Data-driven Character Animation

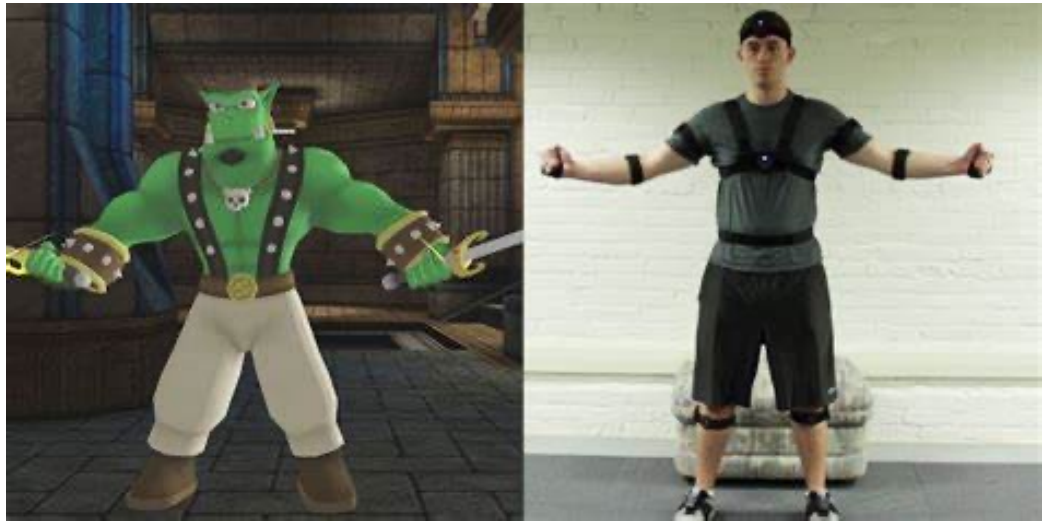
Outline

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

Motion Capture

How to get motion data?

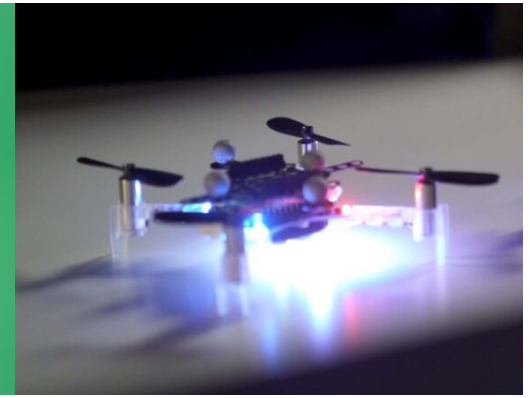
Motion Capture



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
  - ……



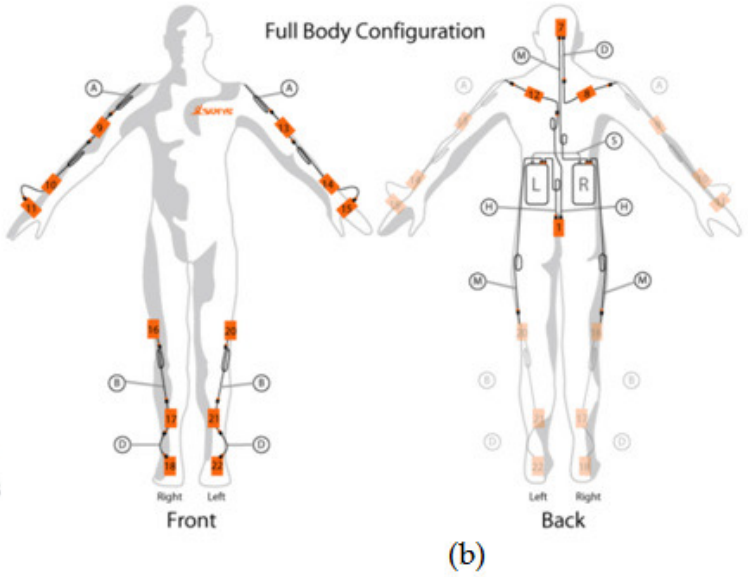
Modern Mocap System

Mechanical Mocap

- Exoskeleton

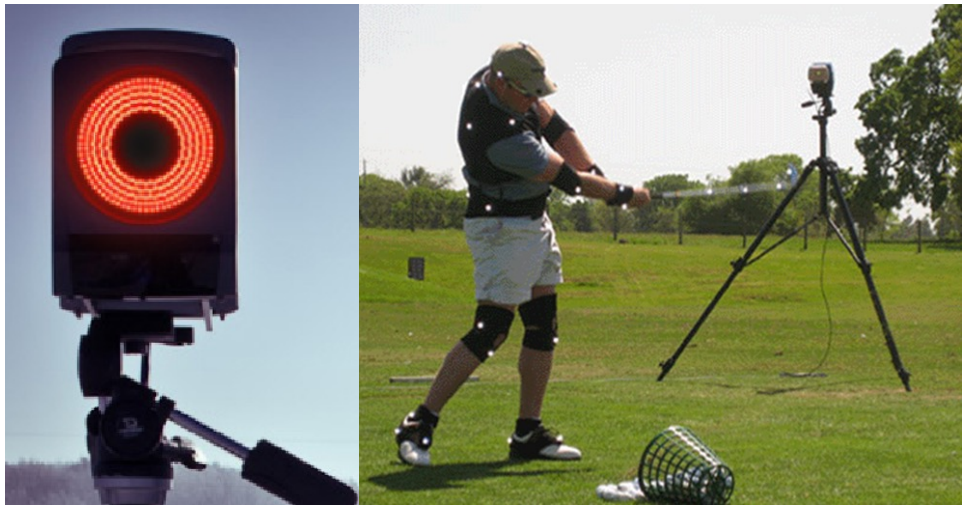
Inertial Mocap

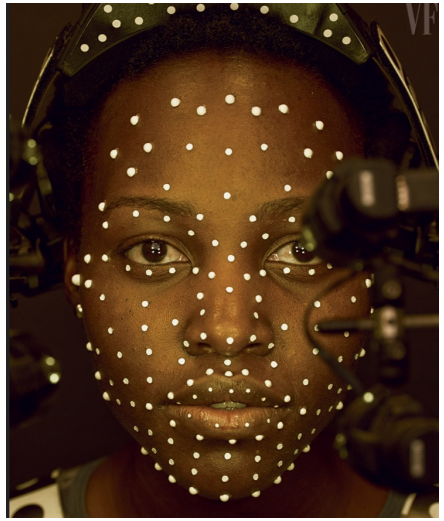
- Inertial Measurement Unit (IMU)
  - Accelerometers (3dof) + axis gyroscope (3dof)
- Optionally other sensors

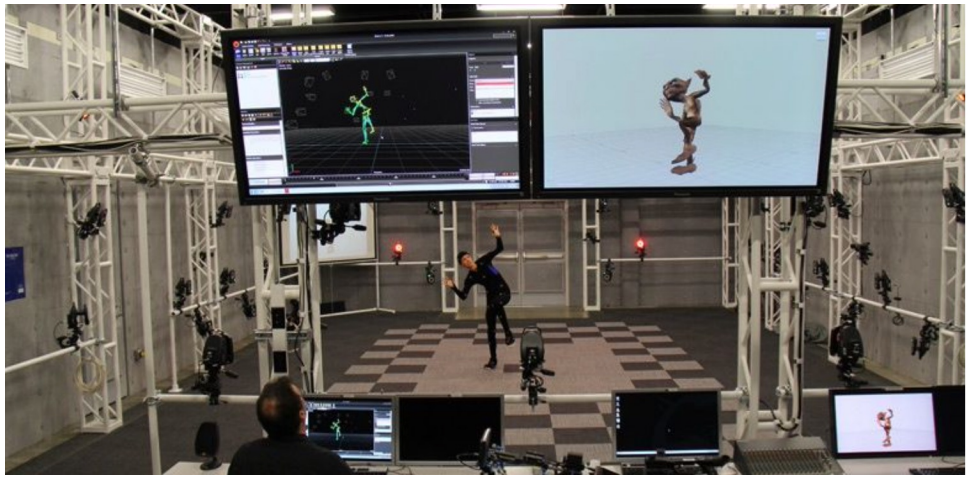


Optical Mocap

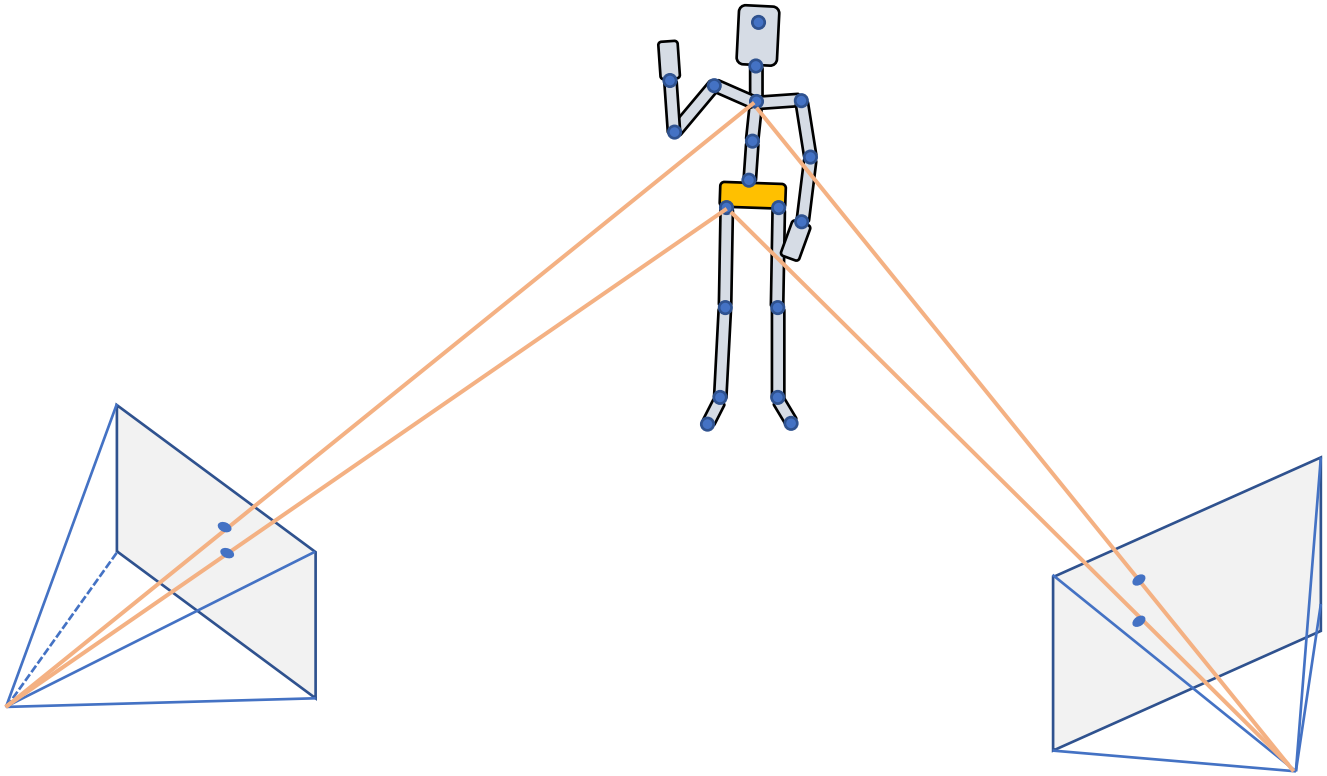
- Reflective/light-emitting markers
- Multi-view geometry
- Solve body motions based on marker positions







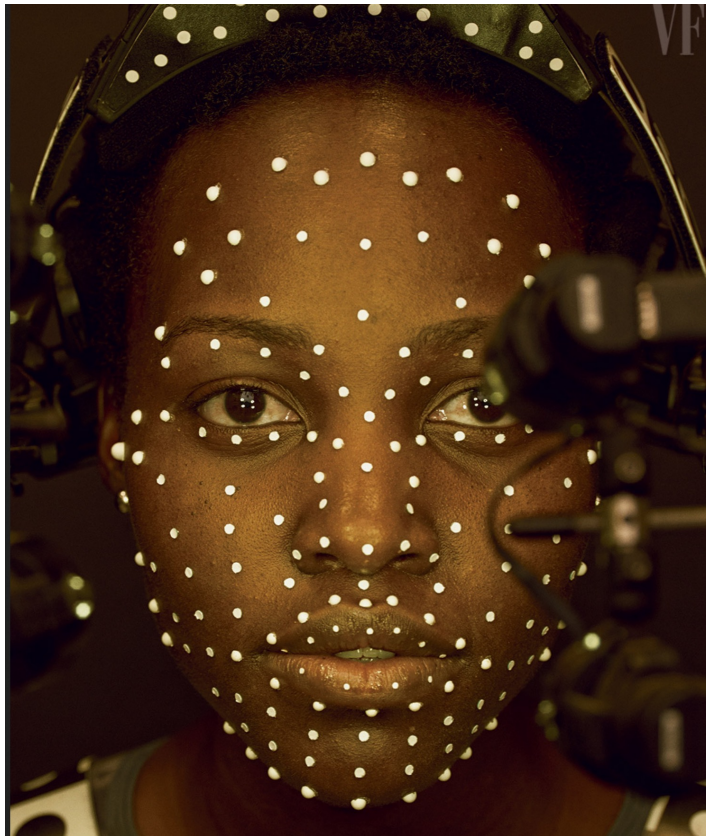
Optical Mocap

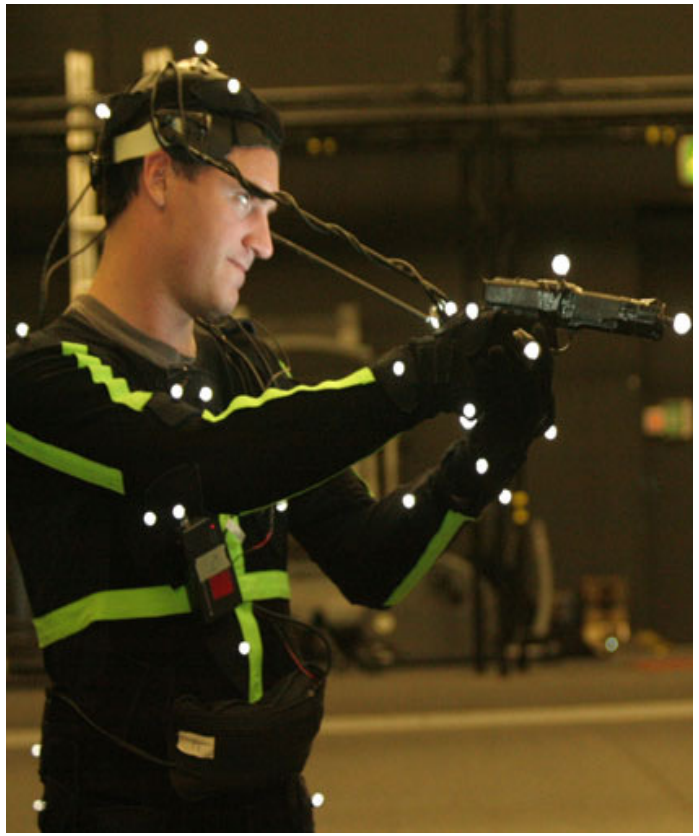


Optical Mocap

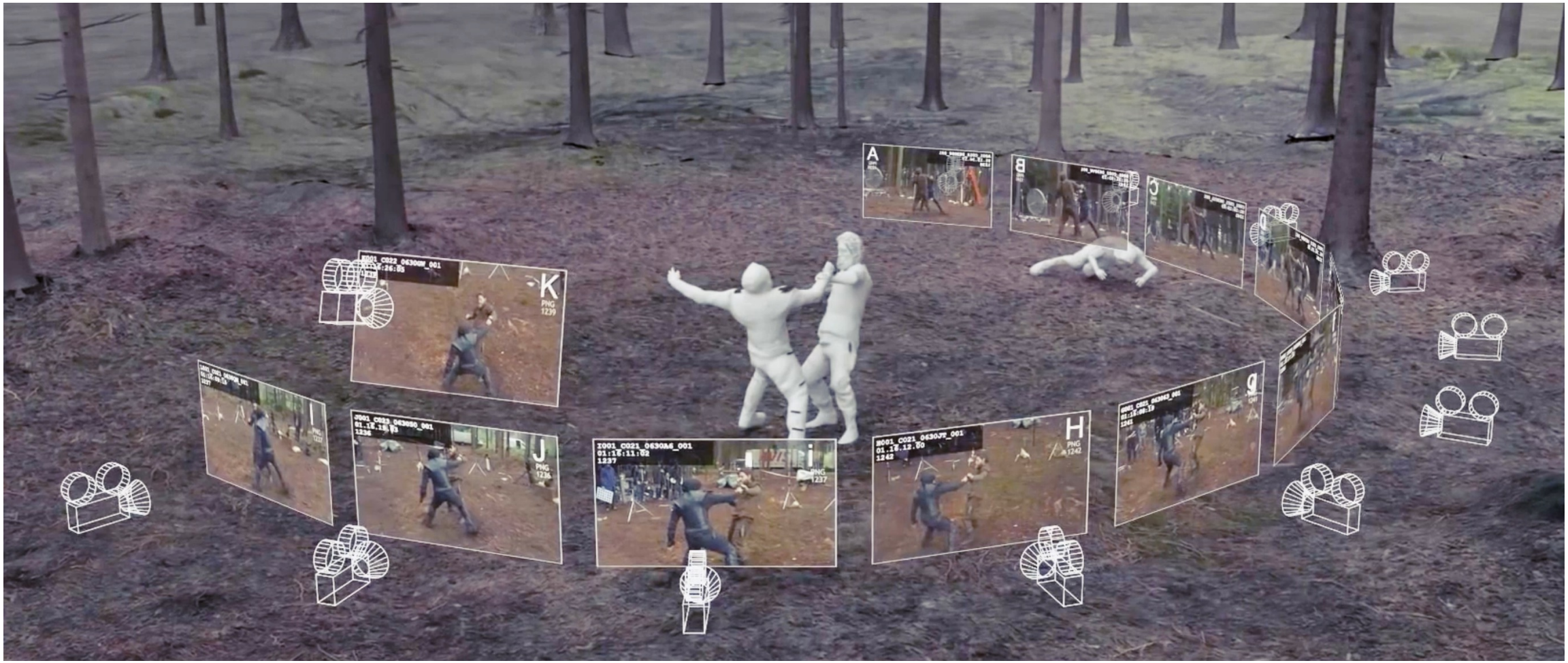
https://toronto.ubisoft.com/performance-capture/

Optical Mocap





Markerless Mocap with Multiple Cameras



https://captury.com/

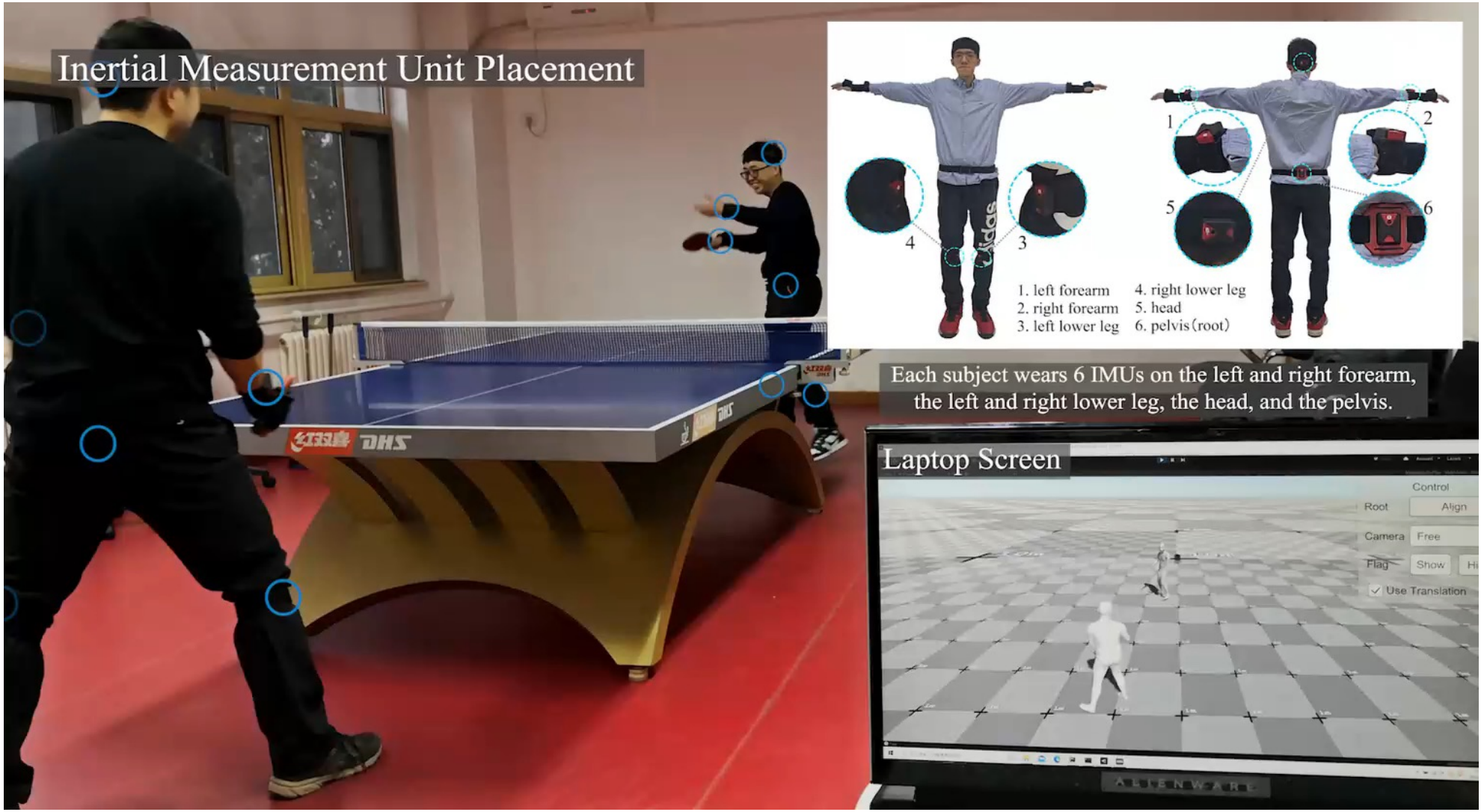
Markerless Mocap with Depth Cameras

Motion Estimation with Monocular Videos

[OpenPose, 2D Pose estimation]

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

Motion Estimation with Sparse Sensor

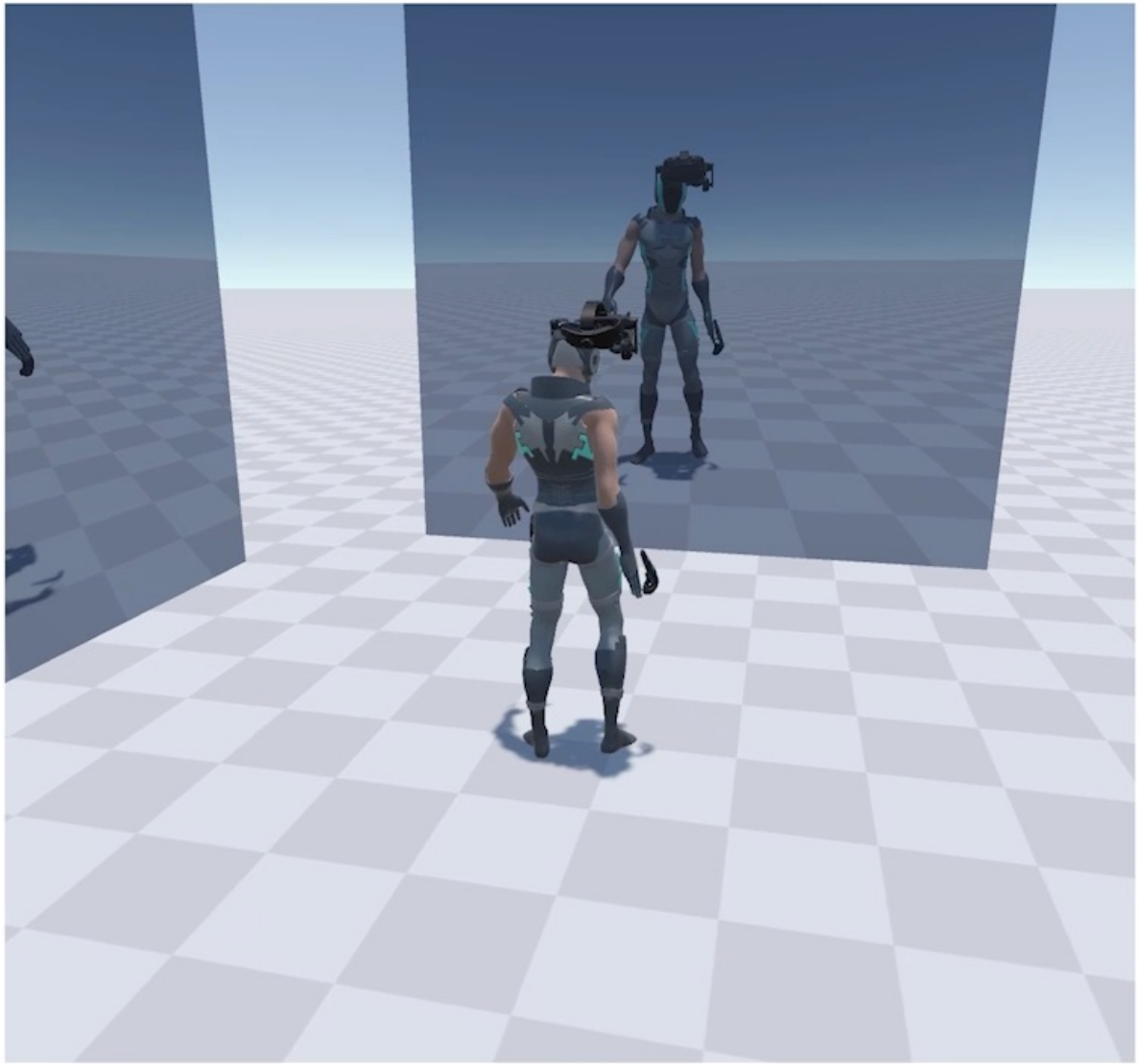


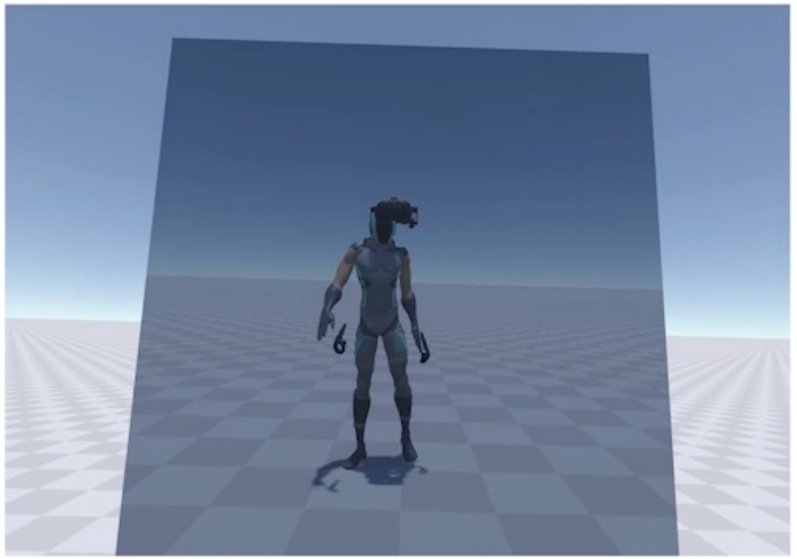
[Yi et al. 2021. TransPose: Real-time 3D Human Translation and Pose Estimation with **Six Inertial Sensors**]

Motion Estimation with Sparse Sensor

[Meta]

Motion Estimation with Sparse Sensor





[Ye et al. 2022: Neural3Points]

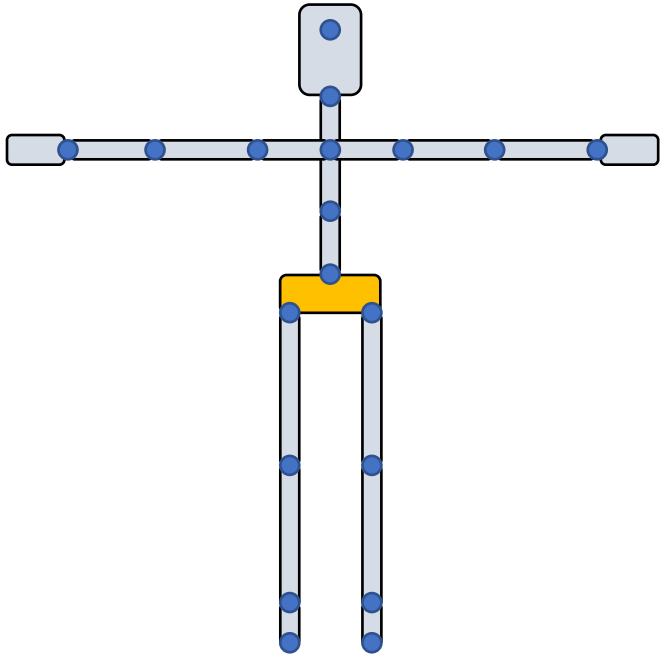
Motion Synthesis

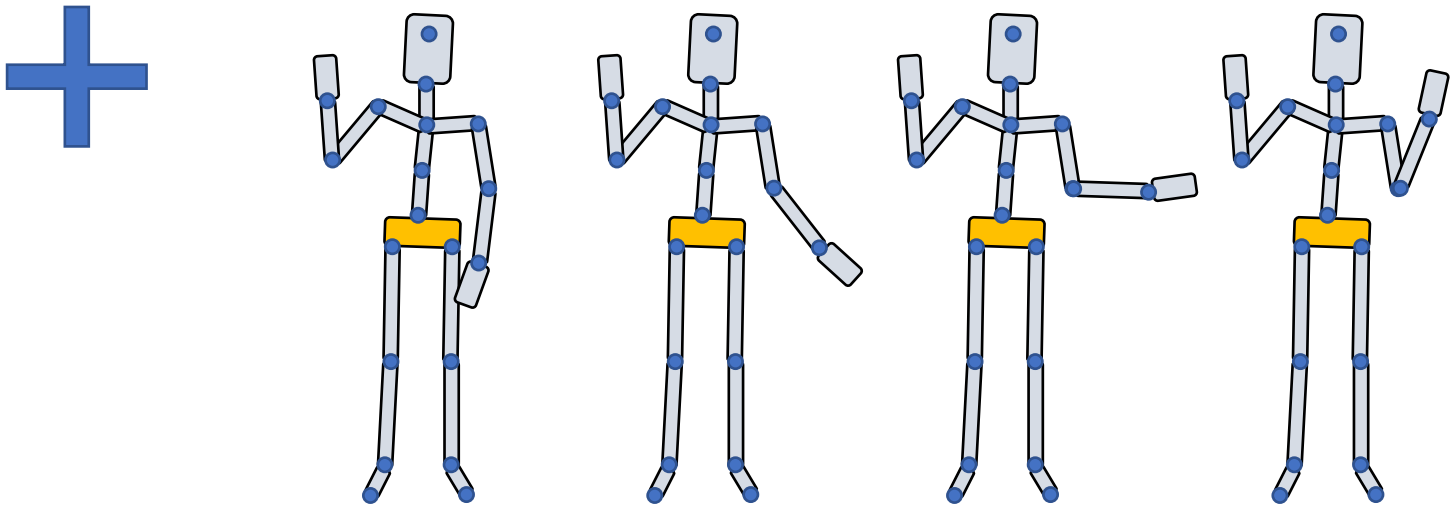
How to use motion data?

Motion Data

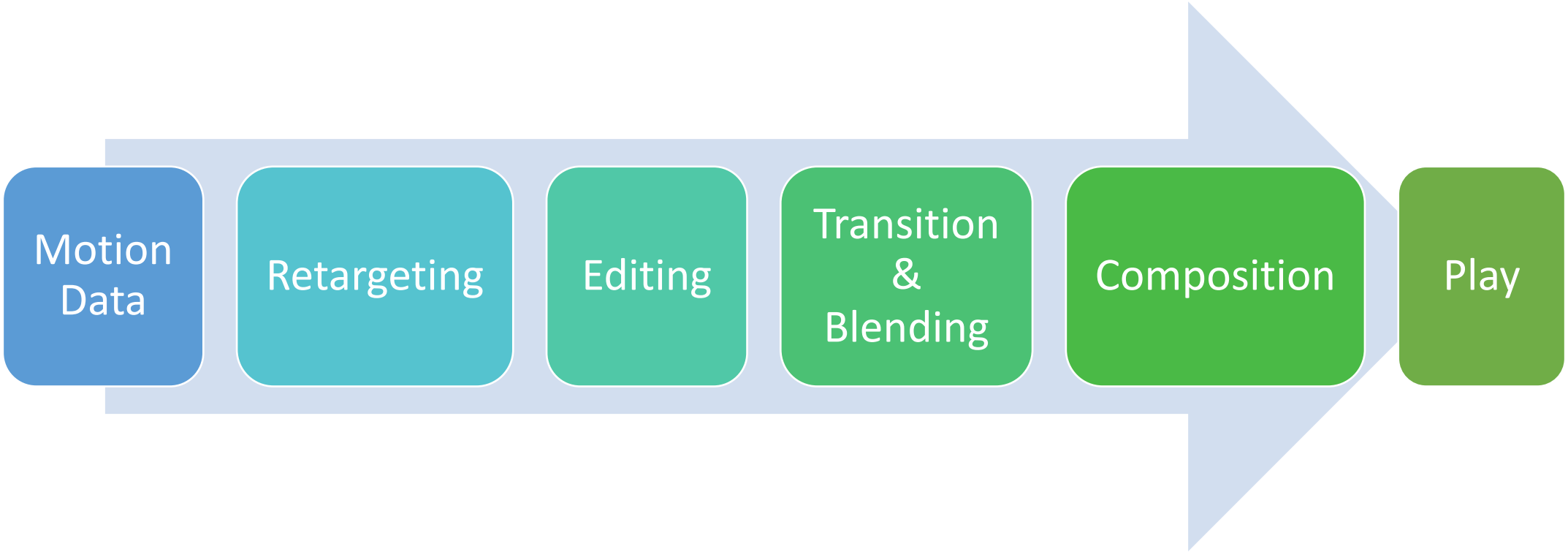
$$\{p_t\}, t = 1, \dots, N$$

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



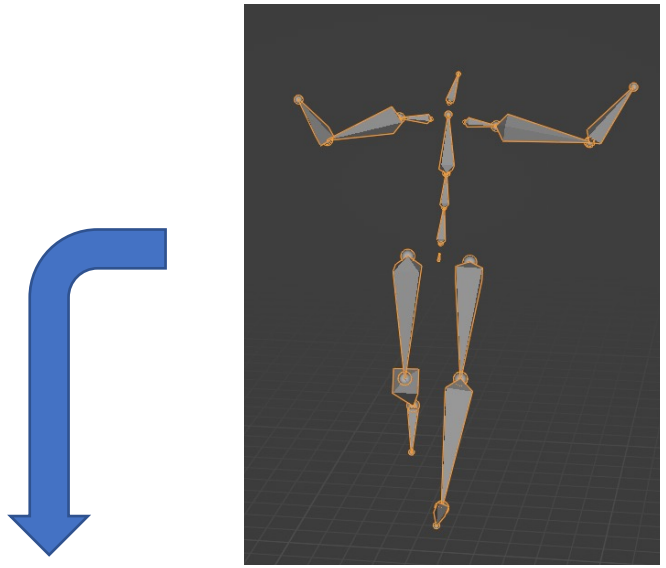


Using Motion Data



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
  - ……



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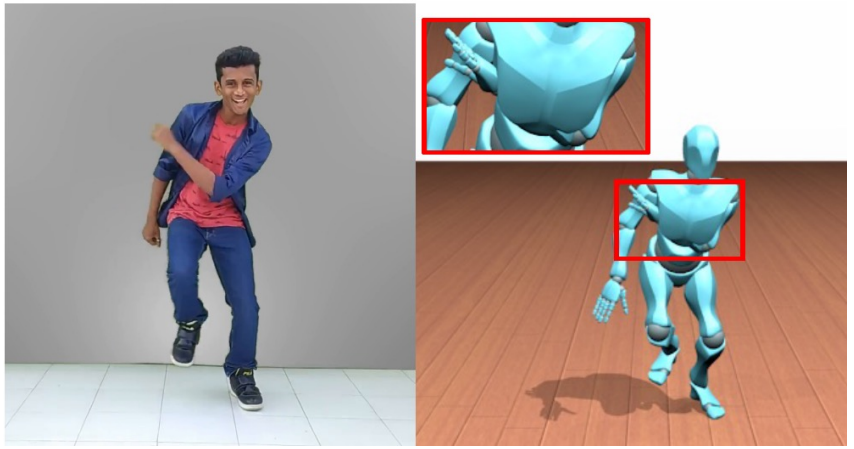
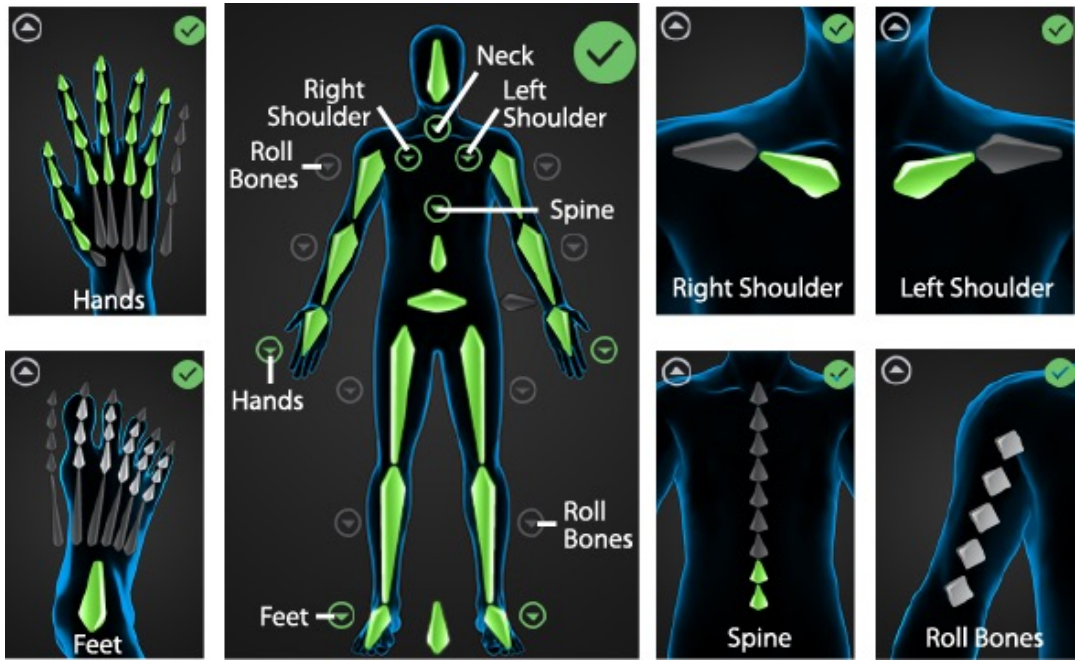


[Villegas et al. 2021, Contact-Aware Retargeting of Skinned Motion]

Motion Retargeting

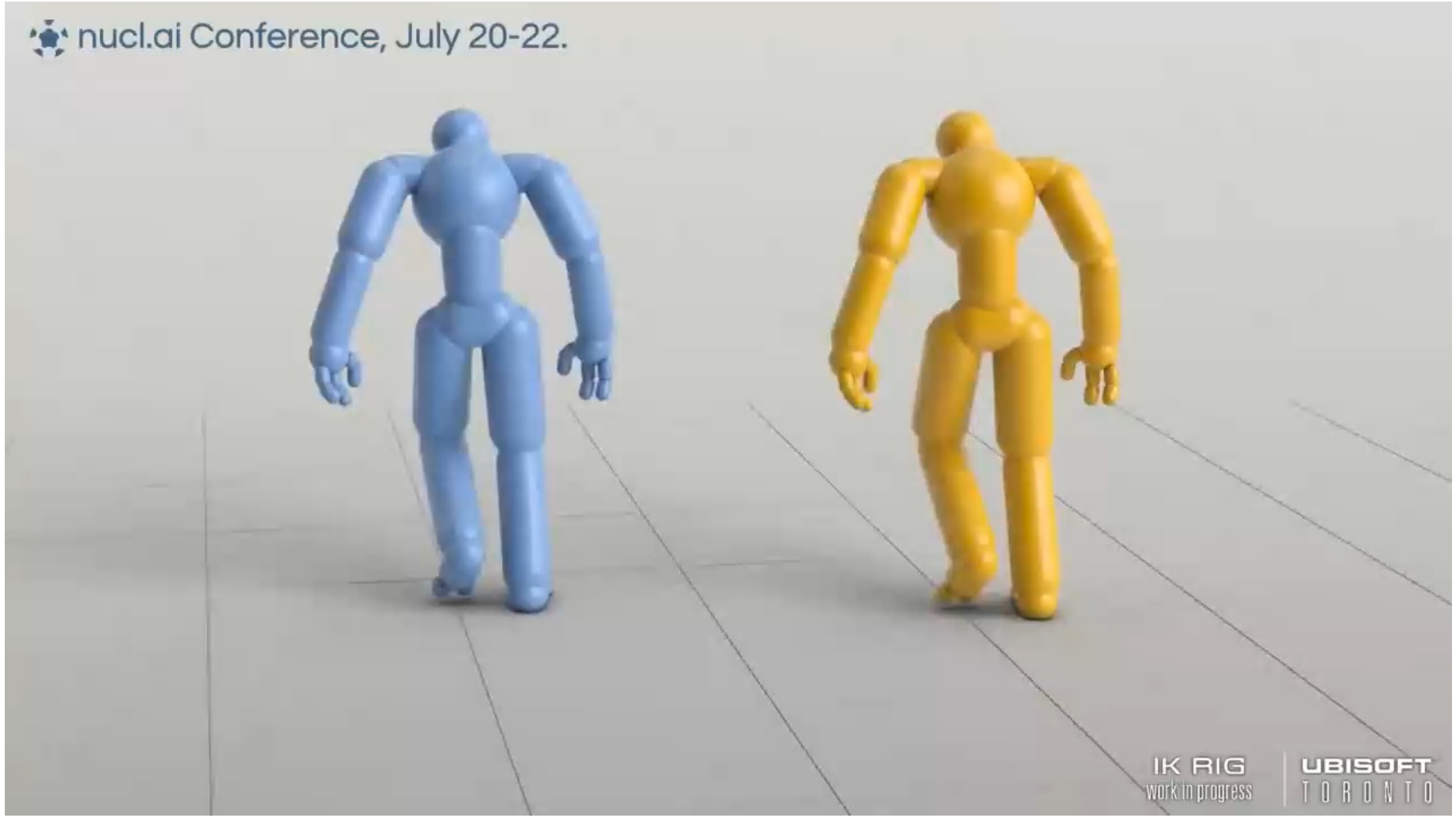
- A possible retargeting pipeline
  - Map bone names
  - Scale translations
  - Copy or retarget joint rotations to fix reference pose
  - Postprocessing with IK
    - Foot-skating
    - Self penetration
  - ……



HumanIK in Autodesk Maya

Motion Retargeting

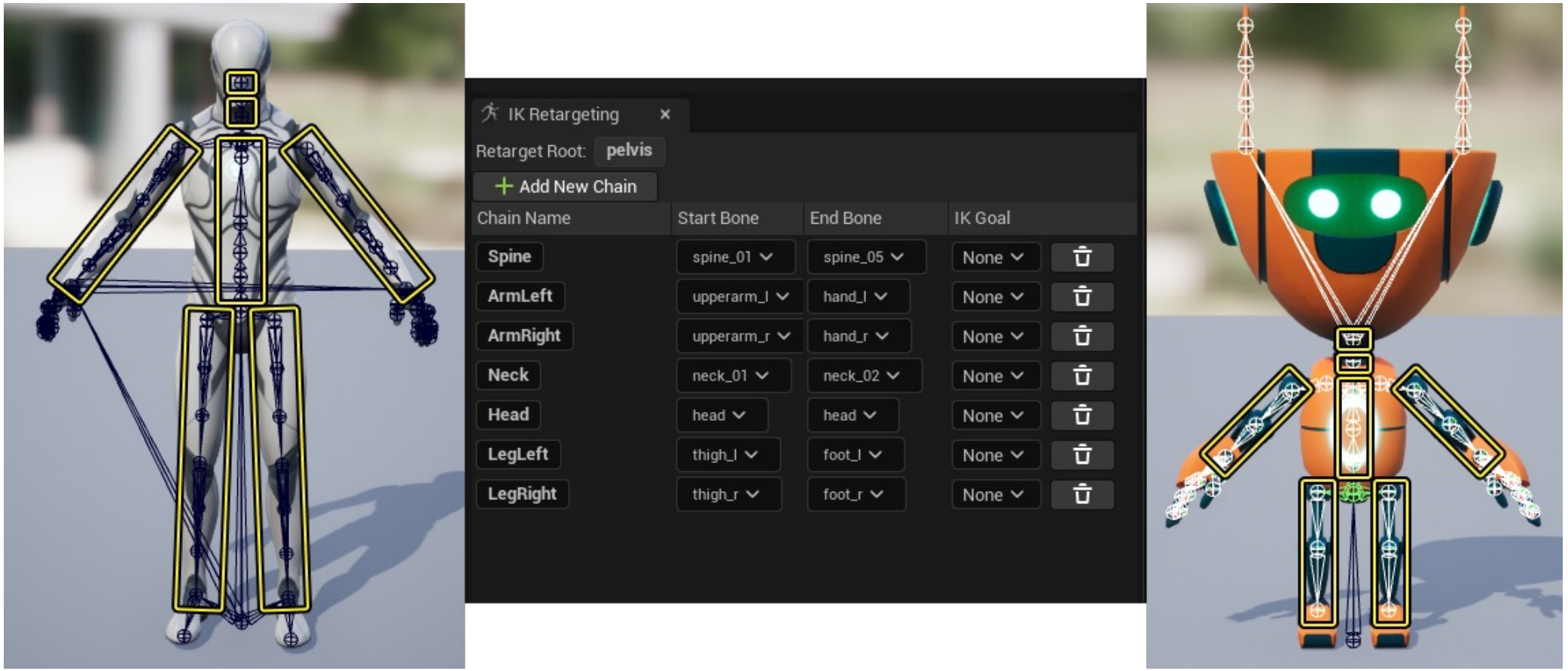
- IK Rig



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

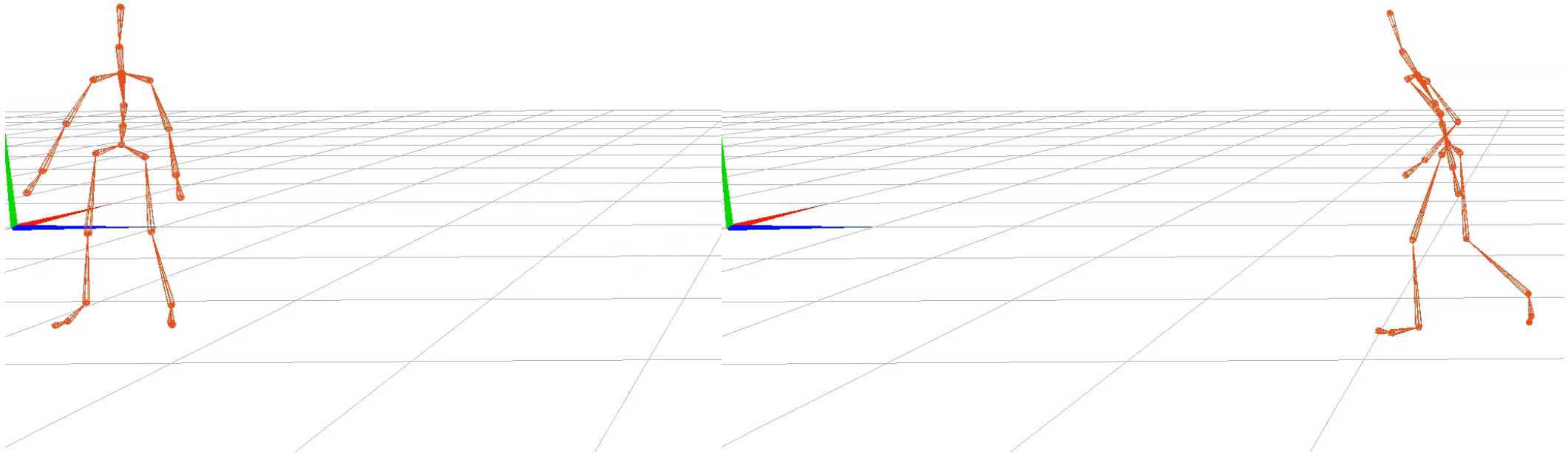
Motion Retargeting

- IK Rig in Unreal

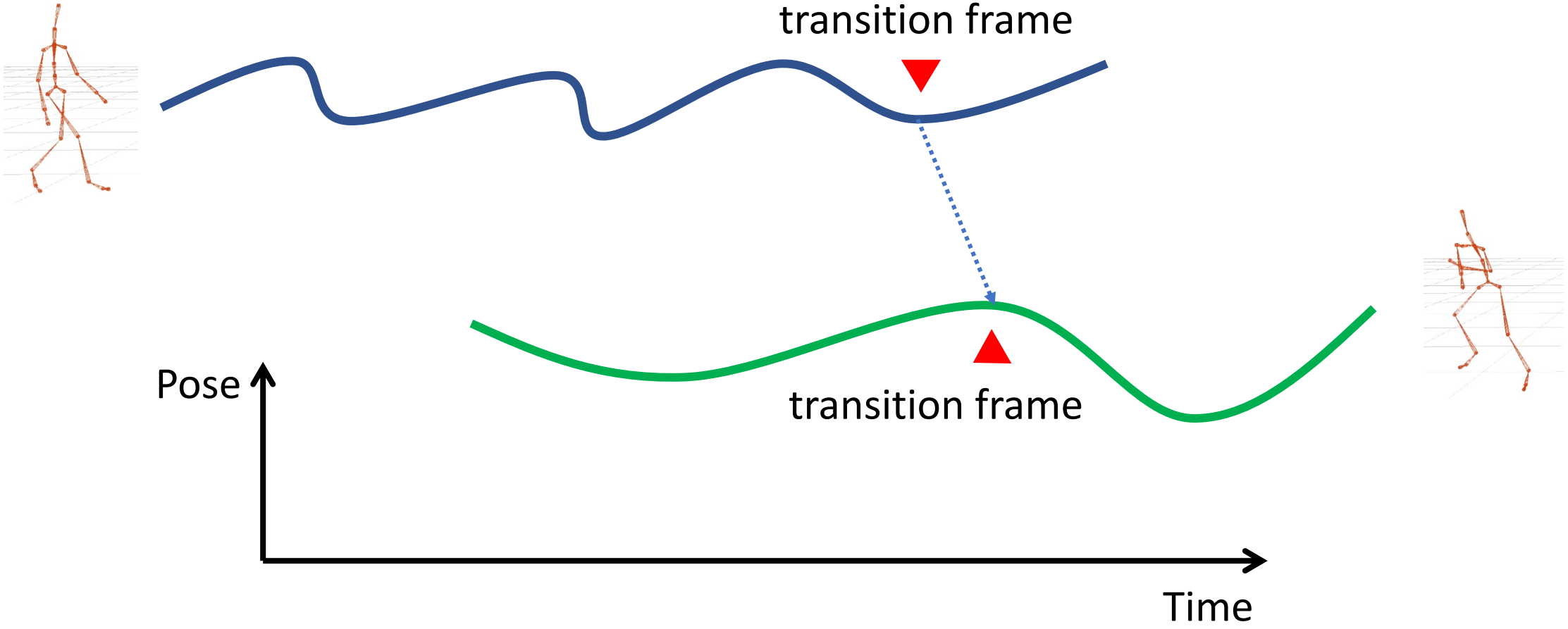


https://docs.unrealengine.com/5.0/en-US/ik-rig-animation-retargeting-in-unreal-engine/

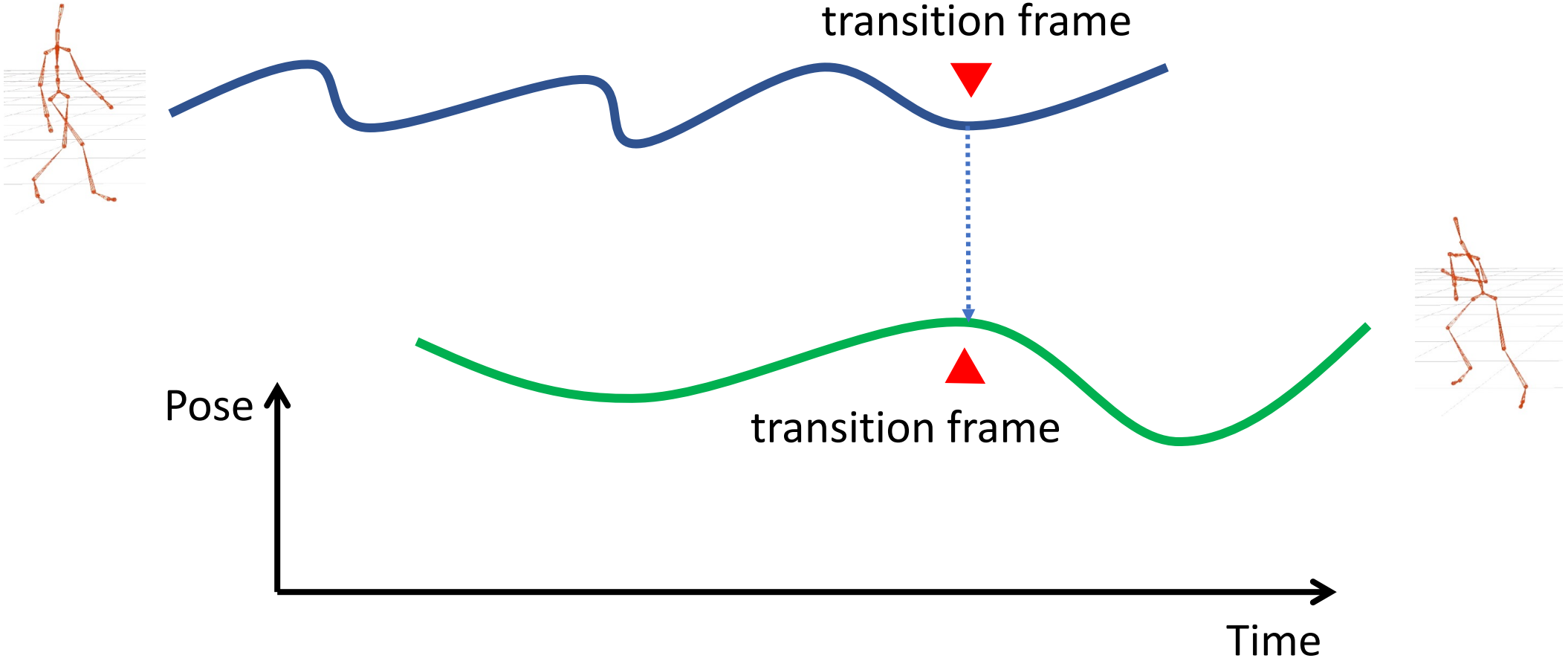
Motion Transition



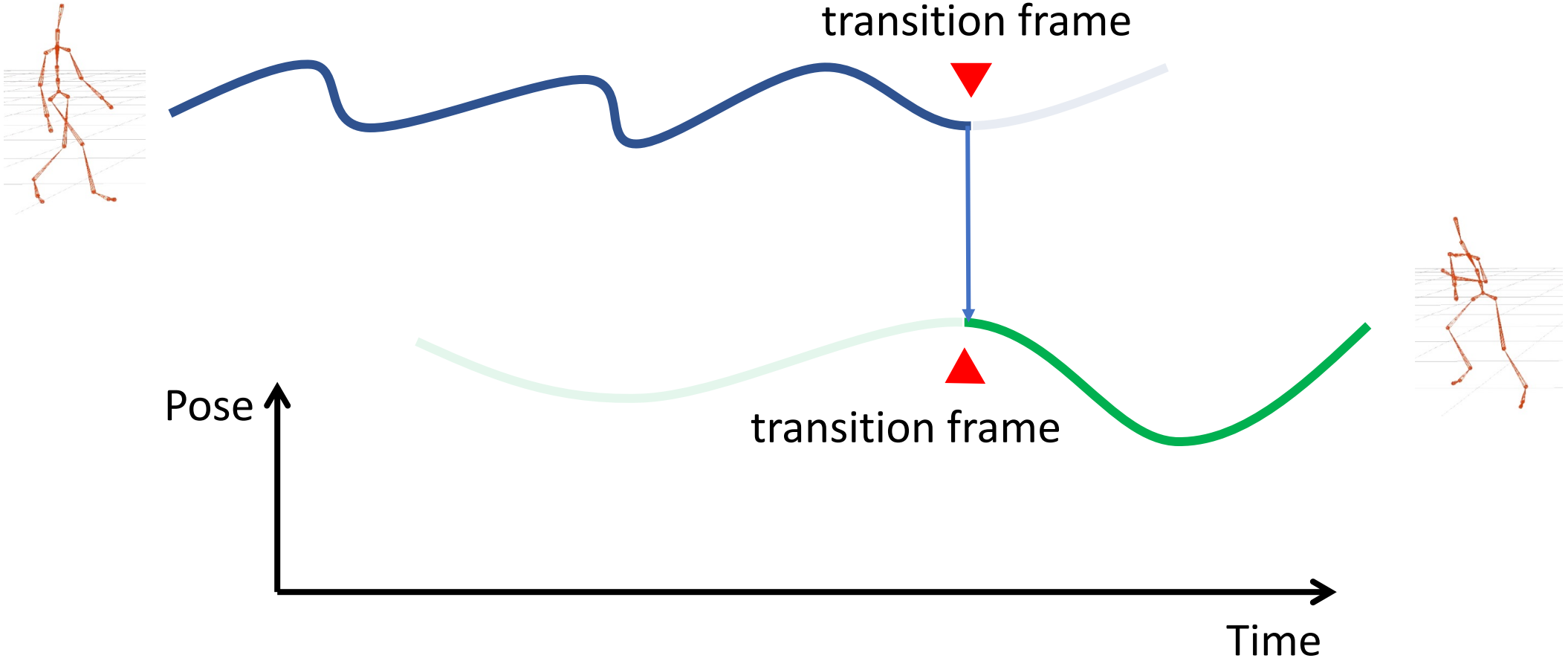
Motion Transition



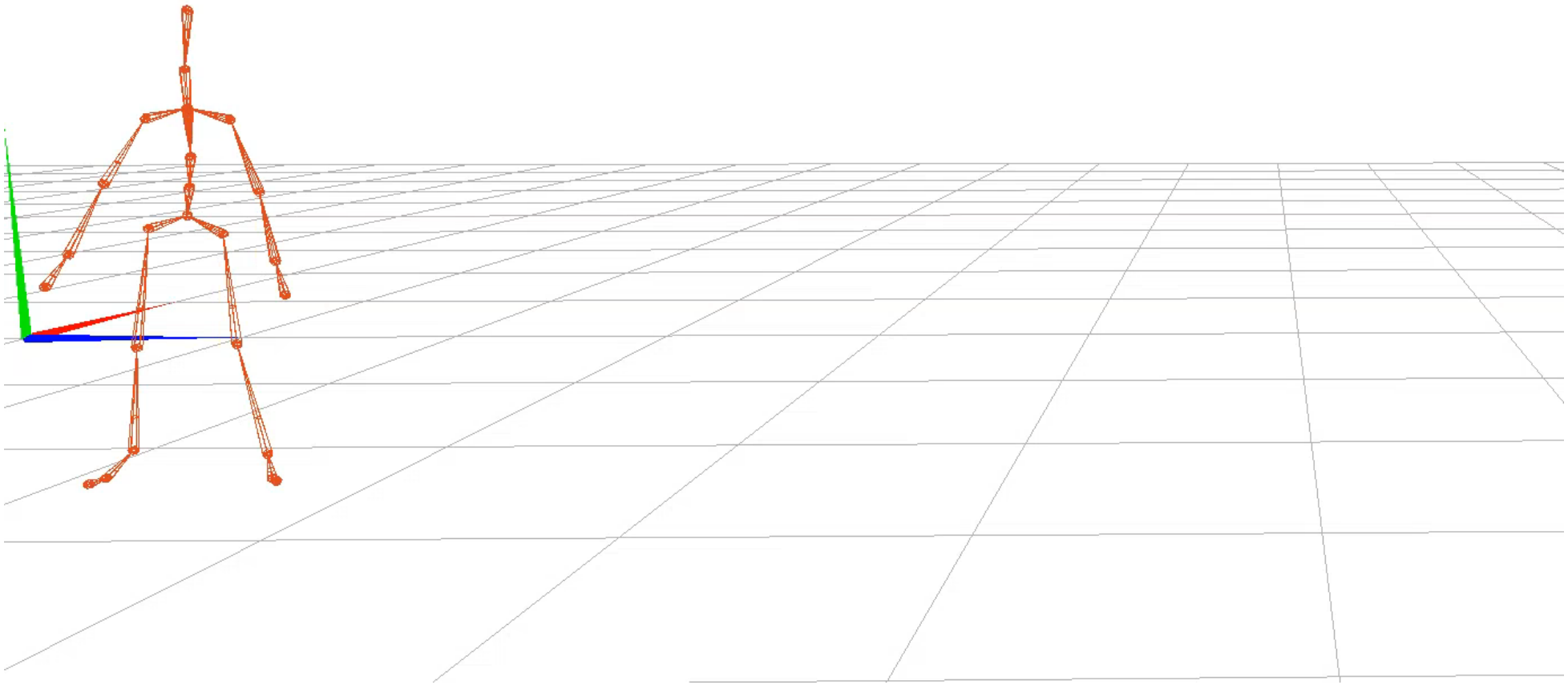
Motion Transition



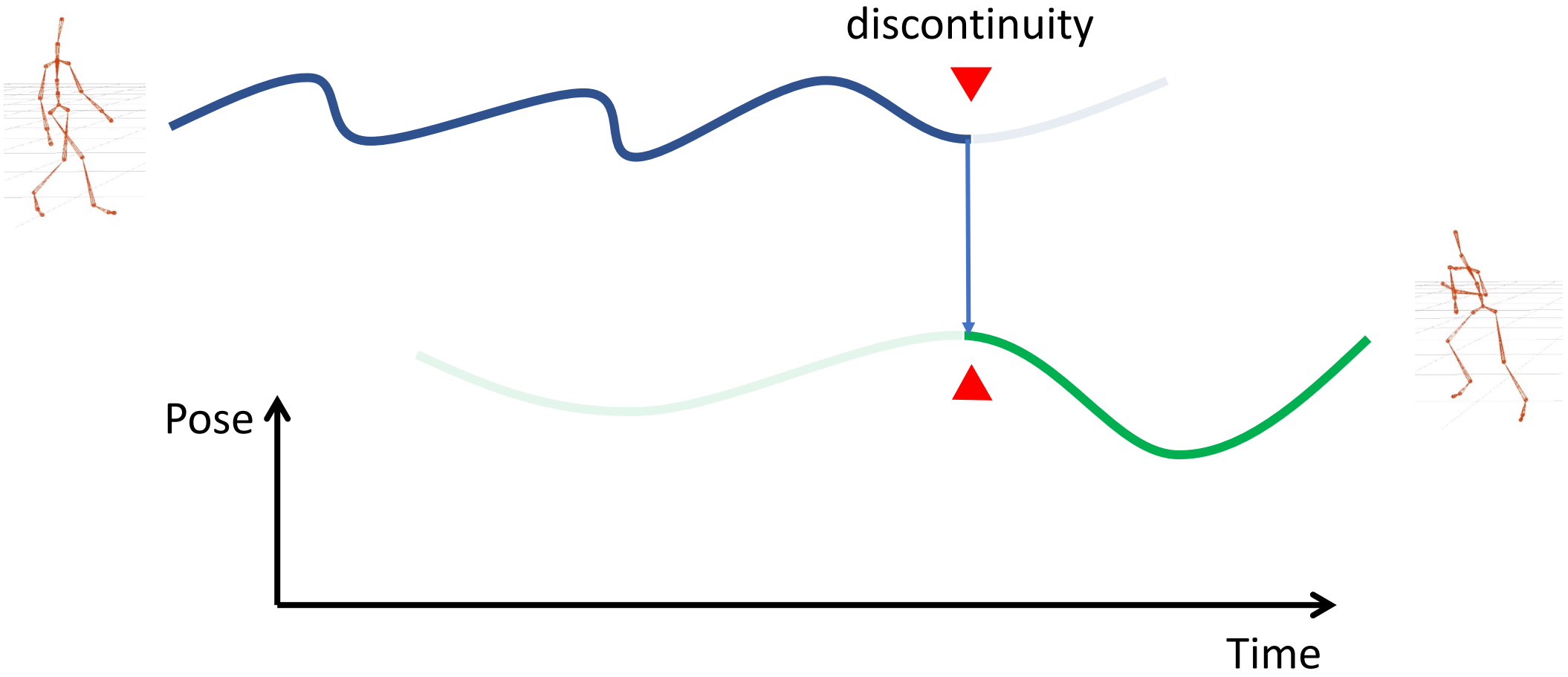
Motion Transition



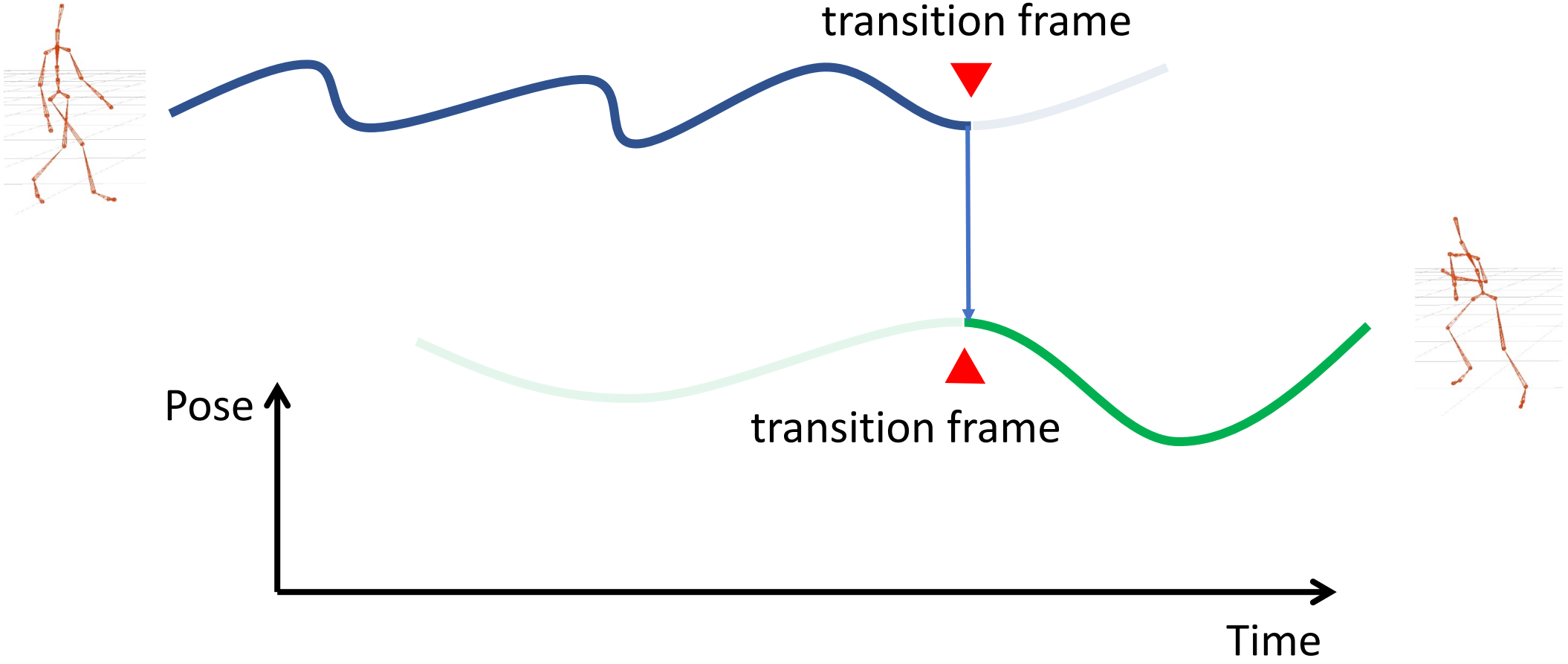
Motion Transition



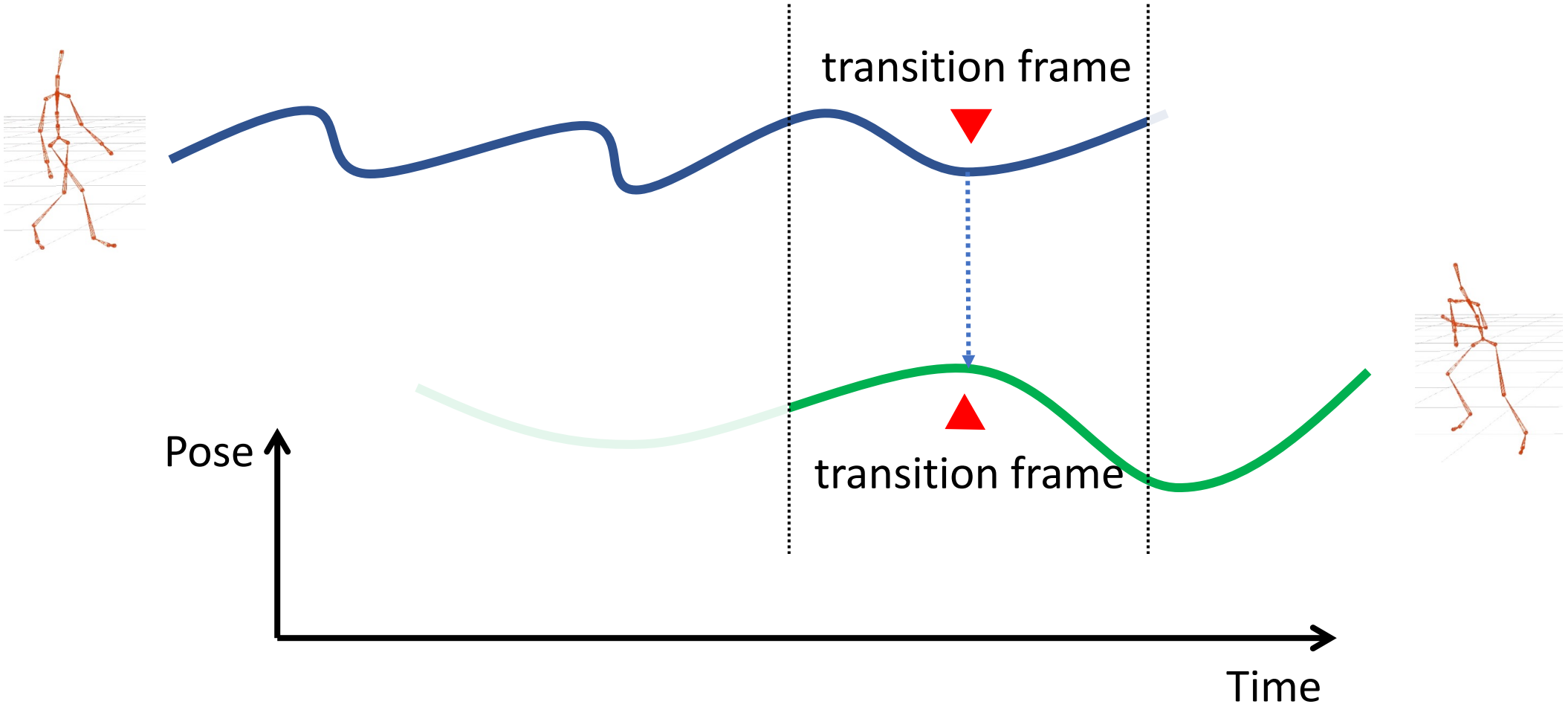
Motion Transition



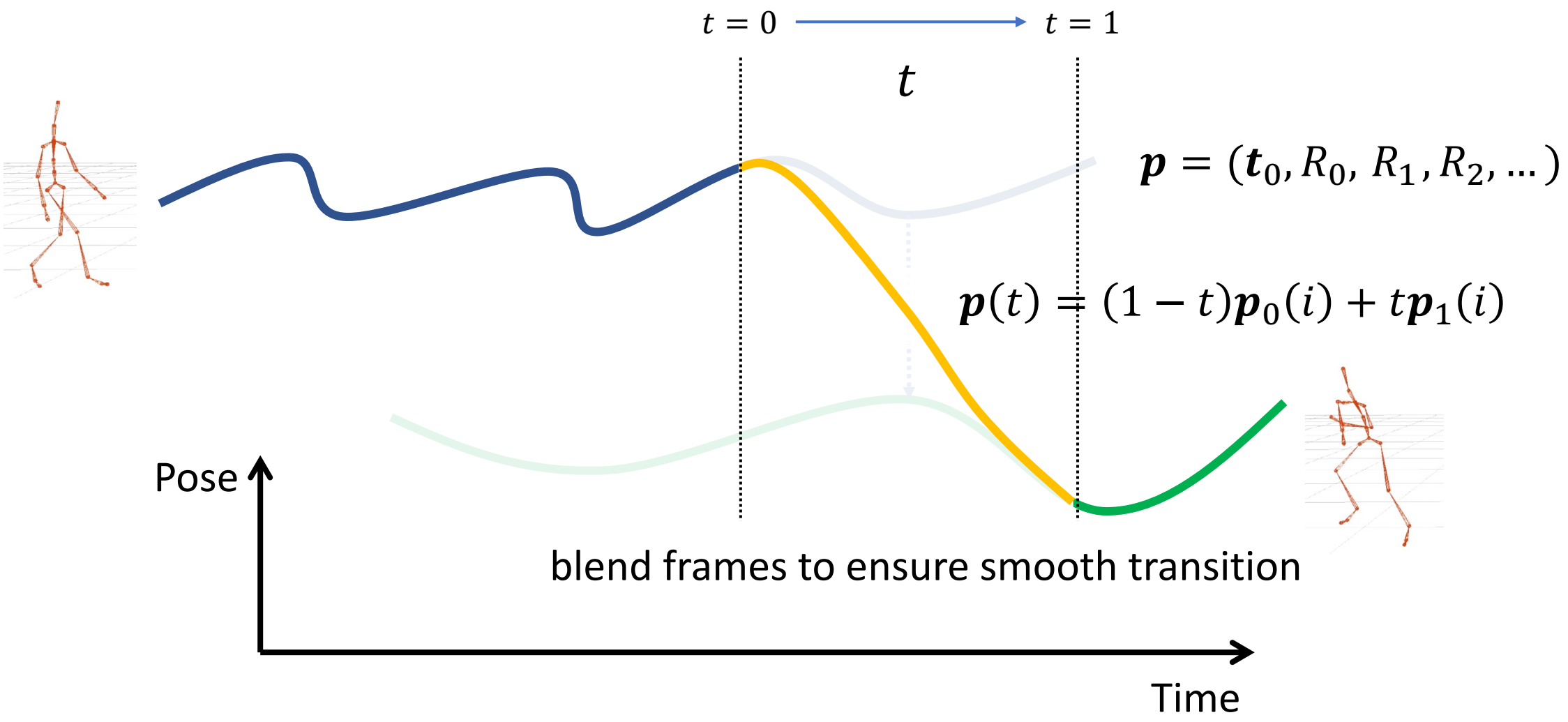
Motion Transition



Motion Transition



Motion Transition



Recall: Interpolation

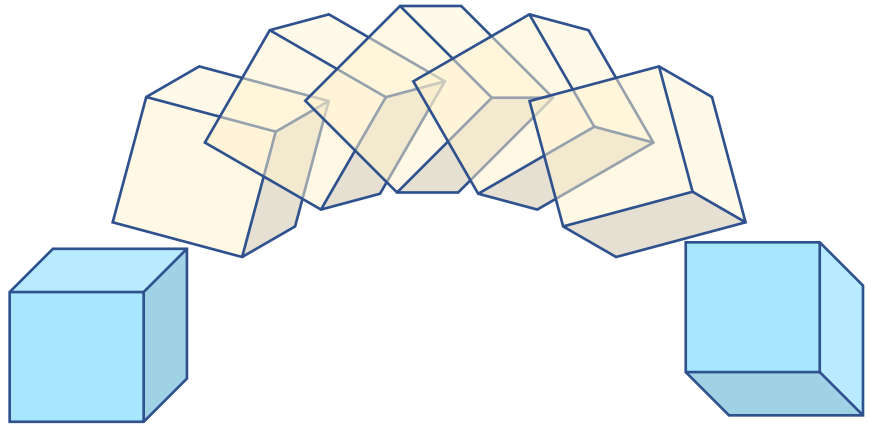
- Directly interpolate between rotation matrix R ?

$$R = (1-t)R_0 + tR_1$$

- Interpolated R is no longer a rotation matrix
  - Not orthogonal

- Solution?
  - interpolate between Euler Angle?

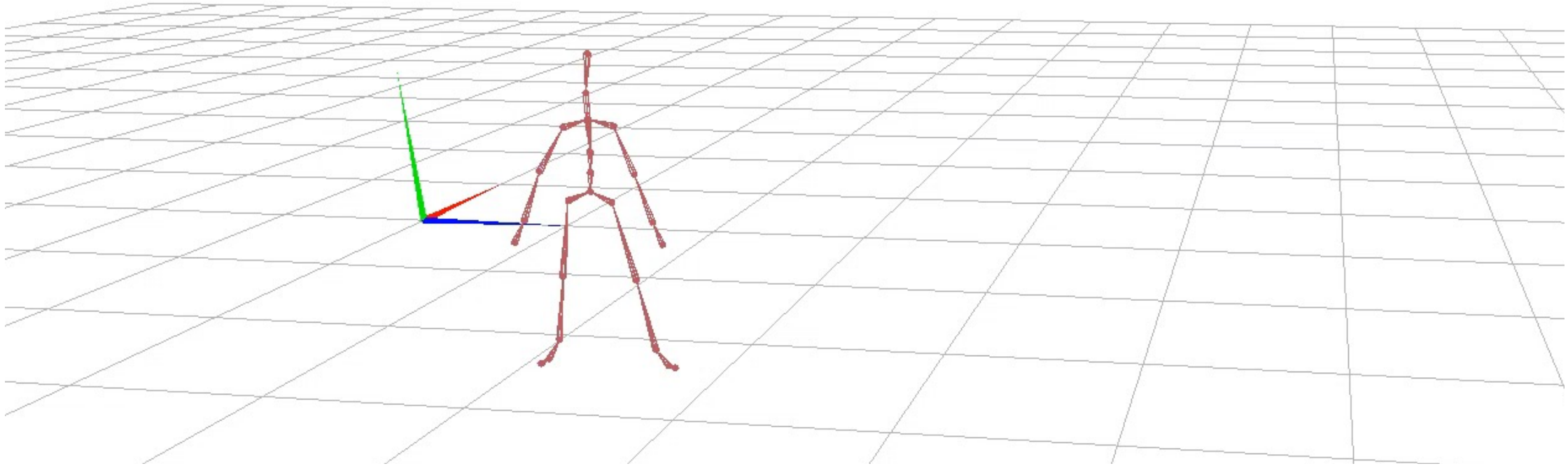
$$\begin{bmatrix}\theta\\ \varphi\\ \psi\end{bmatrix} = (1-t)\begin{bmatrix}\theta_0\\ \varphi_0\\ \psi_0\end{bmatrix} + t\begin{bmatrix}\theta_1\\ \varphi_1\\ \psi_1\end{bmatrix}$$



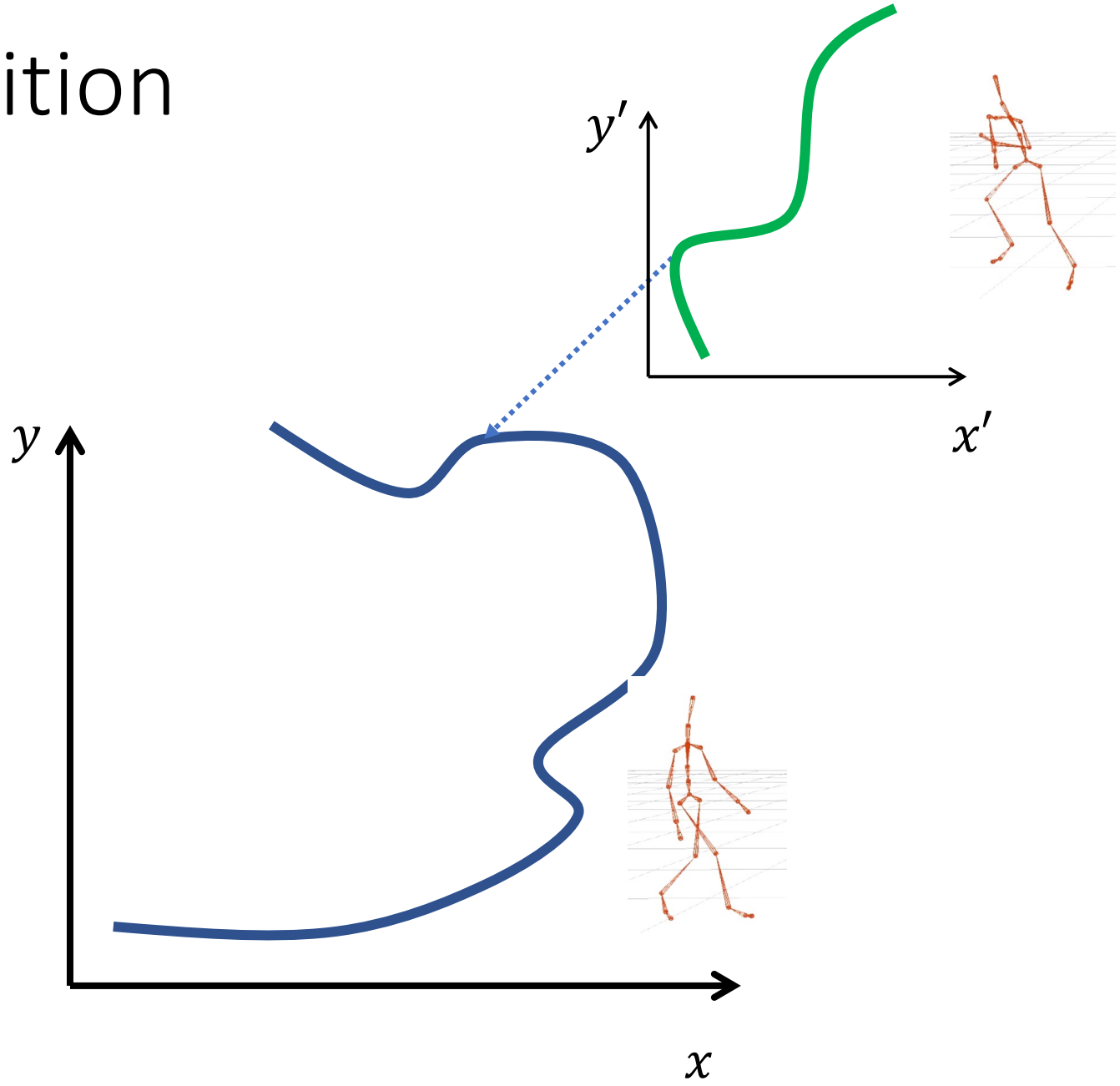
R_0 R_1

$\theta_0, \varphi_0, \psi_0$ $\theta_1, \varphi_1, \psi_1$

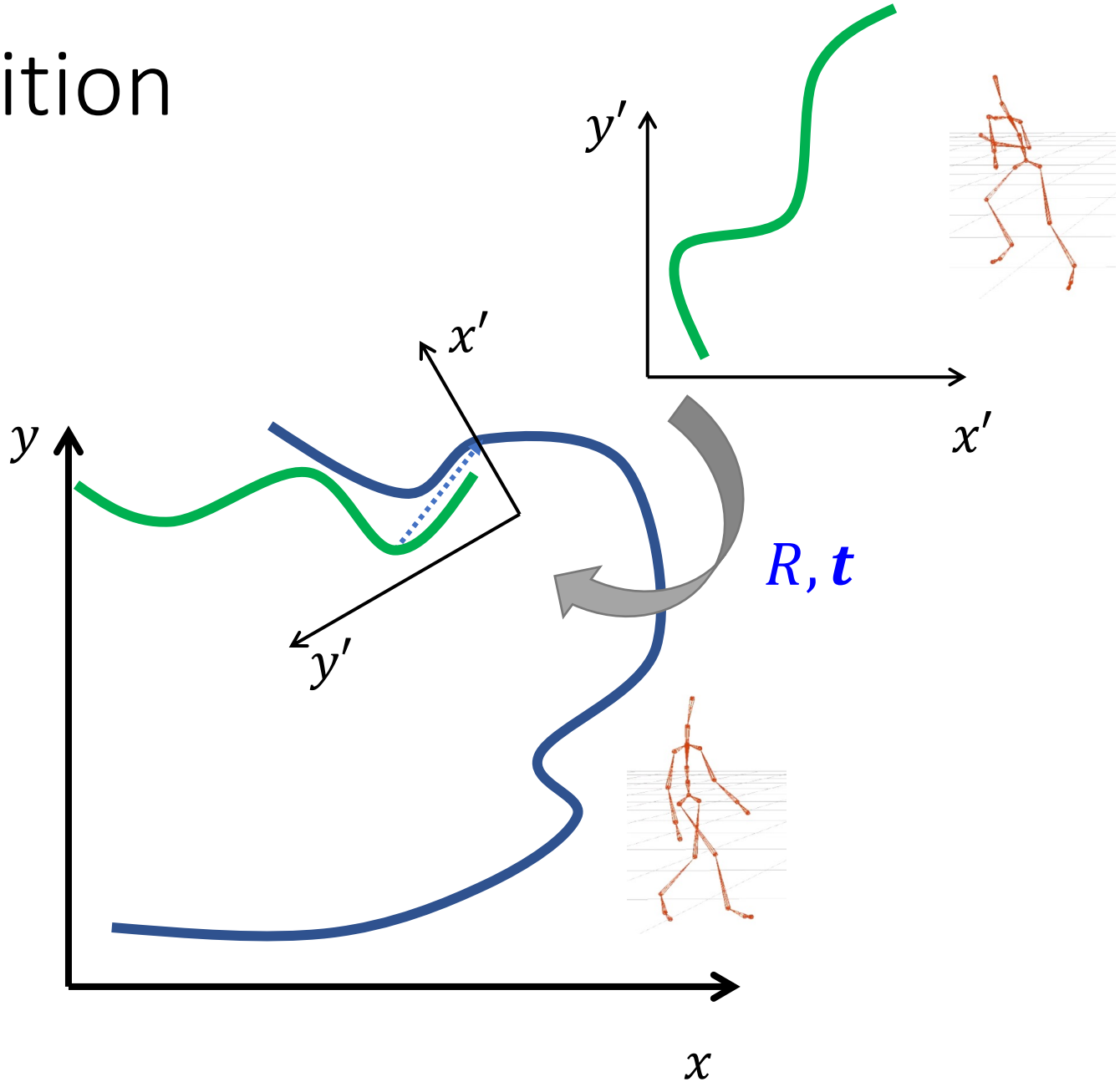
Motion Transition



Motion Transition

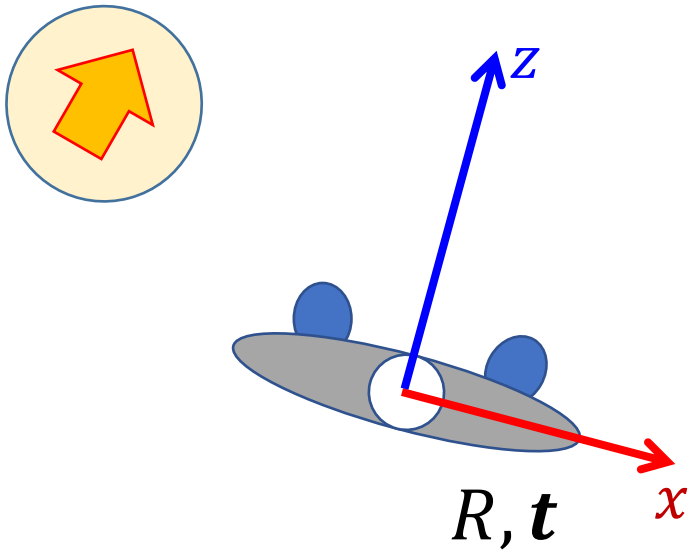


Motion Transition



“Facing Frame”

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



$$R = \theta \boldsymbol{e}_y$$

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

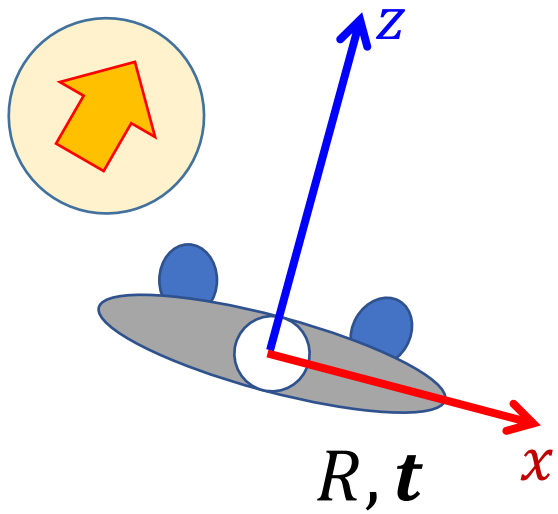
“Facing Frame”

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

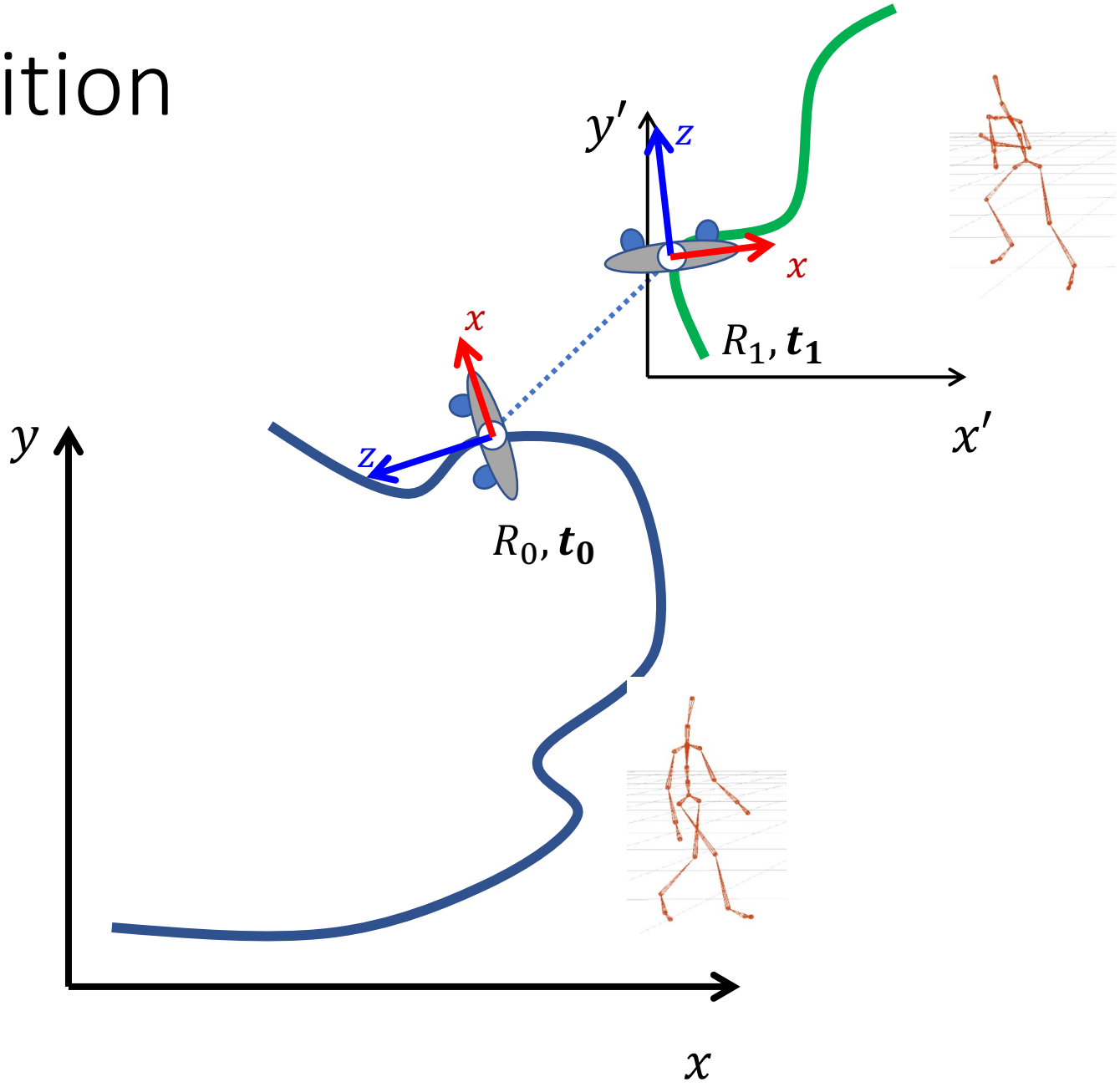
- Possible definitions of R
  - R is the y-rotation that aligns the z-axis of the global frame to the heading direction
  - R is the y-rotation that aligns x-axis of the global frame to the average direction of the vectors between shoulders and hips

$$R = \theta \boldsymbol{e}_y$$

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

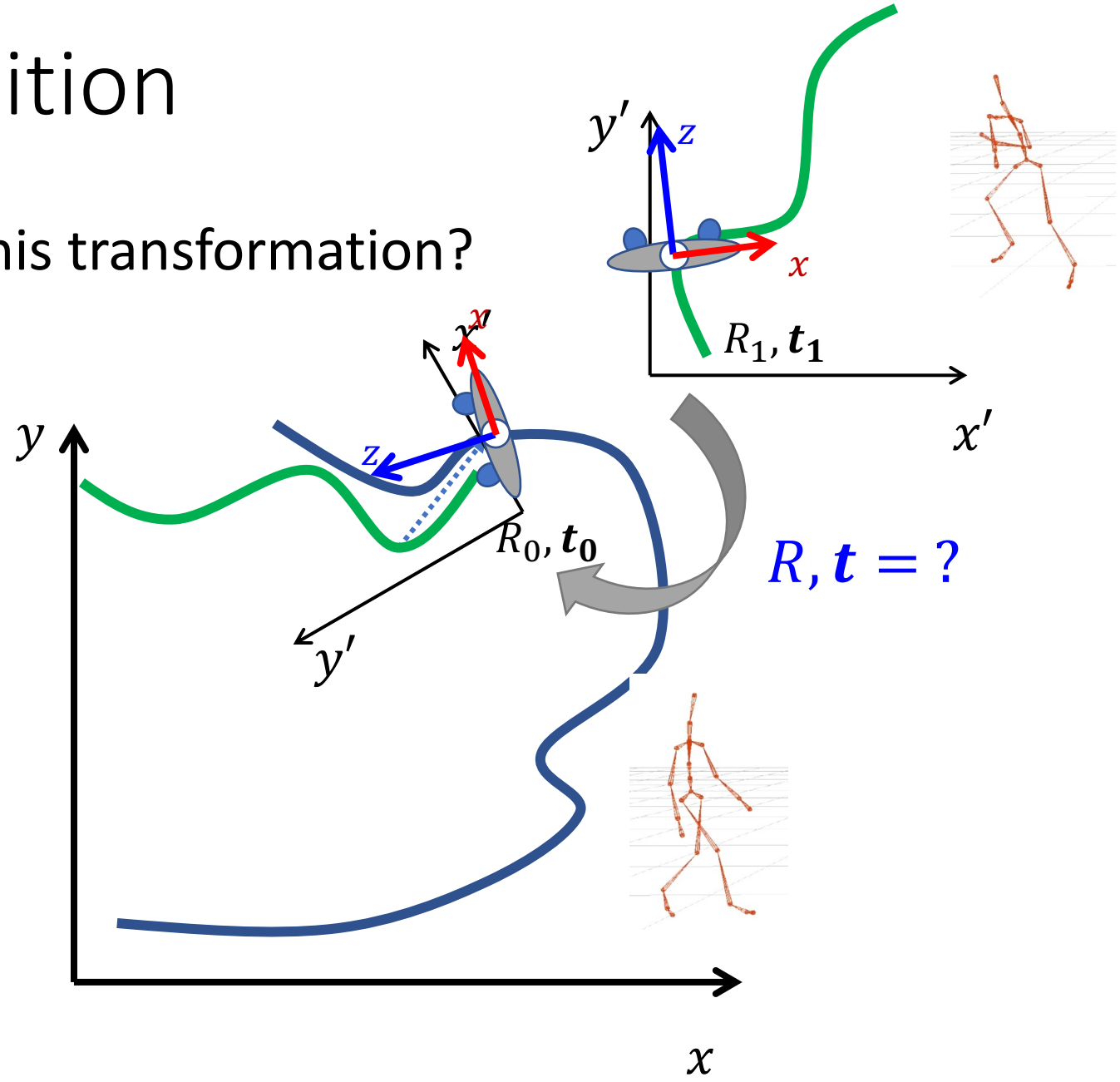


Motion Transition



Motion Transition

- How to compute this transformation?



Motion Transition

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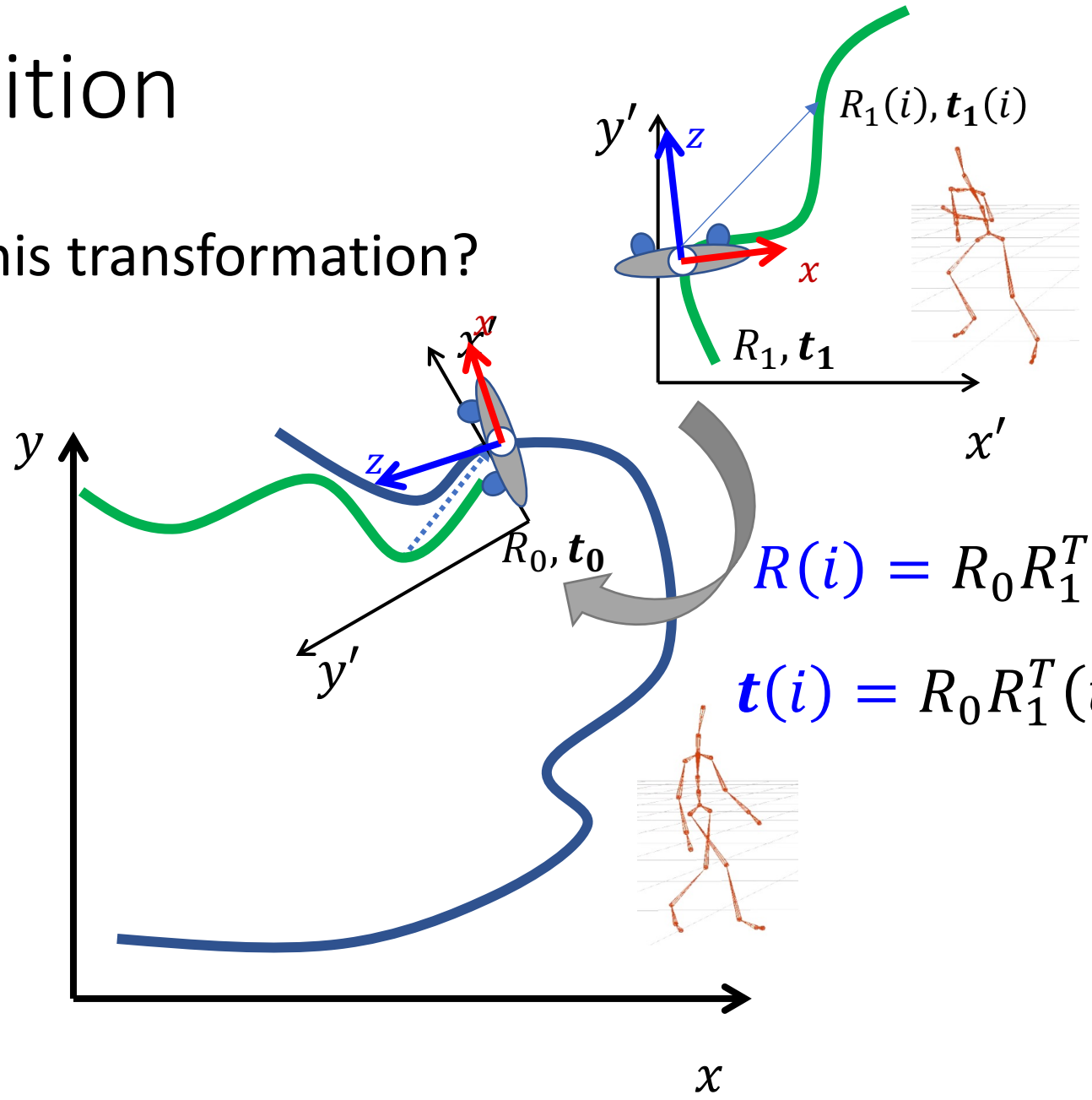
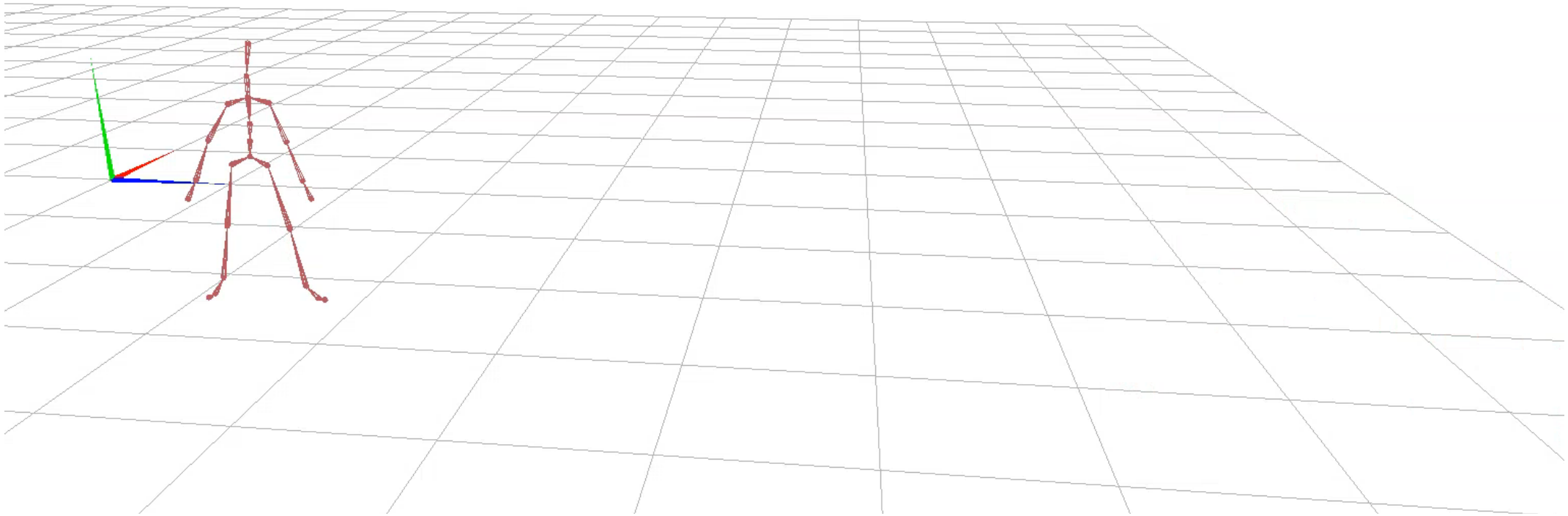


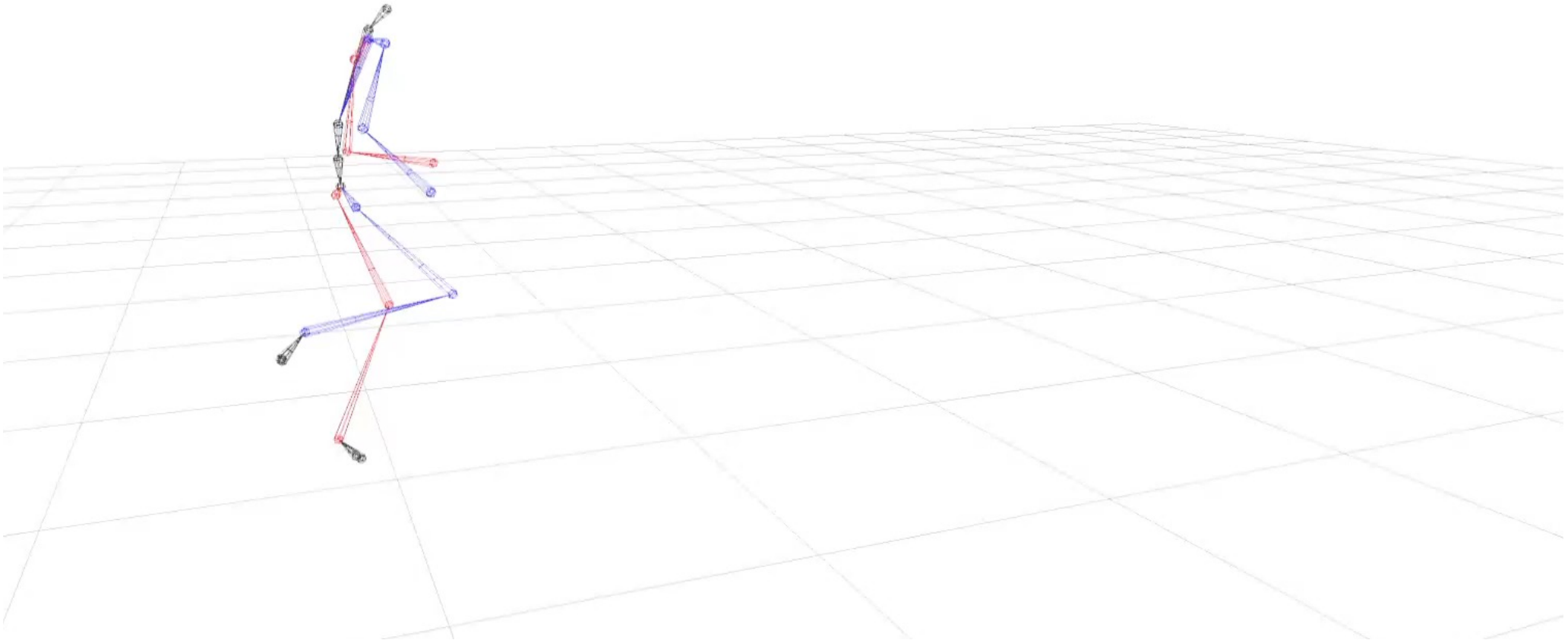
$$R(i) = R_0 R_1^T R_1(i)$$

$$\boldsymbol{t}(i) = R_0 R_1^T (\boldsymbol{t}_1(i) - \boldsymbol{t}_1) + \boldsymbol{t}_0$$

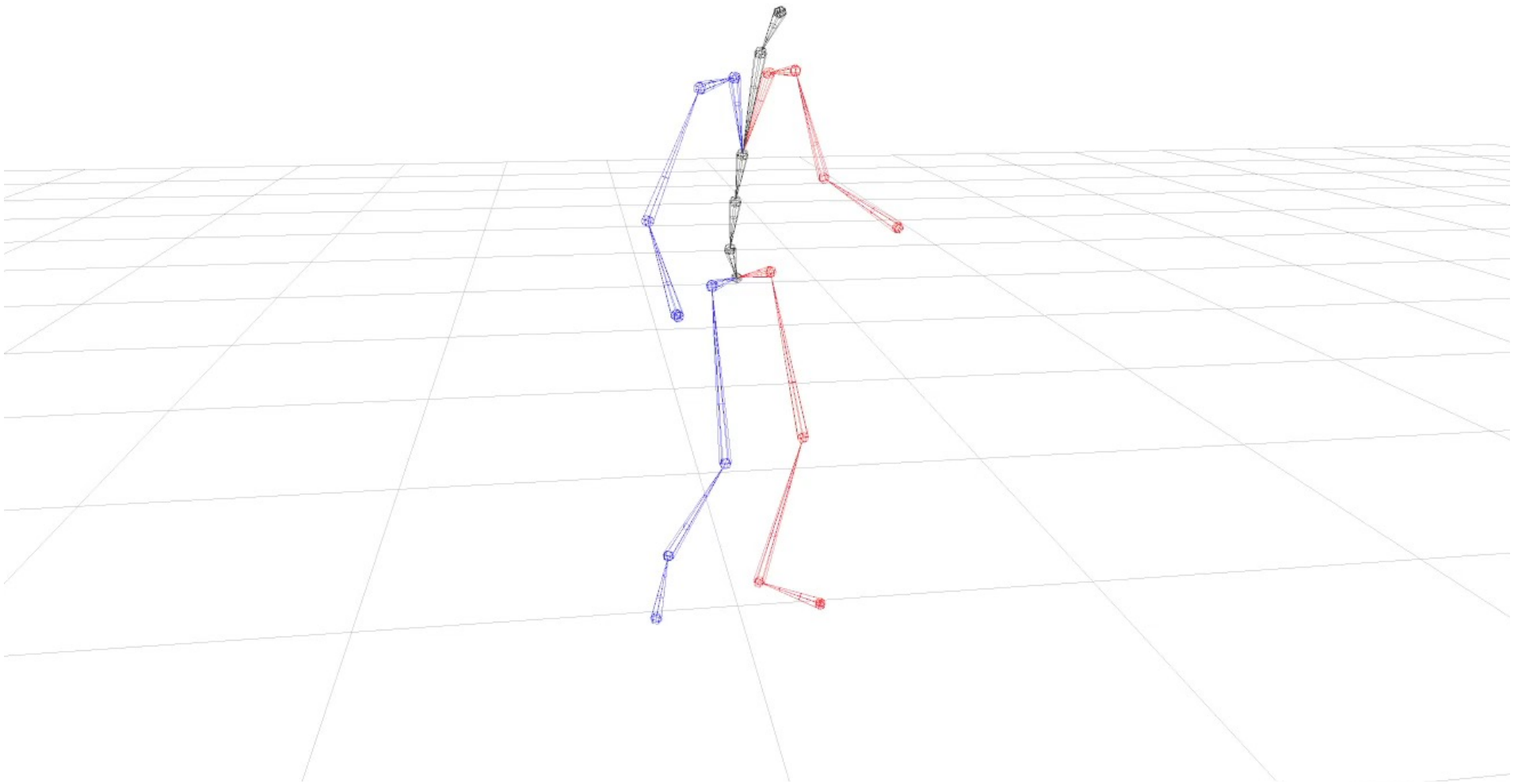
Motion Transition



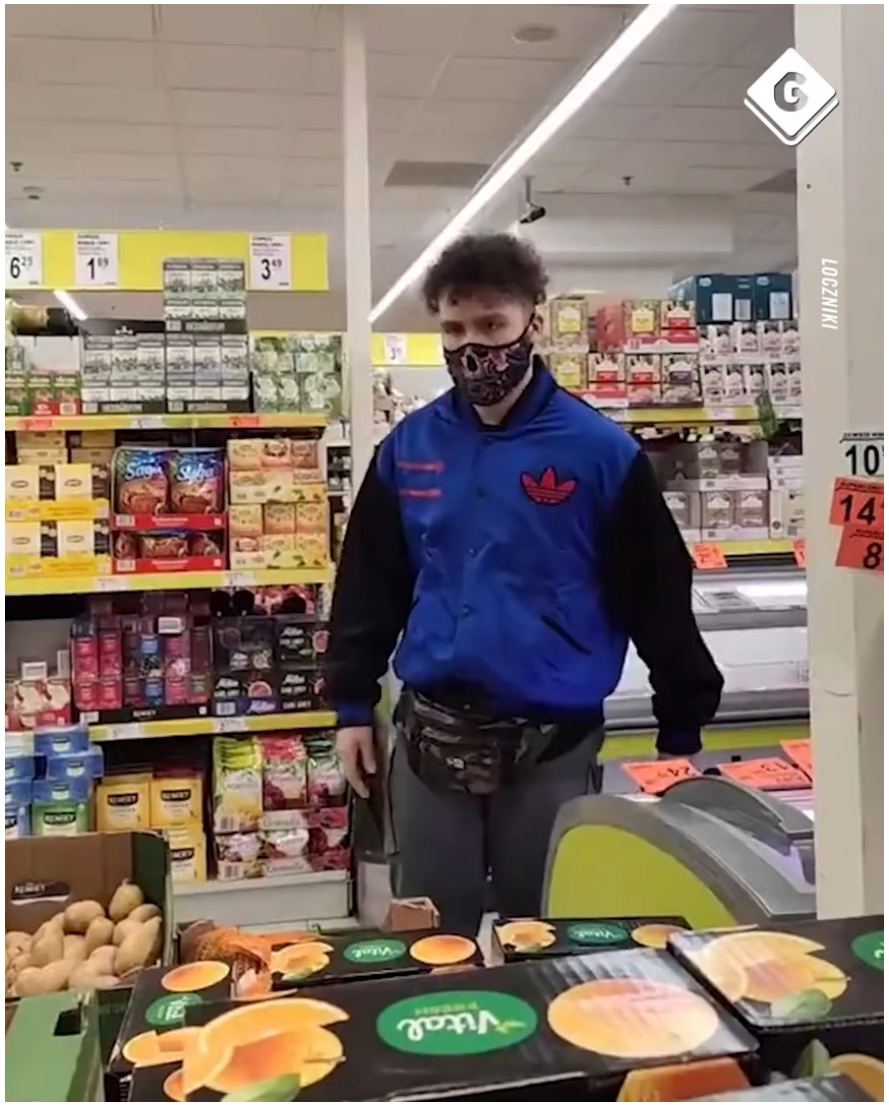
Motion Transition



Motion Data without Root Translation

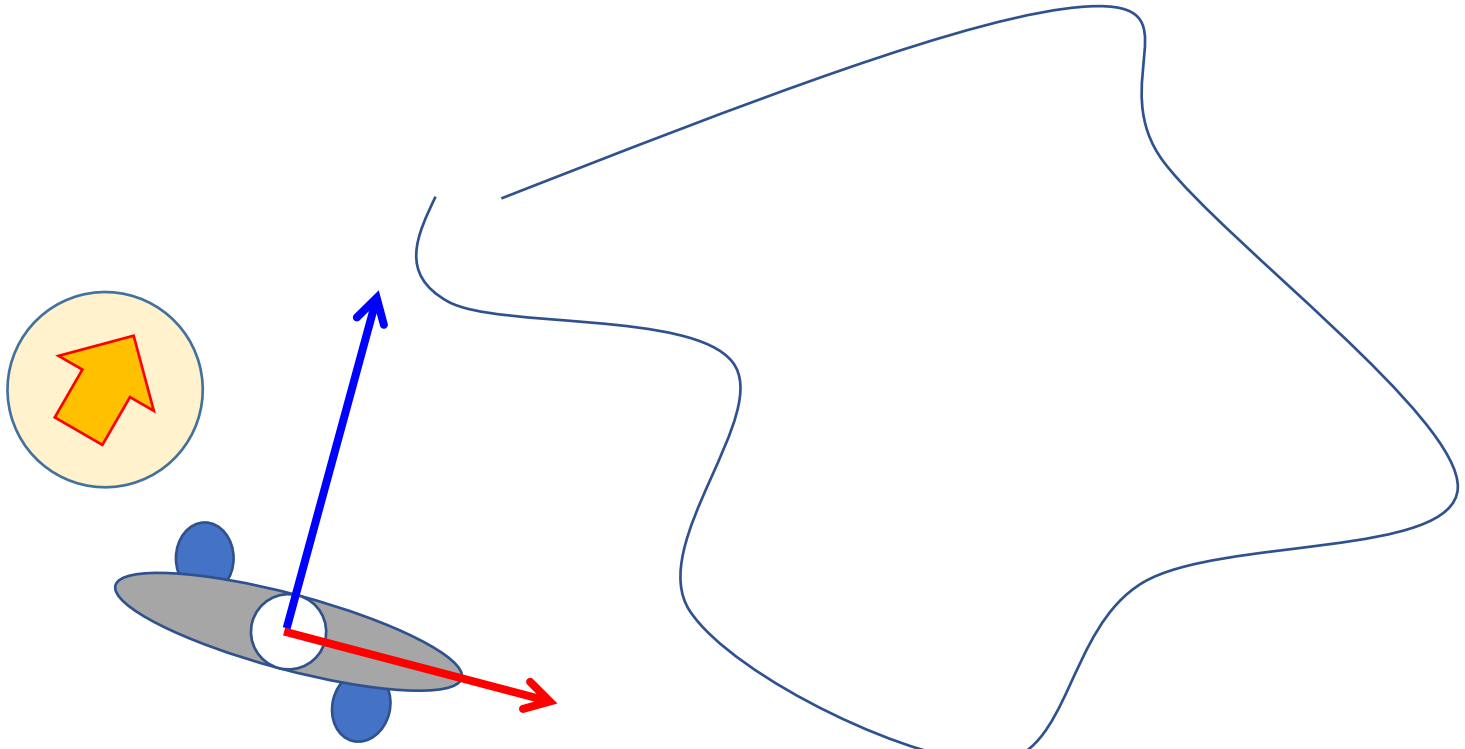


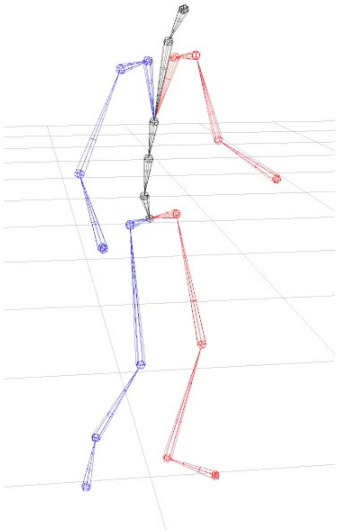
Motion Data without Root Translation



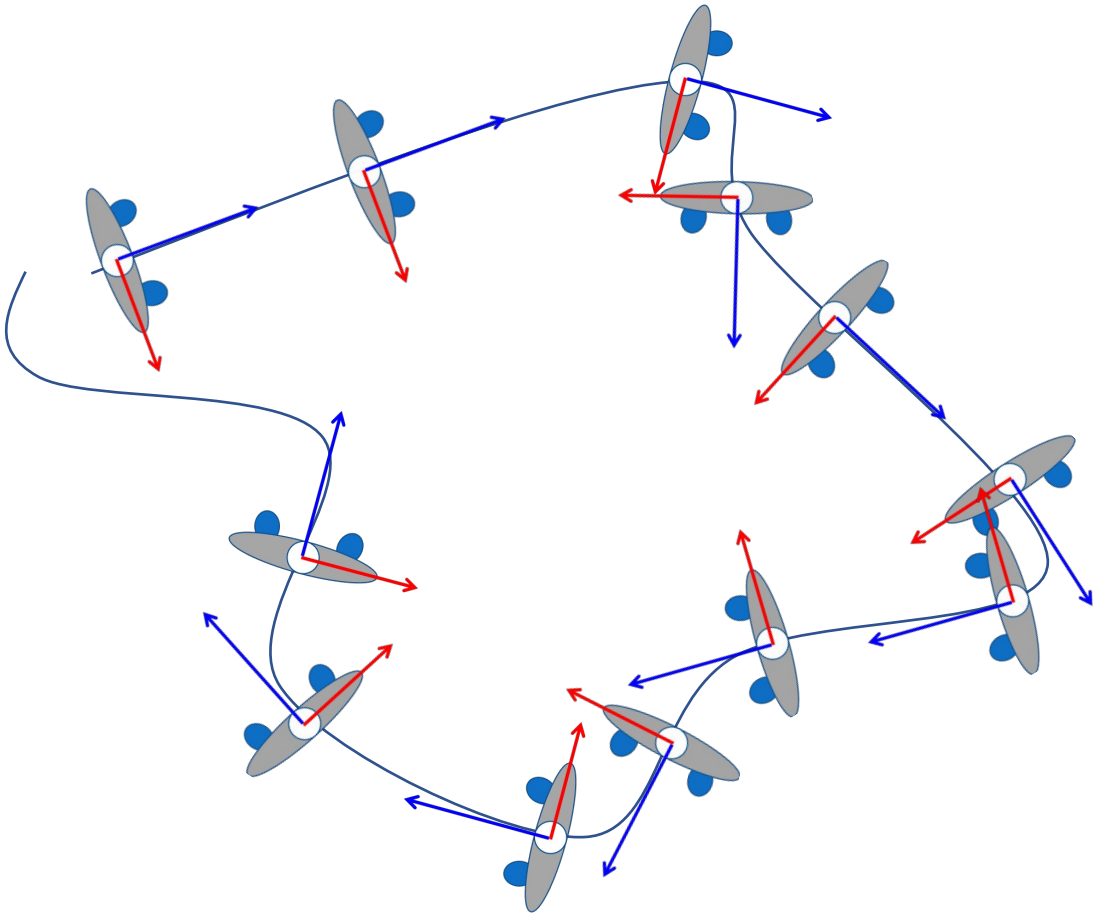
Let's bring back gta characters to real life
https://www.youtube.com/watch?v=DeutKhta1Uo

Path Fitting



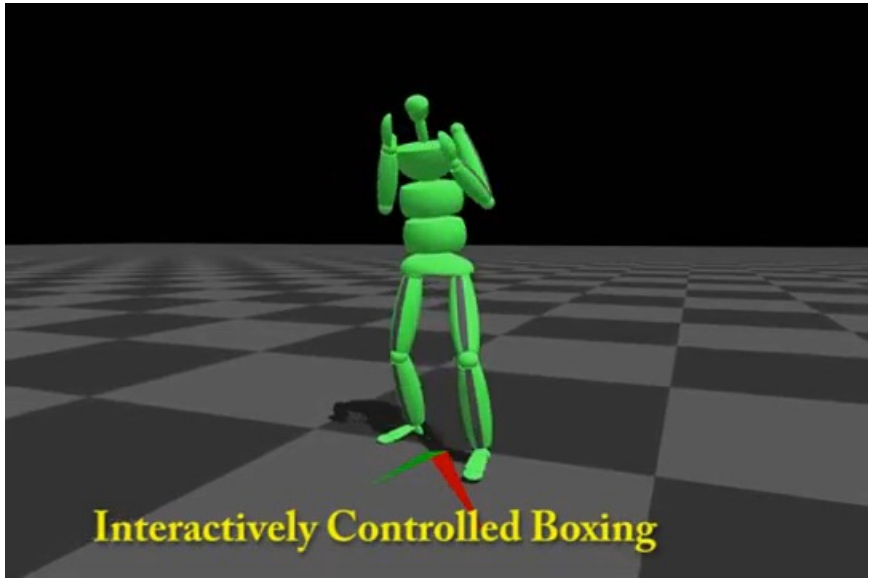


Path Fitting

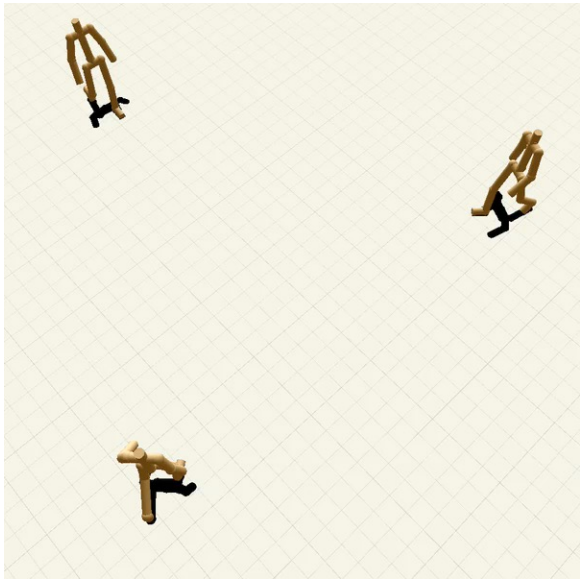


Motion Composition

- 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]

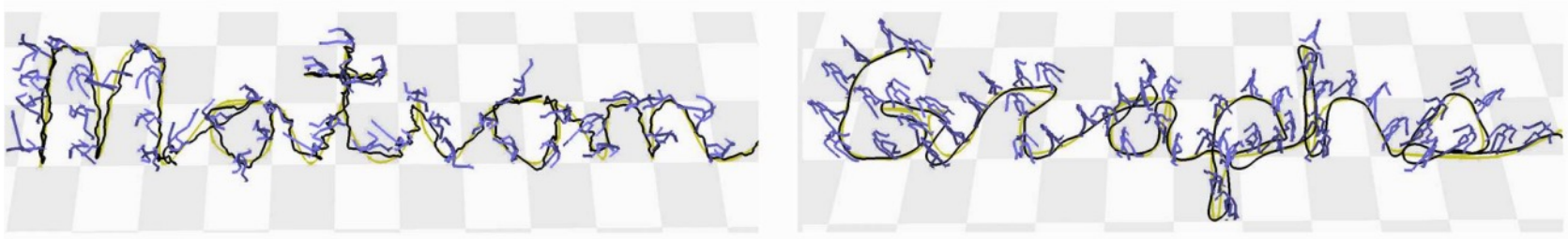
Motion Graphs

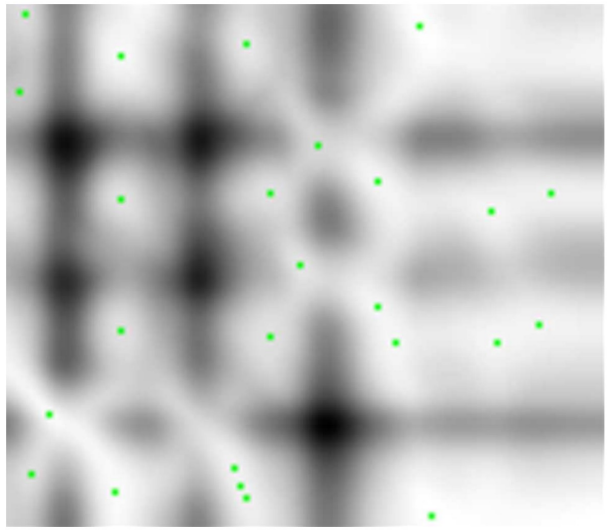
Motion Graphs

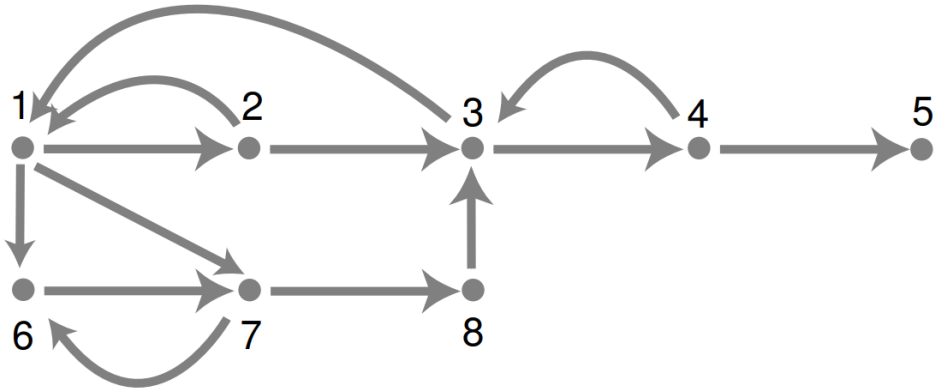
Lucas Kovar
University of Wisconsin-Madison

Michael Gleicher*
University of Wisconsin-Madison

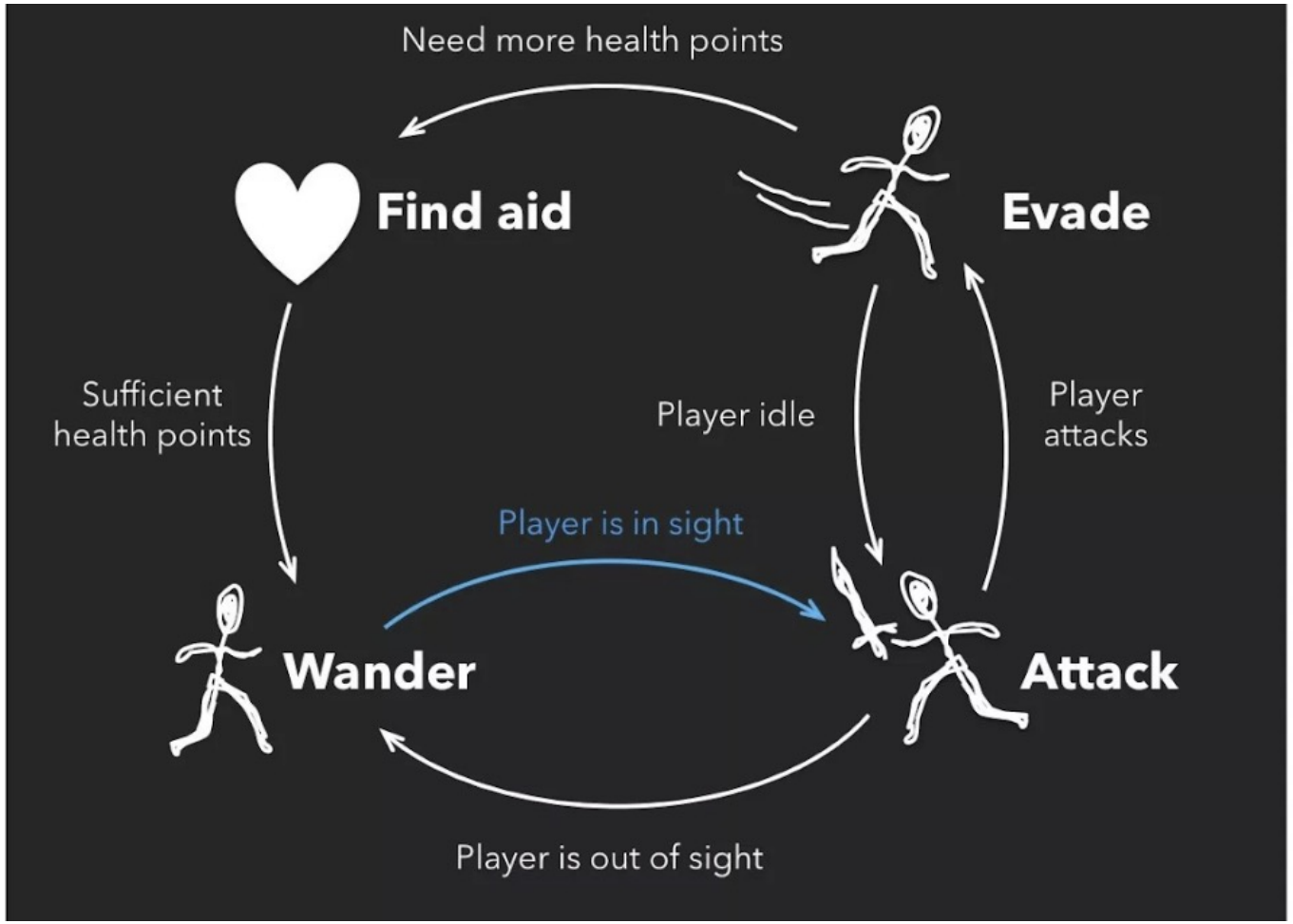
Frédéric Pighin†
University of Southern California
Institute for Creative Technologies





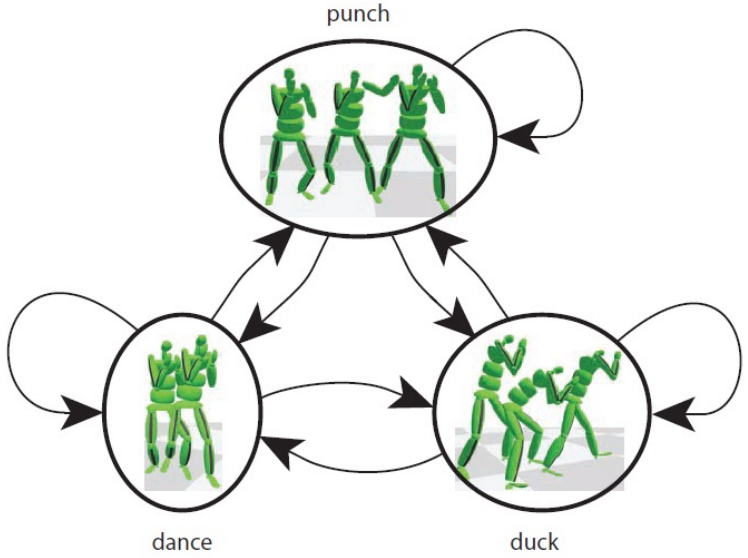


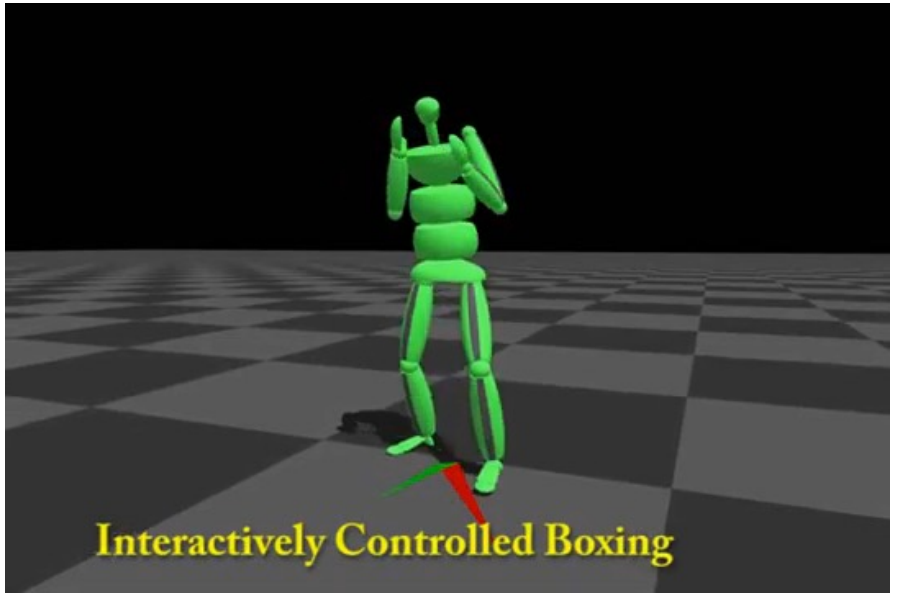
Motion Graphs



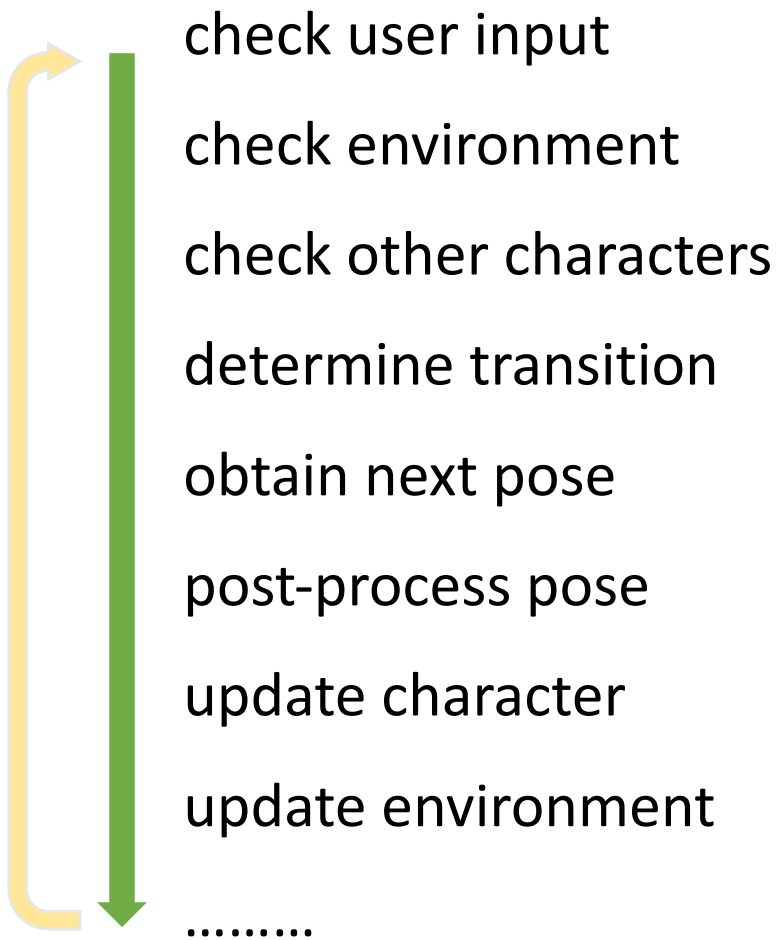
Motion Synthesis

- 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

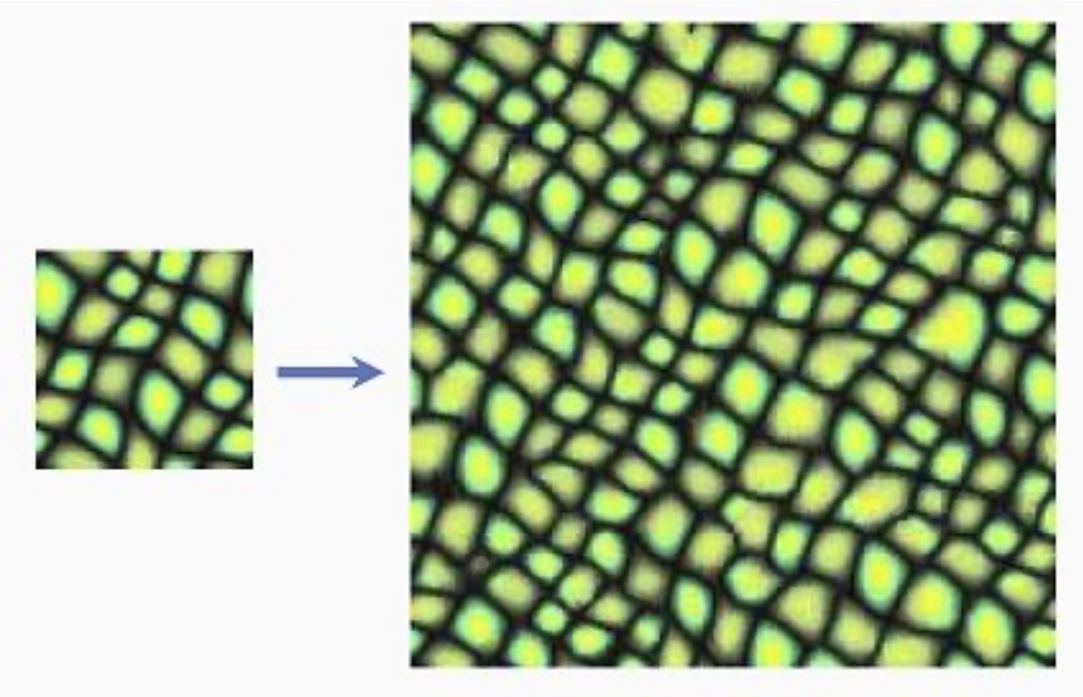


Motion Matching?

Texture Synthesis: How to make it seamless?

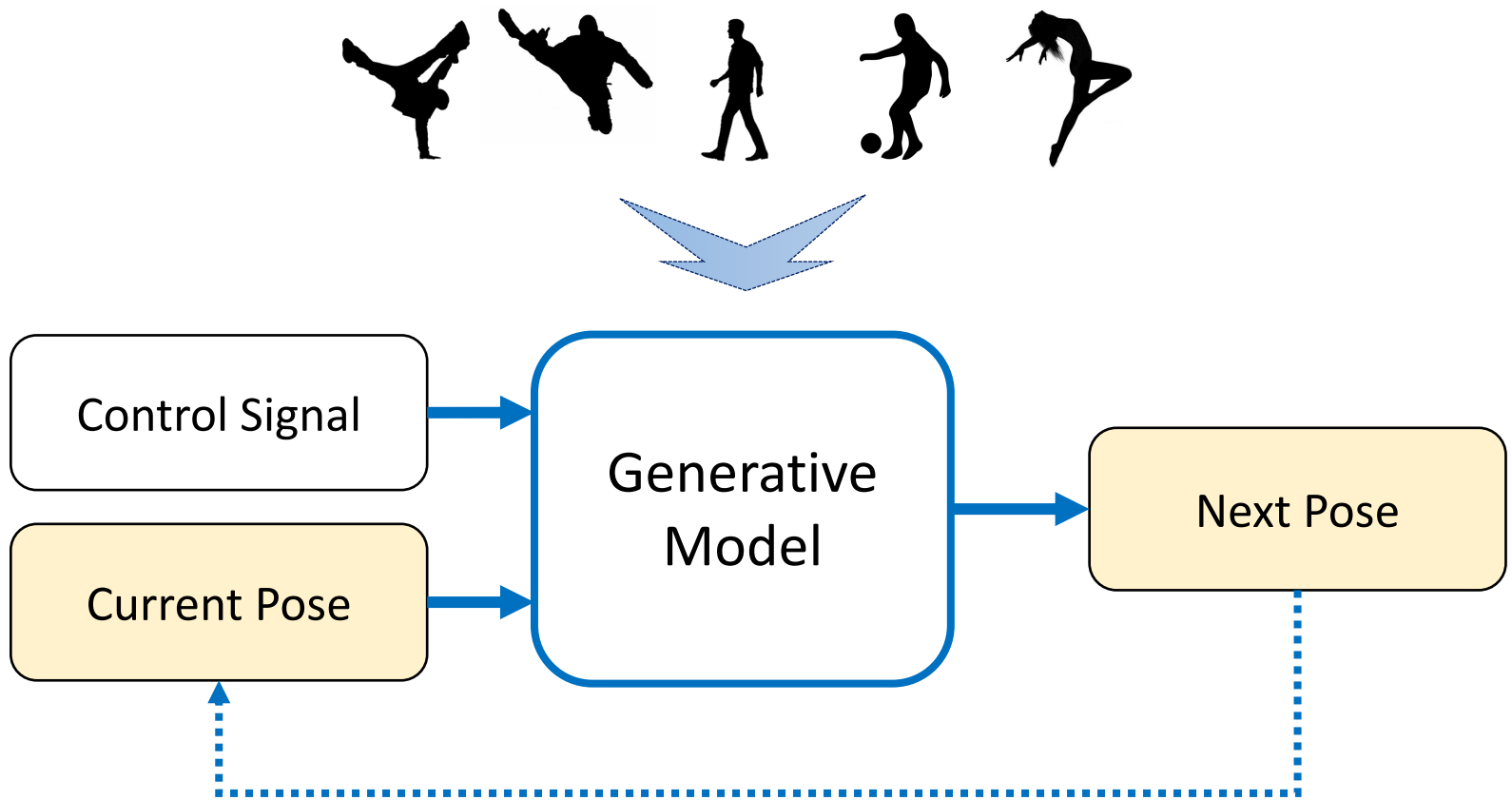
- Manually take care of the edges, or flip it!
- Texture synthesis (big research subject!)

From imgonline.com

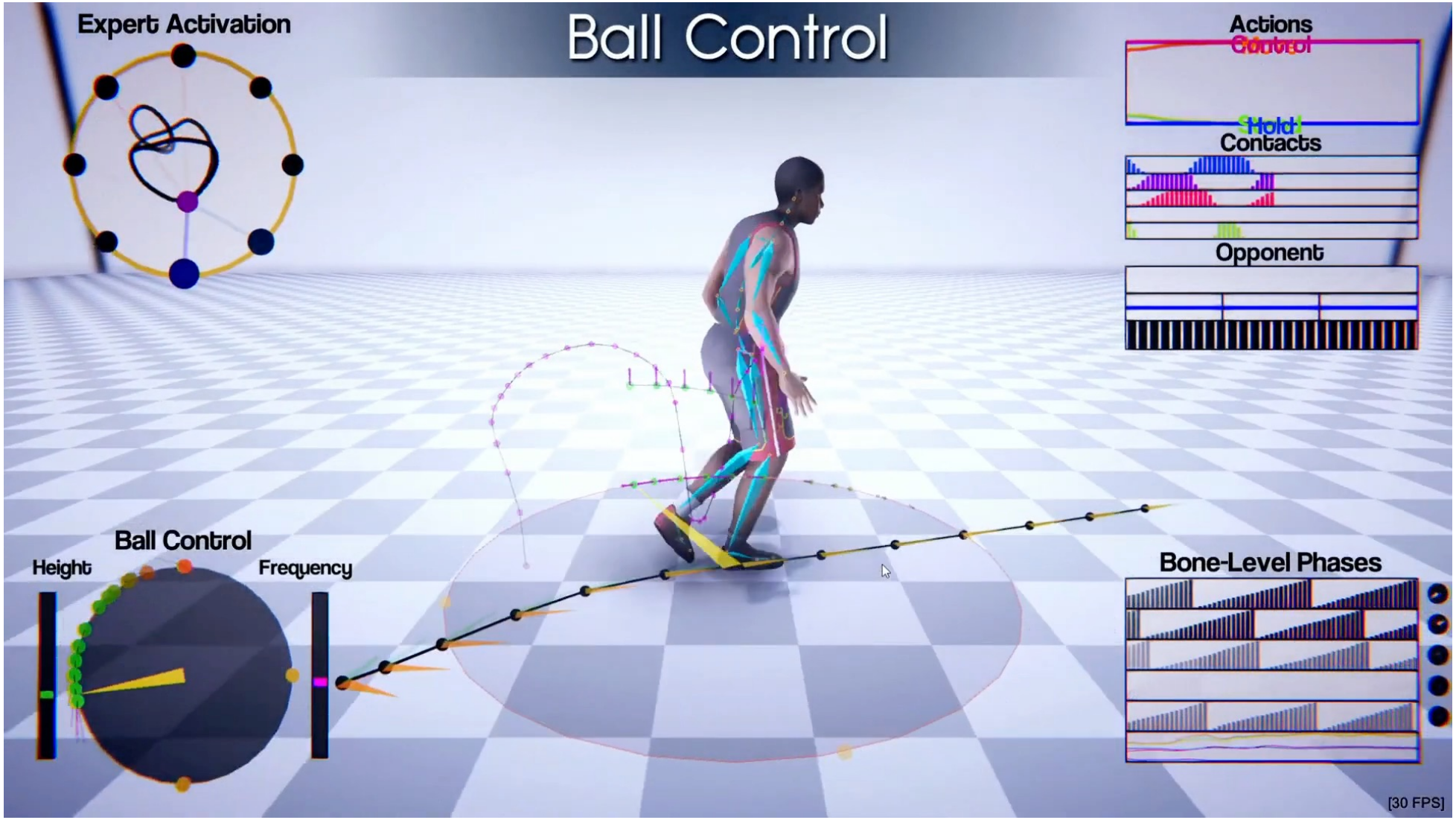


Texture synthesis

Learning-based Approaches



Learning-based Approaches



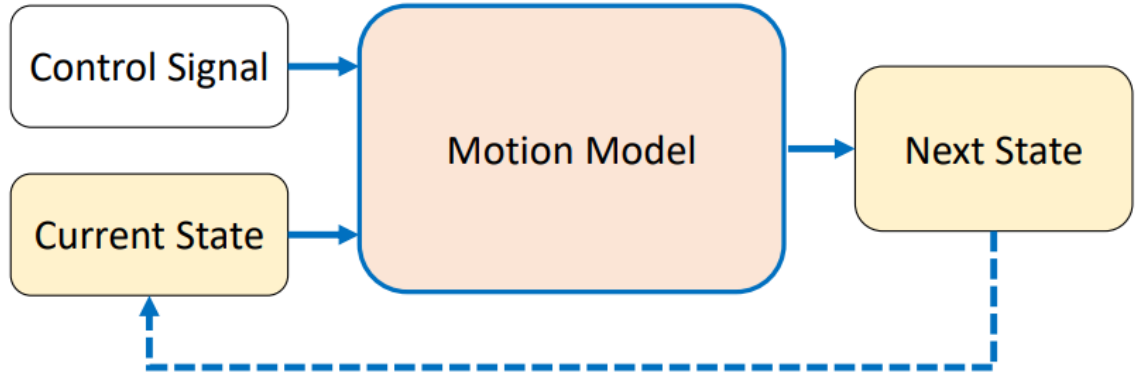
[Starke et al 2020, Local Motion Phases for Learning Multi-Contact Character Movements]

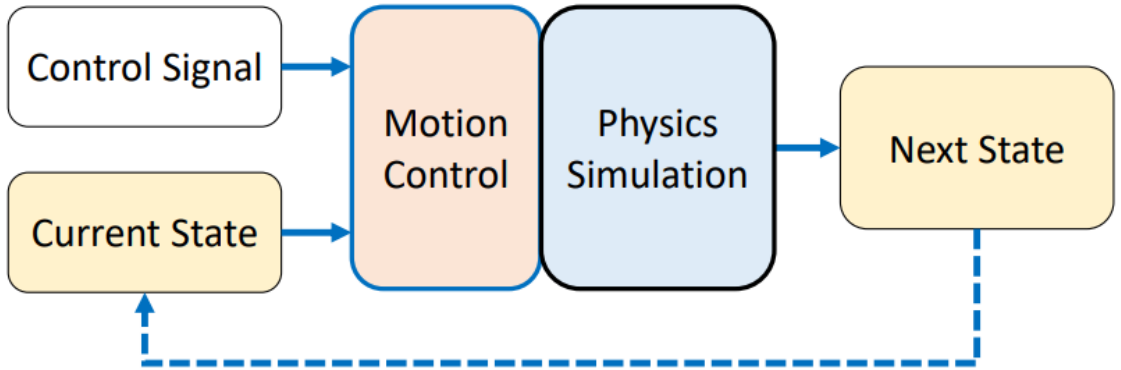
Outline

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

Character Animation Methods

- Kinematics:
  - Keyframe Animation, Inverse Kinematics
  - Motion Capture, Motion Retargeting
  - Motion Graphs, Motion Matching
- Learning-based Methods:
  - Generative Models
- Dynamics:
  - Physics-based motion control

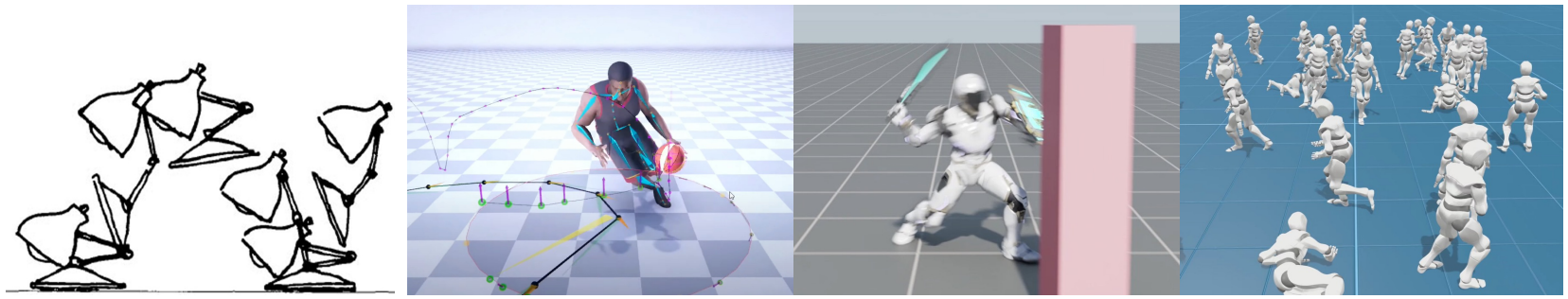




Character Animation & Motion Simulation
角色动画与运动仿真

Libin Liu

School of Intelligence Science and Technology
Peking University



Character Animation & Motion Simulation
角色动画与运动仿真

- 2 credits
- Instructor: Libin Liu (http://libliu.info)
- Prerequisites:
  linear algebra, calculus,
  programming skills (python),
  probability theory, mechanics,
  ML, RL…

Introduction to Character Animation
Rotation, Transformation, and Forward Kinematics
Inverse Kinematics
Keyframe Character Animation
Data-driven Character Animation
Learning-based Character Animation
Skinning and Facial Animation
Physics-based Simulation and Articulated Rigid Bodies
Actuating Character and Feedback Control
Learning to Walk with Simplified Models
Optimal Control and Trajectory Optimization
Reinforcement Learning and Multiskilled Characters

Character Animation & Motion Simulation

角色动画与运动仿真

- What will not be covered
  - How to use Maya/Motion Builder/Houdini/Unity/Unreal Engine…
  - How to become an animator

- What will be covered
  - Methods, theories, and techniques behind animation tools
    - Kinematics of characters
    - Physics-based simulation
    - Motion control

  - Ability to create an interactive character

Questions?