = time / duration$
- $Pose' = \alpha * Pose2(time2) + (1 - \alpha) * Pose0(time0)$

Motion Graphs

- A ***motion graph*** is a directed graph where:
- Edges represent motion clips
- Vertices represent connection points between clips

It maps the motion synthesis problem to that of finding optimal graph paths that satisfy a high level goal.

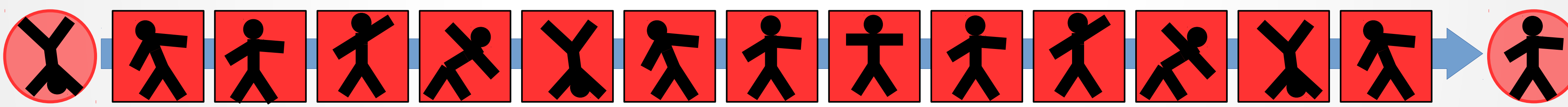


Motion Graphs – Desired Features

- The motion graph should have as many vertices as possible.
- The graph should be strongly connected (every vertex is reachable from any other vertex).

Motion Graphs – The simplest

- A motion clip is an edge in the motion graph.
  - The start and the end frames are the 2 vertices.
  - There is only one edge.



This graph is not strongly connected.

It needs more vertices.

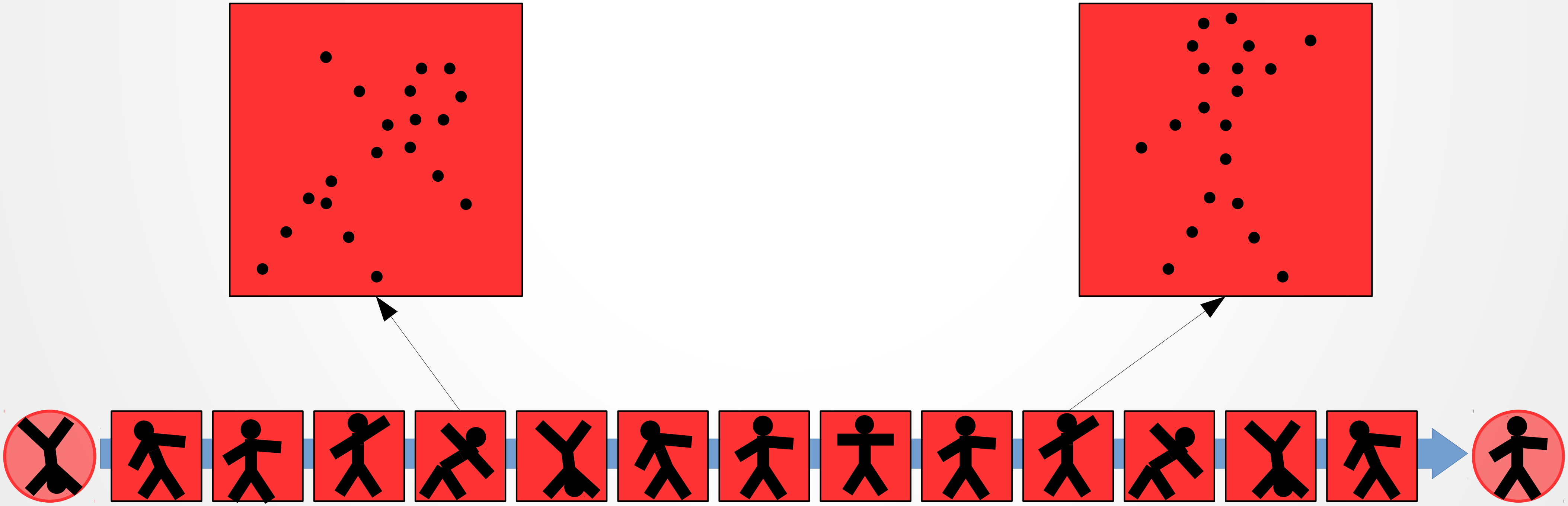
Motion Graphs - Transitions

- ***Transitions*** are automatically generated motion clips.
- They add more vertices to the graph by connecting similar frames.
- Generating transitions is hard and depends on the similarity between motions.

Motion Graphs – Detecting Transitions

- We use a simplified skin mesh to construct a point cloud *p* for every frame in the motion clip.

$$p_i = p_{i,0}, p_{i,1}, \dots, p_{i,N-1} \qquad p_j = p_{j,0}, p_{j,1}, \dots, p_{j,N-1}$$



Motion Graphs – Detecting Transitions

- For any two frames (i, j) compute the square of the Euclidean distance between respective points in the point clouds.

NOT GOOD ENOUGH ➡ $$d(i,j)=\sum_l w_l \| p_{i,l}-p_{j,l} \|^2$$

- Pose can be the same even though the character is rotated around the vertical axis.
- Pose can be the same even though the character is translated on the horizontal plane.

Motion Graphs – Detecting Transitions

- Lets fix it :
  - assume a rotation around the vertical axis
  - and a translation on the horizontal plane

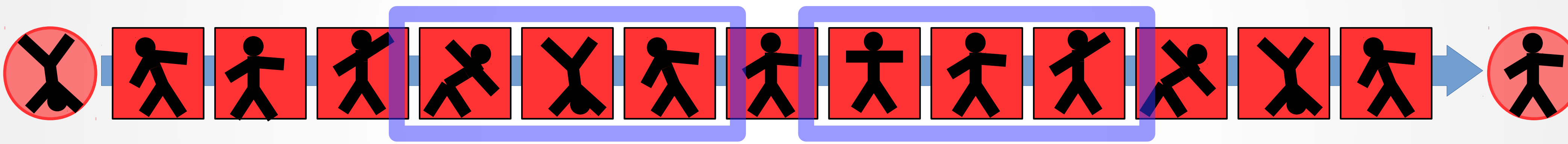
$$d(i,j) = \min_{\theta, x_0, z_0} \sum_l w_l \| p_{i,l} - T_{\theta, x_0, z_0} p_{j,l} \|^2$$

STILL NOT GOOD ENOUGH

  - A good transition should take into account speed and acceleration of moving bones.

Motion Graphs – Detecting Transitions

- Lets fix it :
  - Use a window of m frames.



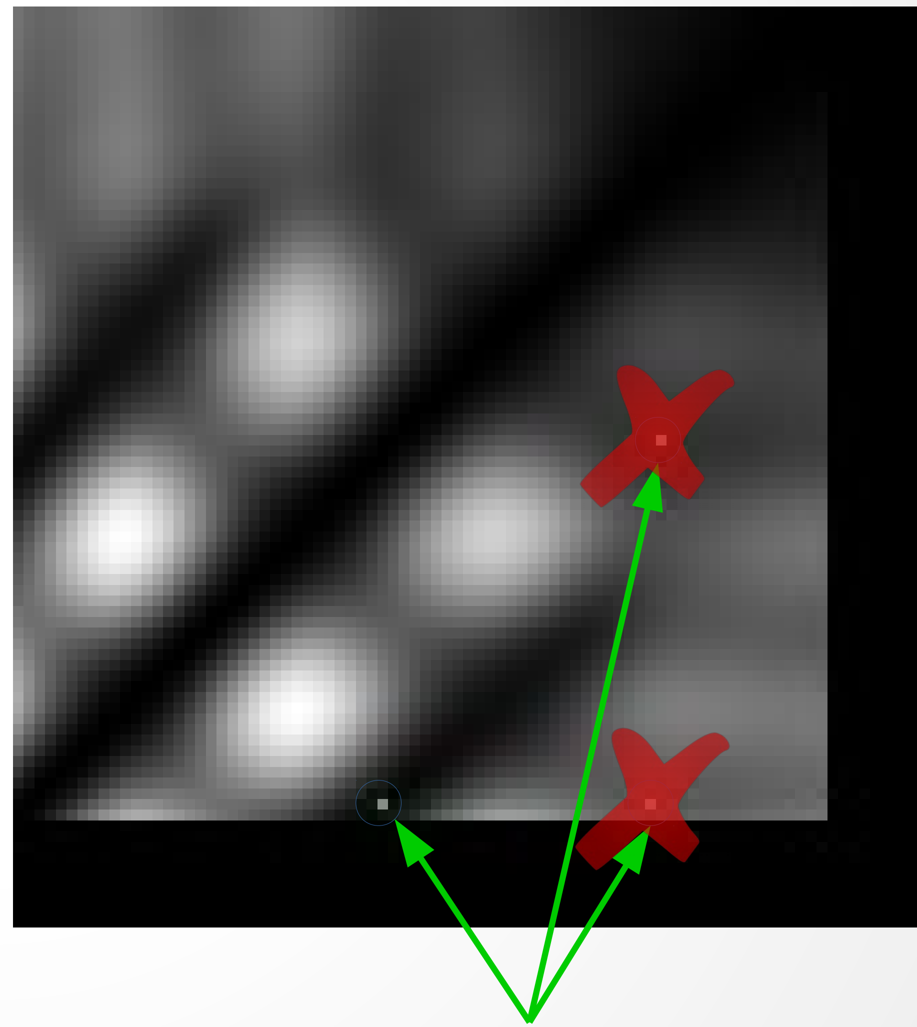
$$d(i,j) = \min_{\theta, x_0, z_0} \left\{ \sum_m \left\{ w_m \sum_l w_l \| p_{i+m,l} - T_{\theta, x_0, z_0} p_{j+m-M,l} \|^2 \right\} \right\}$$

THAT LOOKS COMPLICATED ENOUGH TO BE ON A RESEARCH PAPER

Motion Graphs – Detecting Transitions

- Repeat process for all frames in the motion clips.
- Search for (i,j) for which $d(i,j)$ is a local minima.
- Choose transition points from the local minima using a ε threshold.

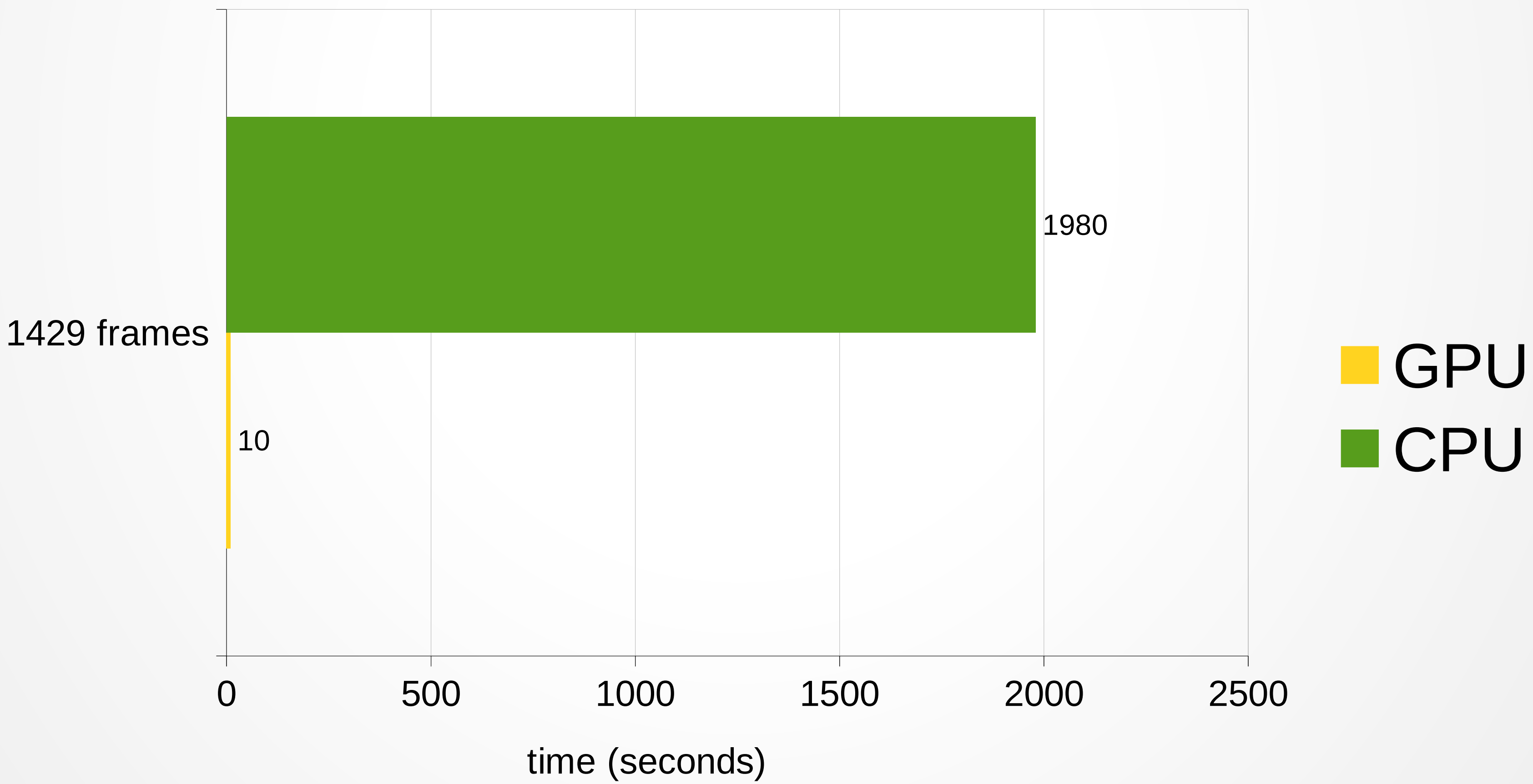
$$d(i,j)<\varepsilon$$



Transitions

Motion Graphs – Detecting Transitions

Creation of point clouds and transition detection are both done entirely on the GPU.

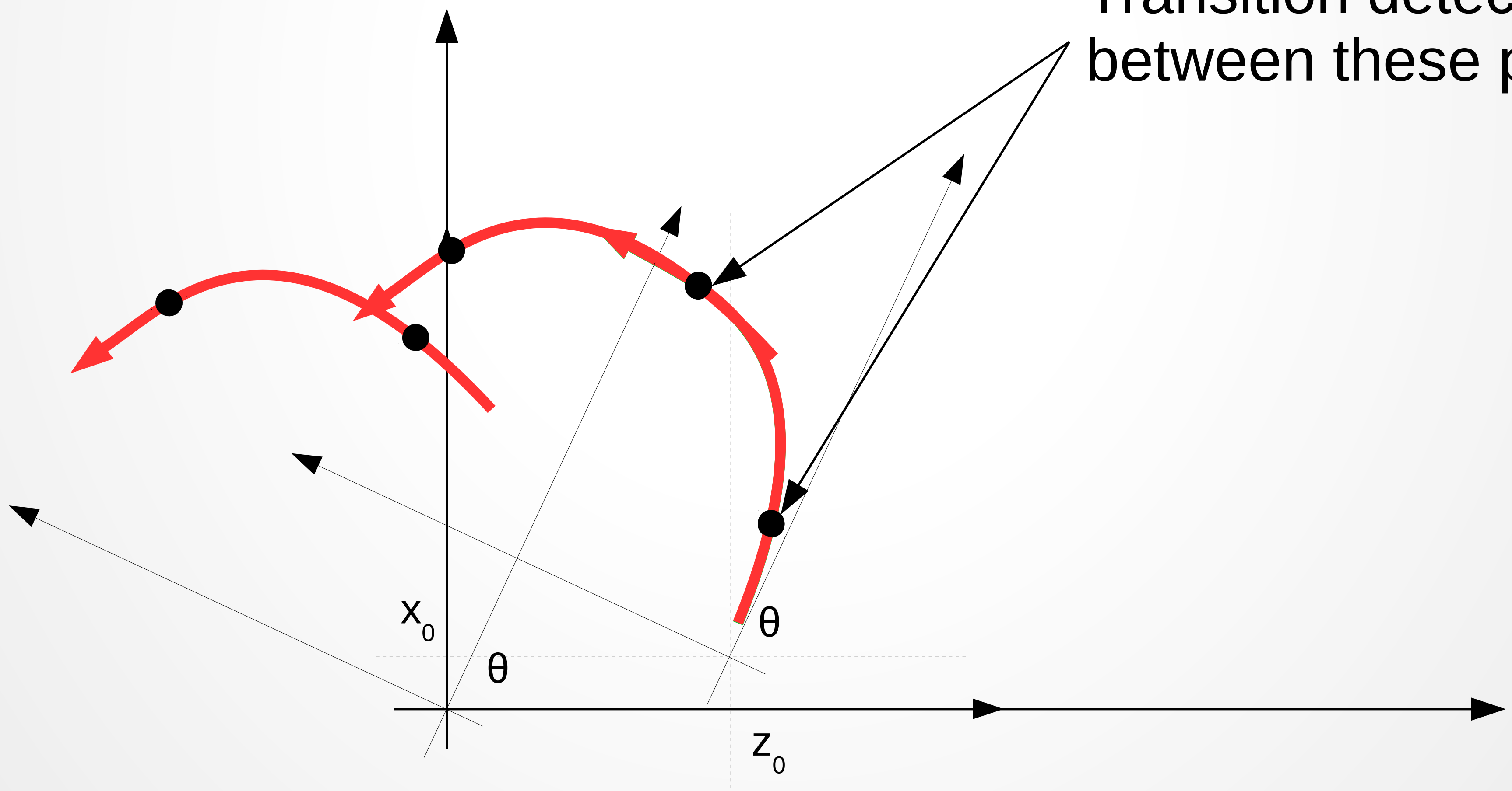


Motion Graphs – Creating Transitions

- Motion alignment

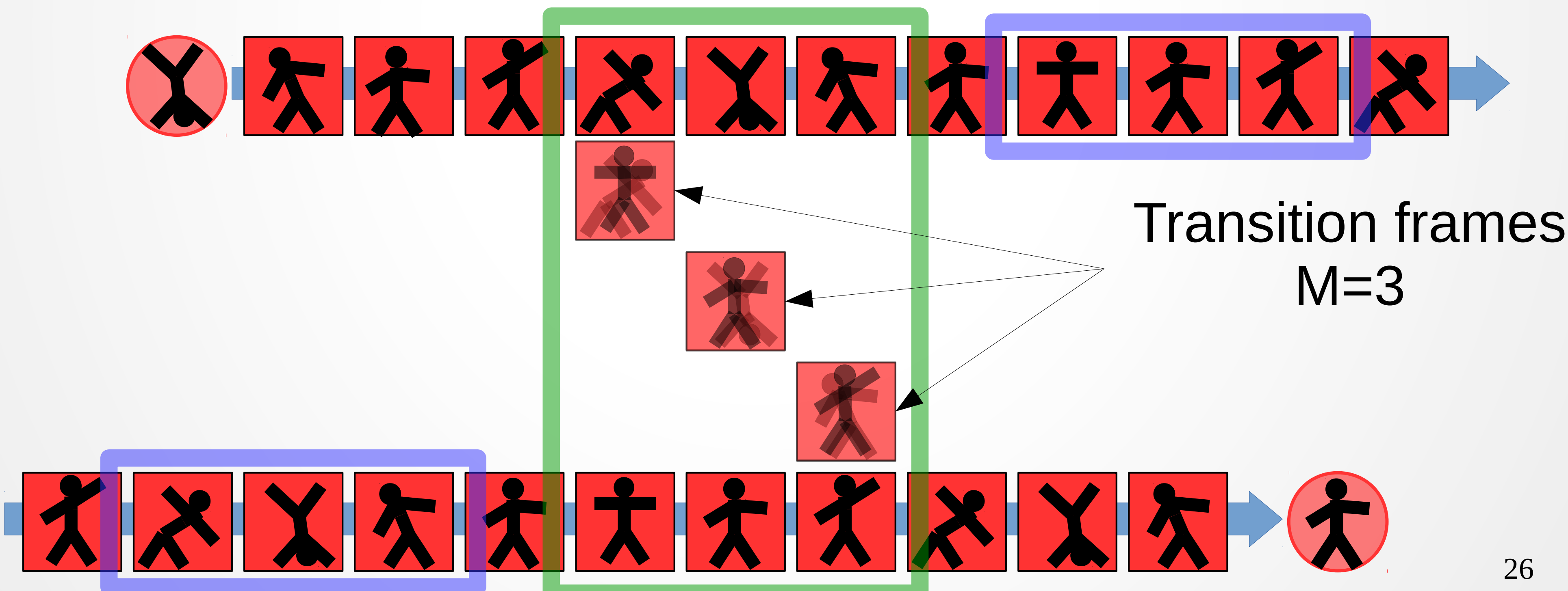
Imagine a walk veering left motion

Transition detected between these points



Motion Graphs – Creating Transitions

- Creating the poses for the transition.
- Transitions are created by blending M frames chosen from the original motion clip and the one we just reoriented and repositioned.

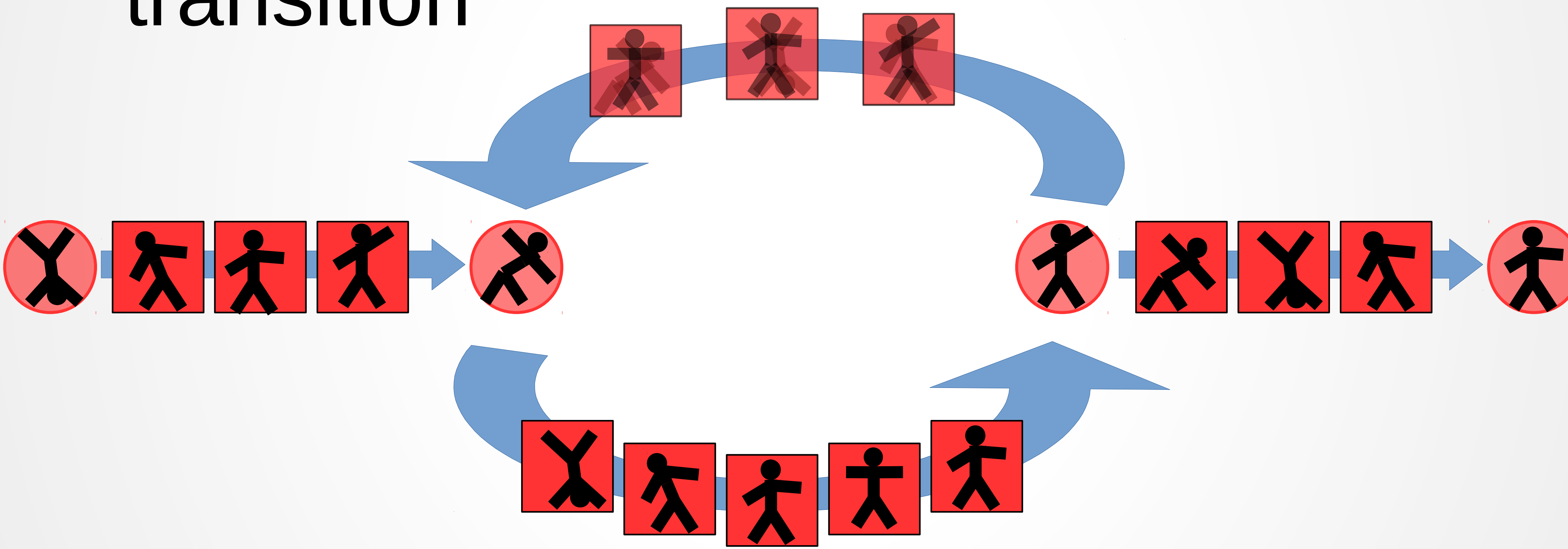


Motion Graphs – Creating Transitions

Transition Demo

Motion Graphs – The simplest

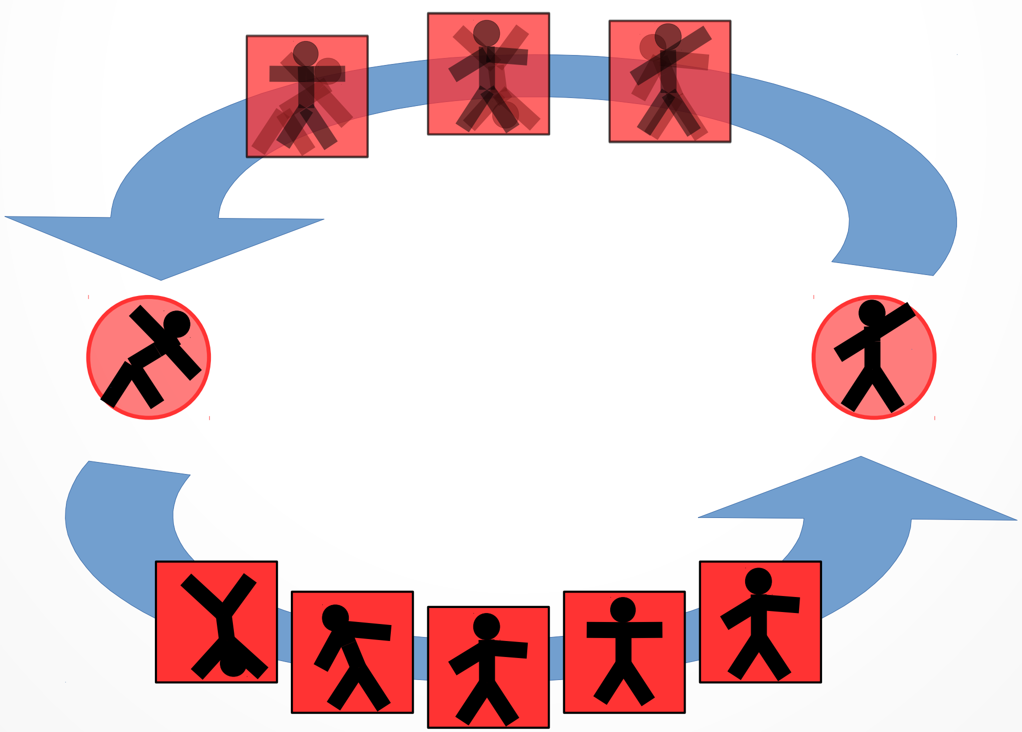
Updated motion graph with a transition



This graph is still not strongly connected.

Motion Graphs – The simplest

Prunning the graph ensures that every vertex is reachable from any other vertex.



Motion Graphs – The simplest

Motion Graph Demos

Backup Slides

Keep flipping ...

Introduction – Pose computation