

# Lecture 05: Data-driven Character Animation

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GAMES105 课程交流



VCL @ PKU

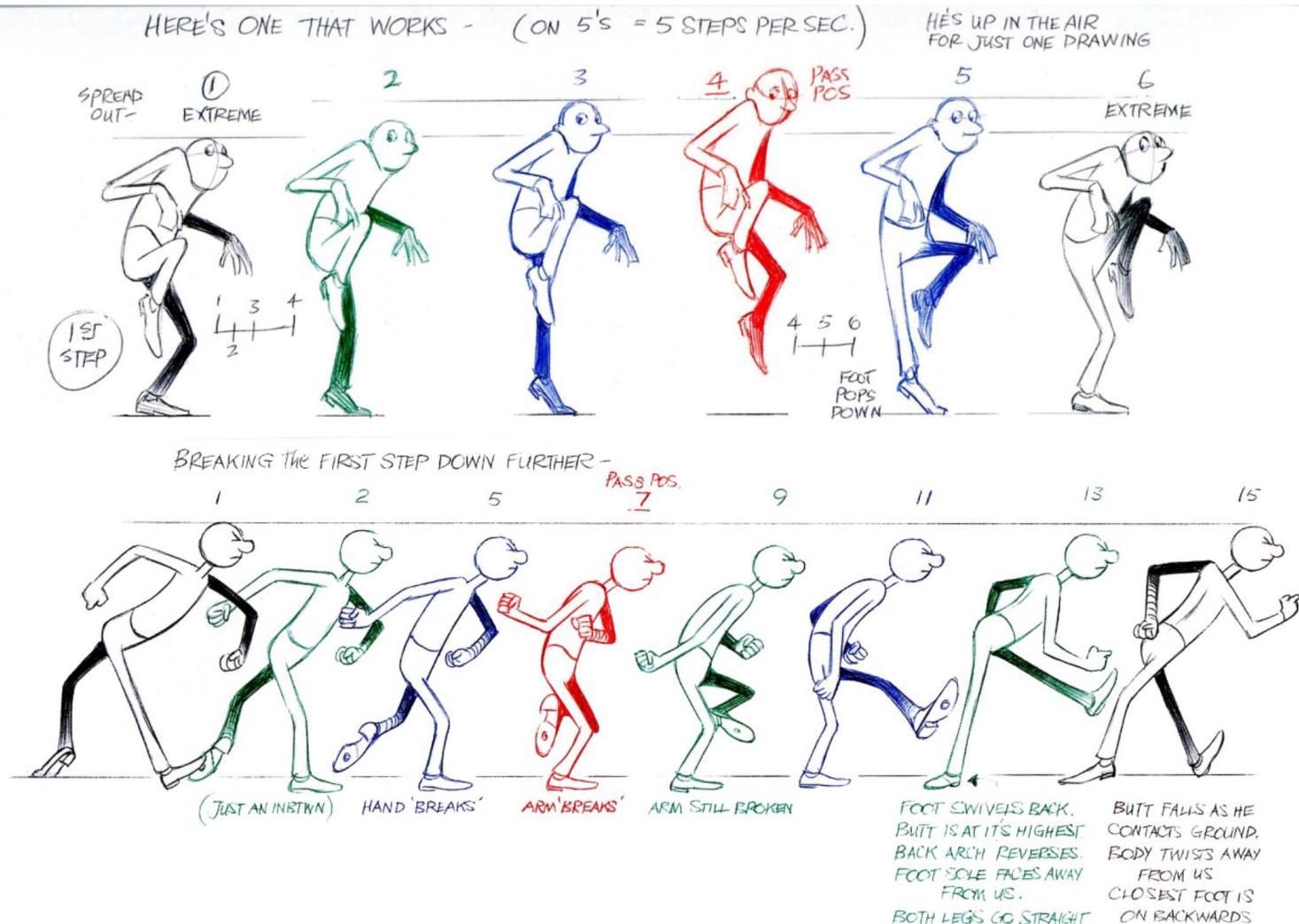
# Outline

- Motion Capture
  - History and modern mocap systems
- Motion Synthesis
  - Motion retargeting
  - Motion transition
  - Motion graph

# Motion Capture

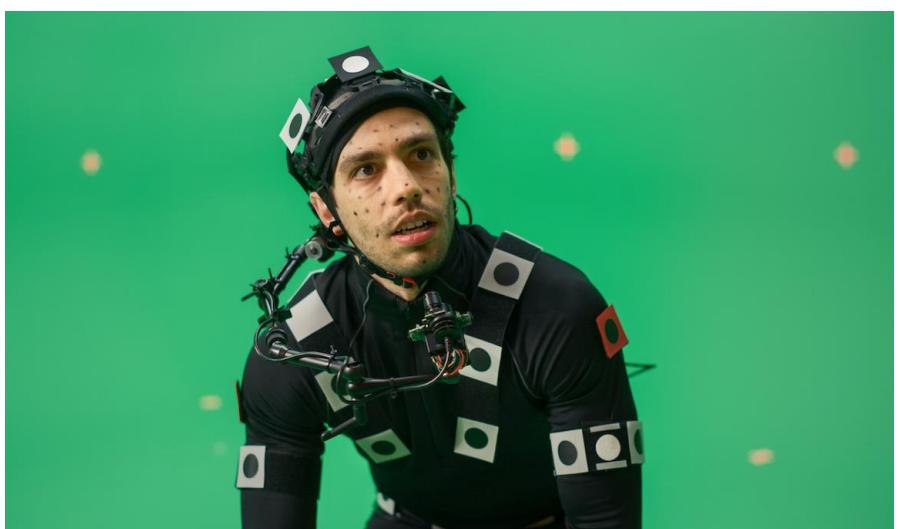
How to get motion data?

# Keyframe Animation



<http://www.theanimatorsurvivalkit.com/>

# Motion Capture



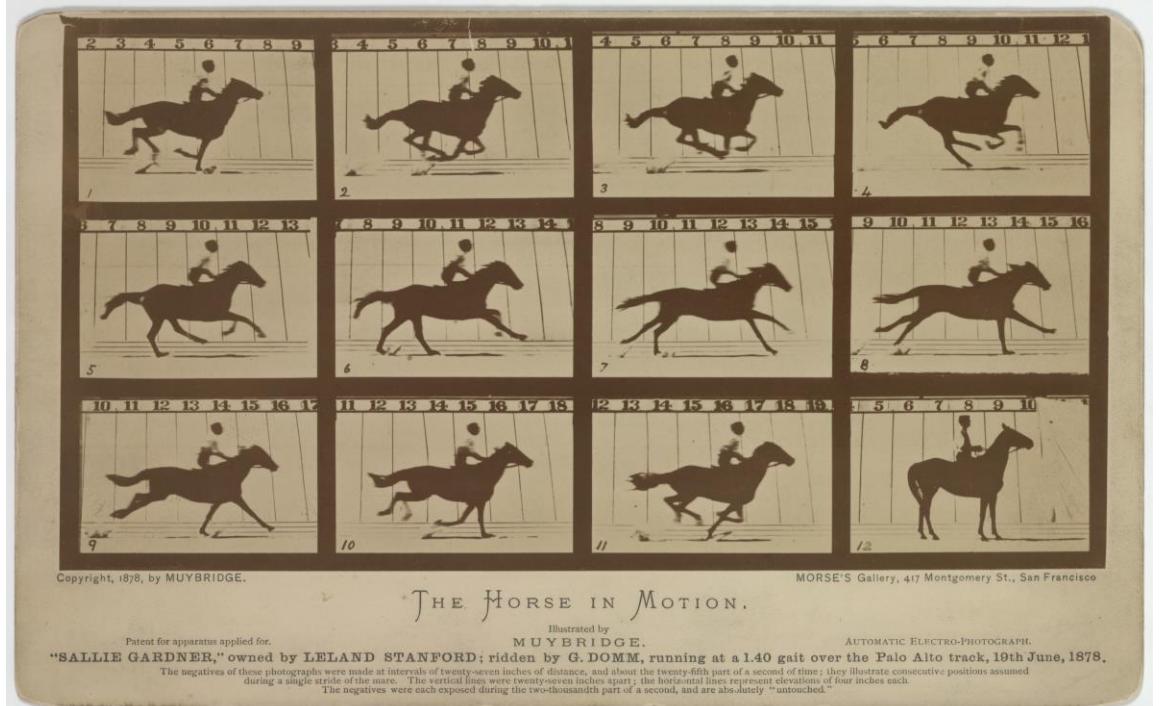
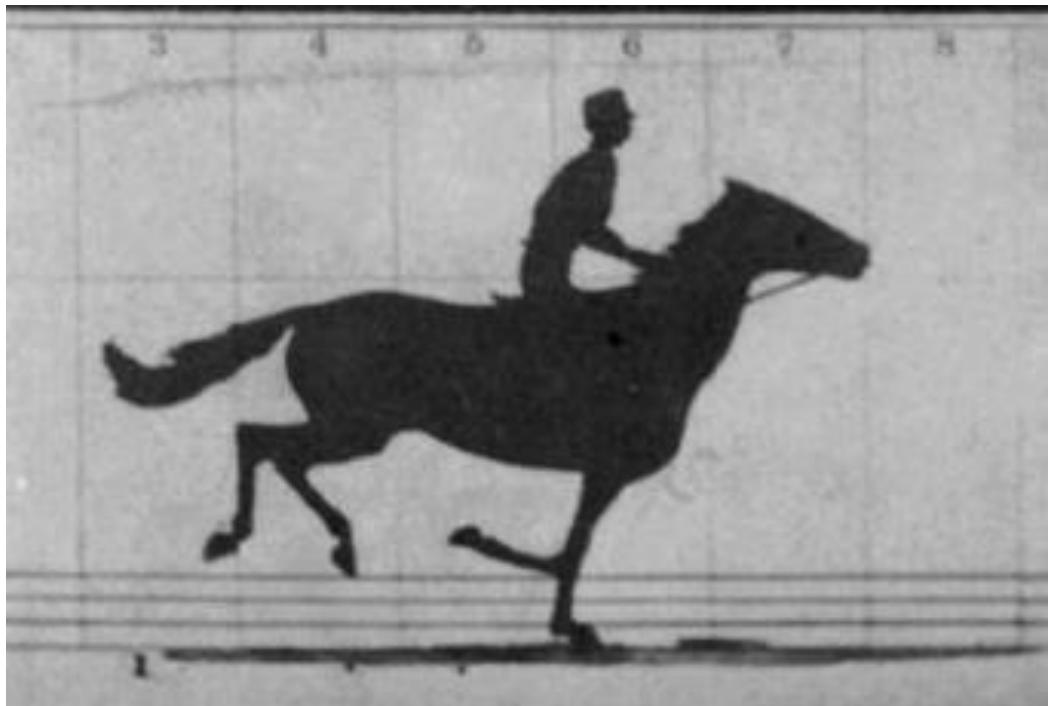
# Motion Capture

- Digitally recording movements of human, animation, and objects
  - Entertainment: games, films, virtual idols, metaverse
  - Sport: professional training, performance optimization
  - Medicine: orthopedics, injury diagnosis and therapy
  - Robotics: tracking and locating
  - .....



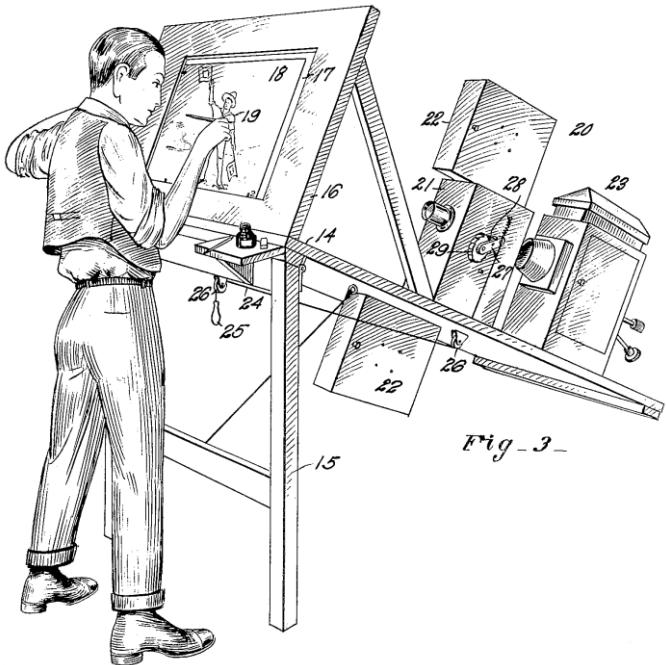
# The History of Mocap

- Study of motions using photography
  - Eadweard Muybridge (1830 –1904)
  - “*The Horse in Motion*” - 1878



# The History of Mocap

- Rotoscoping (~1914)
  - Max Fleischer (1883 – 1972)



[US patent 1242674]



*Alice in Wonderland*, 1951

# The History of Mocap

- Rotoscoping (~1914)
  - Rotoscope in Animation



*Snow White and the Seven Dwarfs*, 1939



*Alice in Wonderland*, 1951

# The History of Mocap

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# The History of Mocap

- Rotoscoping (~1914)
  - Rotoscope in Animation



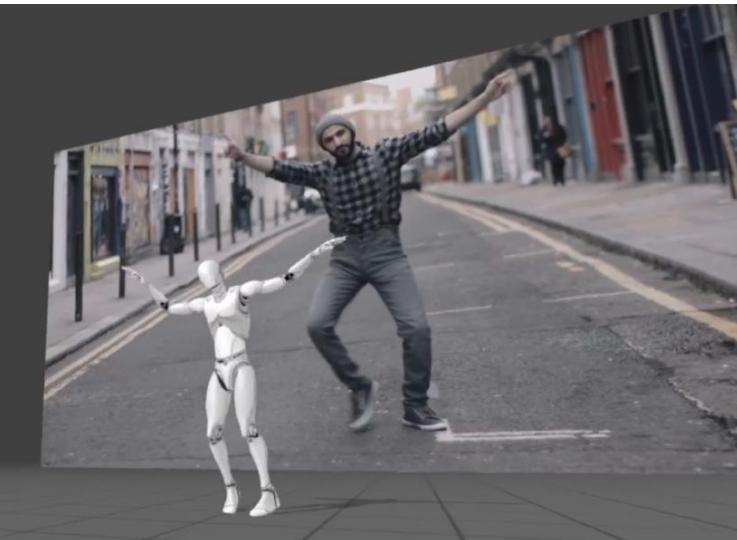
*The Princess of Iron Fan* (铁扇公主), Wan brothers (万氏兄弟), 1941

# Rotoscoping in 3D



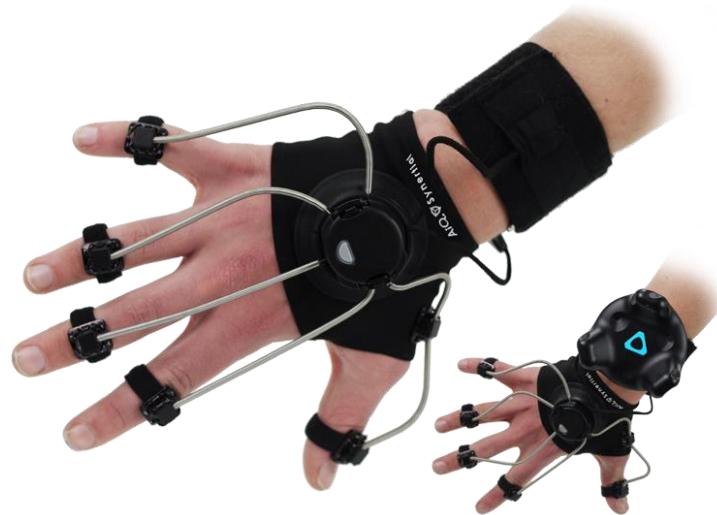
How to Animate 3D Characters in 1 Minute <https://www.youtube.com/watch?v=TjJLiuFKA20>

# Modern Mocap System



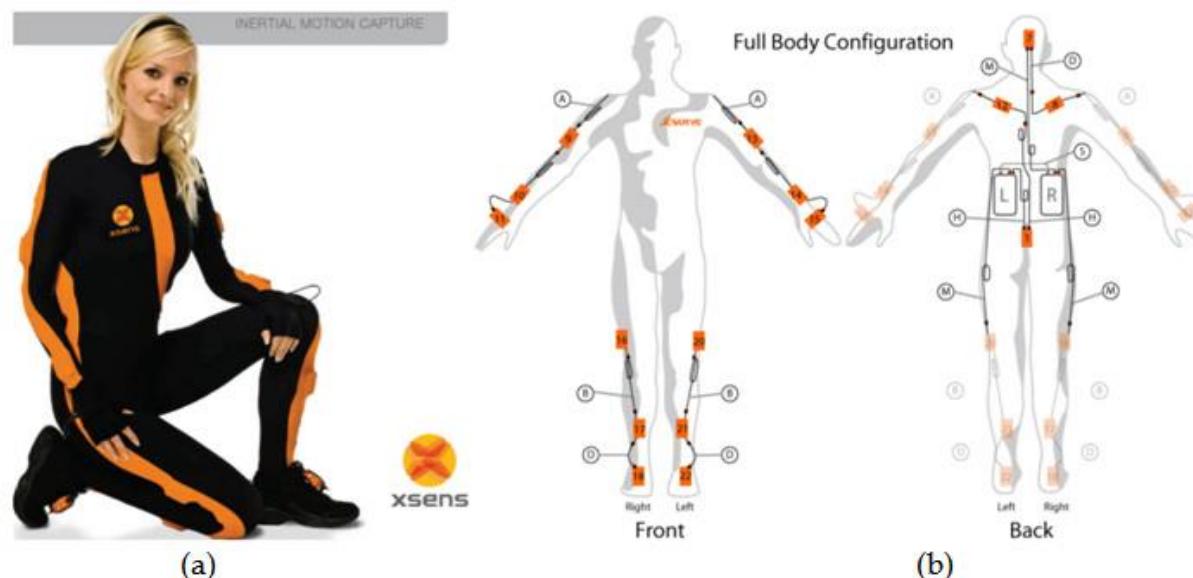
# Mechanical Mocap

- Exoskeleton



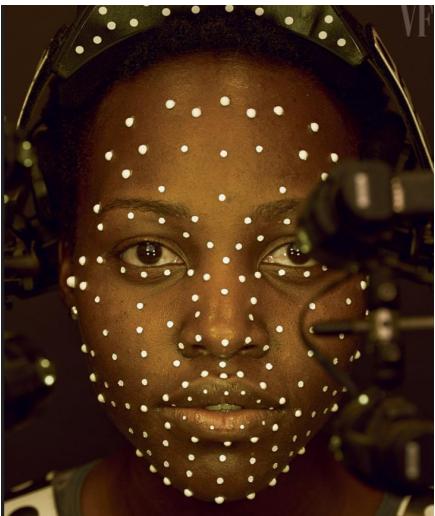
# Inertial Mocap

- Inertial Measurement Unit (IMU)
  - Accelerometers (3dof) + axis gyroscope (3dof)
- Optionally other sensors

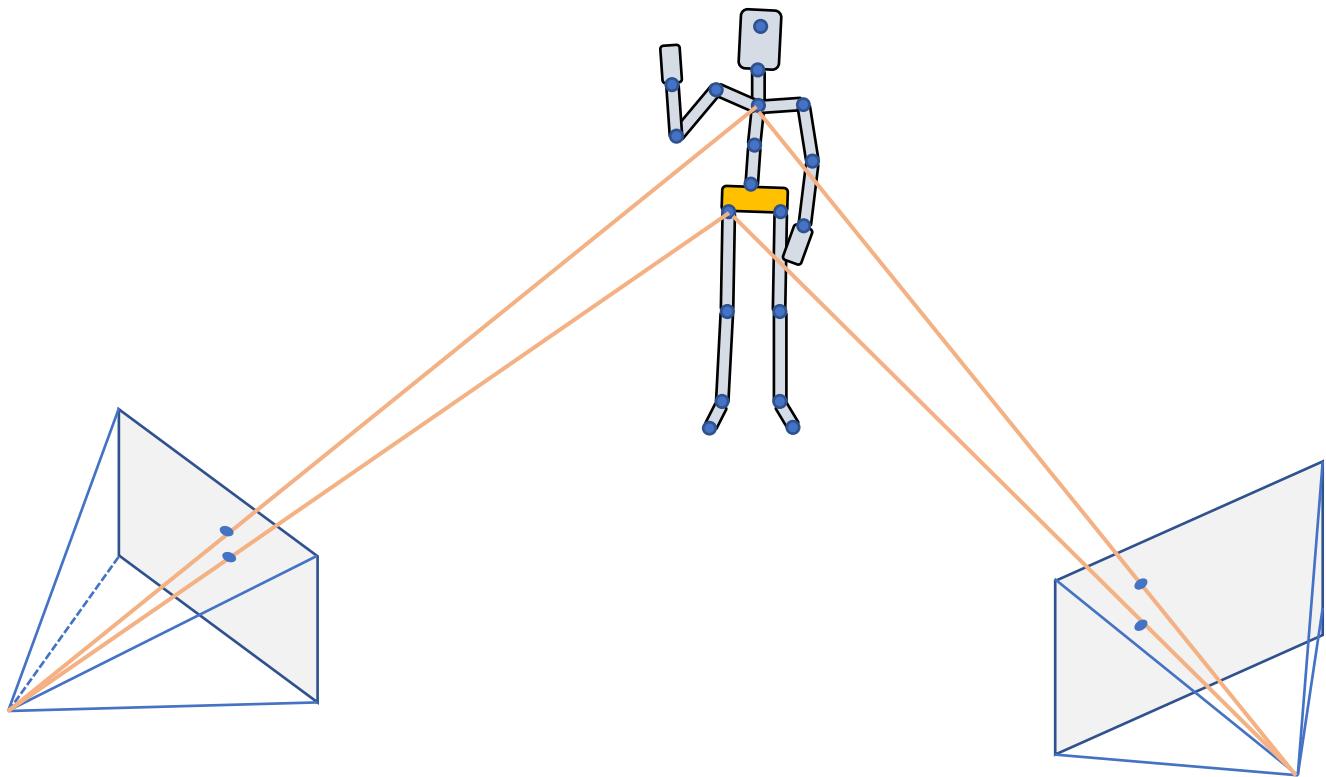


# Optical Mocap

- Reflective/light-emitting markers
- Multi-view geometry
- Solve body motions based on marker positions



# Optical Mocap

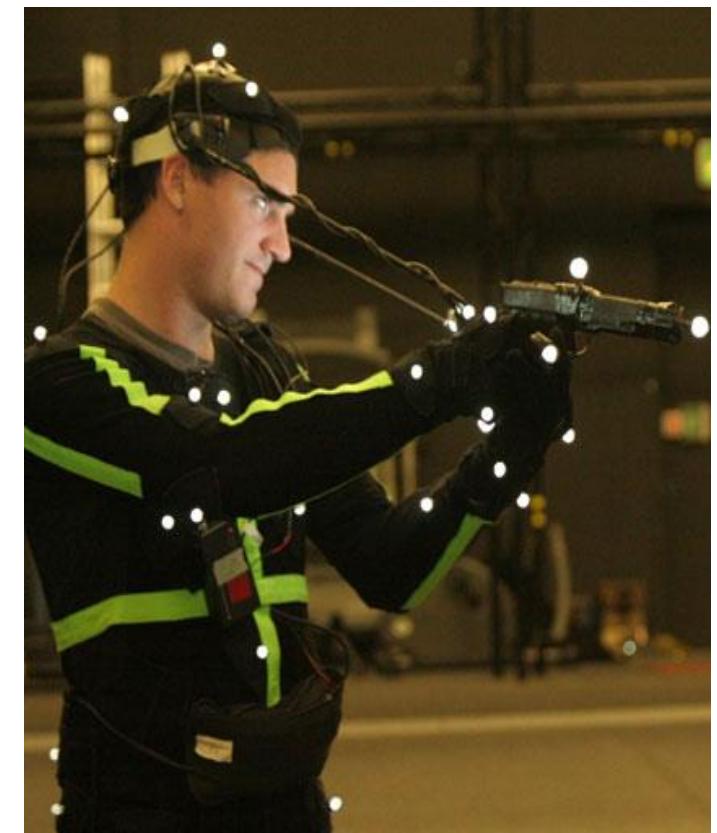
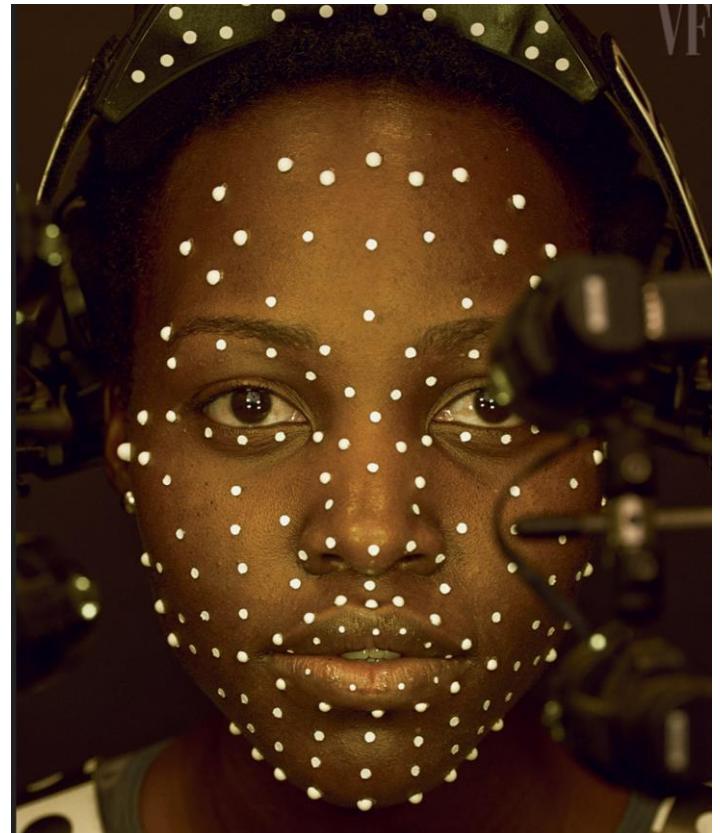


# Optical Mocap



<https://toronto.ubisoft.com/performance-capture/>

# Optical Mocap

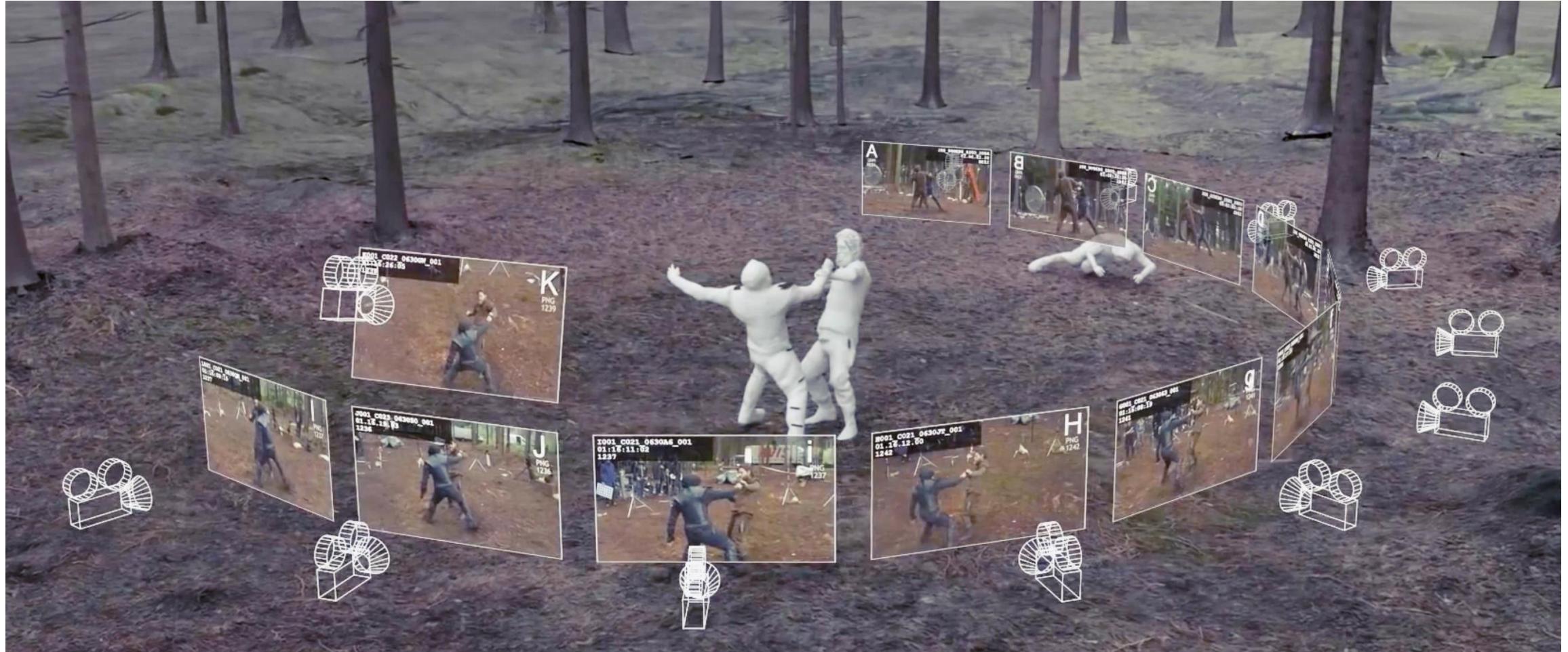


# Optical Mocap



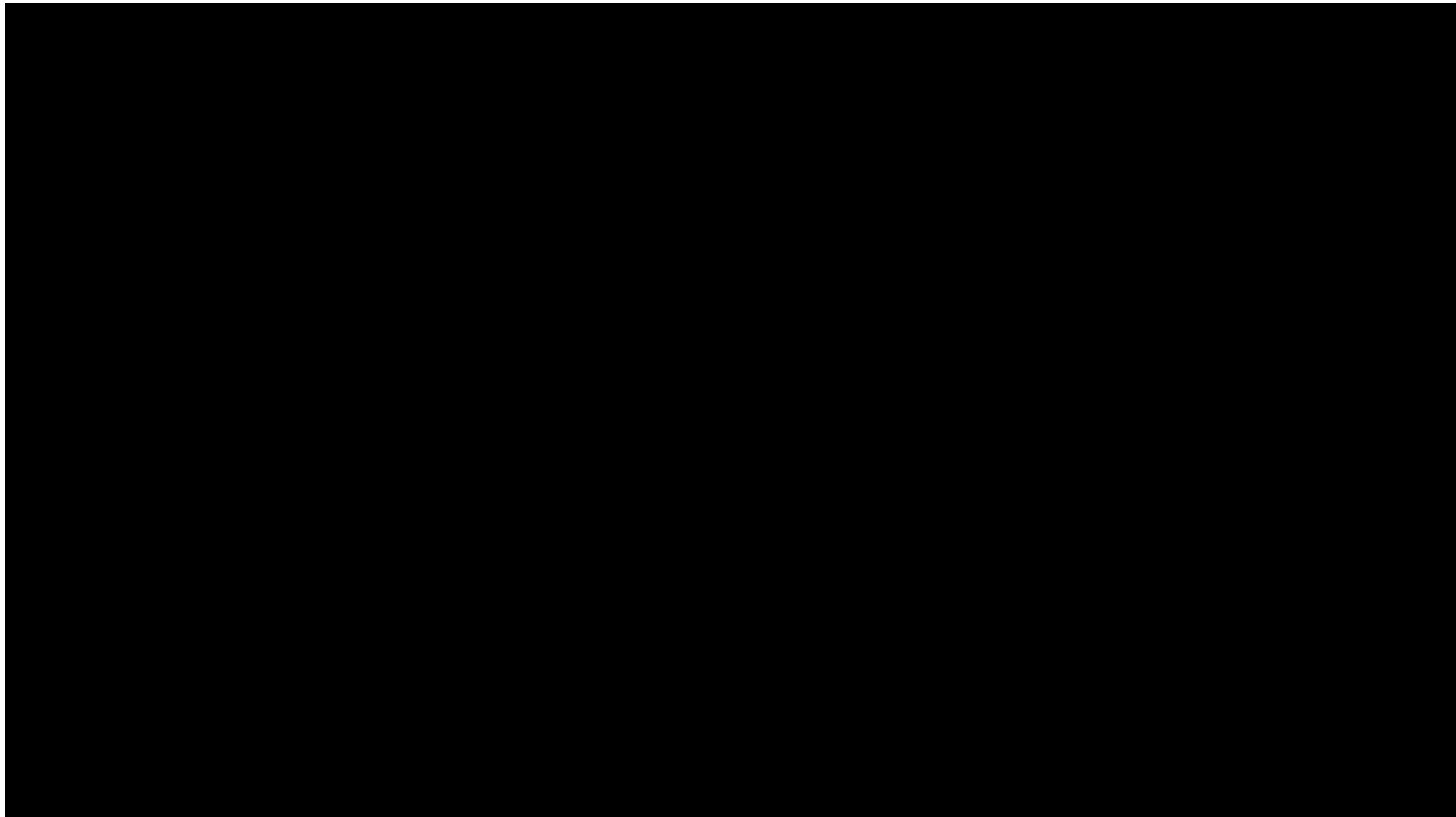
[Holden 2018 - Robust Solving of Optical Motion Capture Data by Denoising]

# Markerless Mocap with Multiple Cameras



<https://captury.com/>  
21

# Markerless Mocap with Multiple Cameras



<https://www.theiamarkerless.ca>

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# Markerless Mocap with Depth Cameras



# Motion Estimation with Monocular Videos

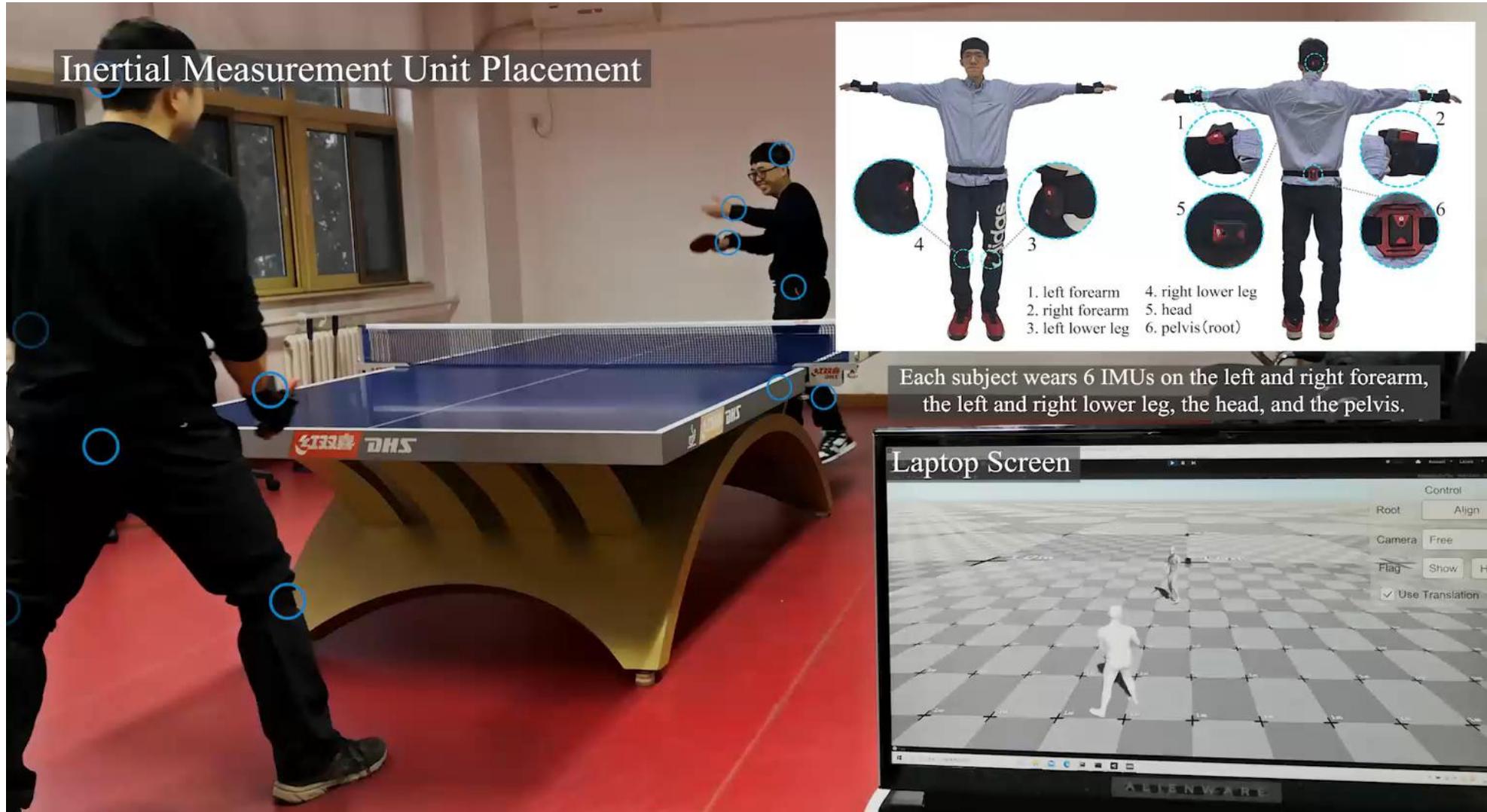


[OpenPose, 2D Pose estimation]



[3D Video-based Pose estimation, source: DeepMotion Inc.]

# Motion Estimation with Sparse Sensor



[Yi et al. 2021. TransPose: Real-time 3D Human Translation and Pose Estimation with Six Inertial Sensors] 25

# Motion Estimation with Sparse Sensor



[Meta]

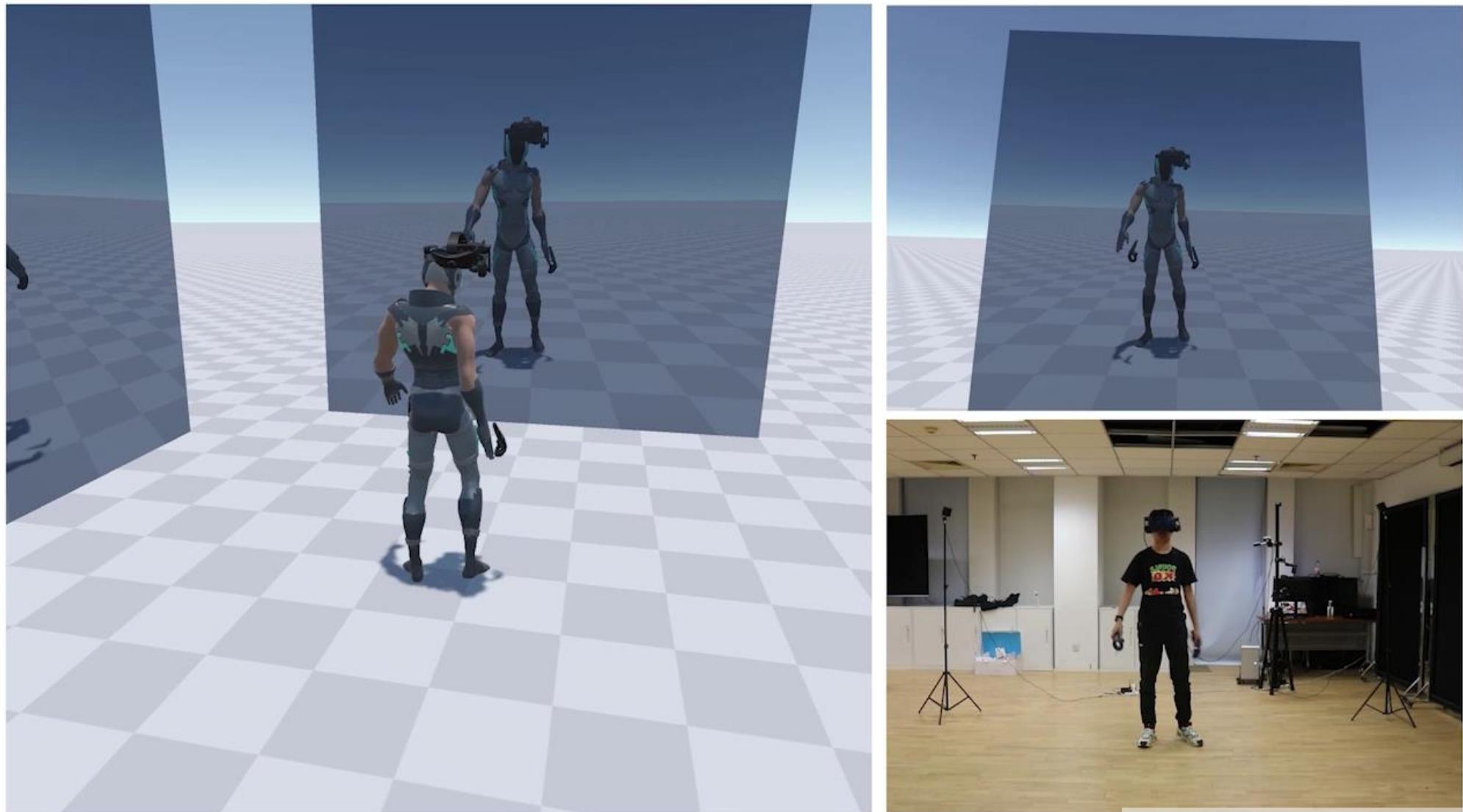
# Motion Estimation with Sparse Sensor



[Meta]

27

# Motion Estimation with Sparse Sensor



[Ye et al. 2022: Neural3Points] 28

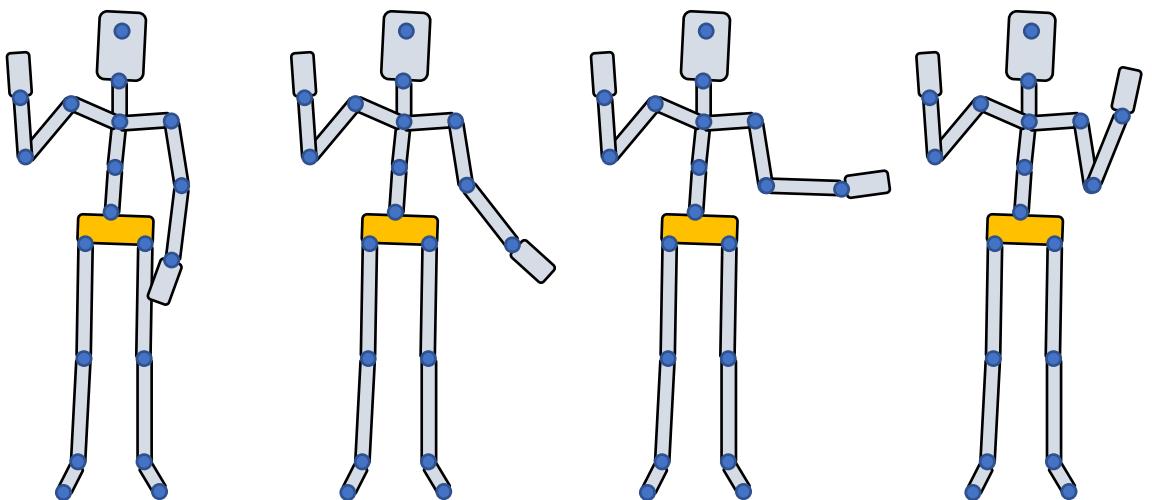
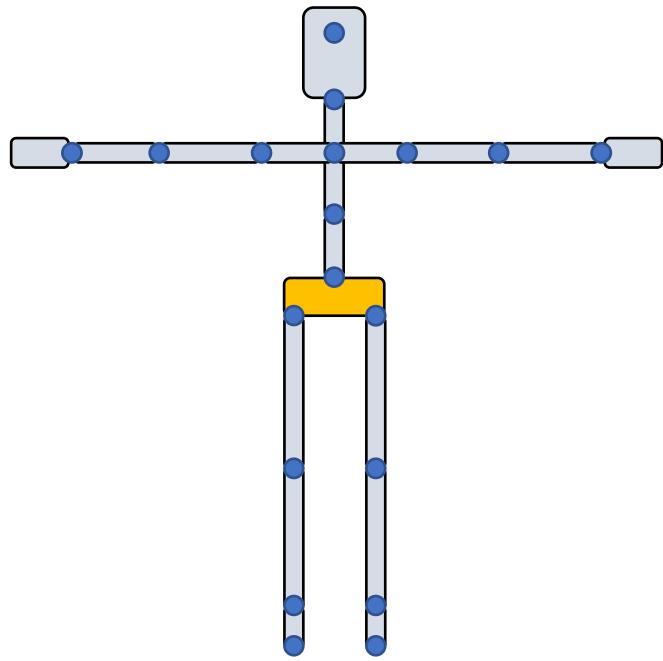
# Motion Synthesis

How to use motion data?

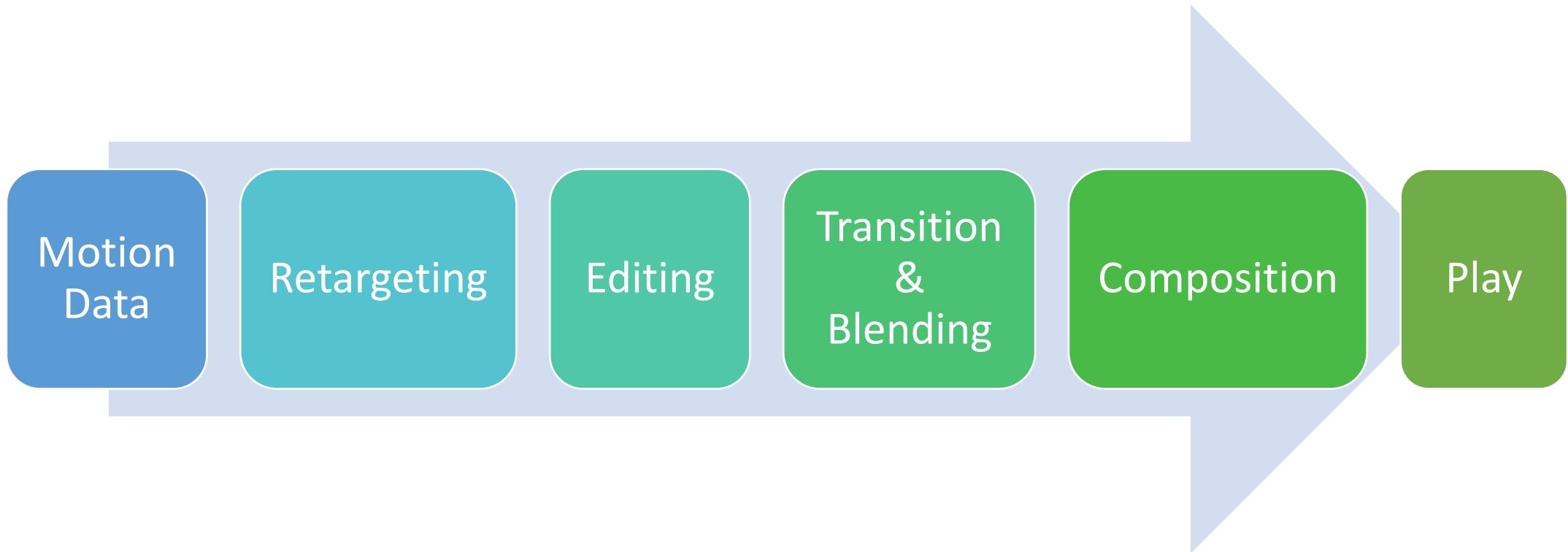
# Motion Data

$\{p_t\}, t = 1, \dots, N$

$p_t = (\mathbf{t}_0, R_0, R_1, R_2, \dots)$

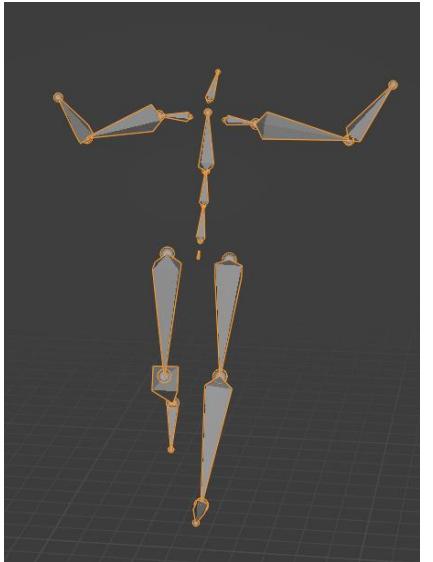
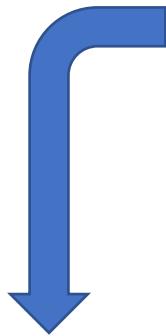


# Using Motion Data



# Motion Retargeting

- Retarget a motion to drive a character with
  - Different number of bones
  - Different bone names
  - Different reference pose
  - Different bone ratios
  - Different skeletal structure
  - .....



# Motion Retargeting

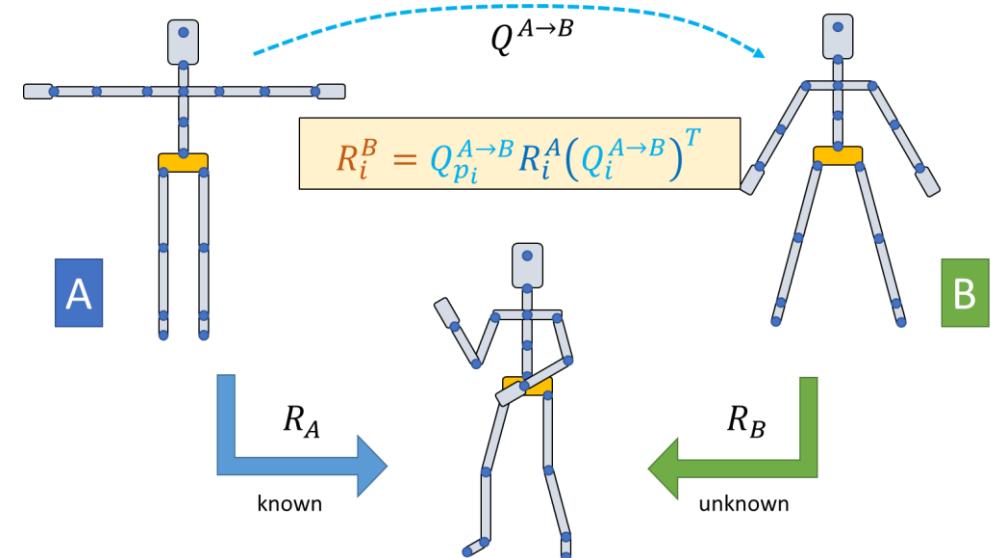
- Retarget a motion to drive a character with
  - Different number of bones
  - Different bone names
  - Different reference pose
  - Different bone ratios
  - Different skeletal structure
  - .....



[Villegas et al. 2021, Contact-Aware Retargeting of Skinned Motion]

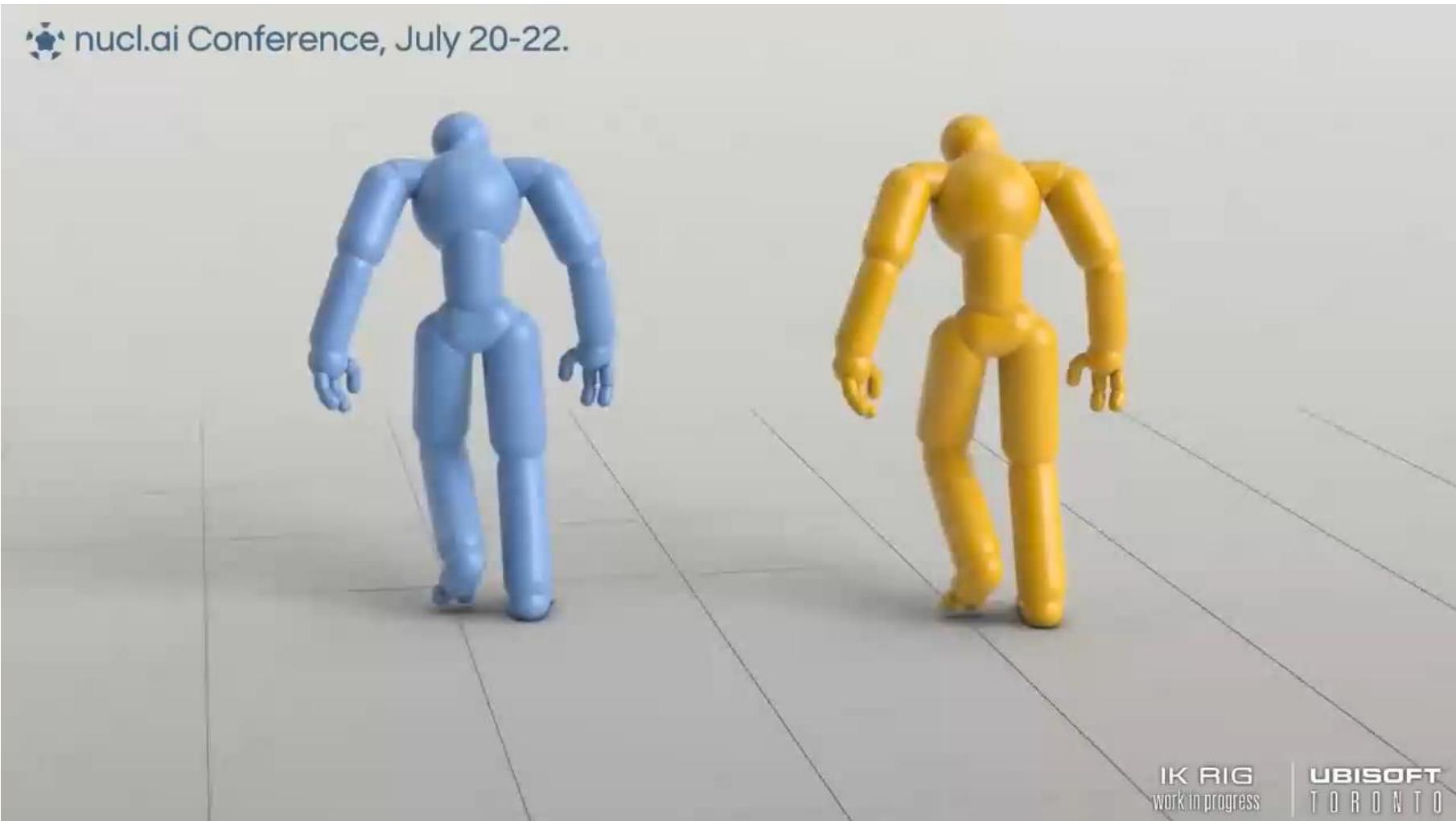
# Motion Retargeting

- A possible retargeting pipeline
  - Map bone names
  - Scale translations
  - Copy or retarget joint rotations to fix reference pose
  - Postprocessing with IK
    - Foot-skating
    - Self penetration
  - .....



# Motion Retargeting

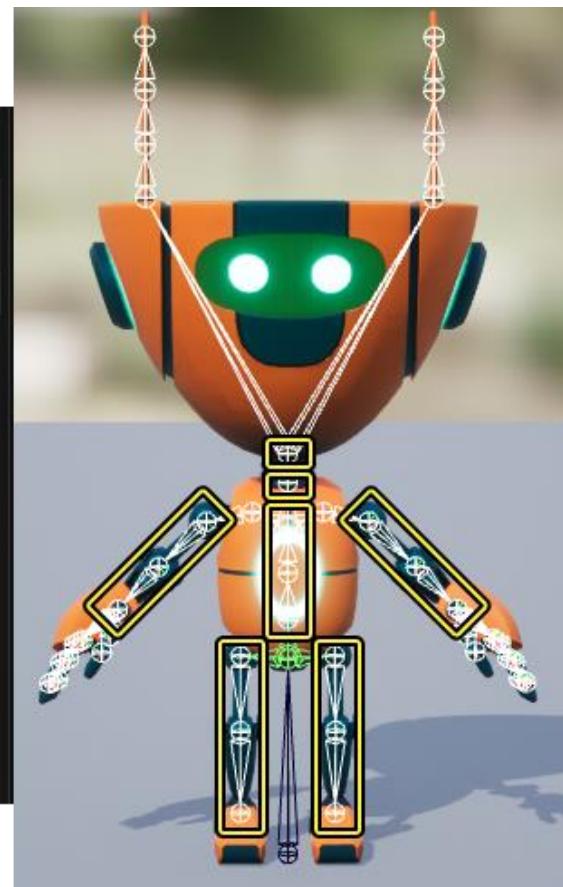
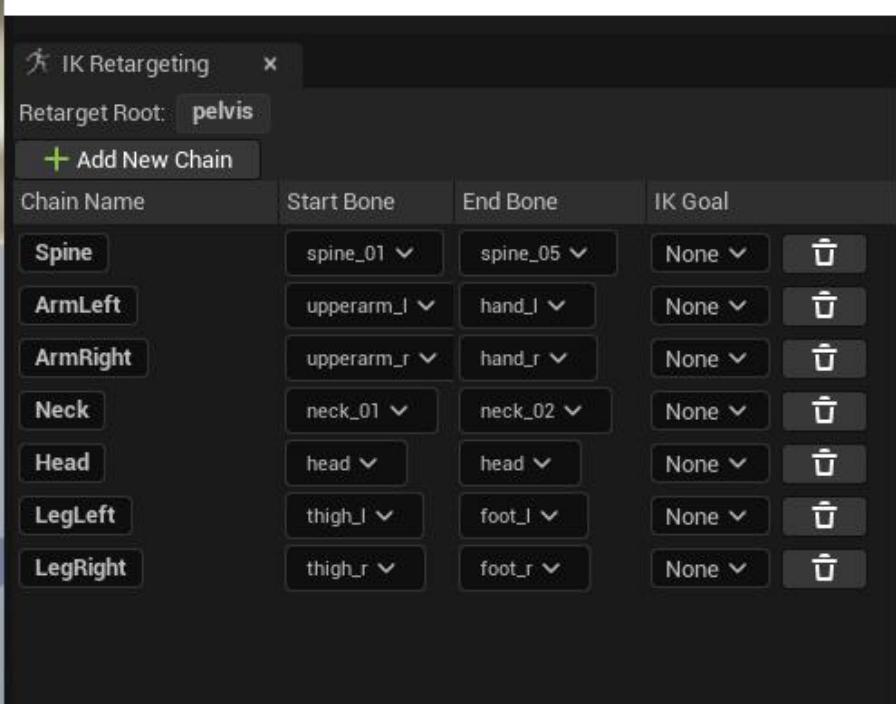
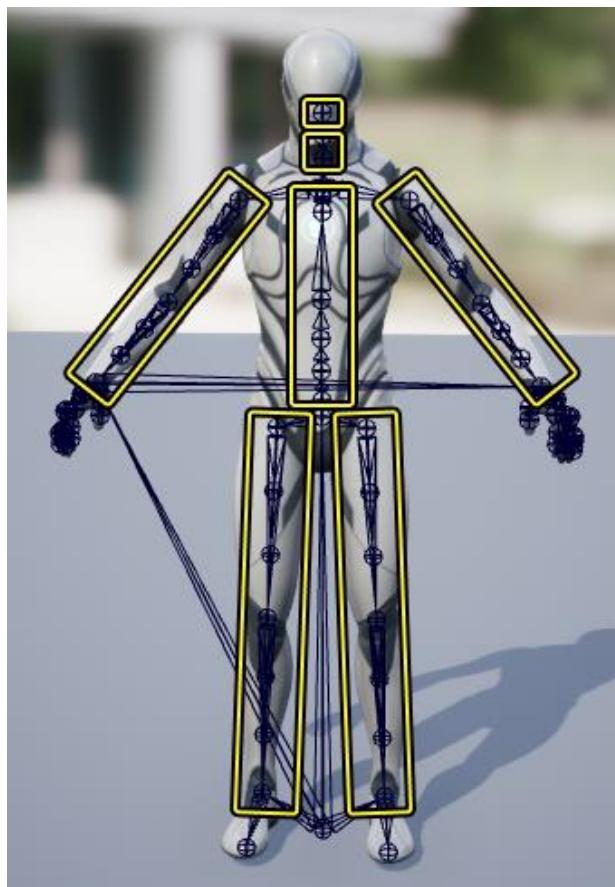
- IK Rig



**nucl.ai Conference: Ubisoft Toronto "IK Rig" Prototype** <https://www.youtube.com/watch?v=V4TQSeUpH3Q>

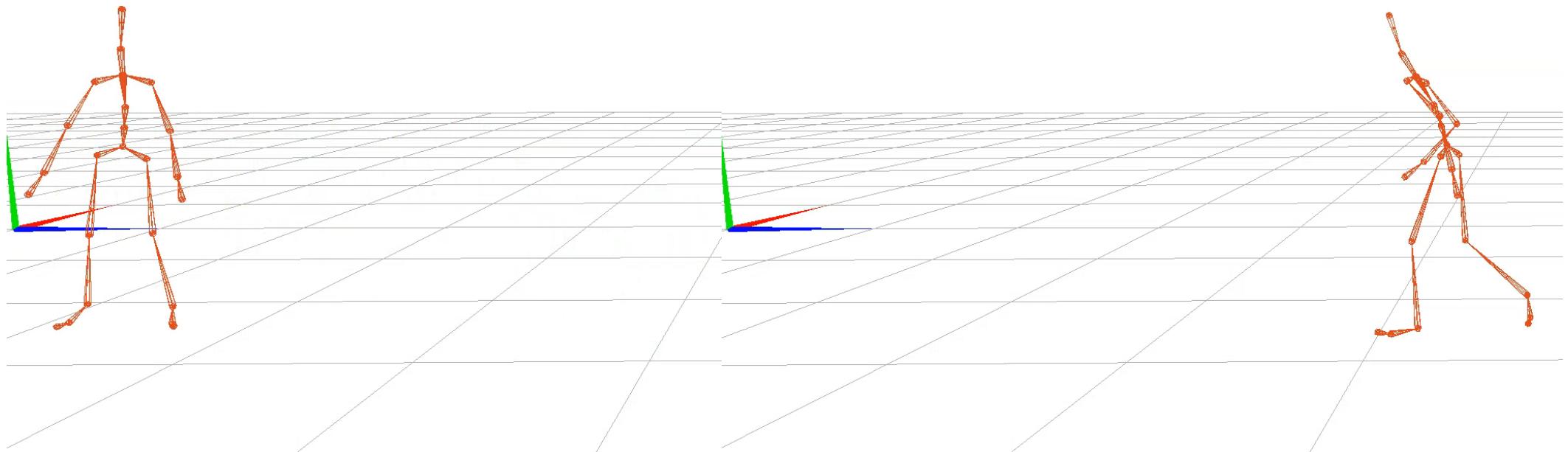
# Motion Retargeting

- IK Rig in Unreal

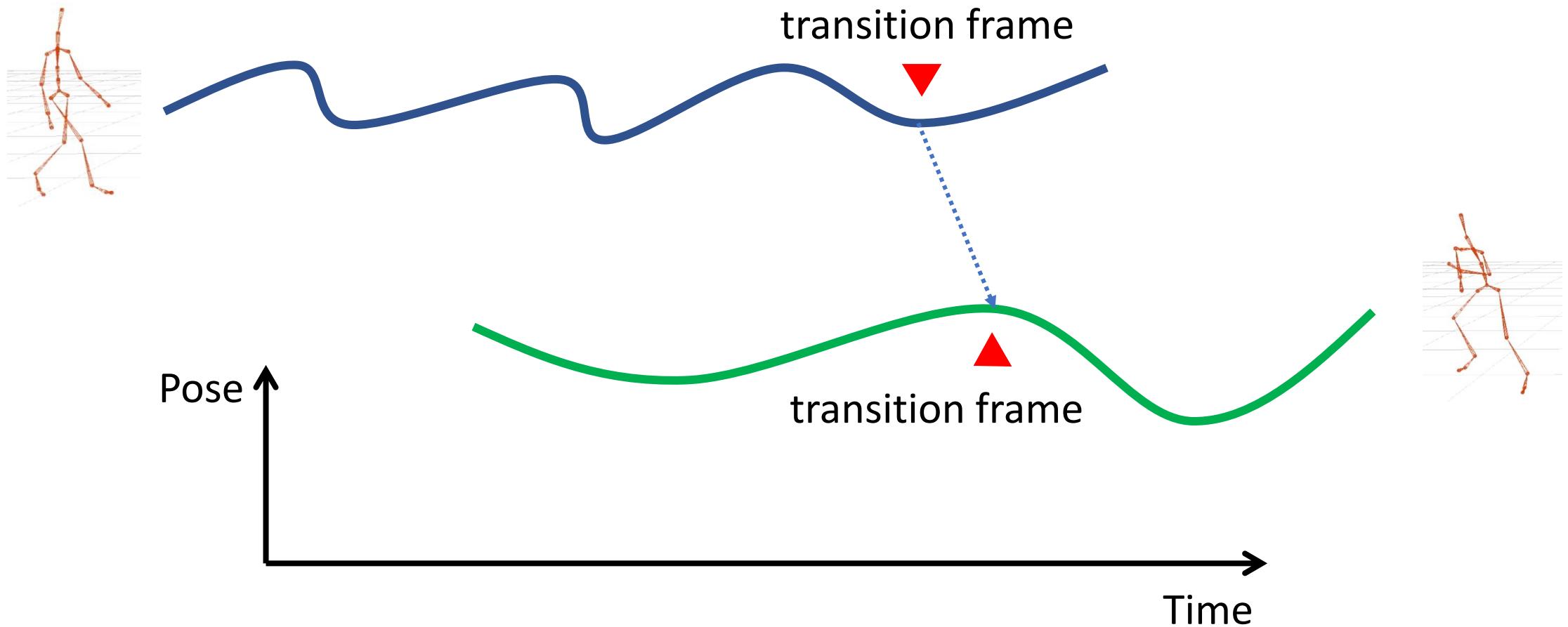


<https://docs.unrealengine.com/5.0/en-US/ik-rig-animation-retargeting-in-unreal-engine/>

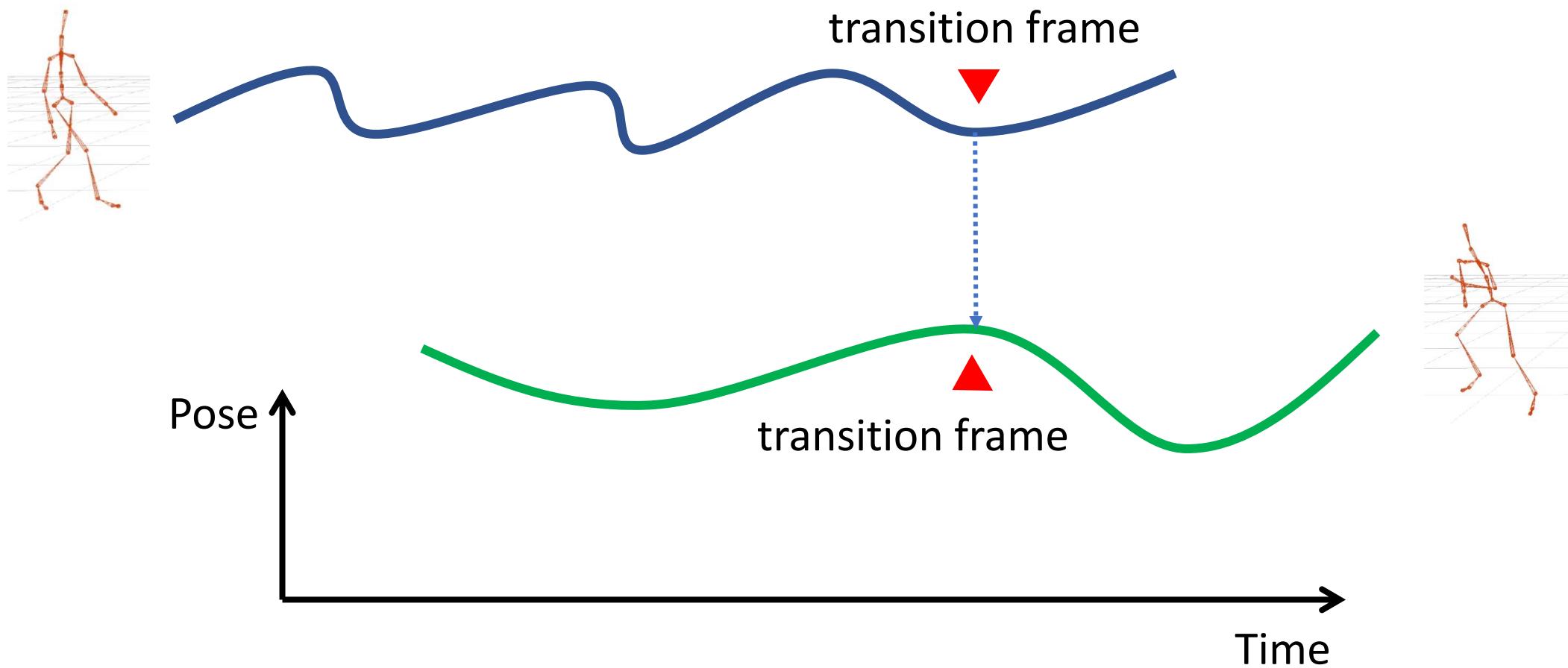
# Motion Transition



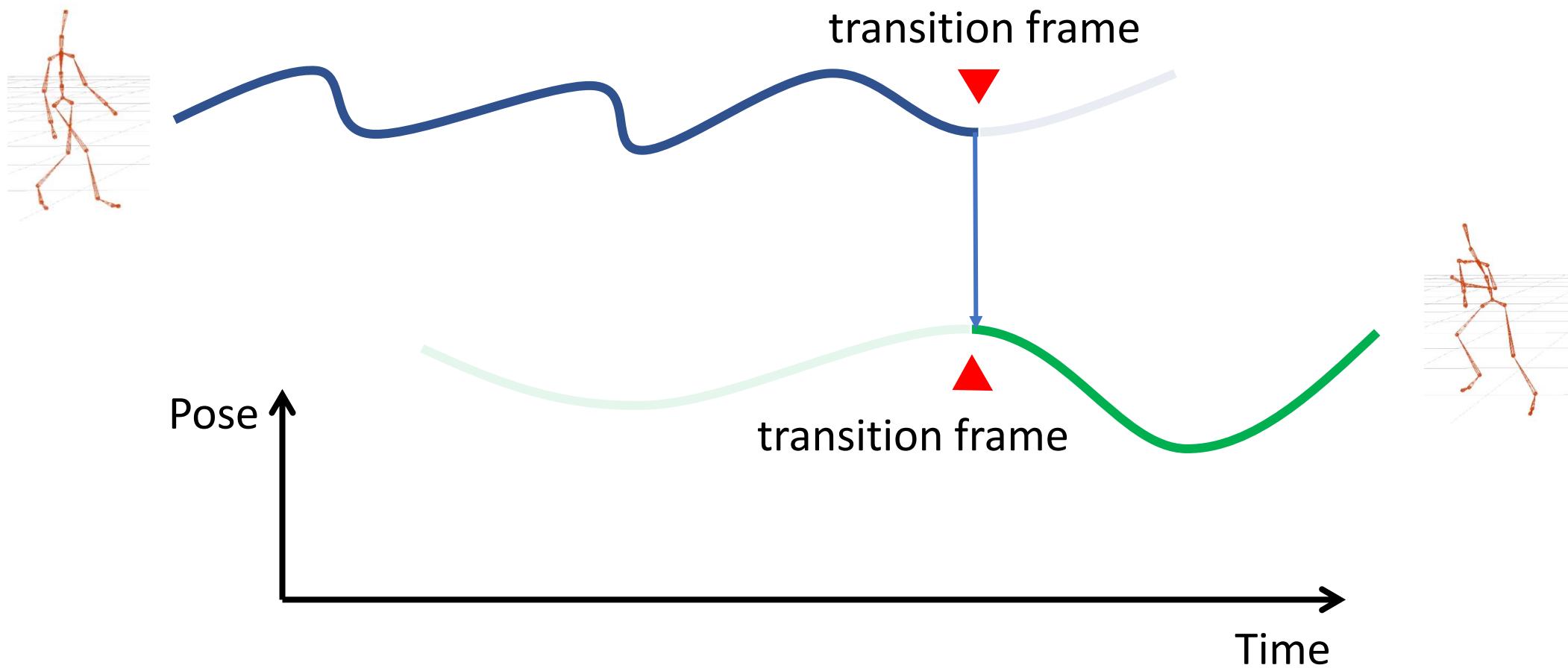
# Motion Transition



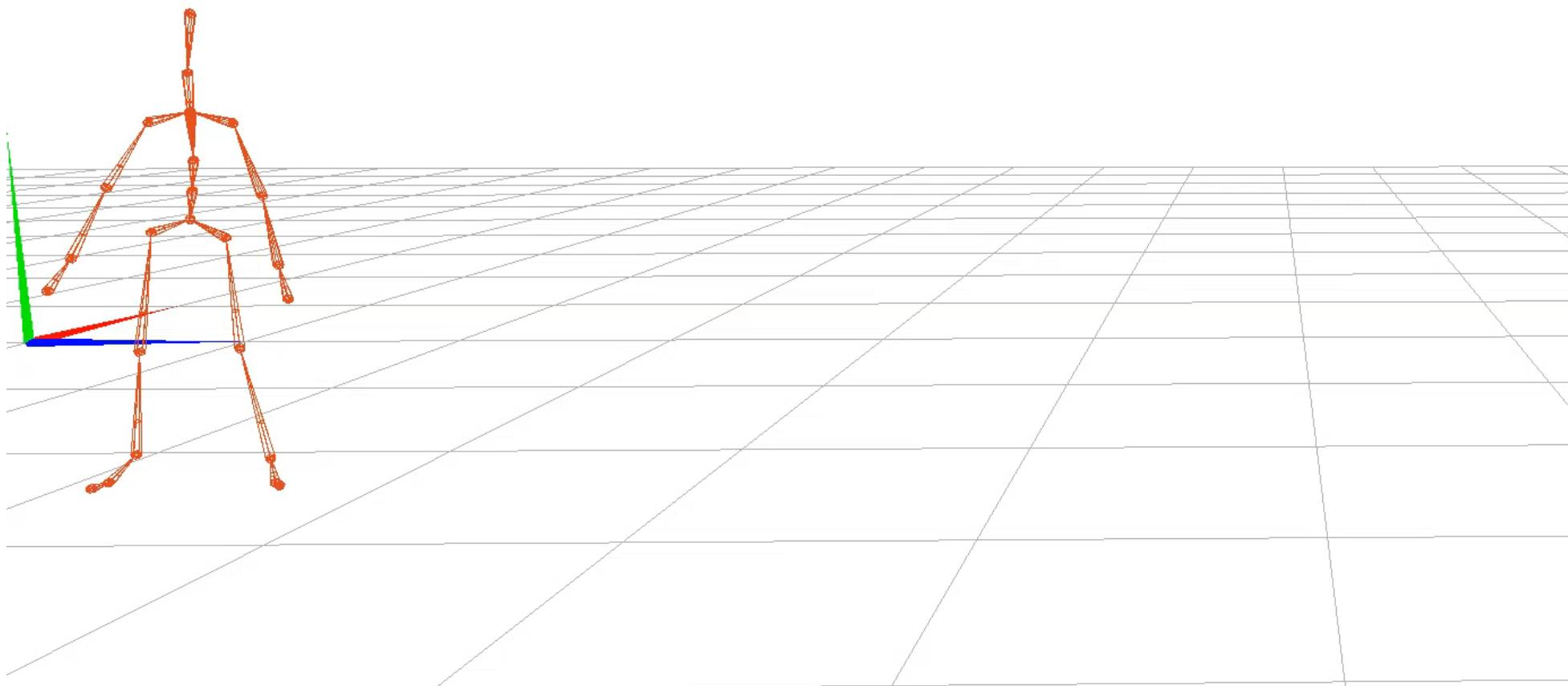
# Motion Transition



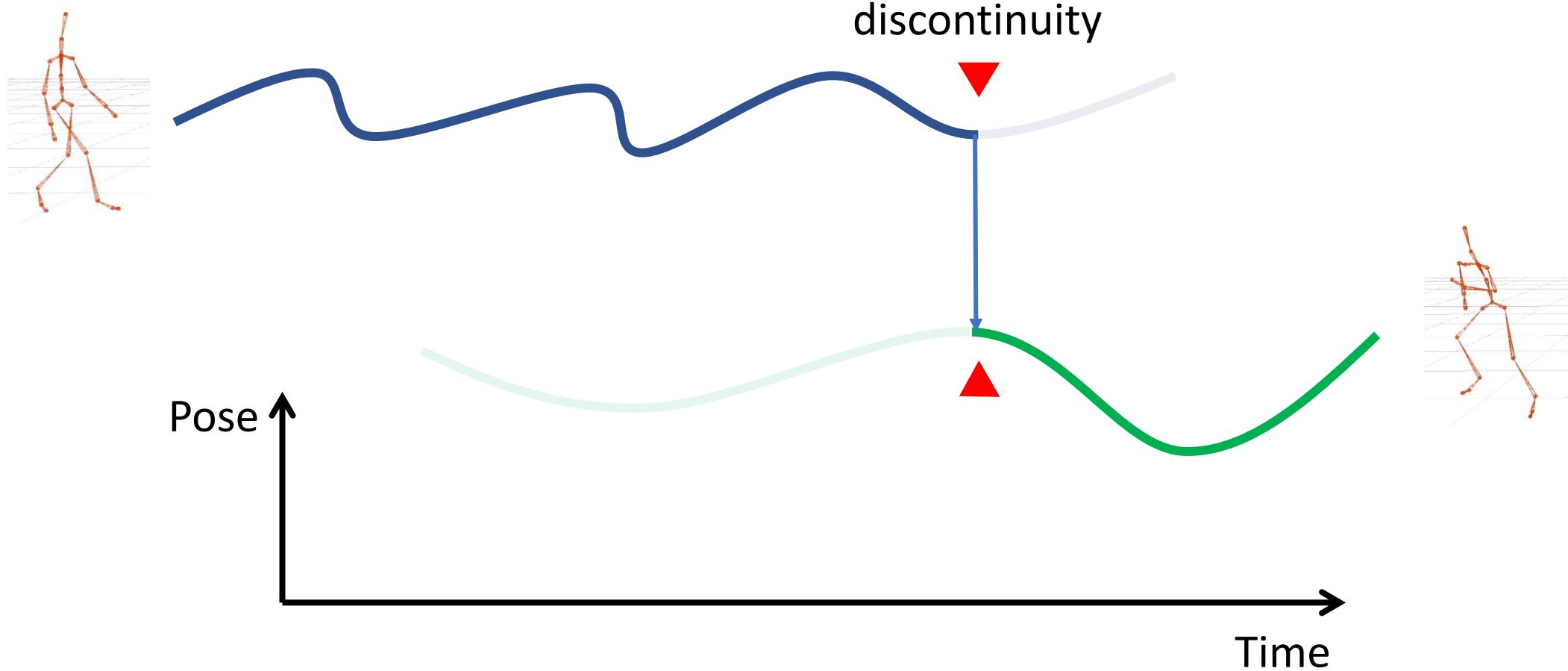
# Motion Transition



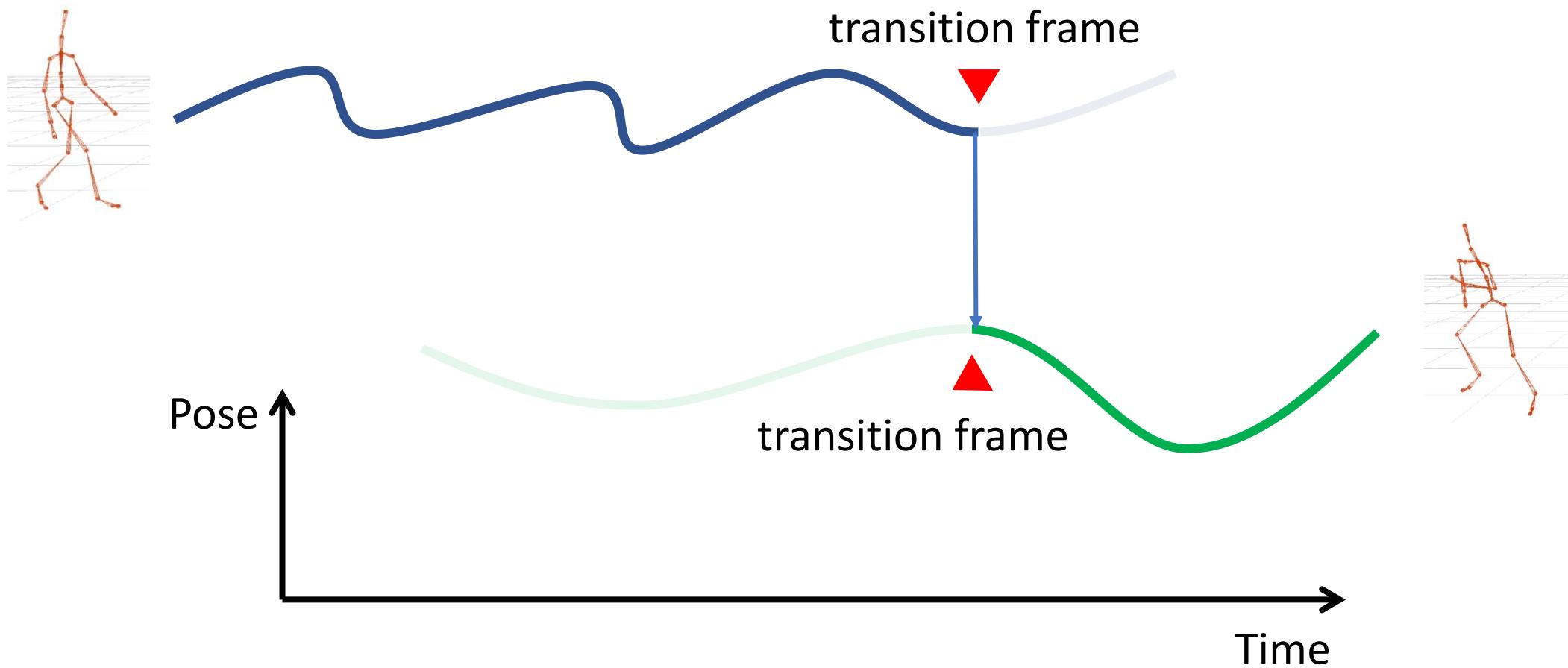
# Motion Transition



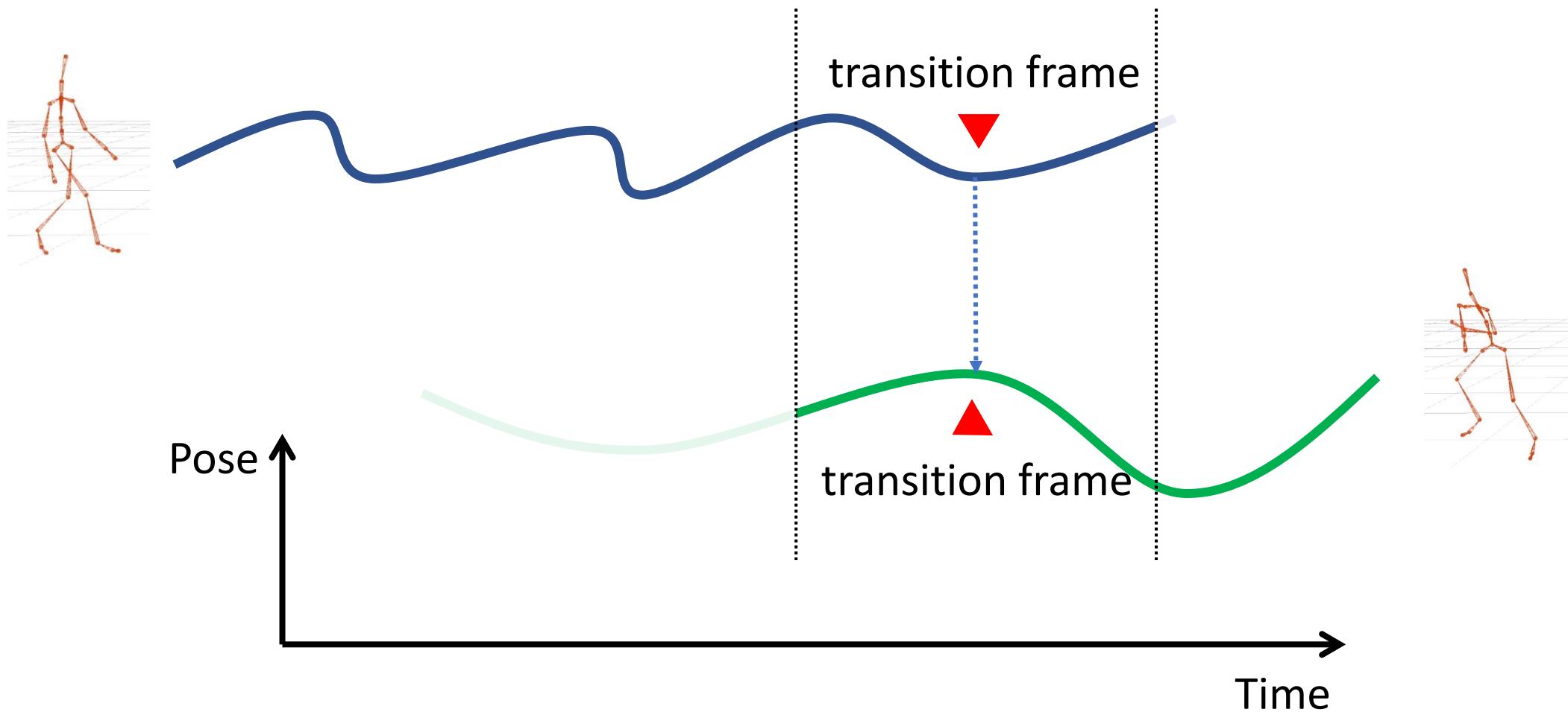
# Motion Transition



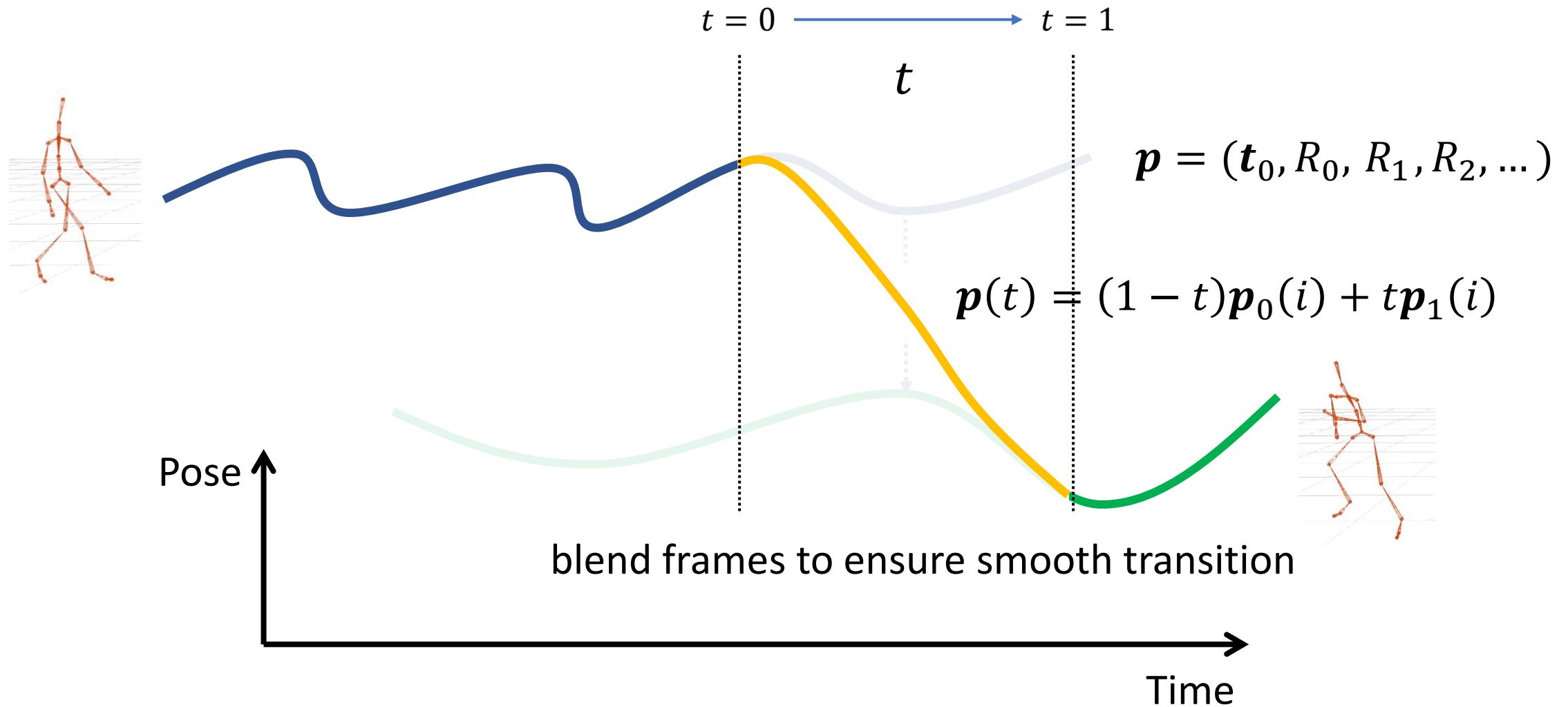
# Motion Transition



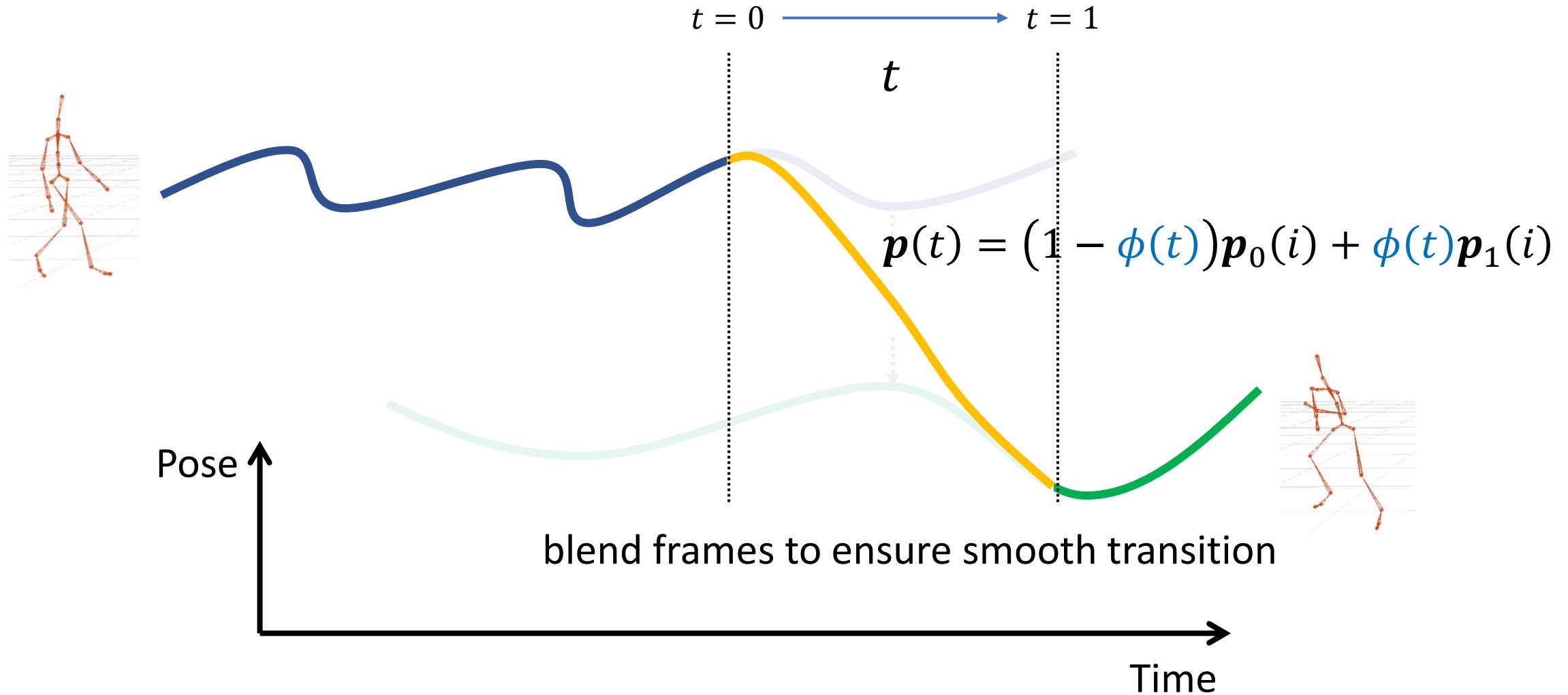
# Motion Transition



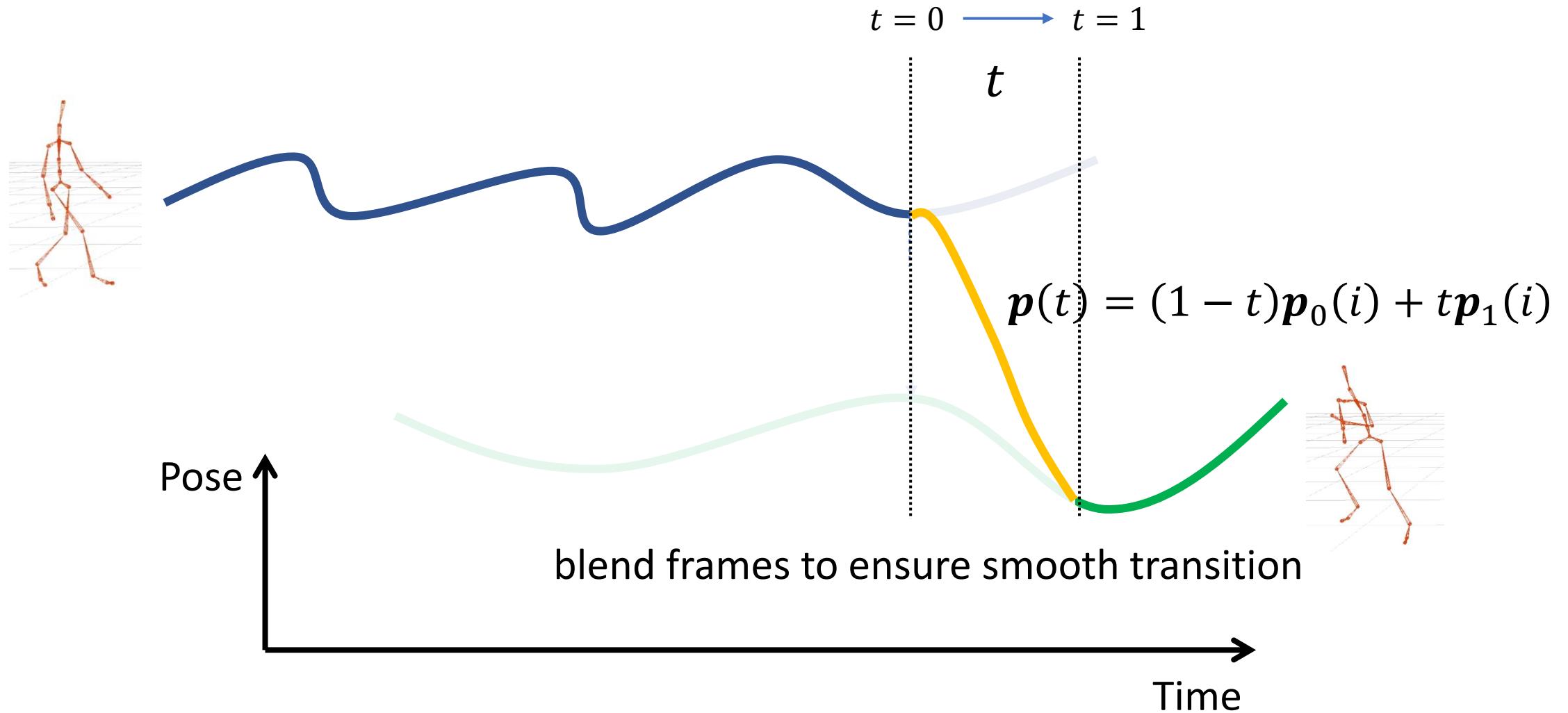
# Motion Transition



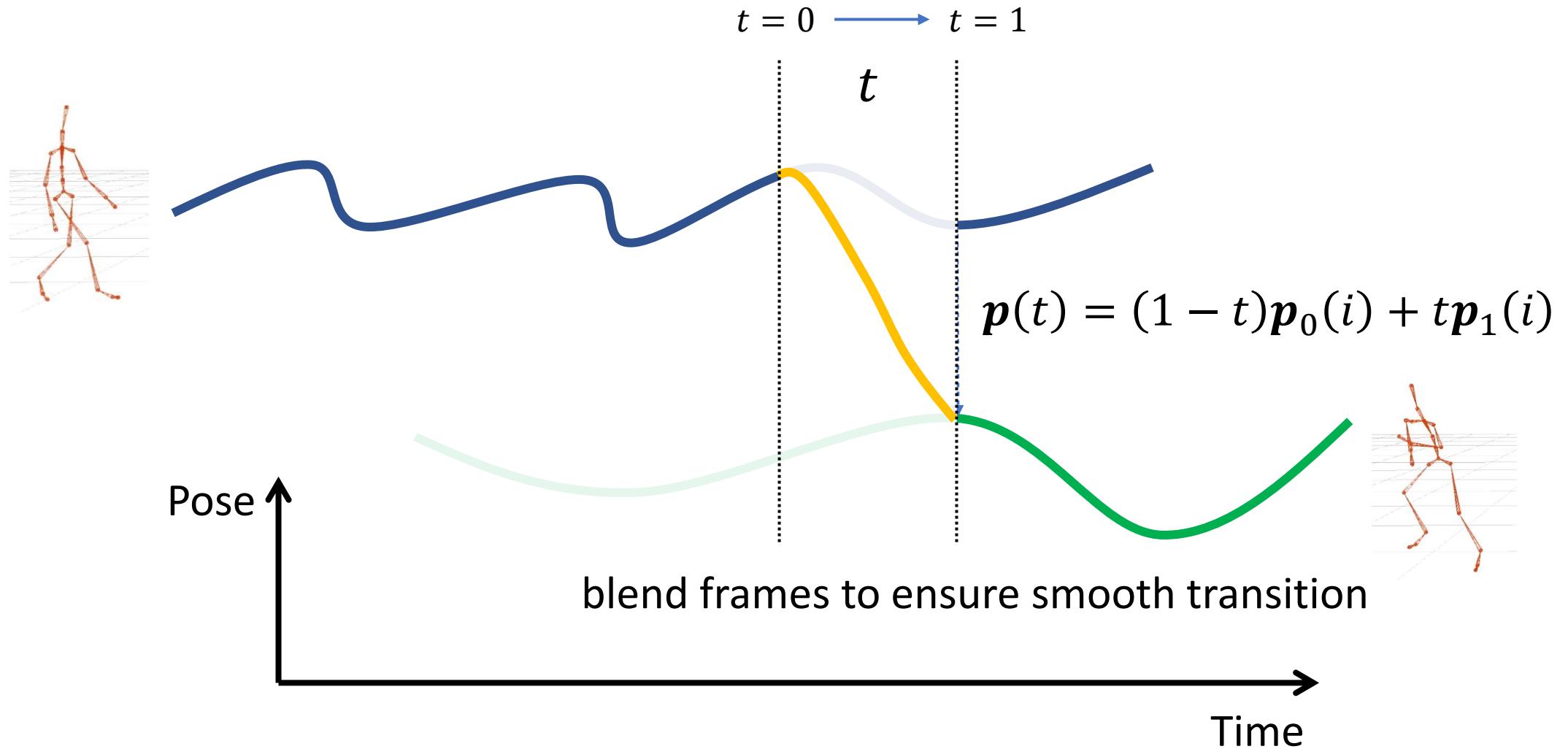
# Motion Transition



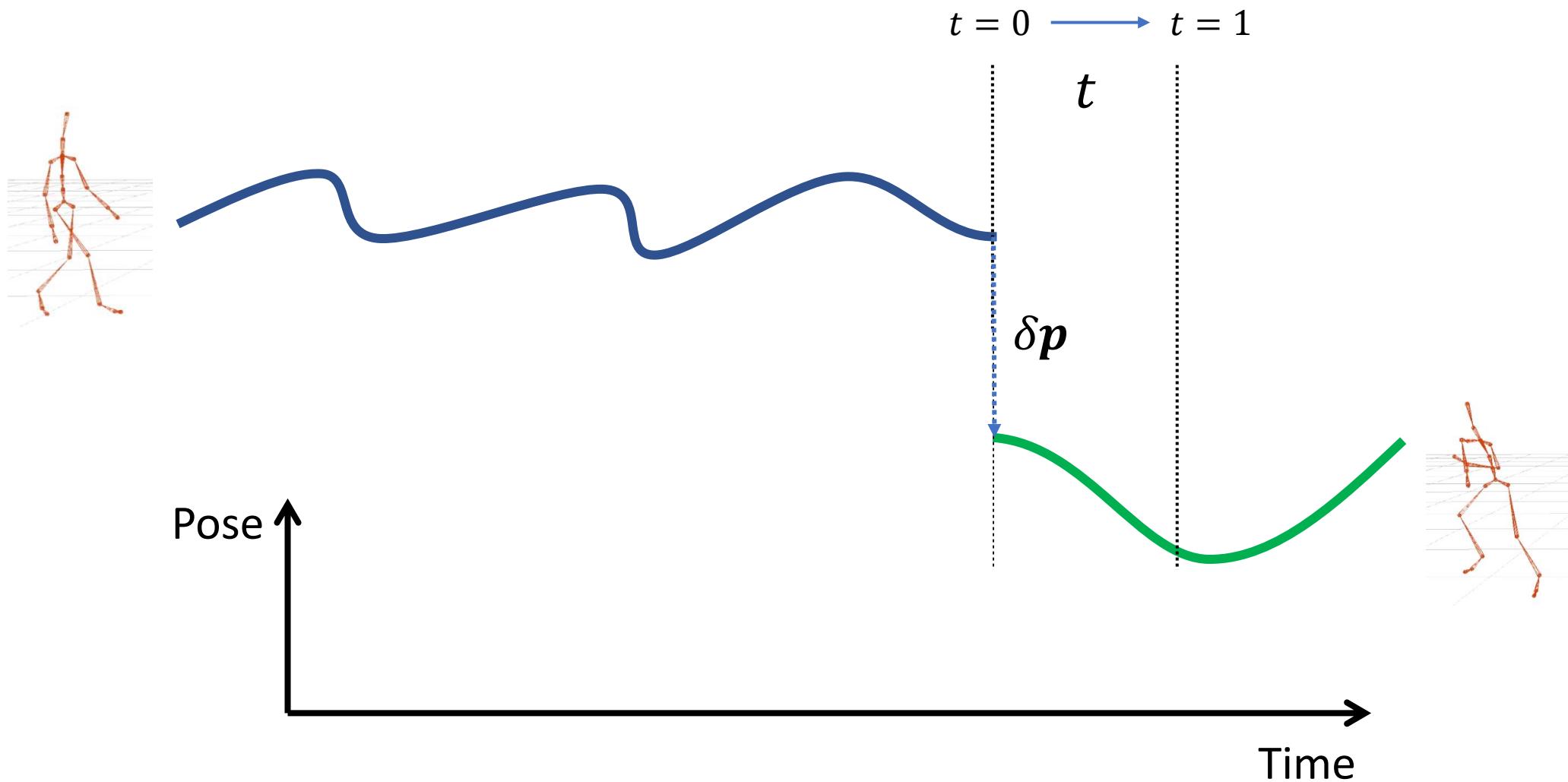
# Motion Transition



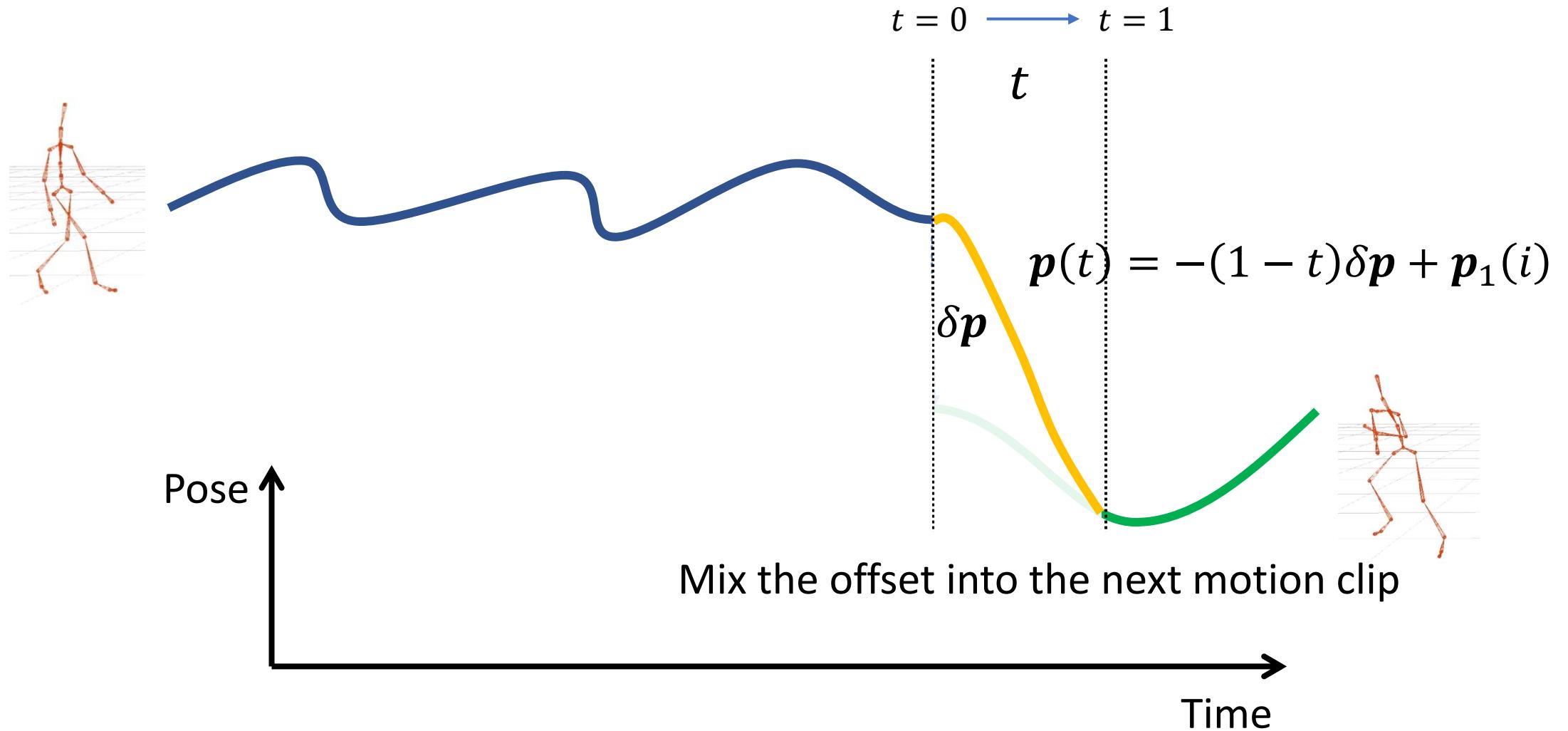
# Motion Transition



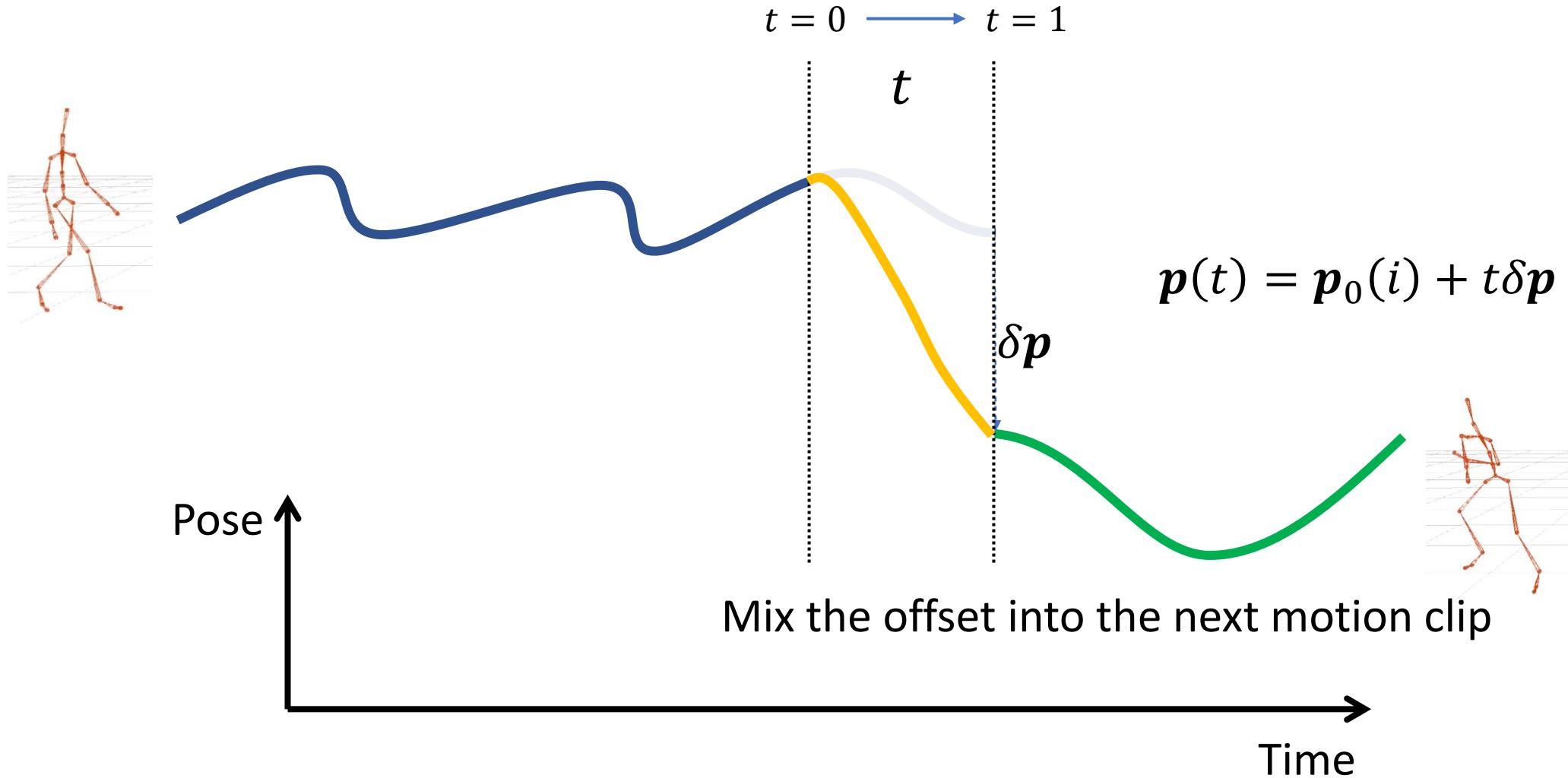
# Motion Transition



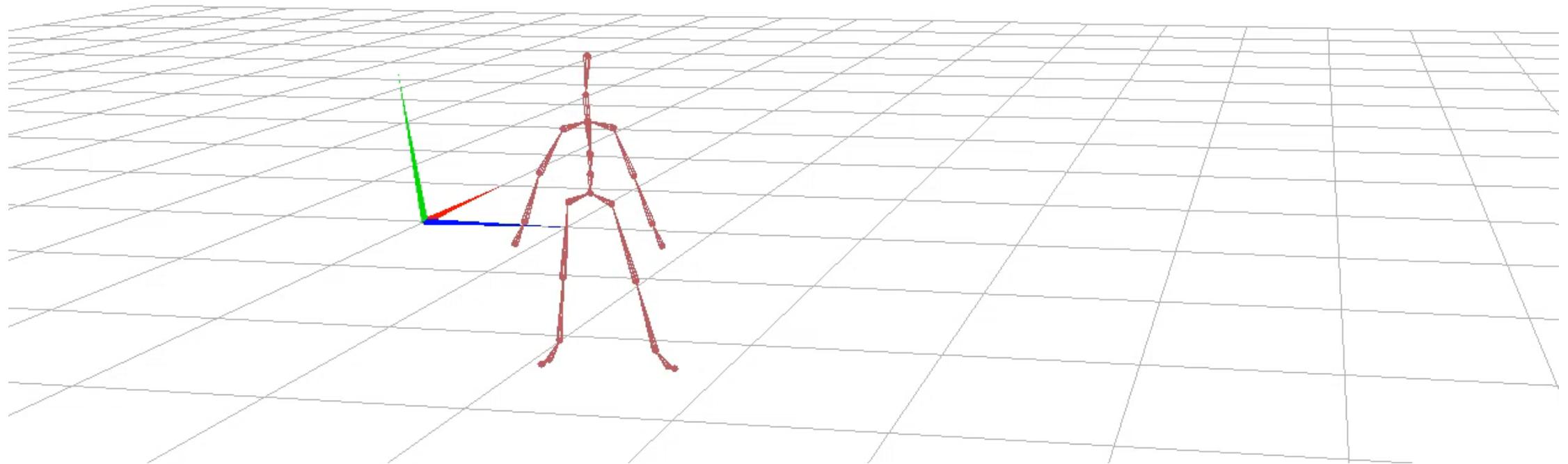
# Motion Transition



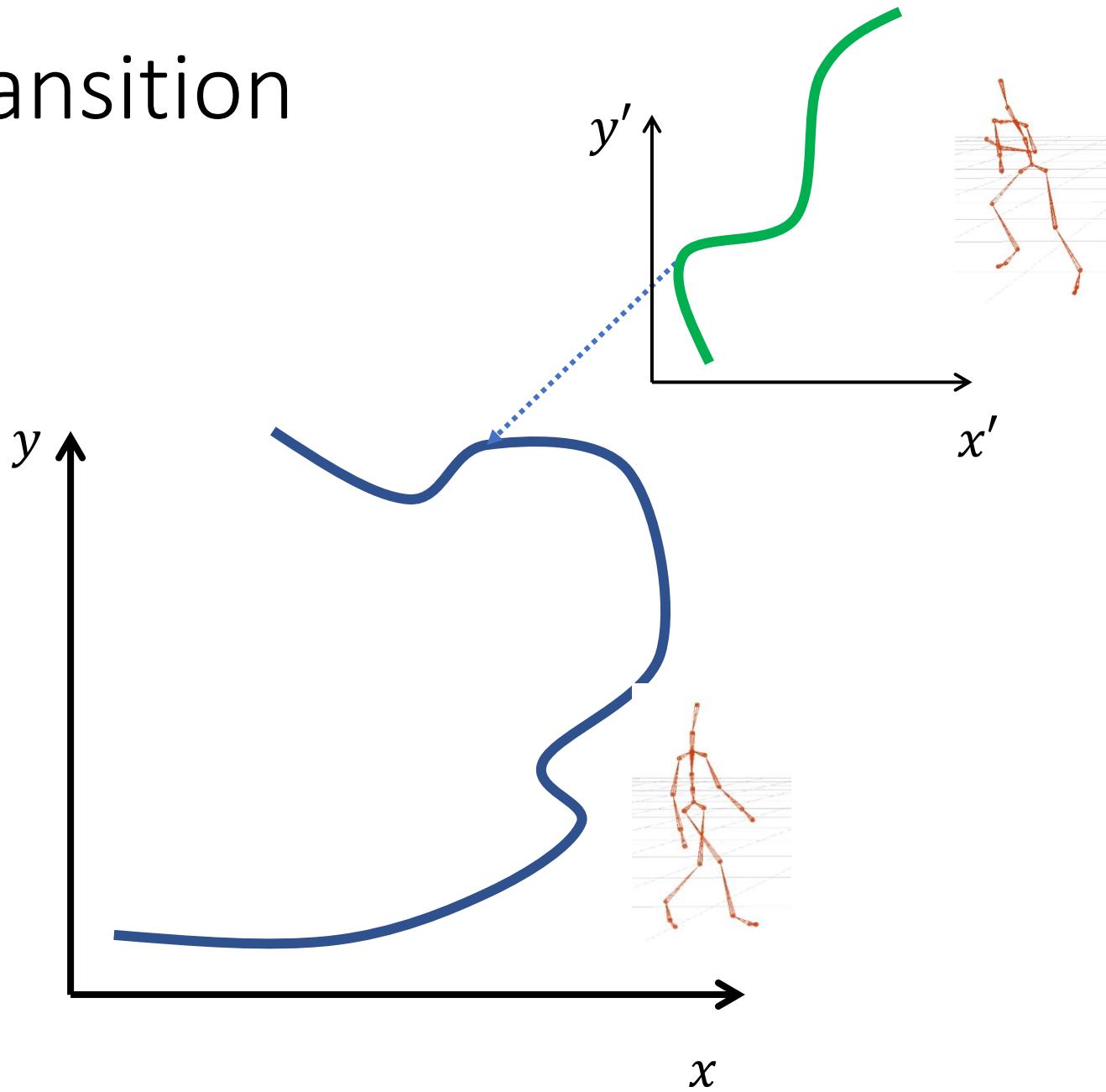
# Motion Transition



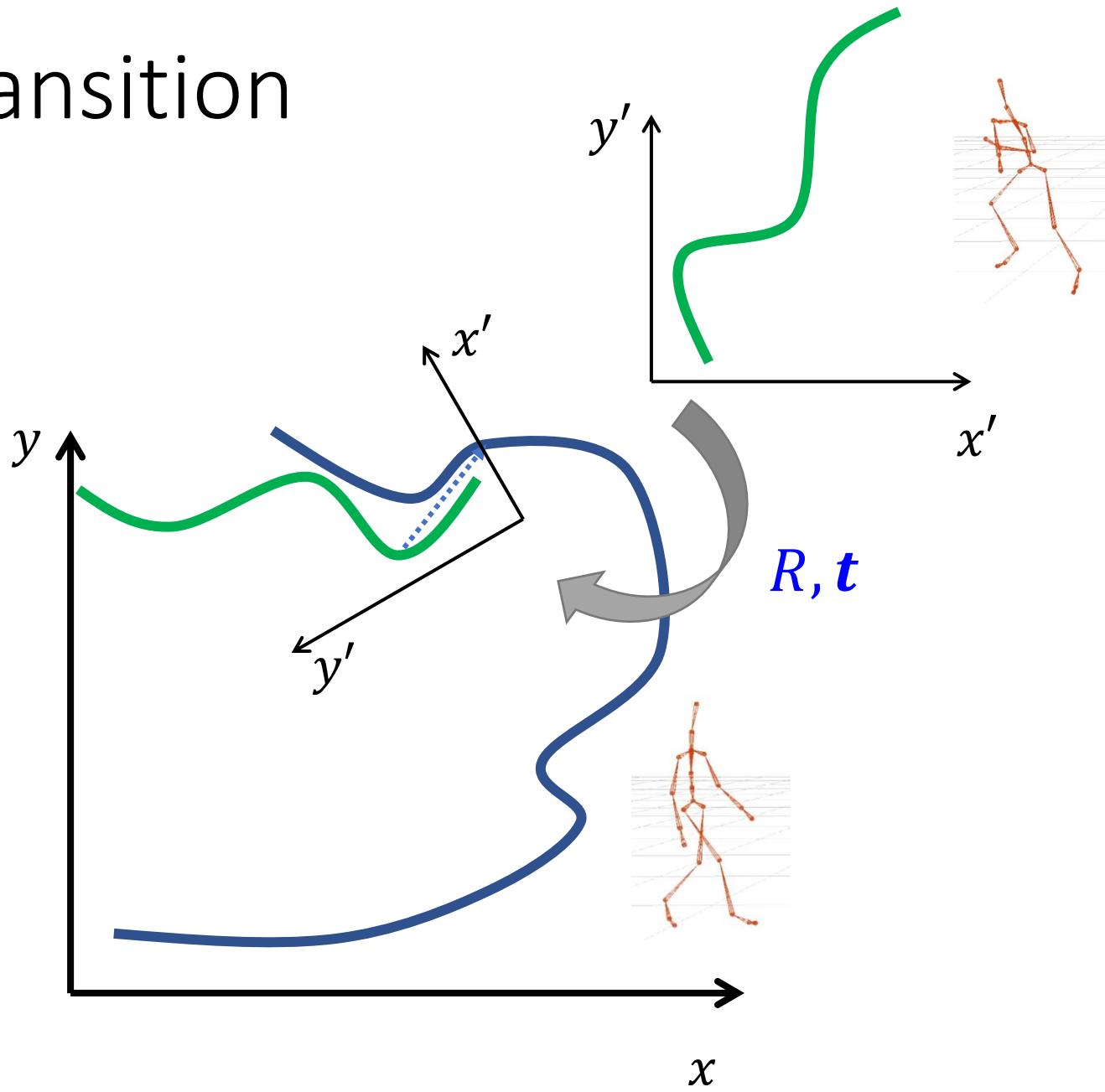
# Motion Transition



# Motion Transition

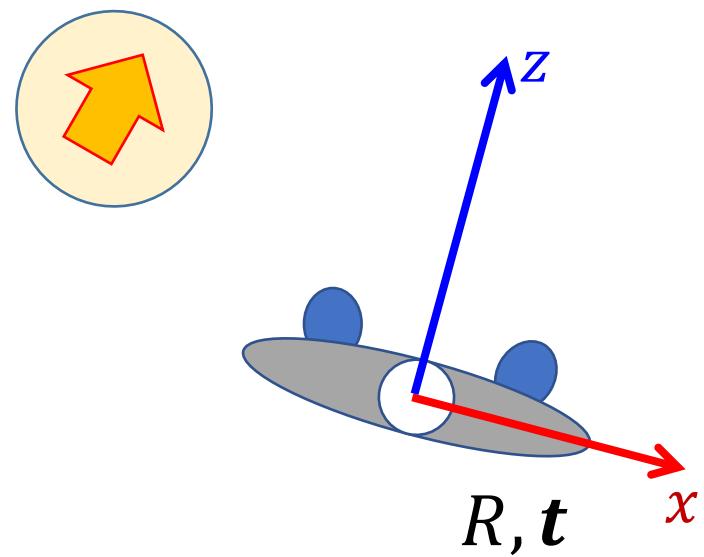


# Motion Transition



# “Facing Frame”

- A special coordinate system that moves horizontally with the character with one axis pointing to the “facing direction” of the character

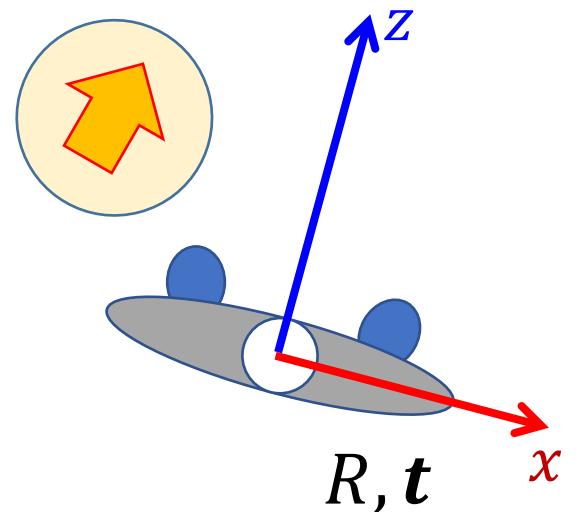


$$R = \theta e_y$$

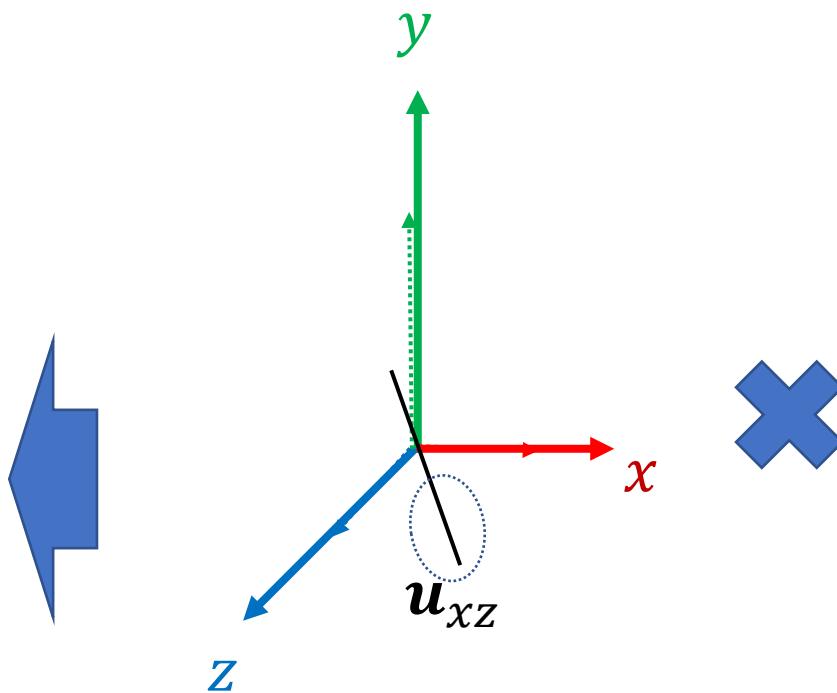
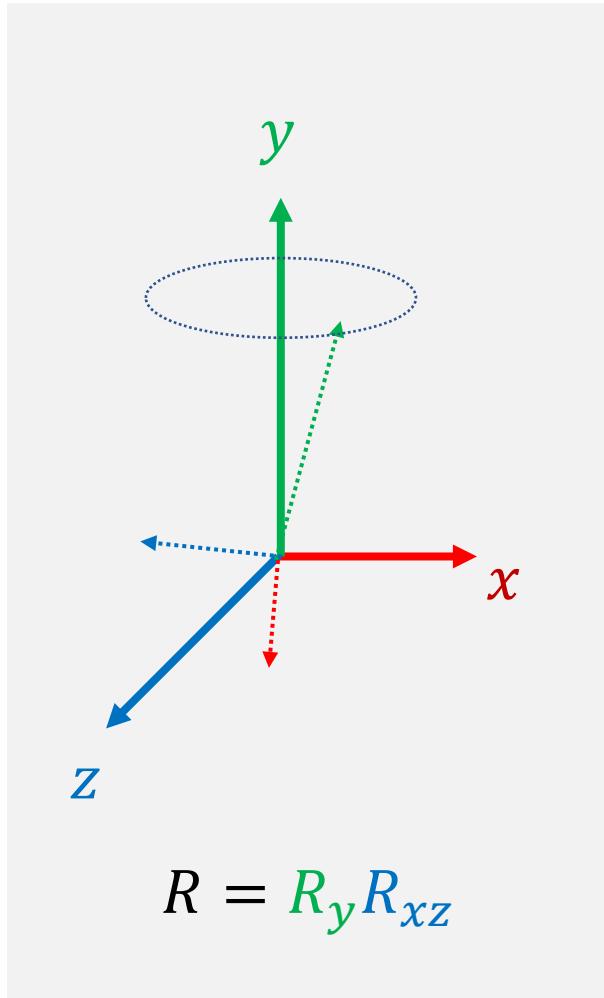
$$\mathbf{t} = (t_x, 0, t_z)$$

# “Facing Frame”

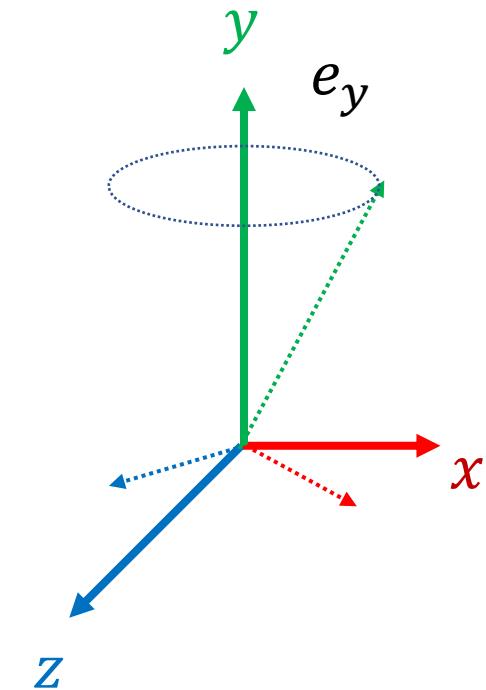
- A special coordinate system that moves horizontally with the character with one axis pointing to the “facing direction” of the character
  - Possible definitions of  $R$ 
    - $R$  is the **y-rotation** that aligns the z-axis of the global frame to the heading direction
    - $R$  is the **y-rotation** that aligns x-axis of the global frame to the average direction of the vectors between shoulders and hips
    - Decomposition root rotation as  $R_0 = R_y R_{xz}$
- $R = \theta e_y$   
 $t = (t_x, 0, t_z)$



# Rotation Decomposition

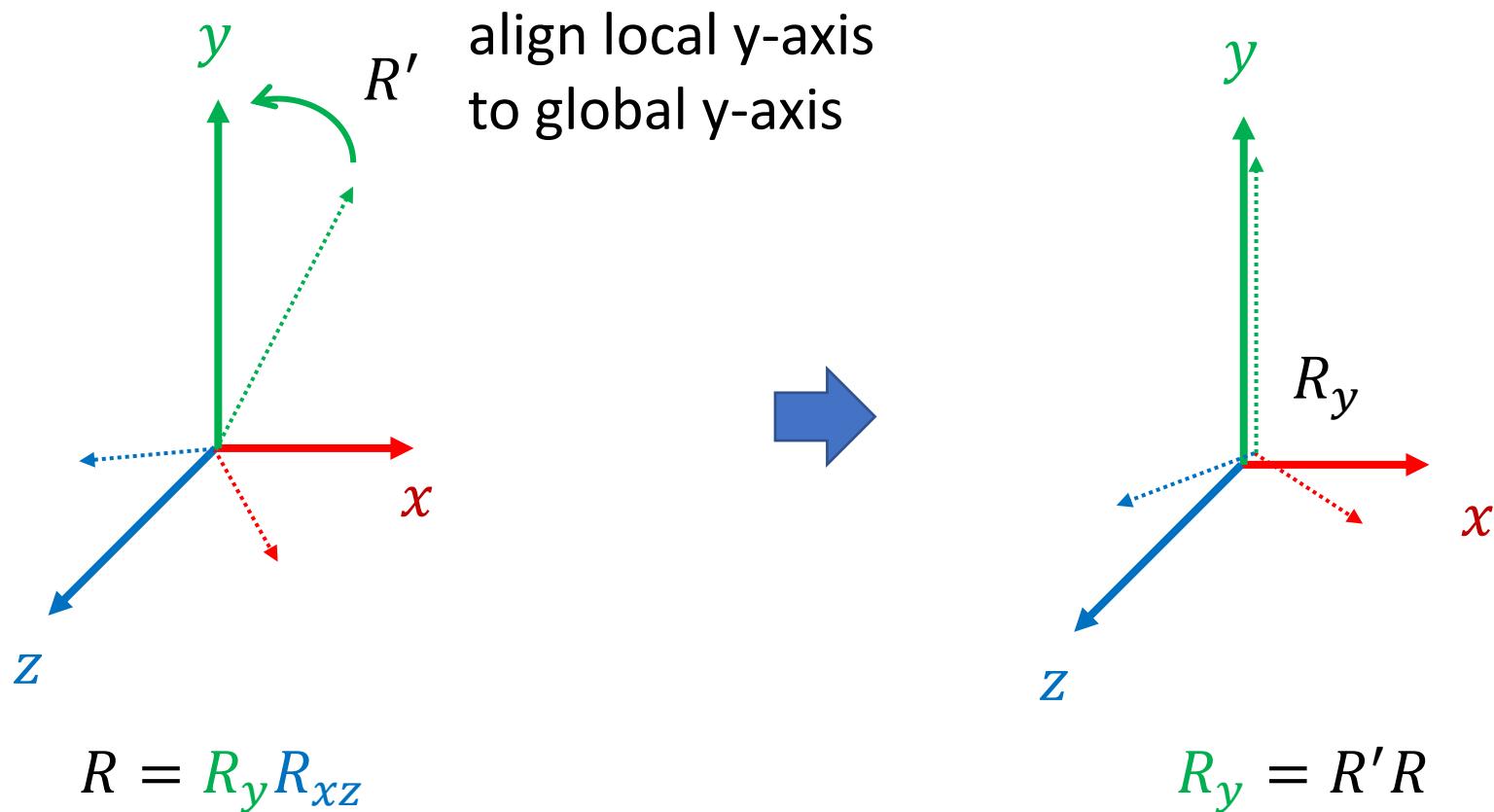


$$\mathbf{u}_{xz} = (u_x, 0, u_z)$$

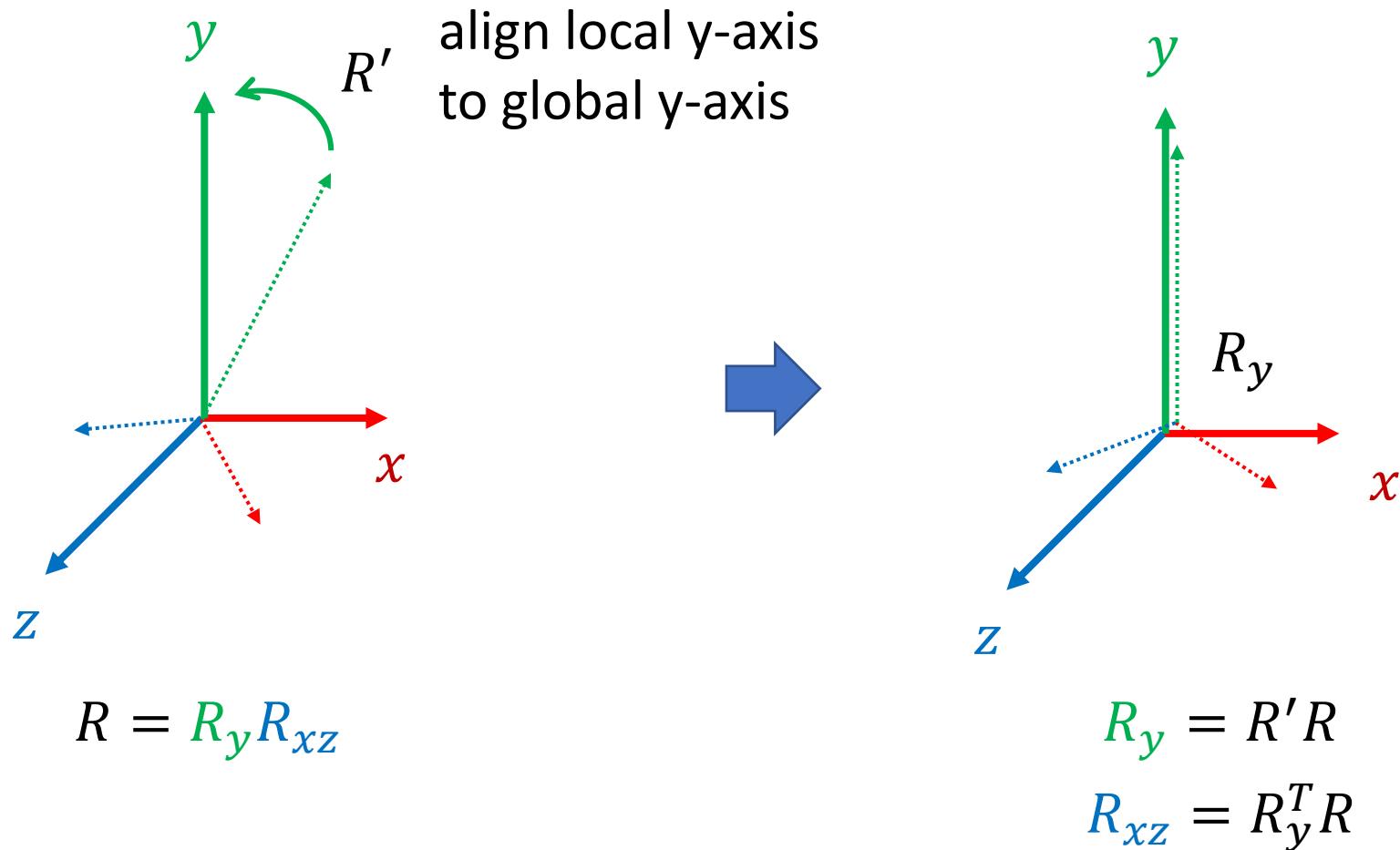


$$R_y = \theta_y \mathbf{e}_y$$

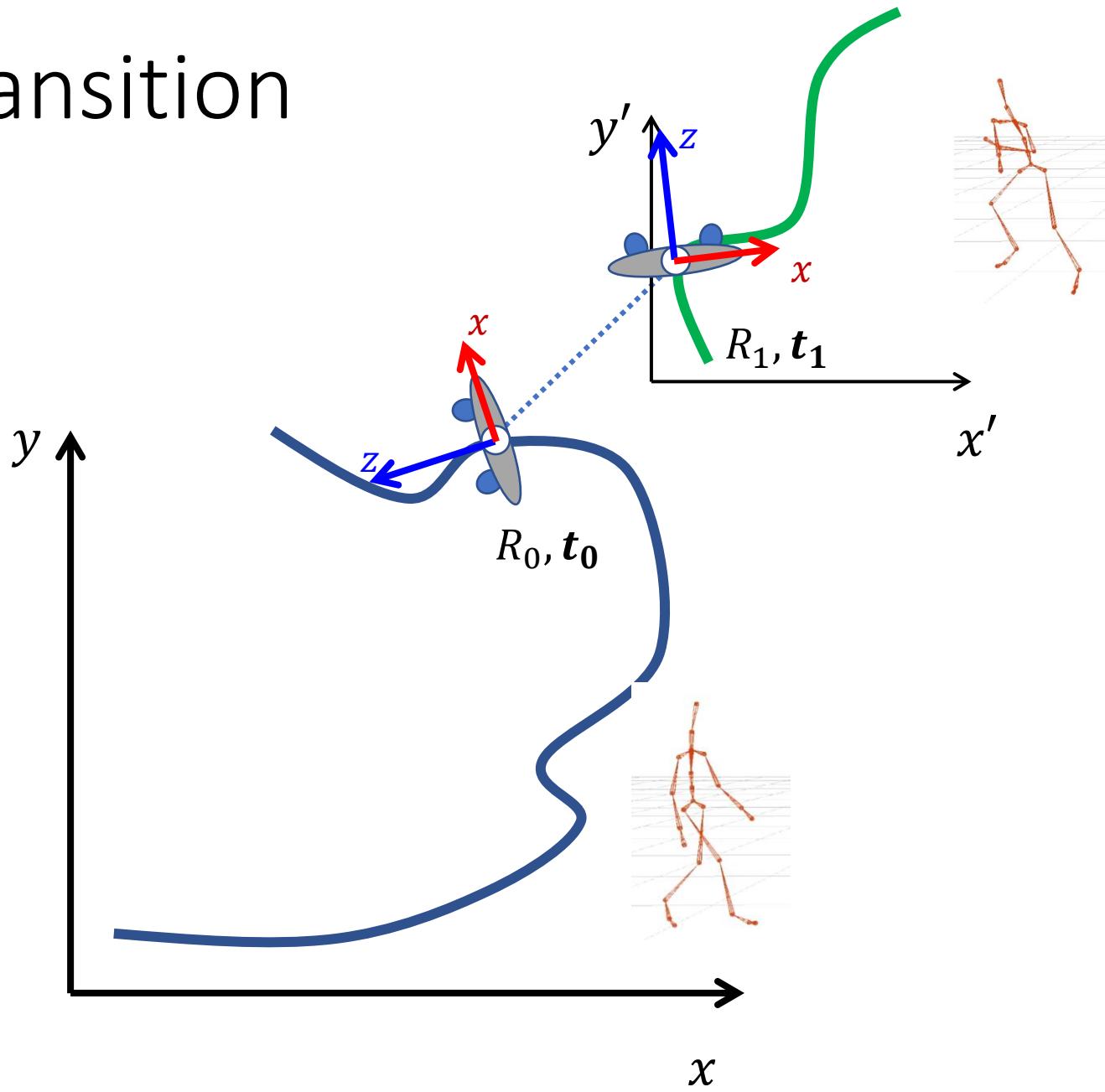
# Rotation Decomposition



# Rotation Decomposition

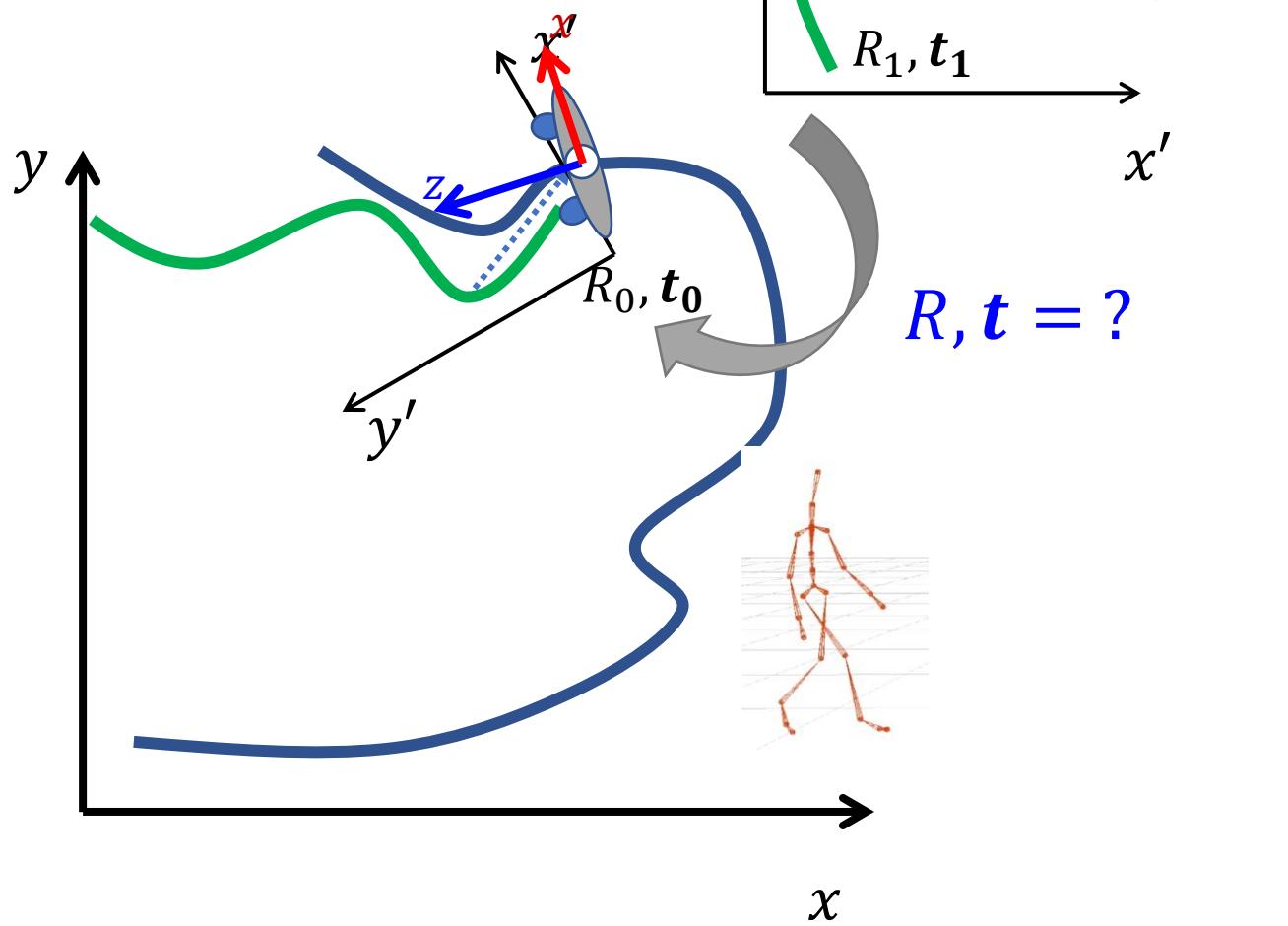


# Motion Transition



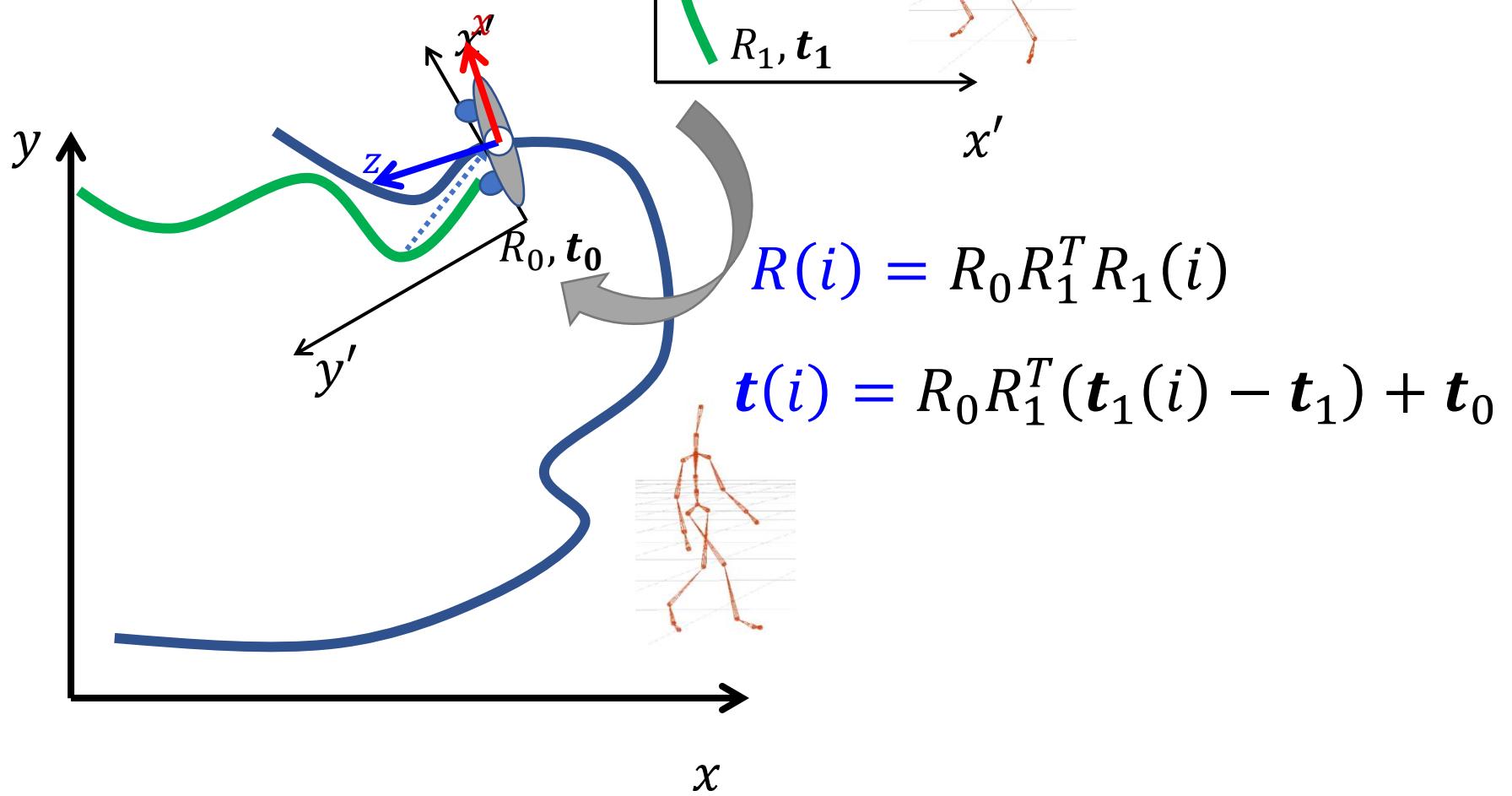
# Motion Transition

- How to compute this transformation?

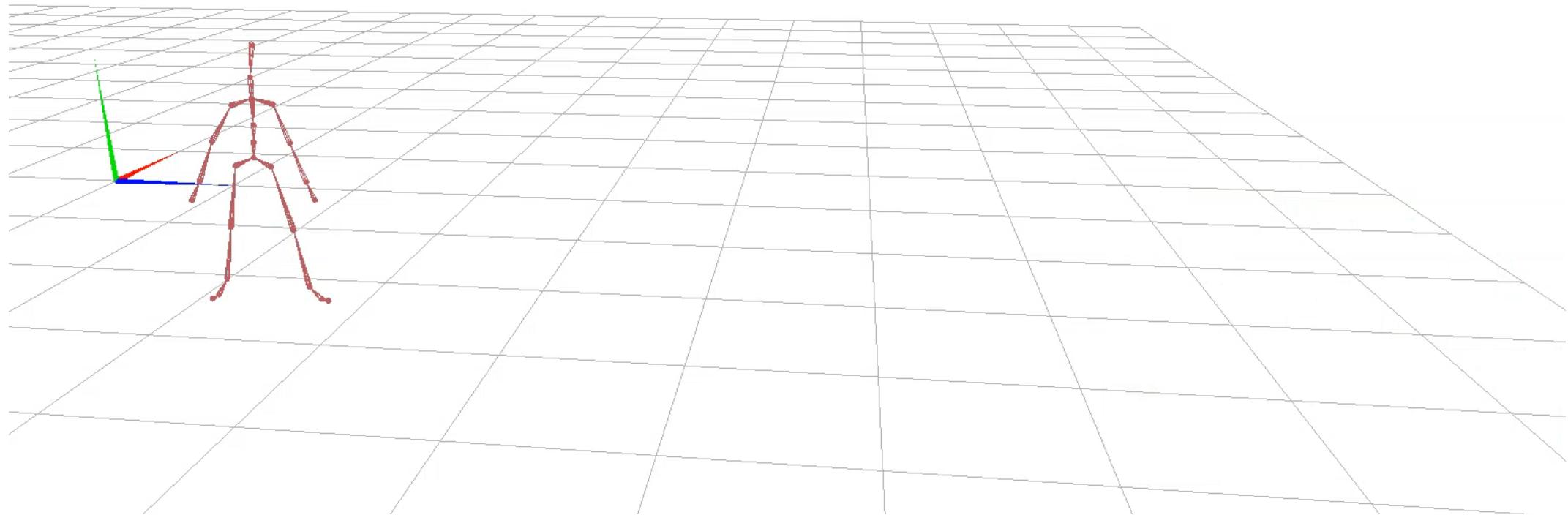


# Motion Transition

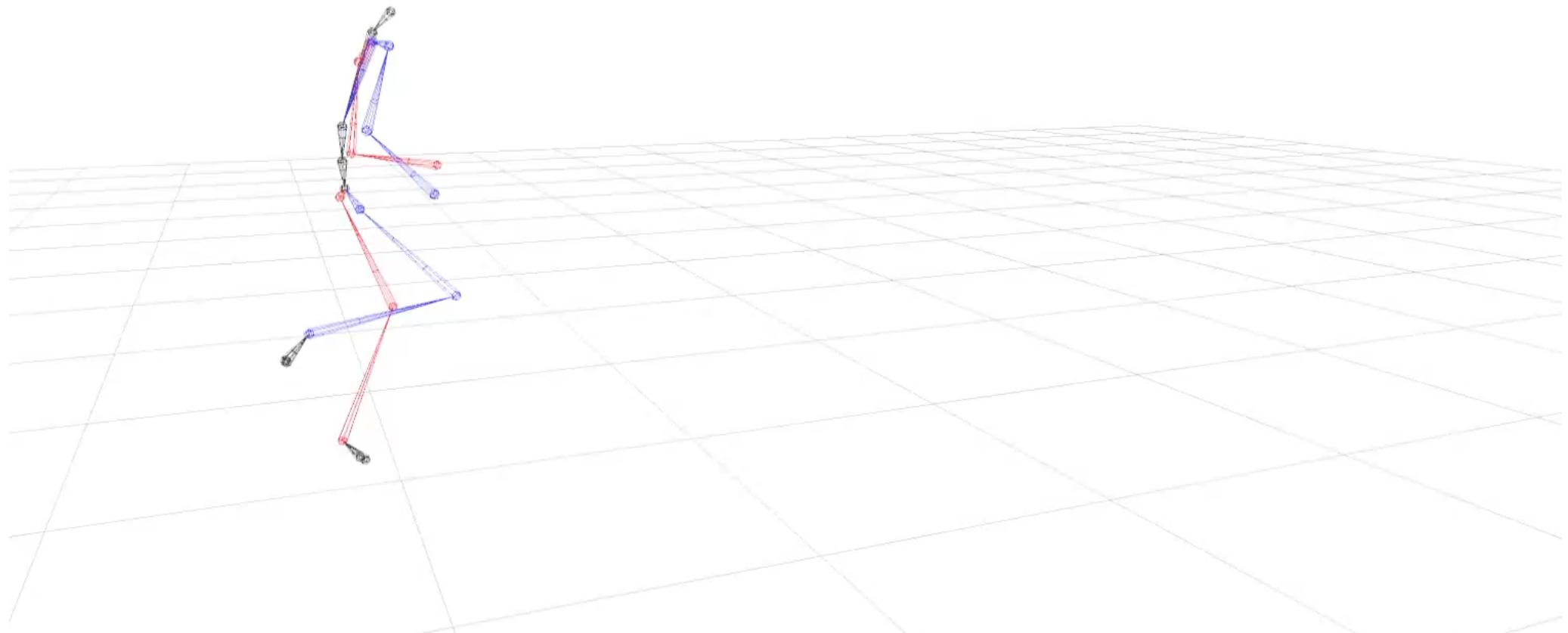
- How to compute this transformation?



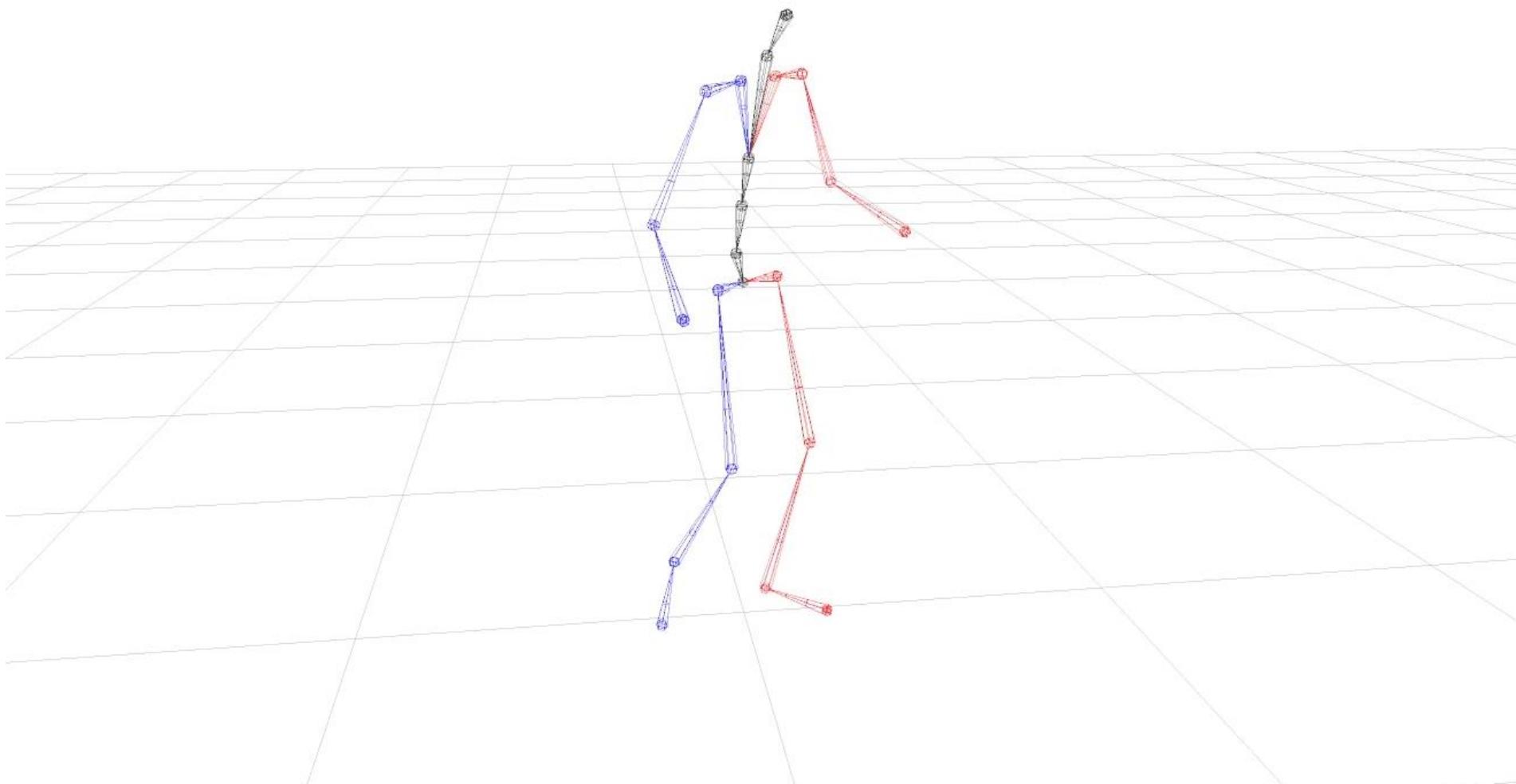
# Motion Transition



# Motion Transition



# Motion Data without Root Translation

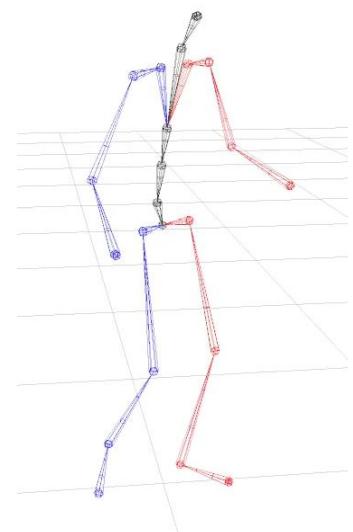
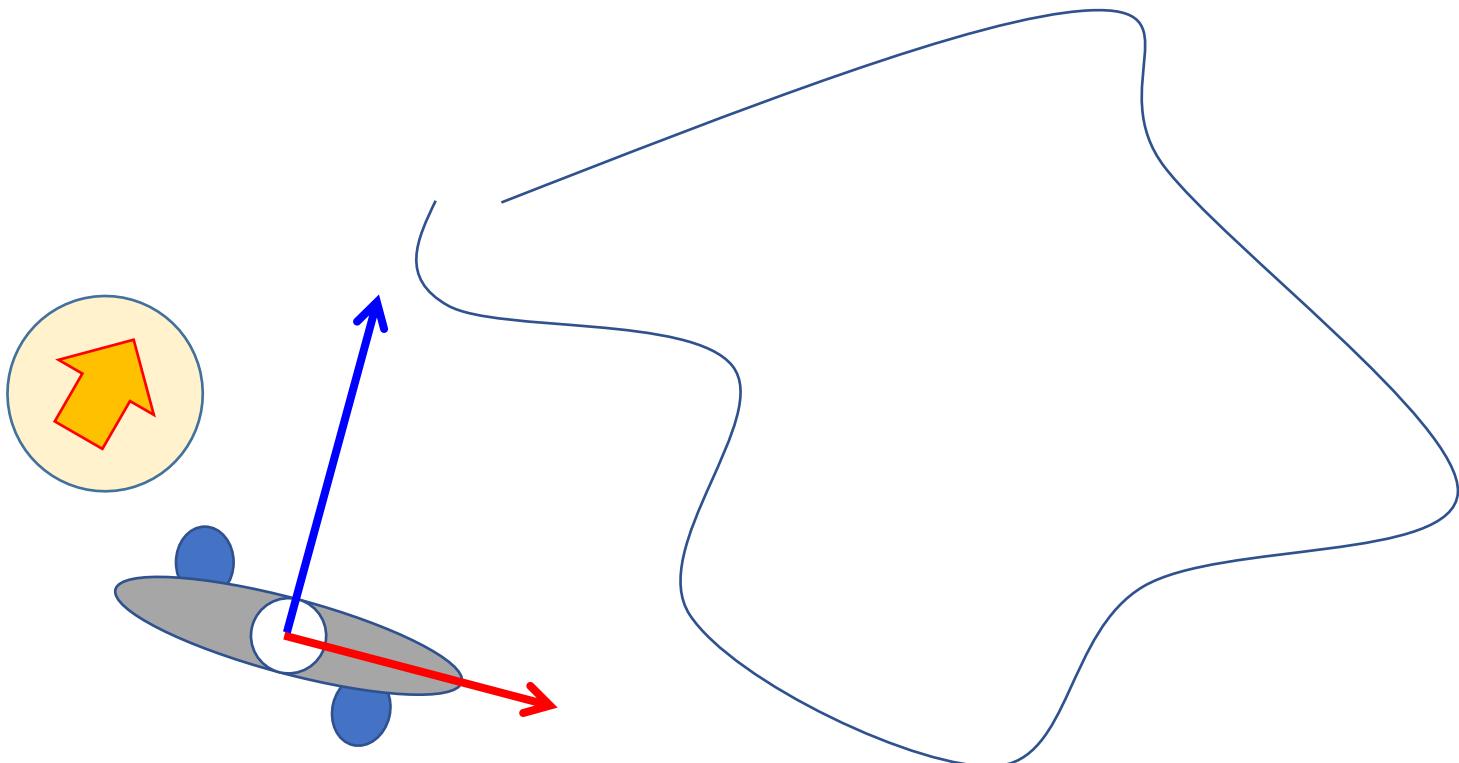


# Motion Data without Root Translation

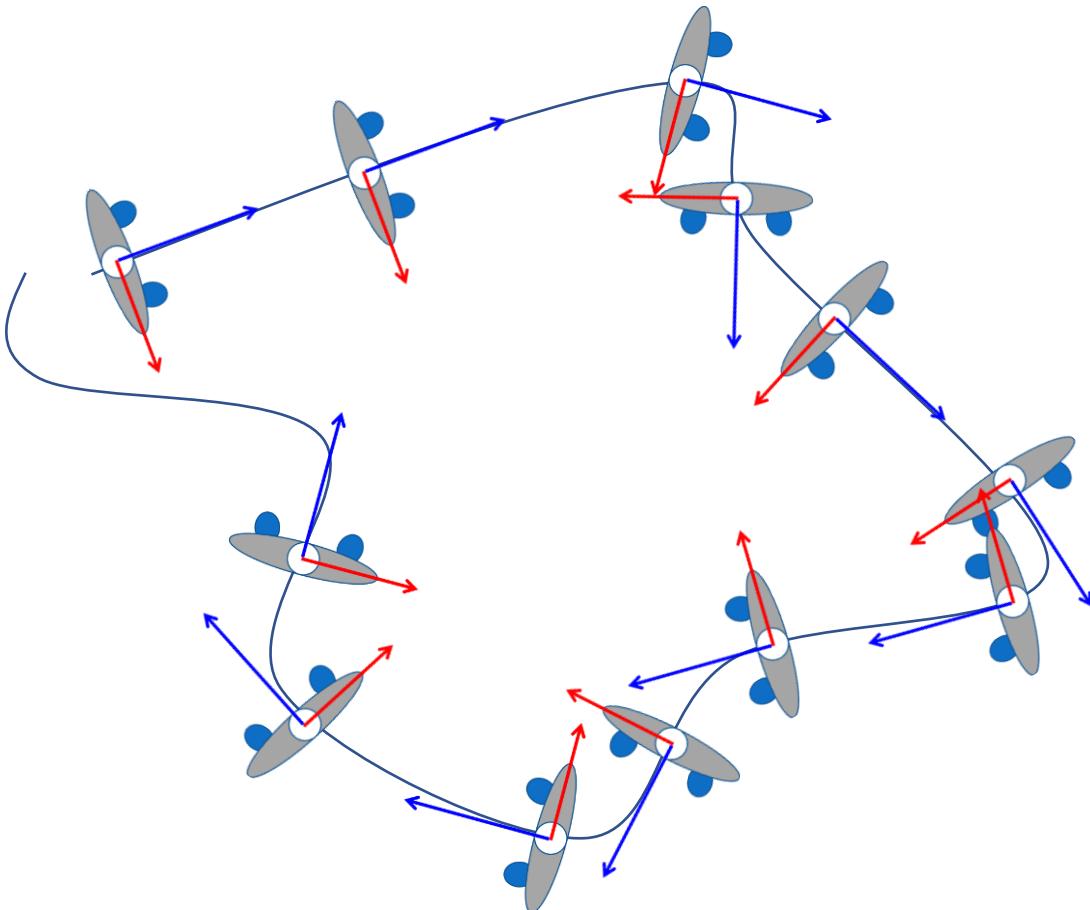


**Let's bring back gta characters to real life**  
<https://www.youtube.com/watch?v=DeutKhta1Uo>

# Path Fitting

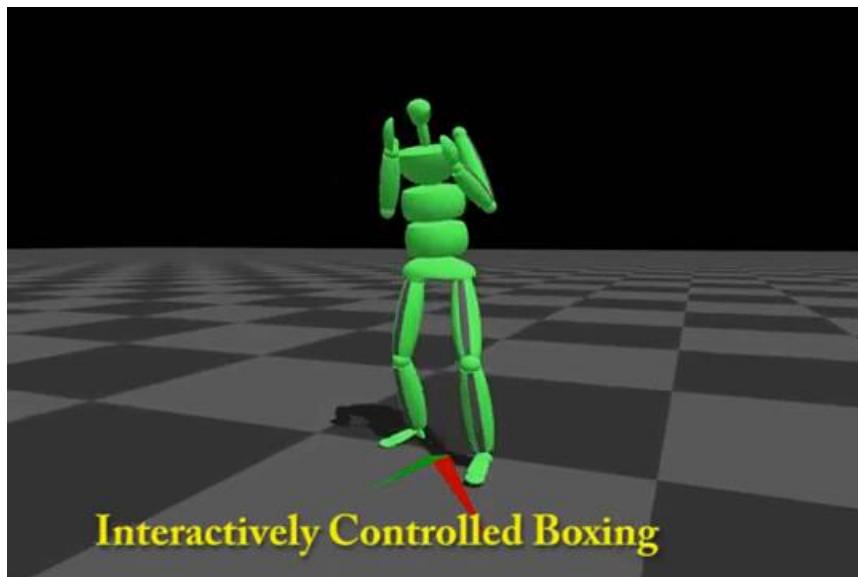


# Path Fitting

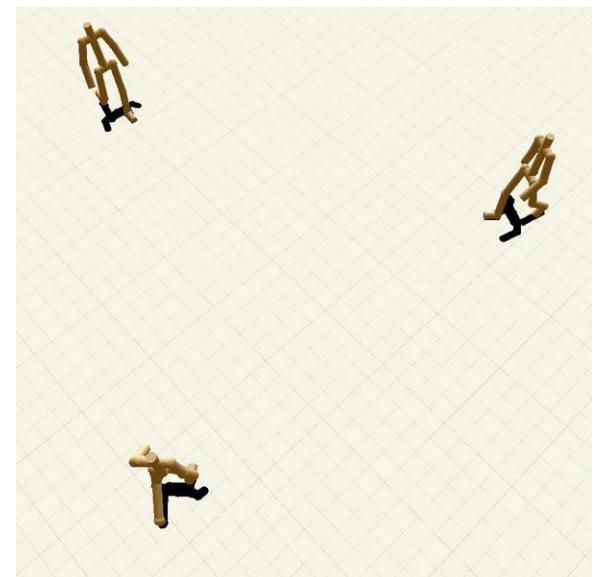


# Motion Composition

- Computationally generating motions according to
  - User control
  - Objects in the same environment
  - Movements of other characters
  - .....



[Heck and Gleicher 2007, Parametric Motion Graphs]



[Treuille et al. 2007, Near-optimal character animation with continuous control]

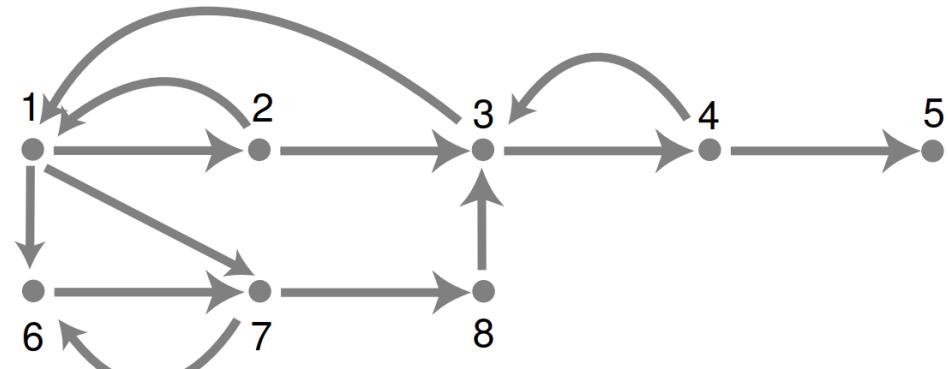
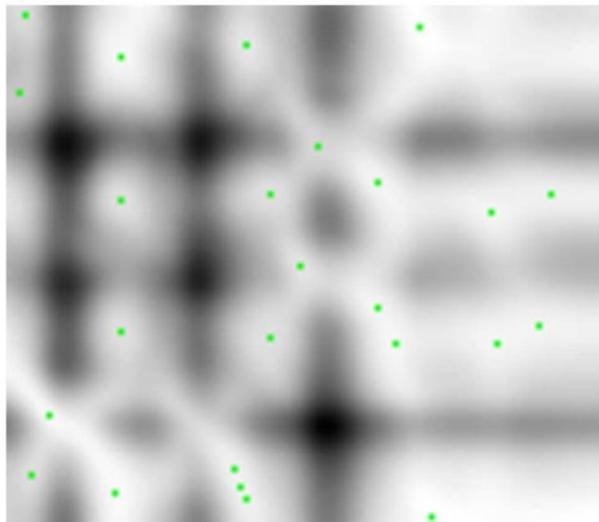
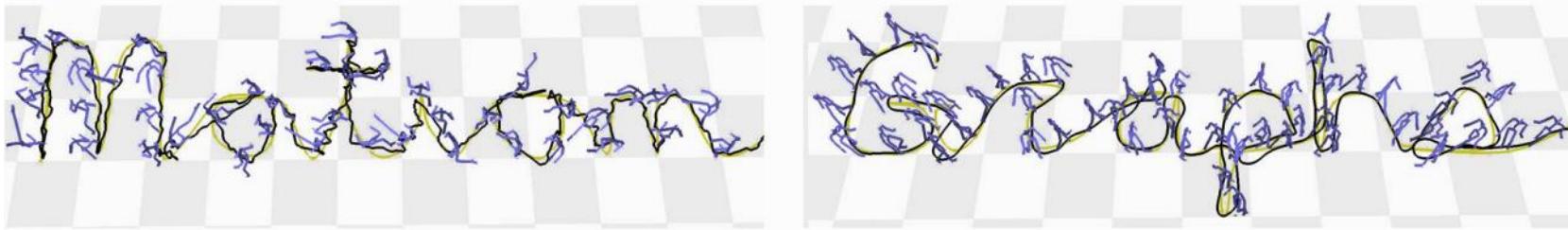
# Motion Graphs

## Motion Graphs

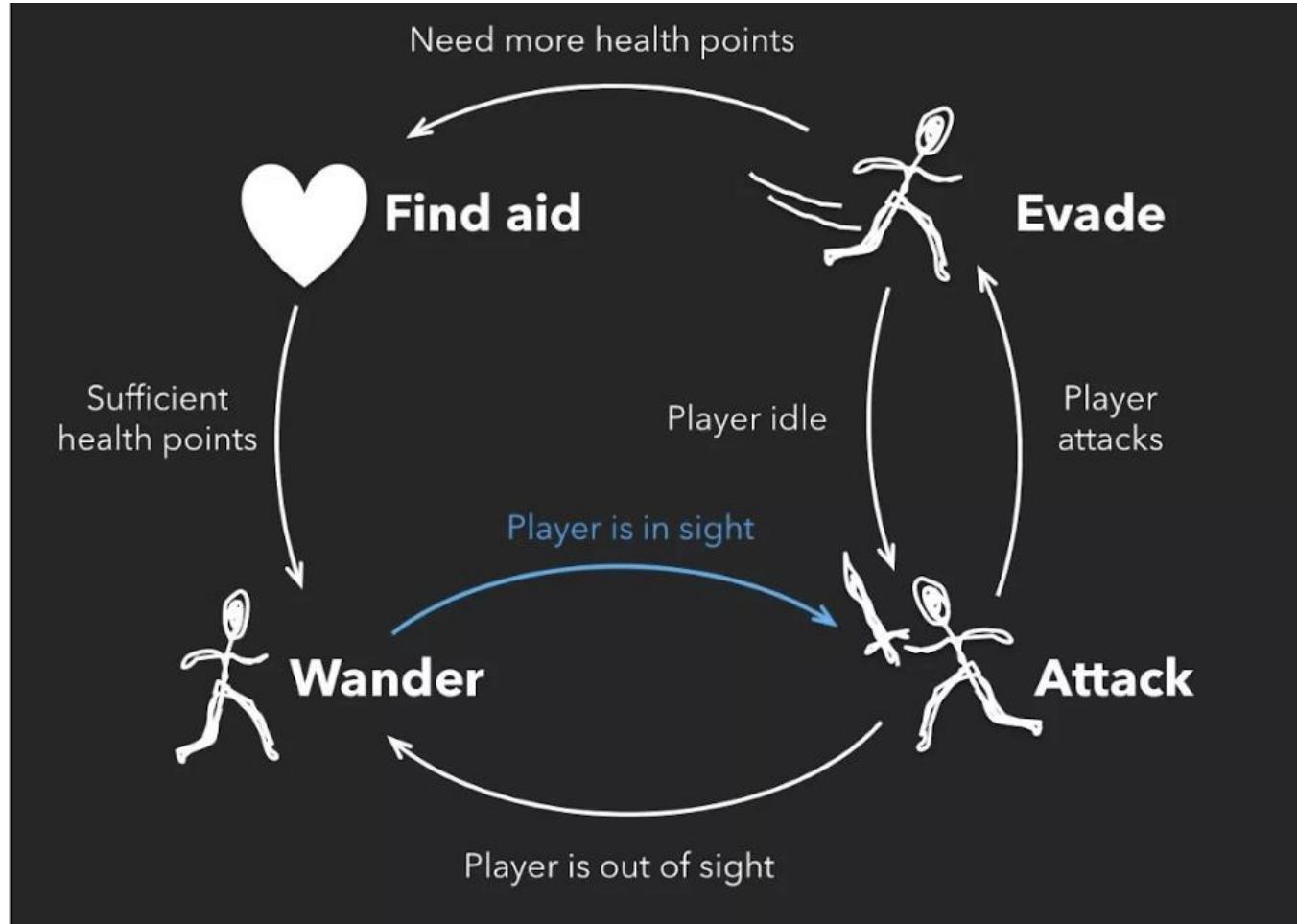
Lucas Kovar  
University of Wisconsin-Madison

Michael Gleicher\*  
University of Wisconsin-Madison

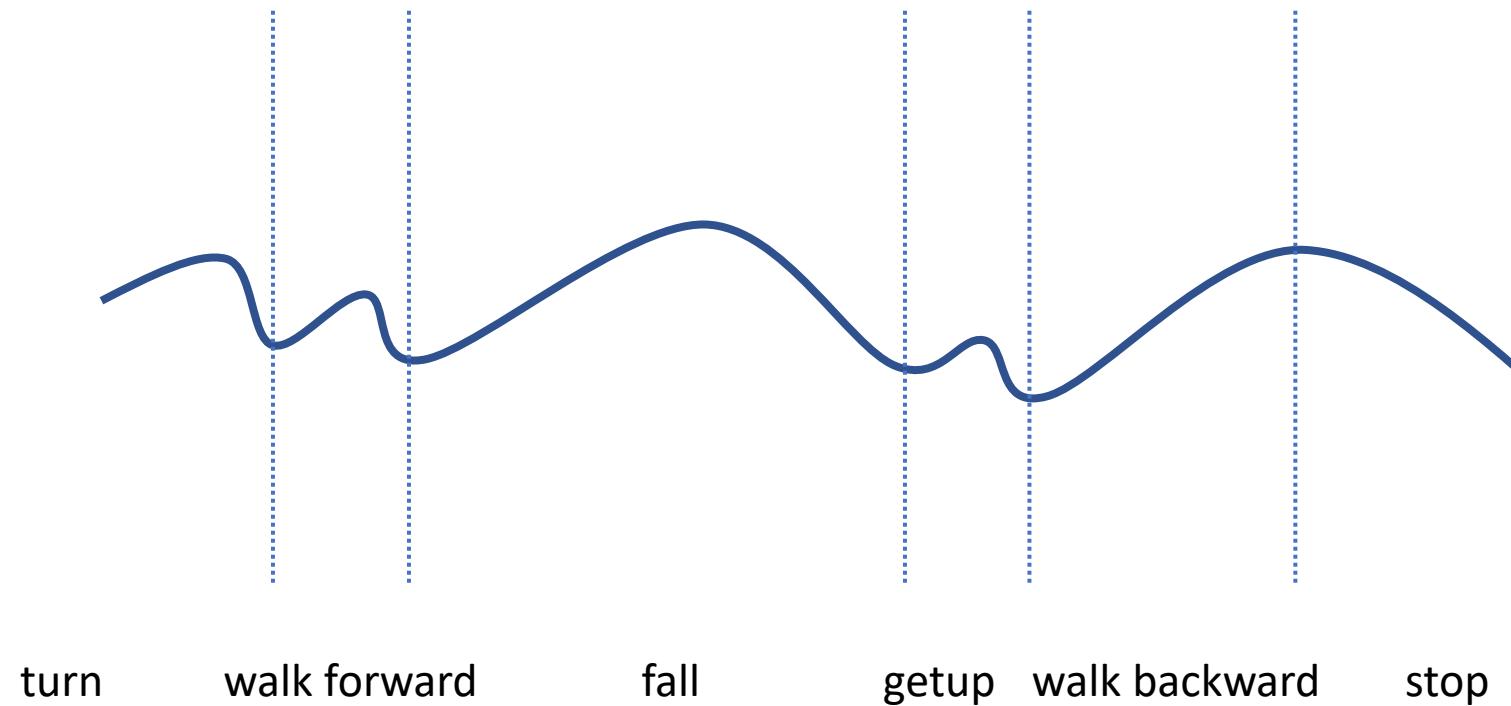
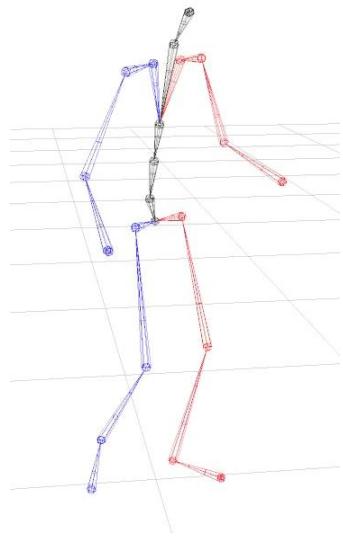
Frédéric Pighin†  
University of Southern California  
Institute for Creative Technologies



# Motion Graphs

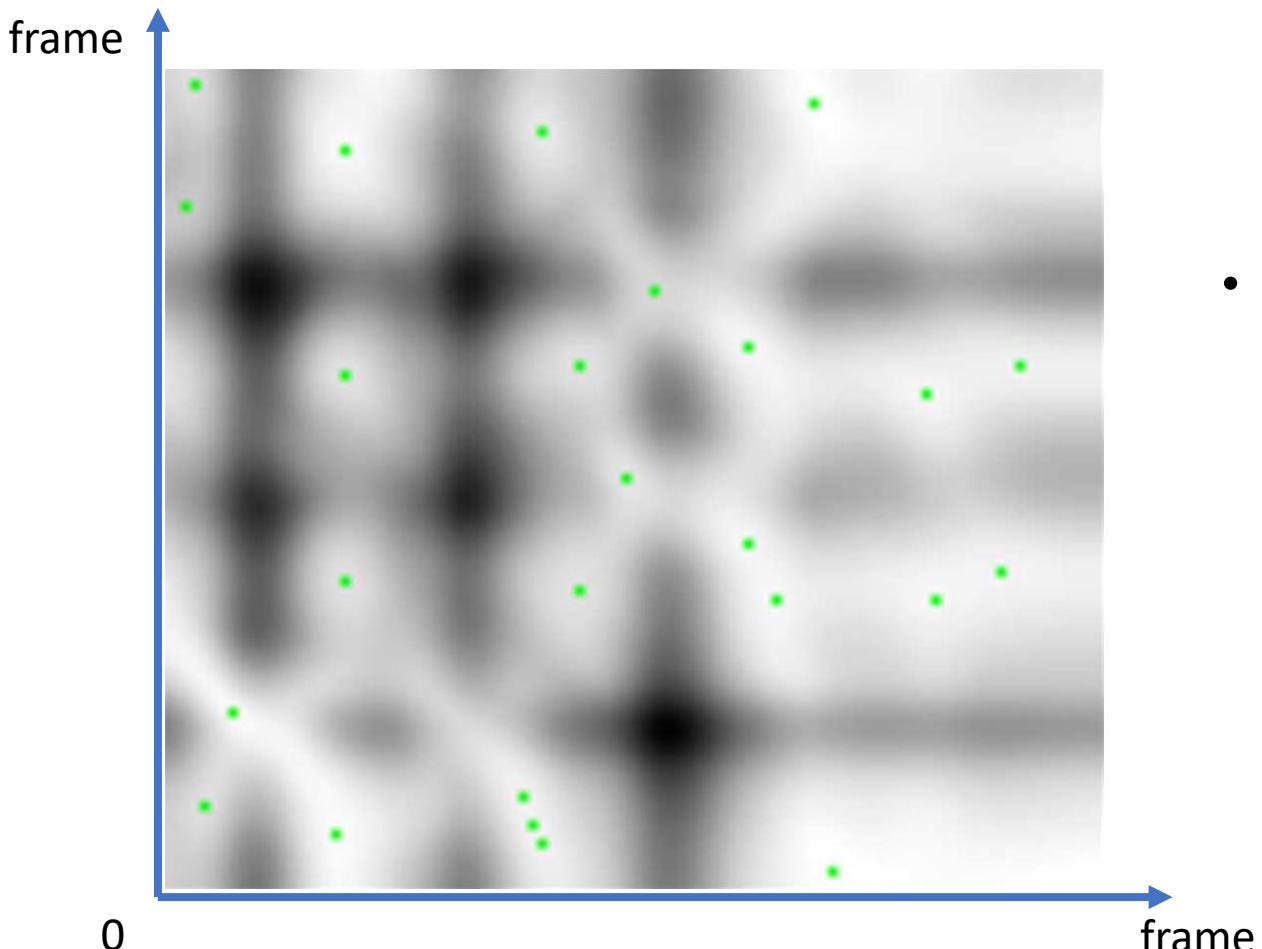


# Segment Motion Data



# Segment Motion Data

- Where to segment?

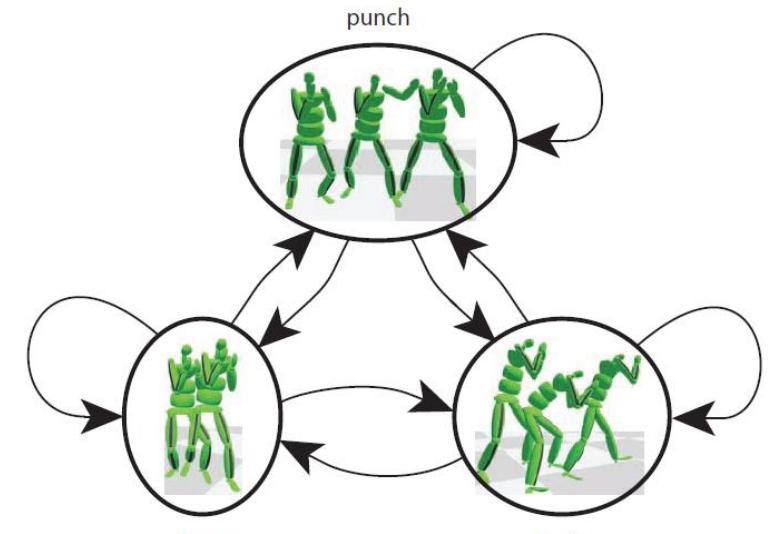


- Distance map
  - Each pixel represents the difference between a pair of poses
  - Local minima are potential transition point

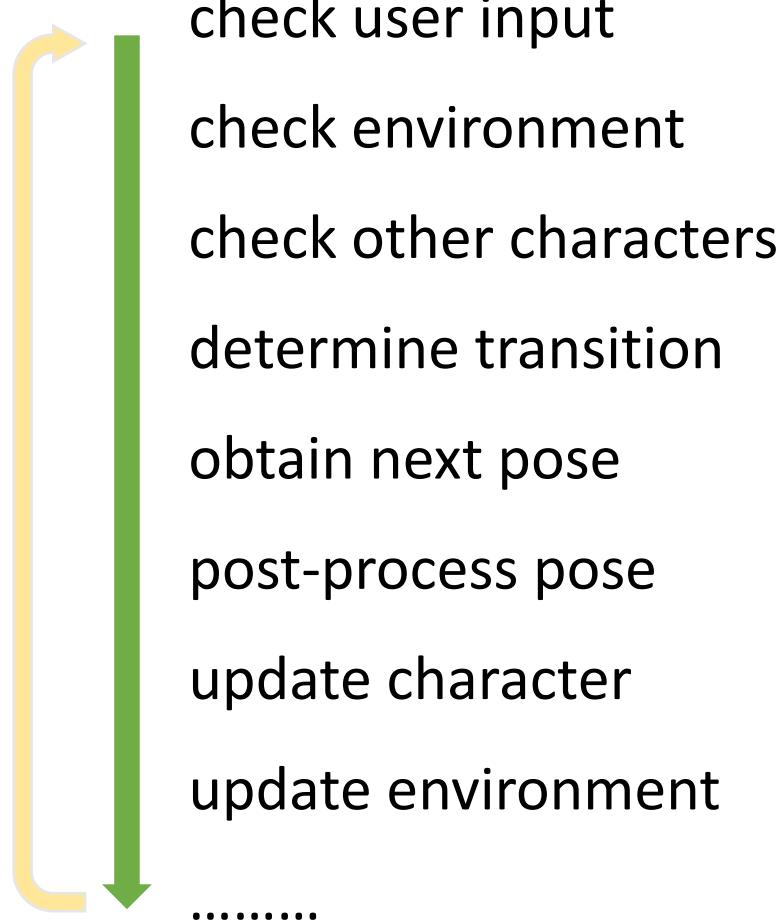
Lucas Kovar, Michael Gleicher, and Frédéric Pighin. 2002. ***Motion graphs***. *ACM Trans. Graph.* 21, 3 (July 2002),

# Motion Synthesis

- State-machines
  - Nodes represent motion clips
  - Edges represent potential transitions
  - Transitions are triggered when necessary
    - User input
    - Clip end
  - Check immediate connections for the next clip
    - May need deeper search



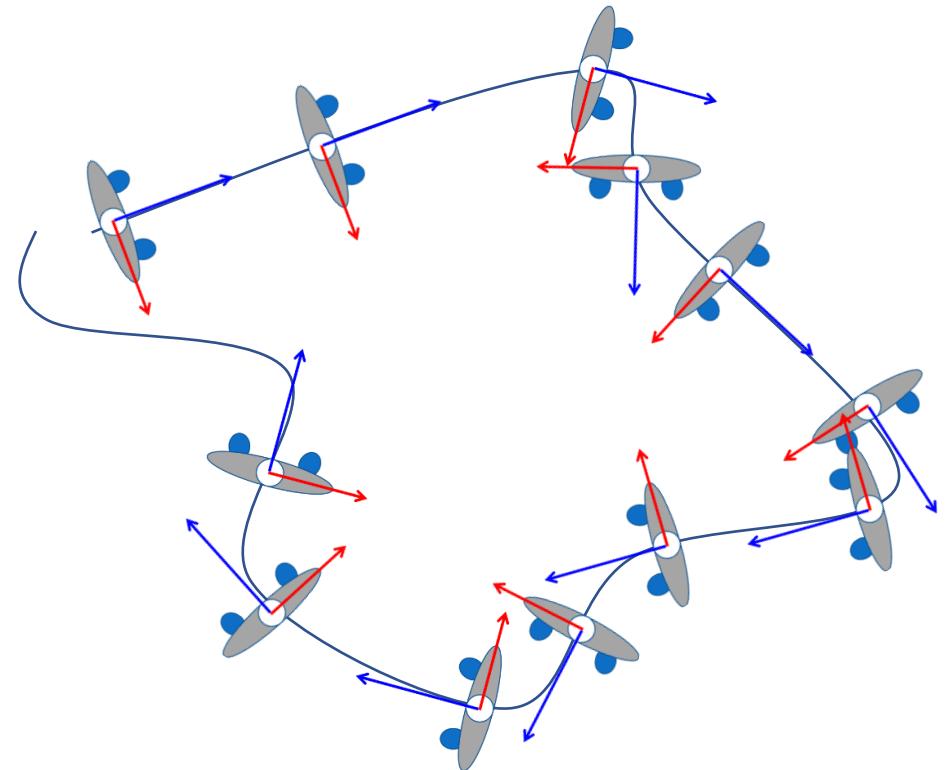
# Interactive Animation Pipeline



# Example: Path Fitting



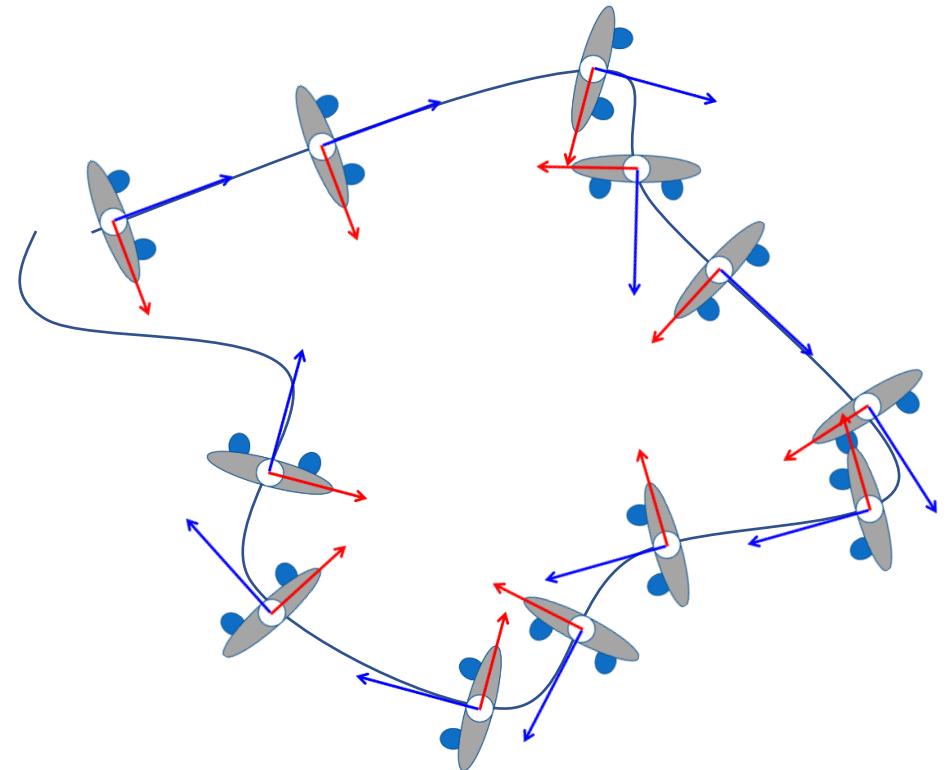
[Motion Graphs]



# Example: Path Fitting



[Motion Graphs]



# Motion Matching?

- Clip → Pose
- Short clip →  
“Raw” and long motion data



# Outline

- Motion Capture
  - History and modern mocap systems
- Motion Synthesis
  - Motion retargeting
  - Motion transition
  - Motion graph

# Questions?

