

Lecture 01:
Introduction to
3D Character Animation

Libin Liu

School of Intelligence Science and Technology
Peking University



GAMES105 课程交流



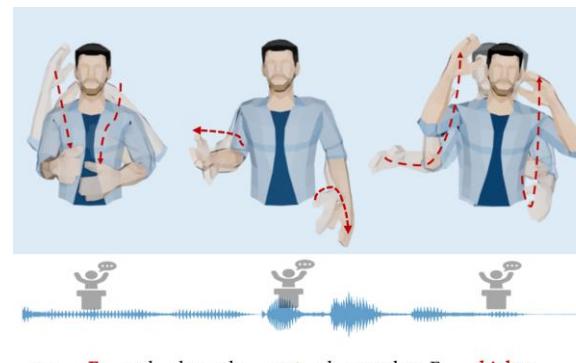
VCL @ PKU

Instructor



Libin Liu 刘利斌

- Assistant Professor
- School of Intelligence Science and Technology,
Peking University
- <http://libliu.info>



an F and please do not play another F higher ...



VCL @ PKU

Welcome & Course Information

- Instructor: Libin Liu (<http://libliu.info>)
- Website: <https://games-105.github.io/>
- Lecture: Monday 8:00PM to 9:00PM (12 Weeks)
- Prerequisites: linear algebra, calculus, programming skills (python), probability theory, mechanics, ML, RL...
- Exercise:
 - Codebase: <https://github.com/GAMES-105/GAMES-105>
 - Submission: <http://cn.ces-alpha.org/course/register/GAMES-105-Animation-2022/>
 - Register code: **GAMES-FCA-2022**
- BBS: <https://github.com/GAMES-105/GAMES-105/discussions>
- QQ Group: 533469817



群名称:GAME105课程交流群
群号:533469817

What is Character Animation



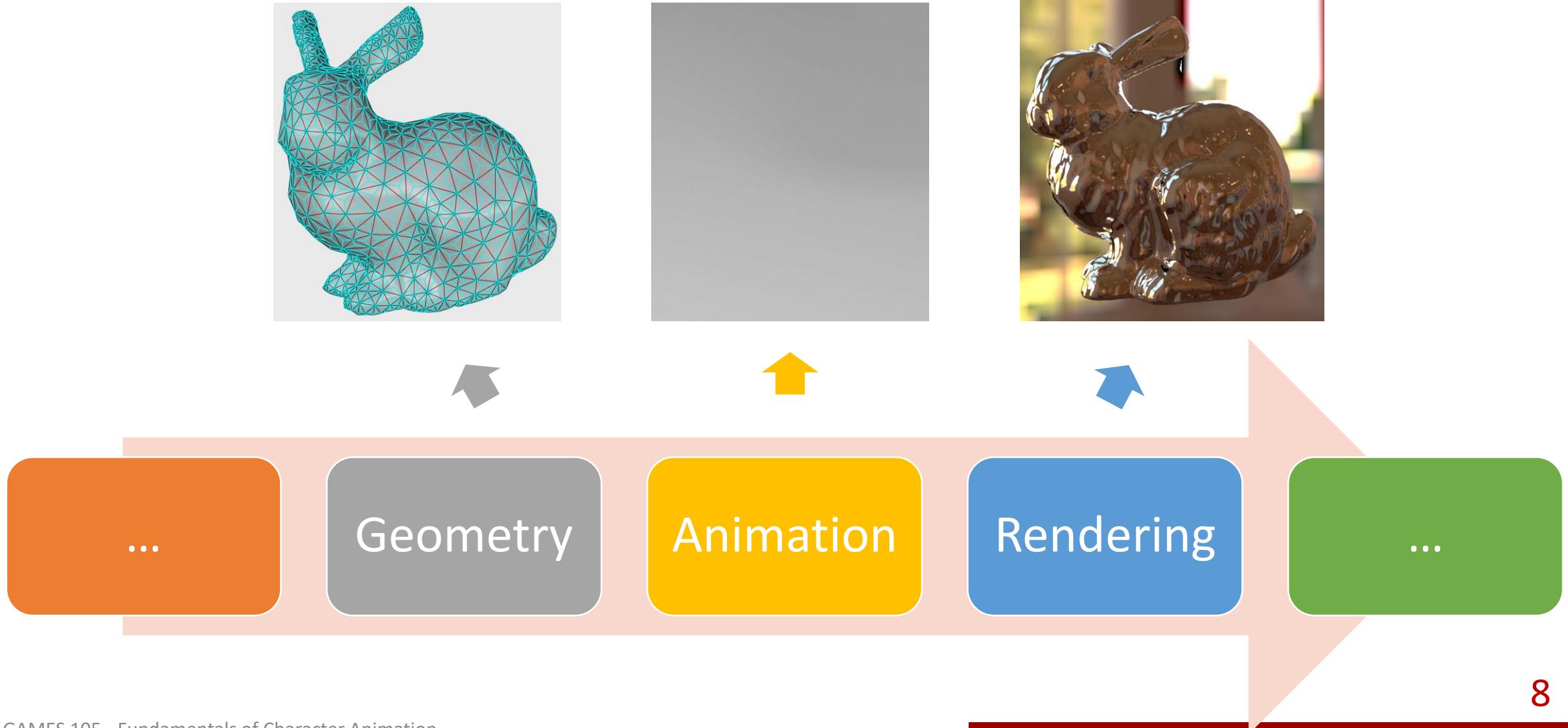
What is Character Animation



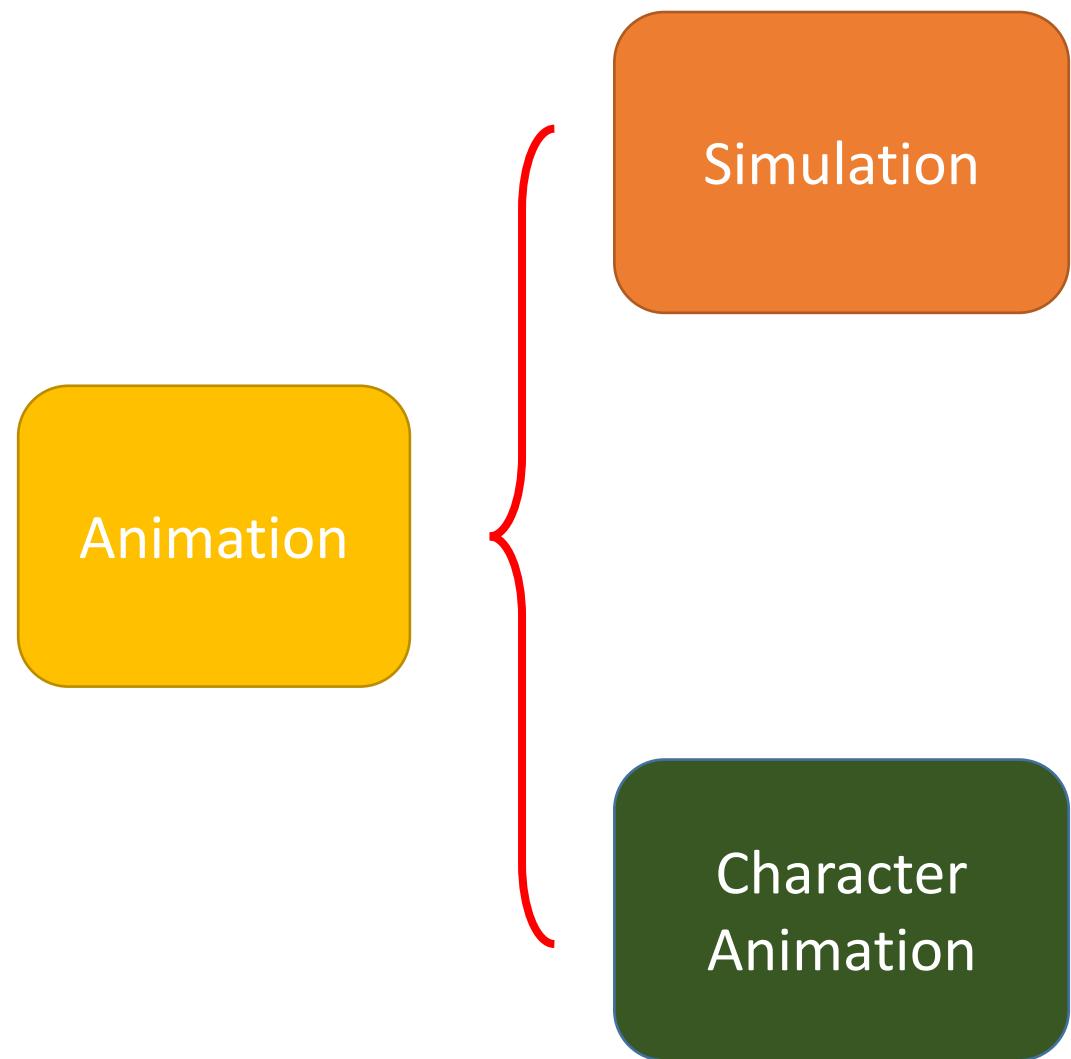
What is Character Animation



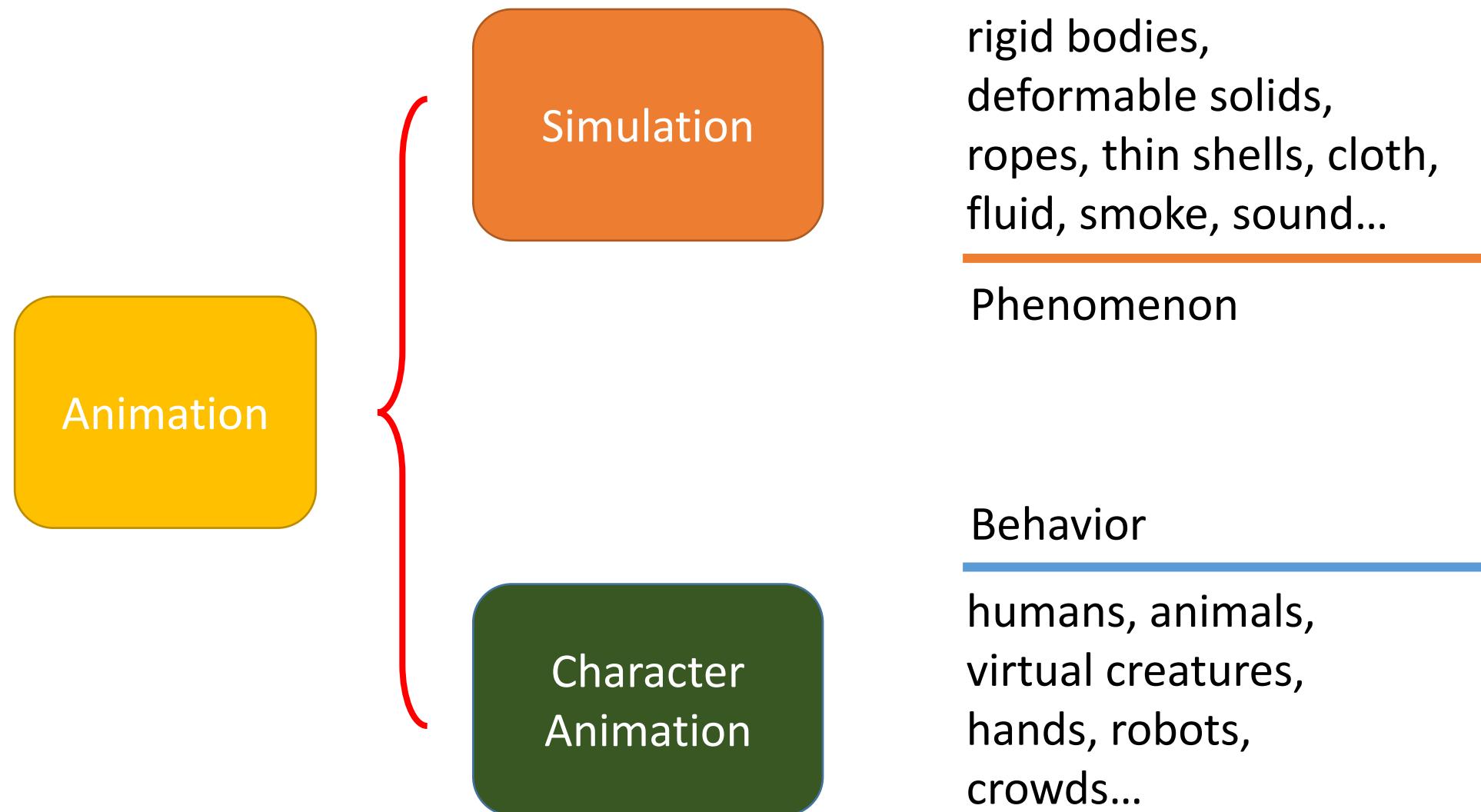
3D Computer Graphics



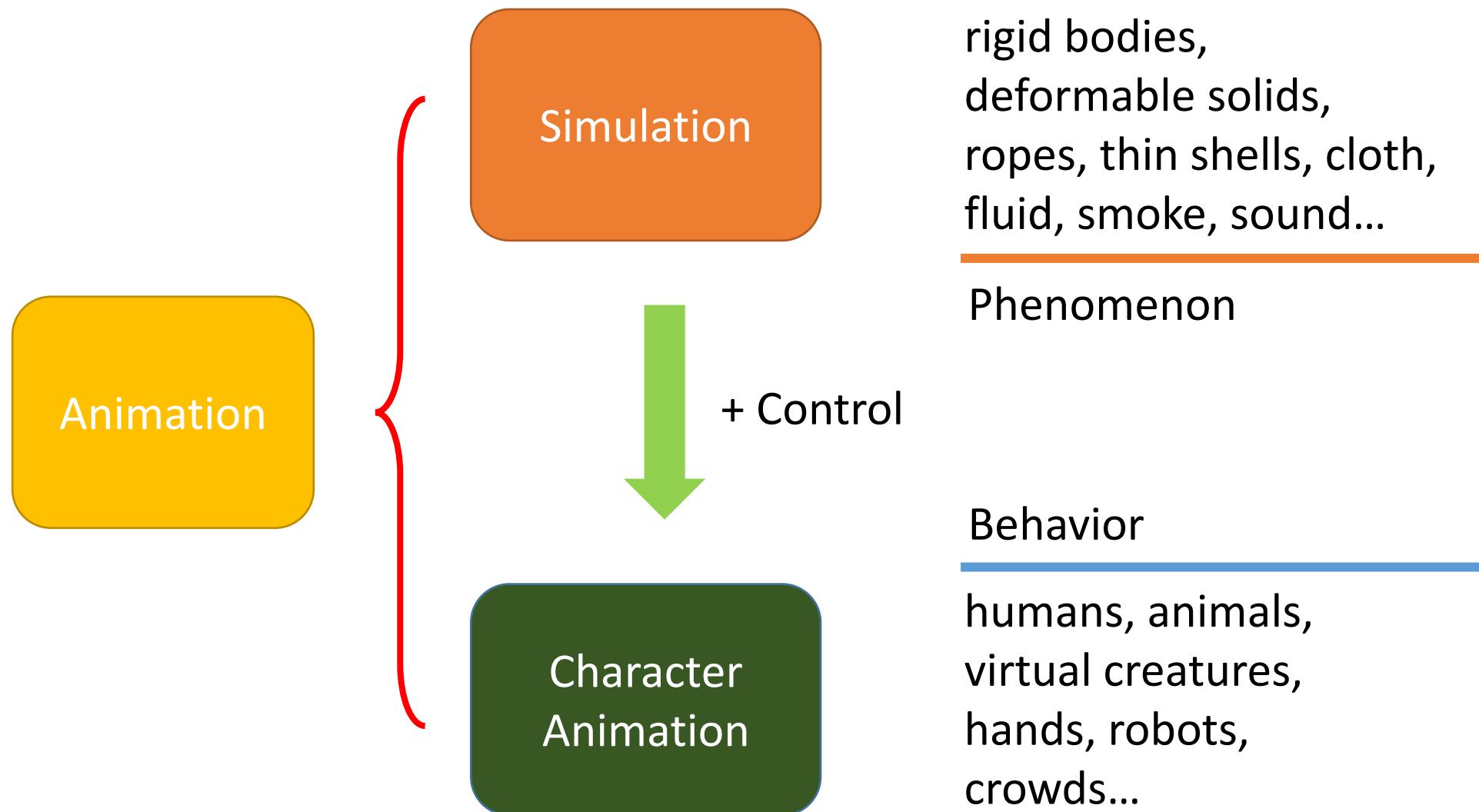
3D Computer Animation



3D Computer Animation

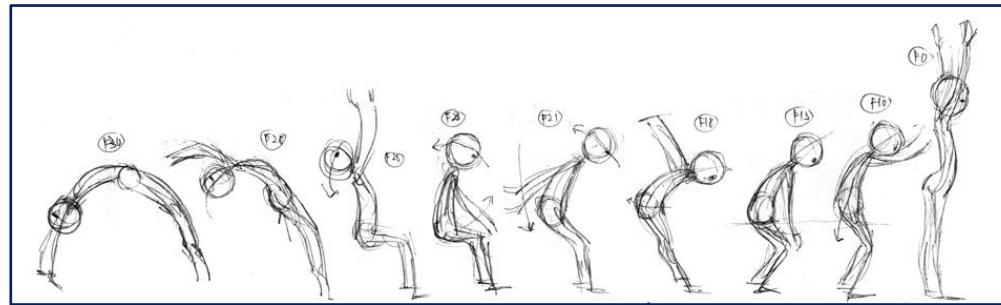


3D Computer Animation

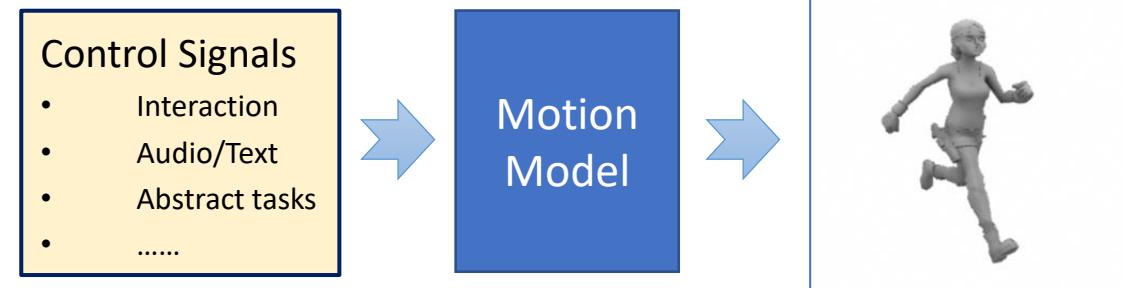


Why Do We Study Character Animation

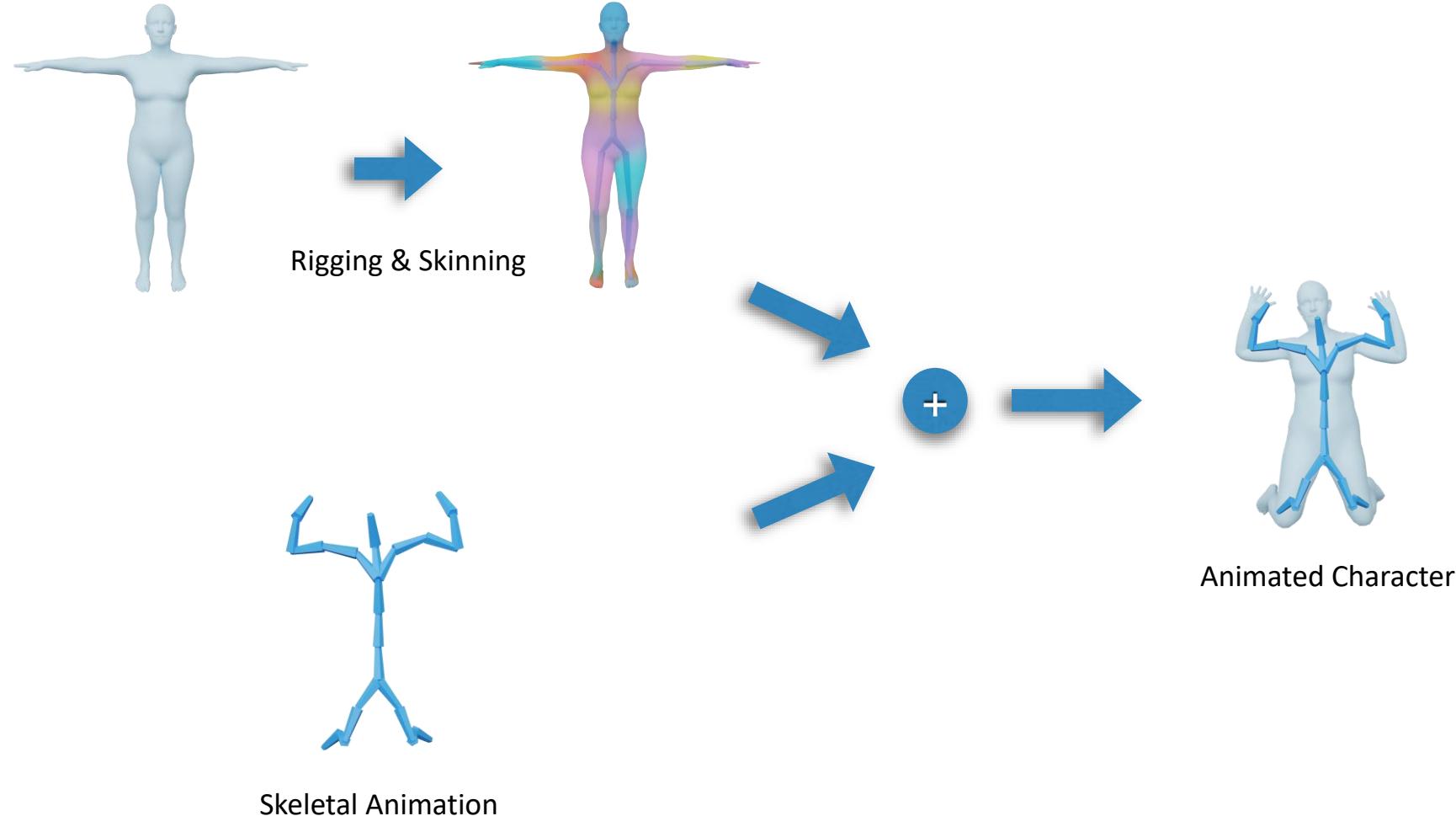
- A character typically has 20+ joints, or 50-100+ parameters
 - It is not super high-dimensional, so most animation can be created manually, by posing the character at keyframes
 - **Labor-intensive, not for interactive applications**



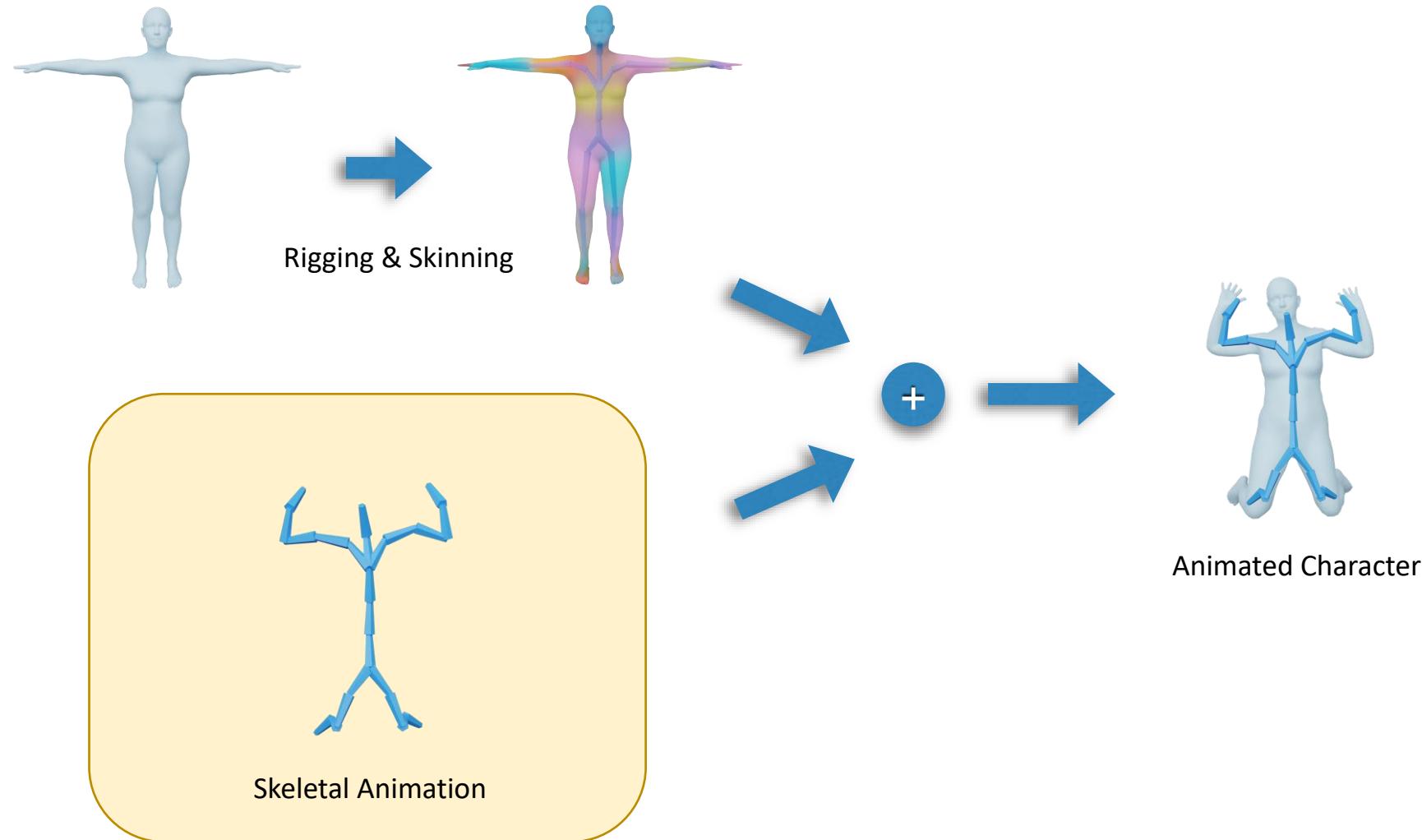
- Character animation techniques
 - Understanding the mechanism behind motions and behaviors
 - Smart editing of animation/ Reuse animation / Generate new animation
 - **“Compute-intensive”**



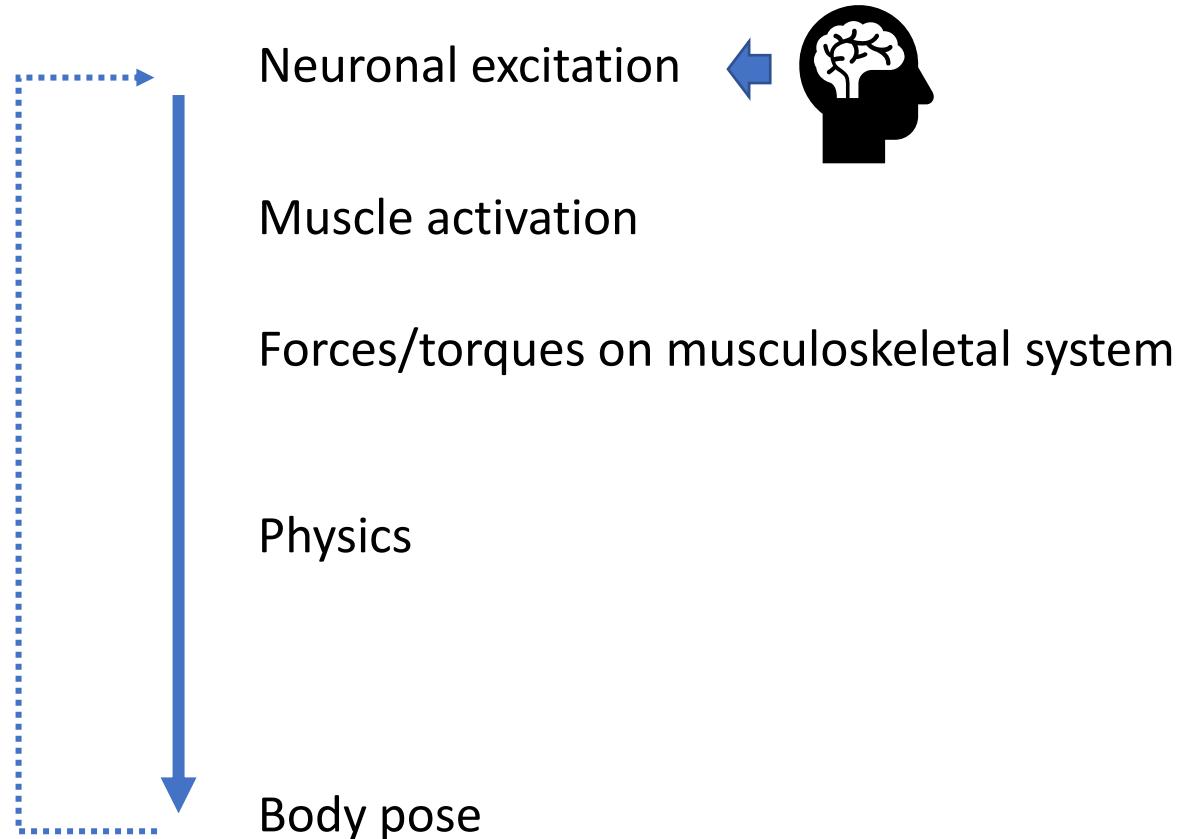
Character Animation Pipeline



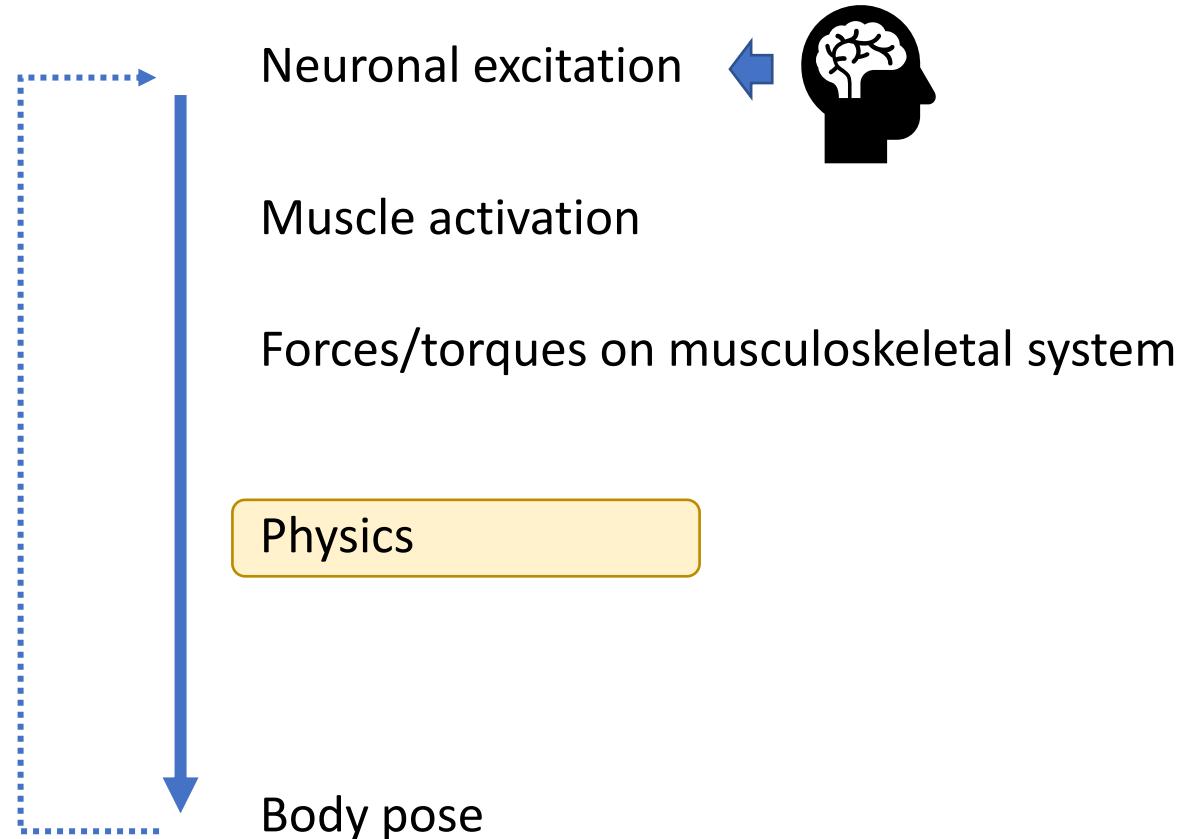
Character Animation Pipeline



Where does a Motion Come From



Where does a Motion Come From



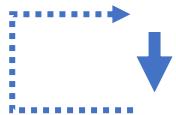
Keyframe-based/Kinematic Approaches

Neuronal excitation

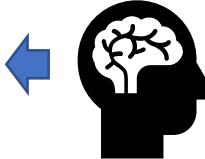
Muscle activation

Forces/torques on musculoskeletal system

Physics

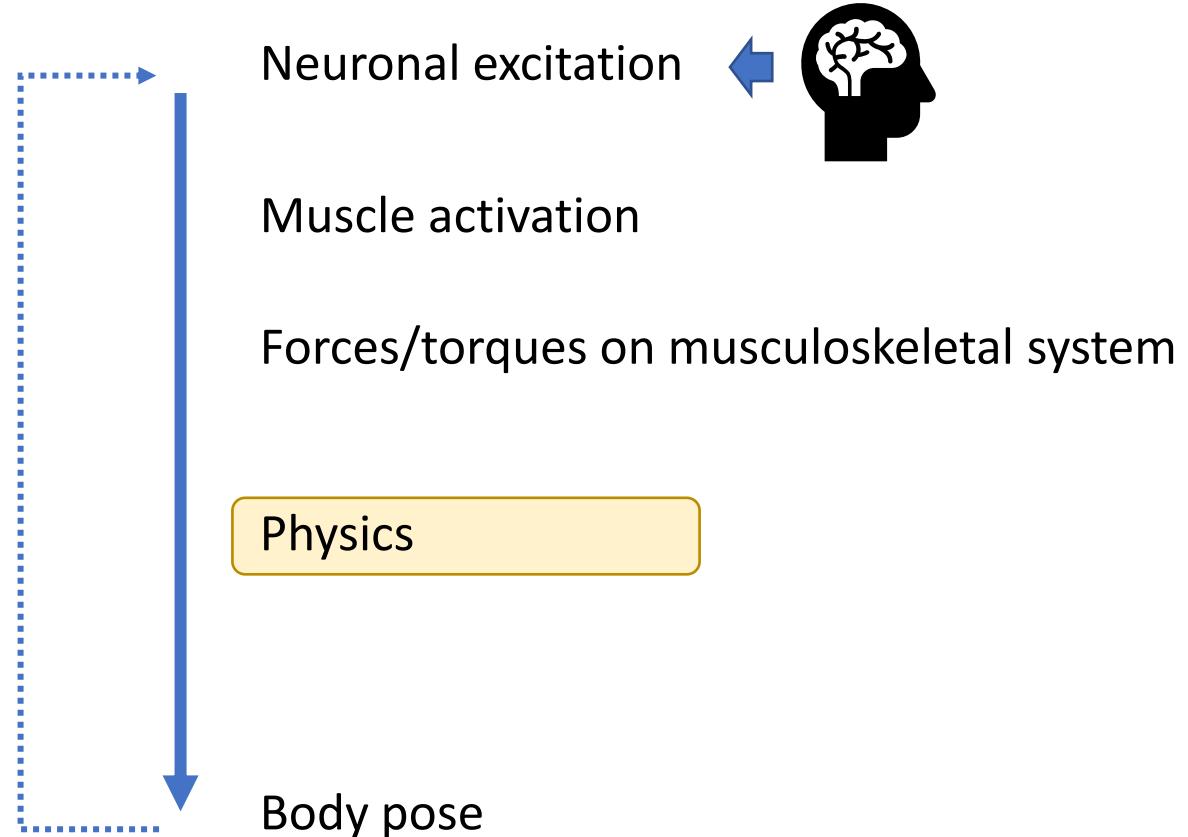


Body pose

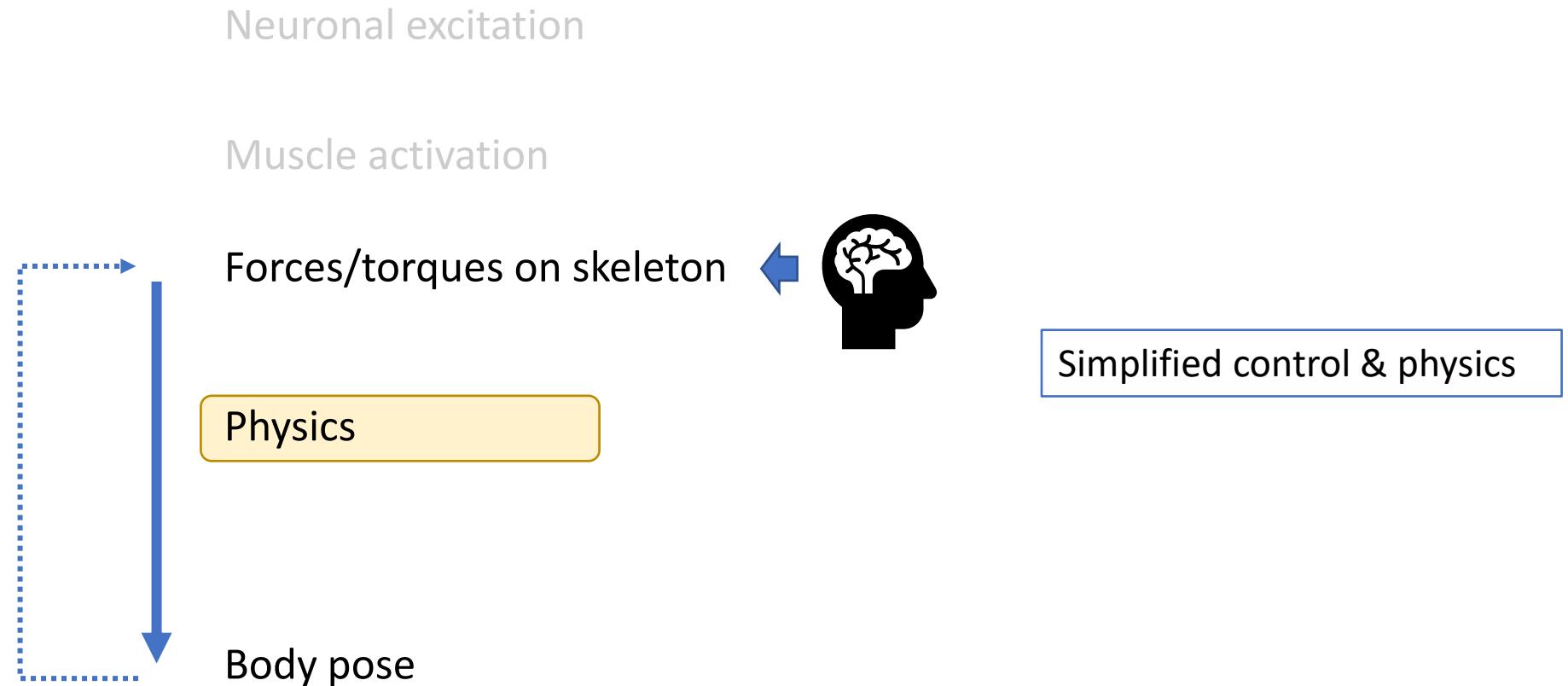


Direct update of character's
pose/velocity/acceleration...

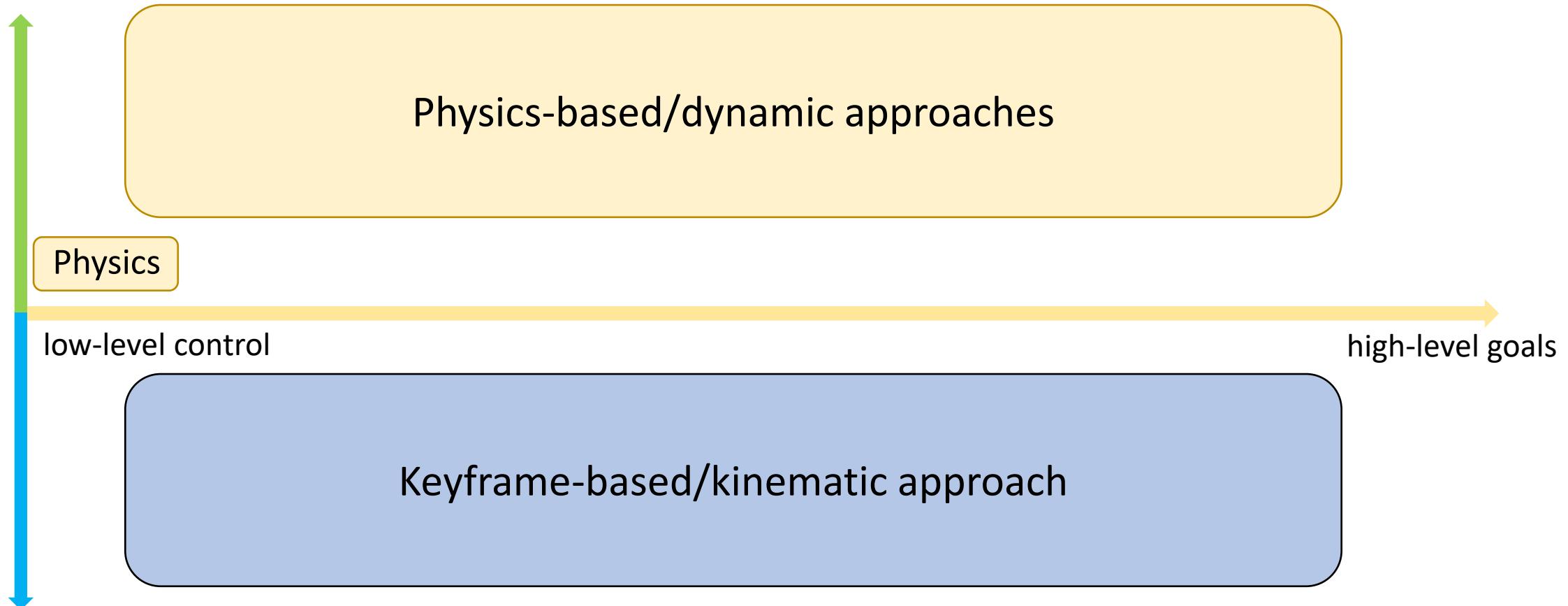
Physics-based/Dynamic Approaches



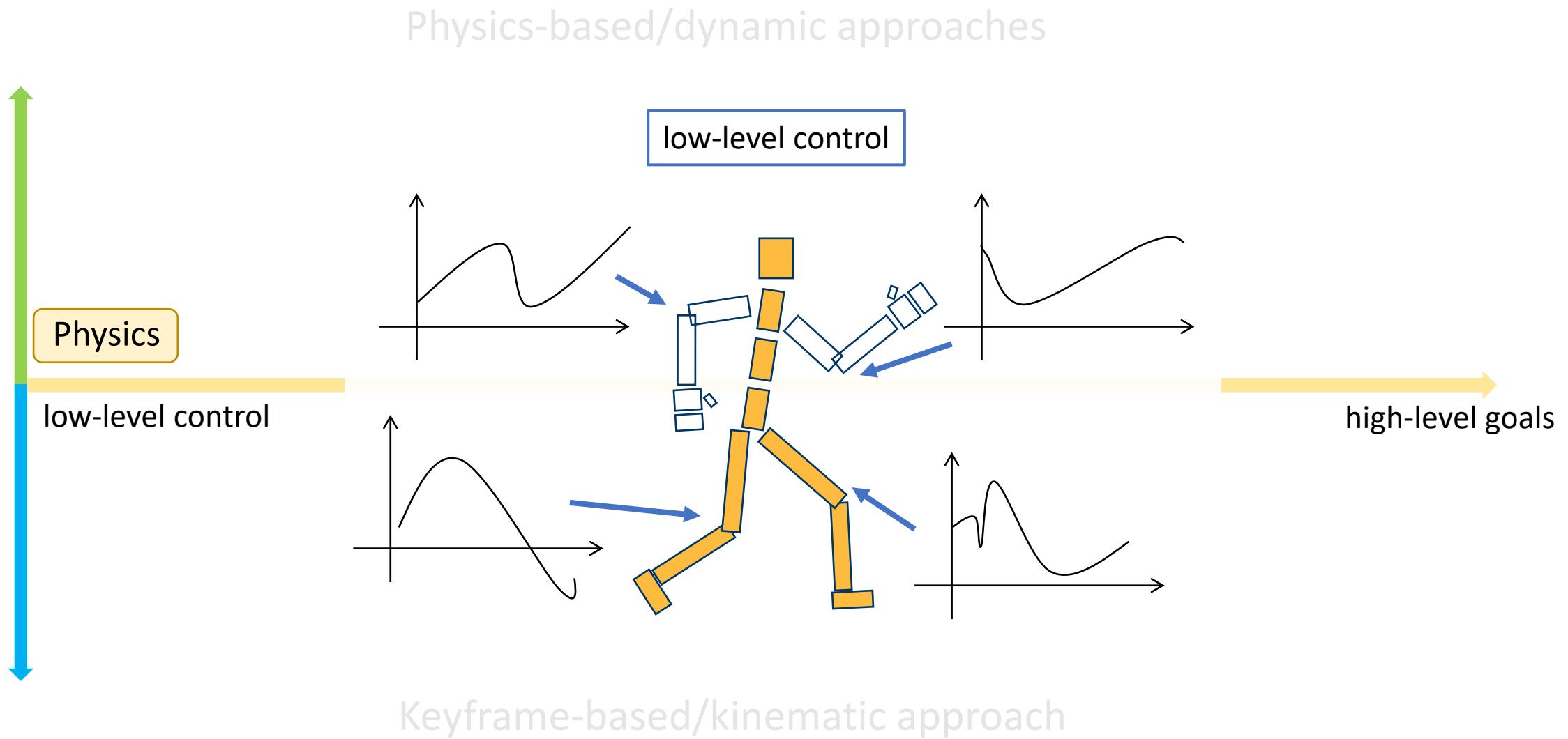
Physics-based/Dynamic Approaches



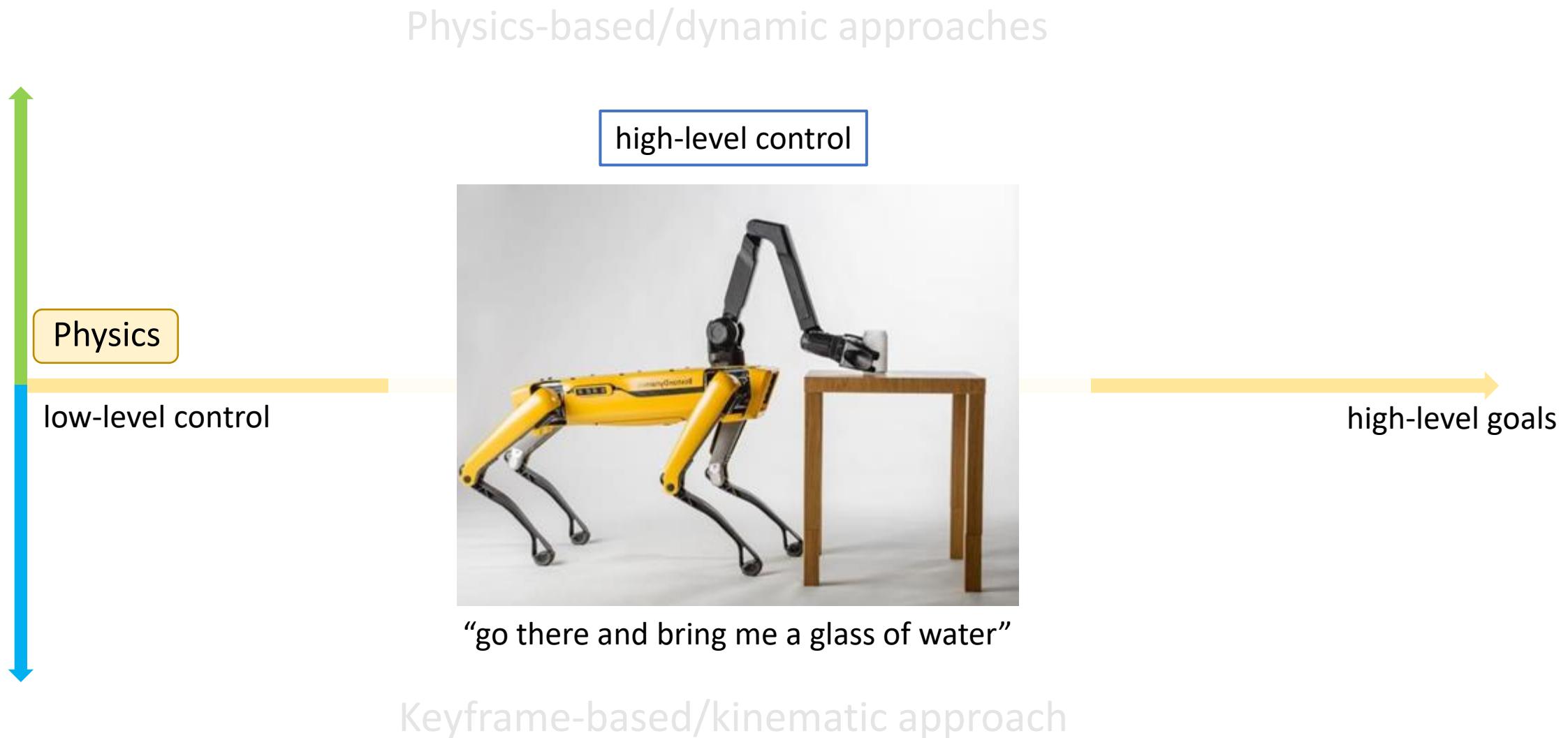
Character Animation Methods



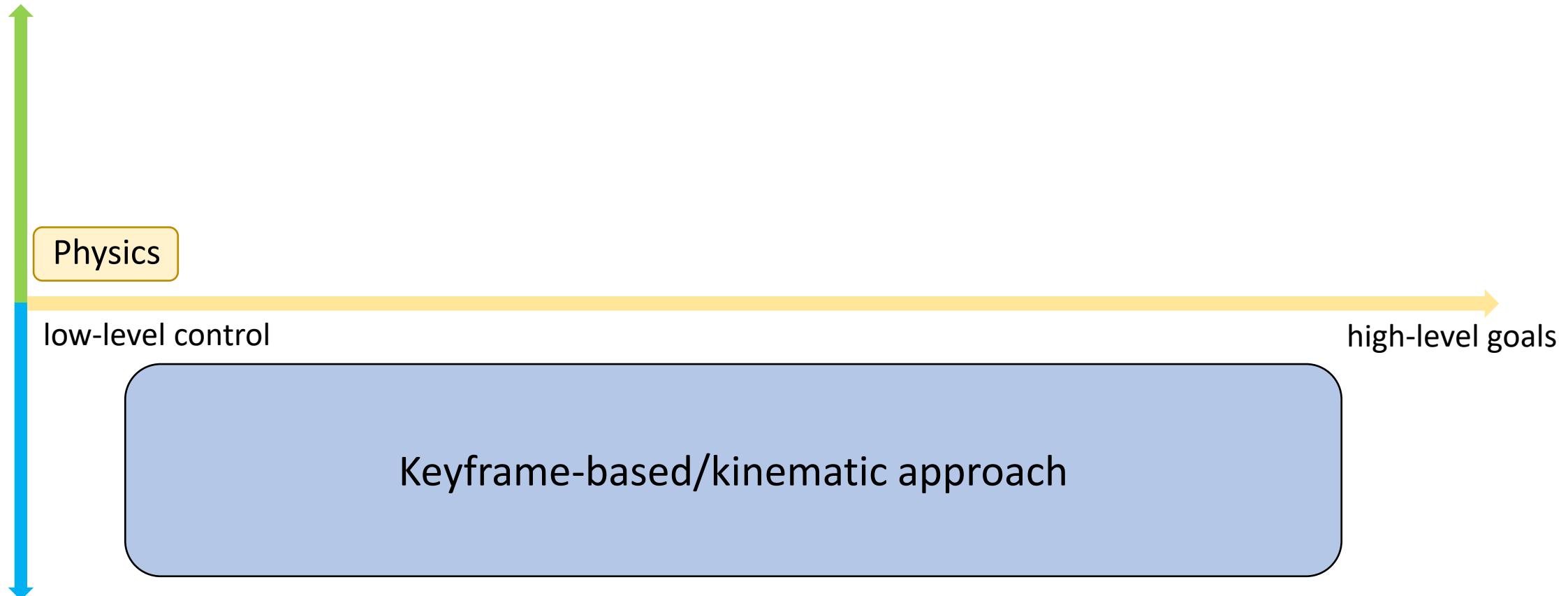
Character Animation Methods



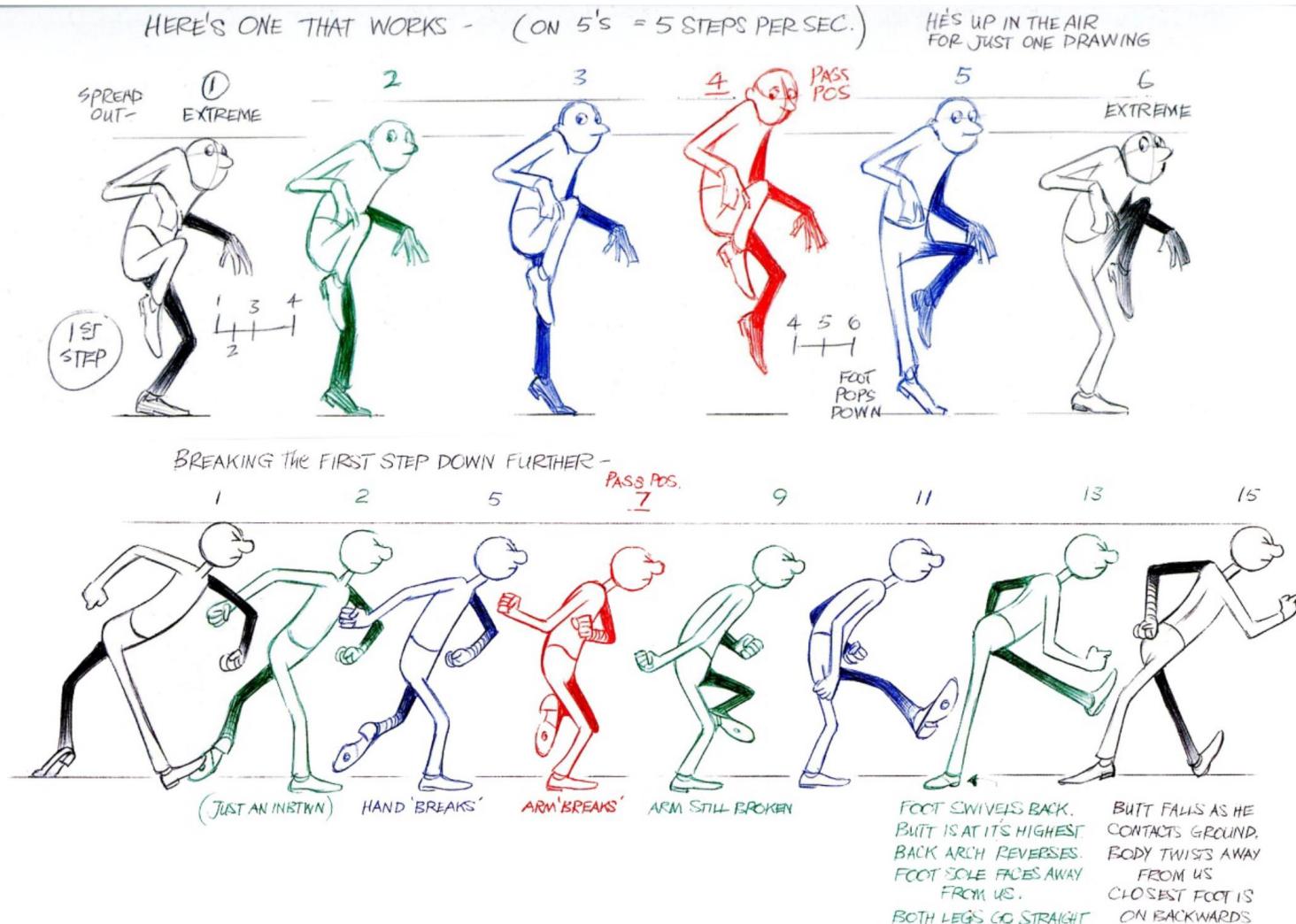
Character Animation Methods



Character Animation Methods

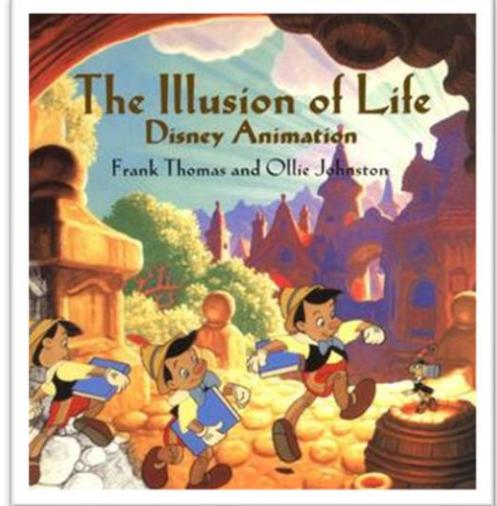
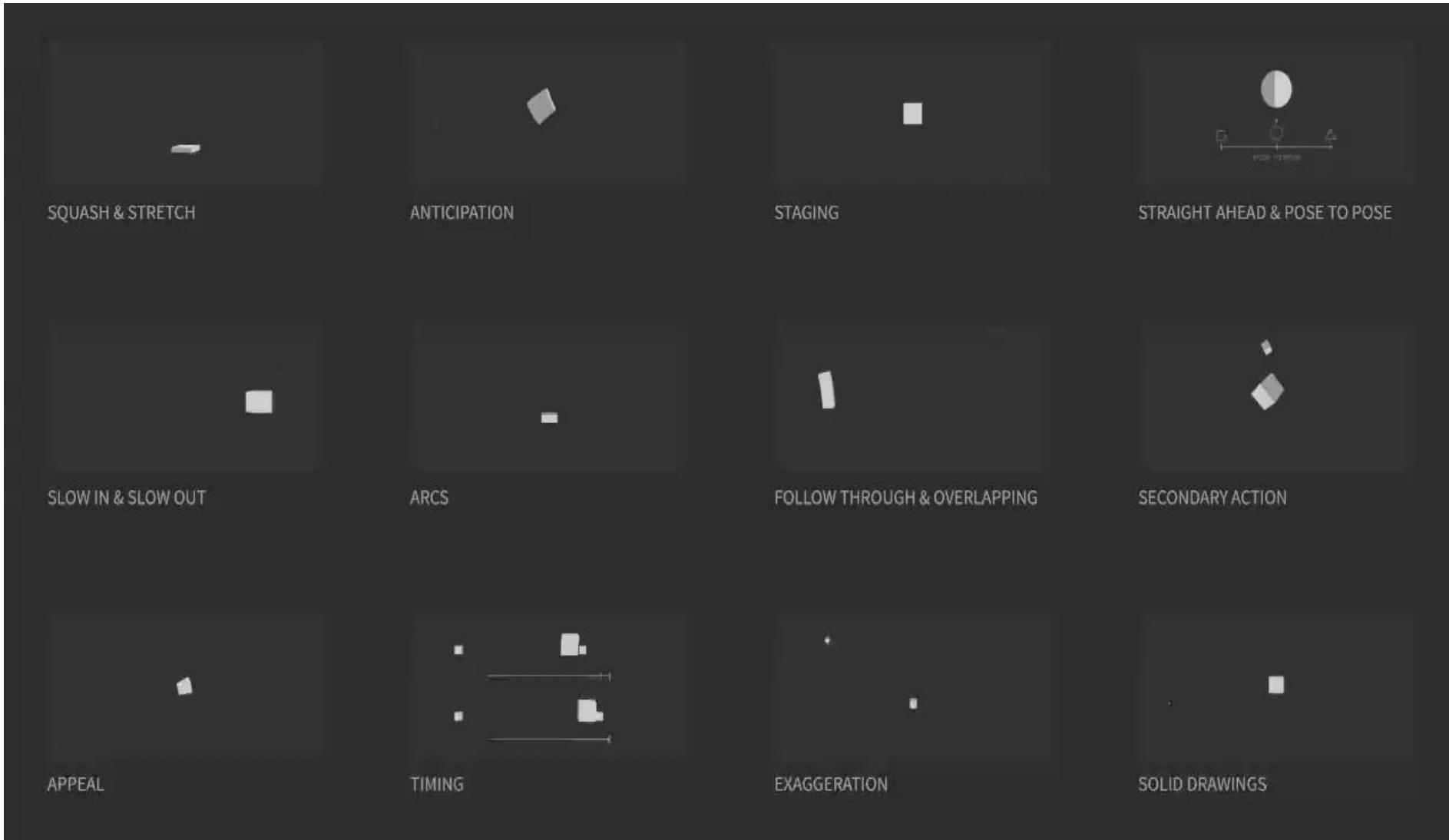


Keyframe Animation



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

Disney's 12 Principles of Animation

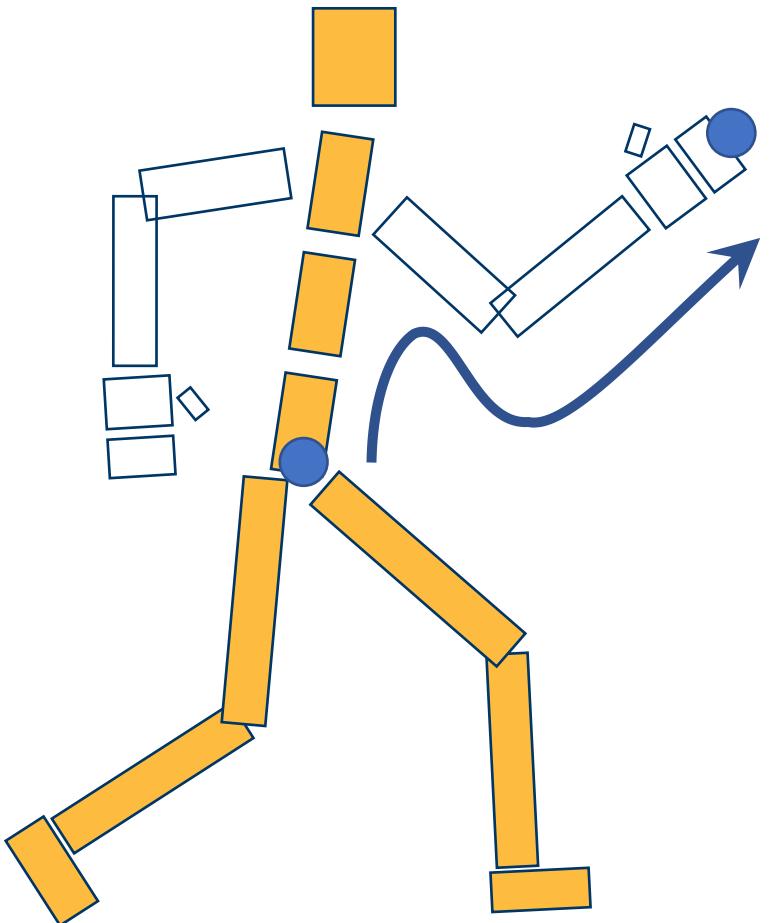


Keyframe 3D Animation



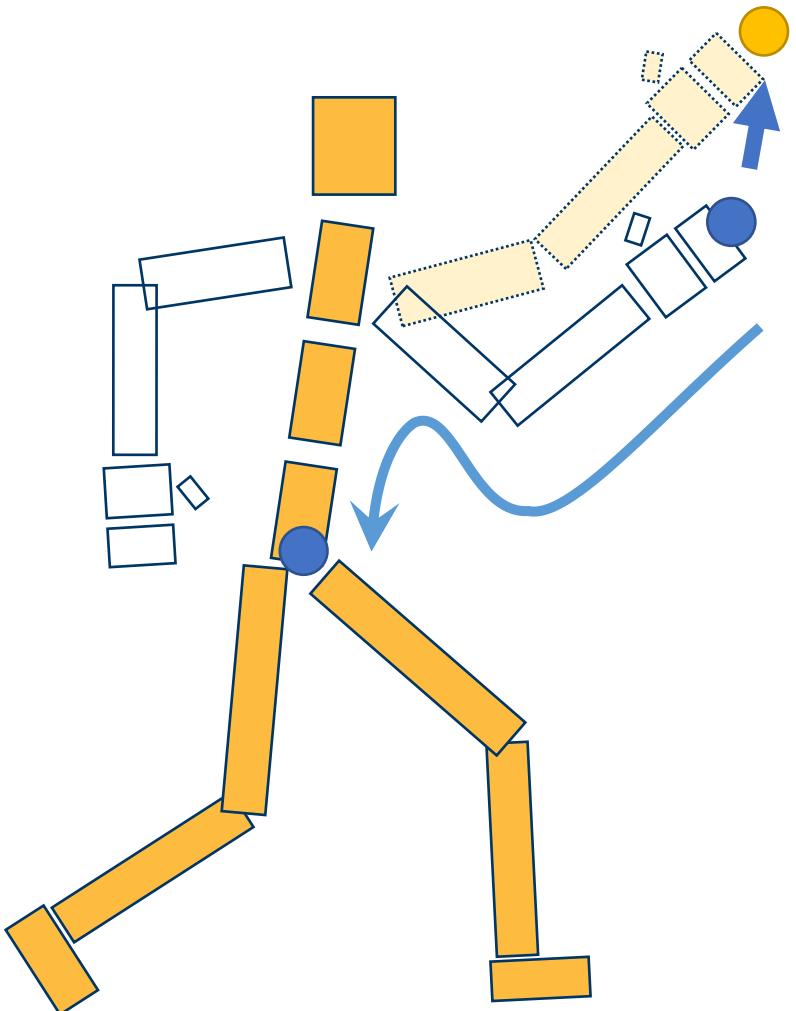
How to Animate 3D Characters in 1 Minute <https://www.youtube.com/watch?v=TjJLiuFKA20>

Forward Kinematics



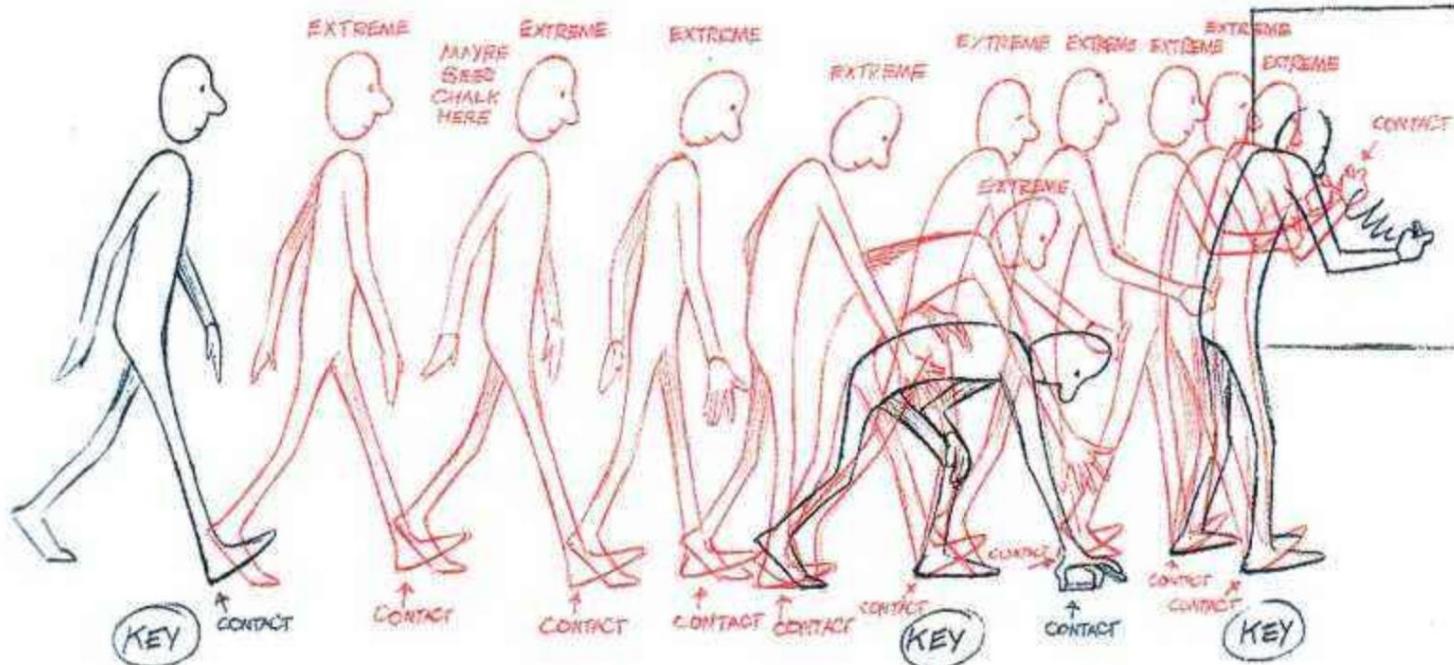
Given rotations of every joints
Compute position of end-effectors

Inverse Kinematics

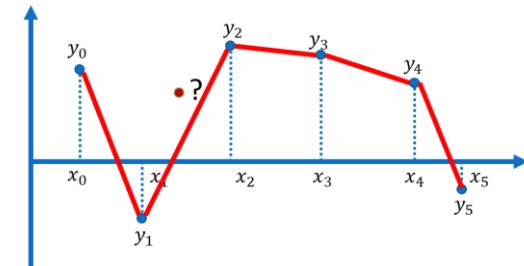


Given position of end-effectors
Compute rotations of every joints

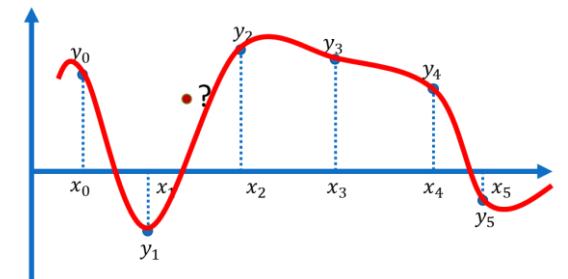
Interpolation



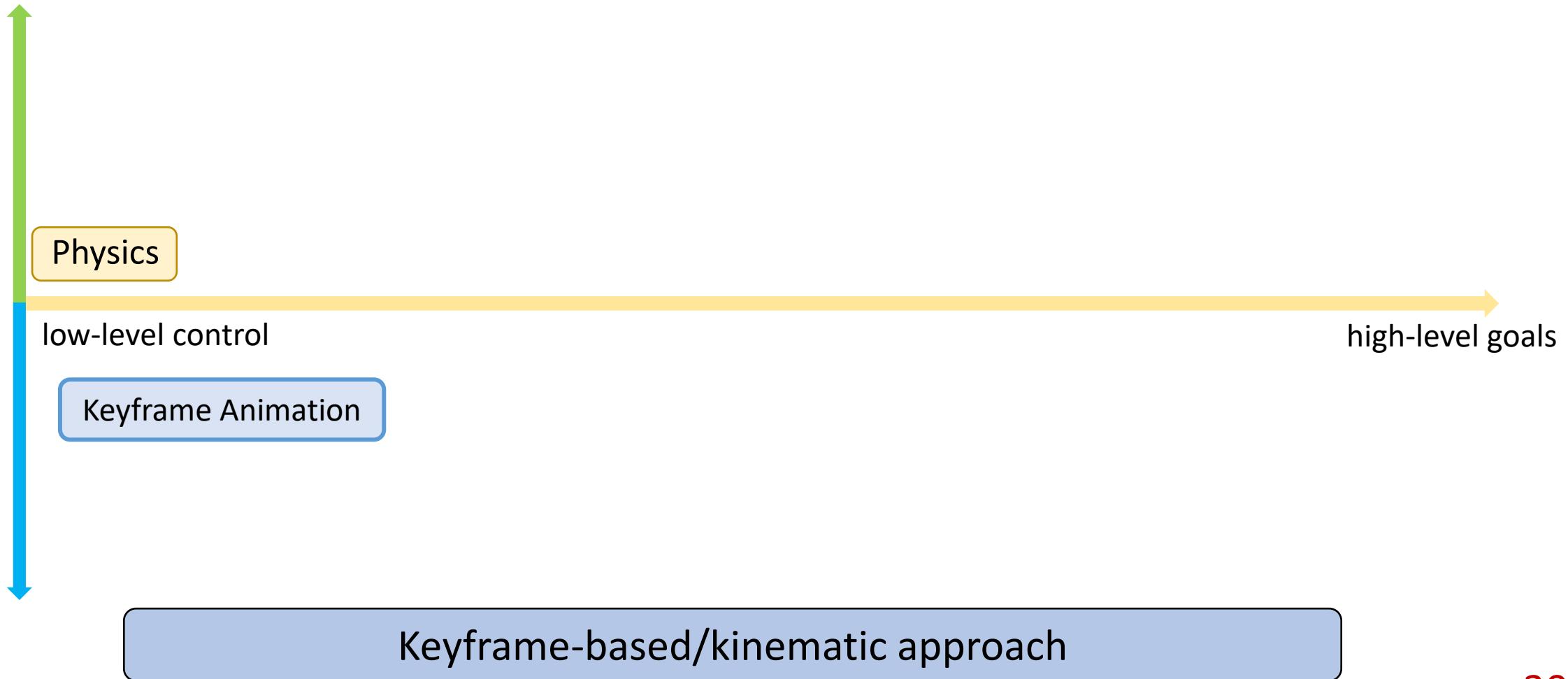
$$f(x) = y_1 + \frac{x - x_1}{x_2 - x_1} (y_2 - y_1)$$



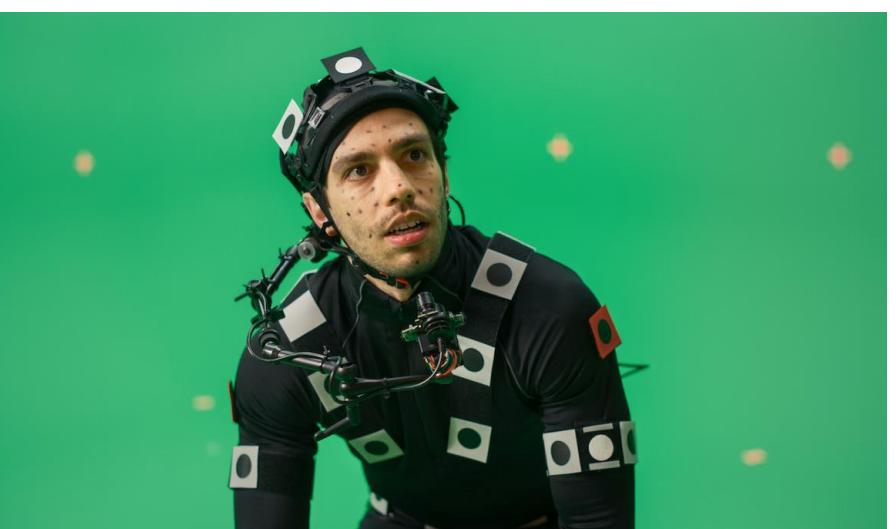
$$S_i(x) = a_i x^3 + b_i x^2 + c_i x + d_i$$



Character Animation Methods



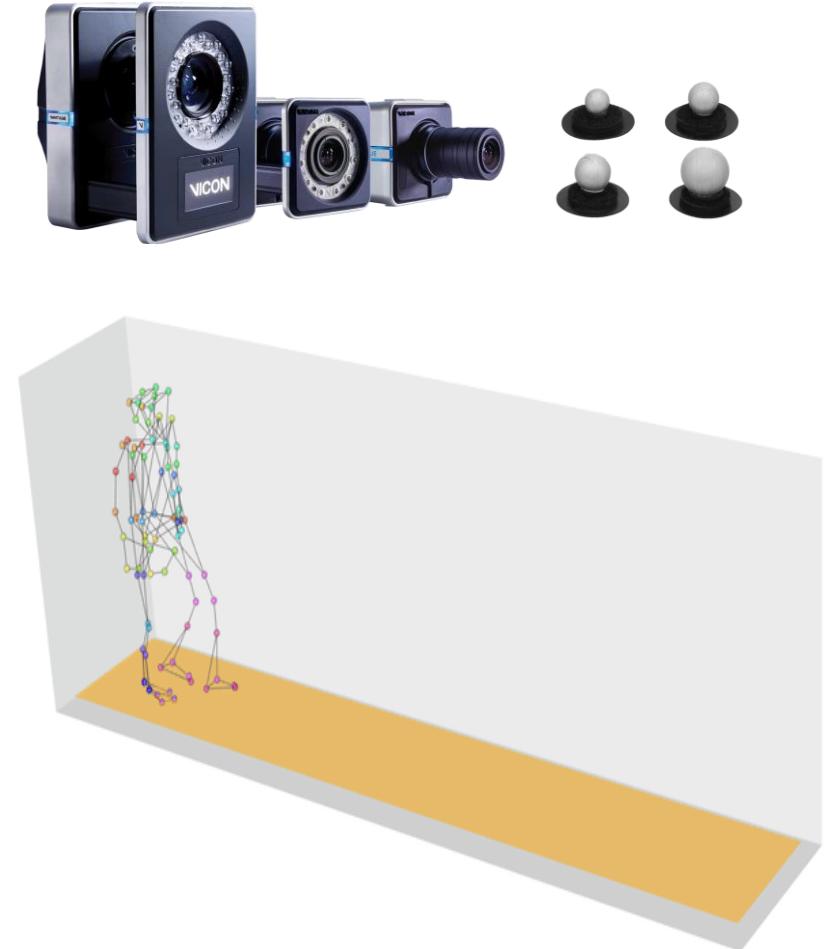
Motion Capture



Motion Capture

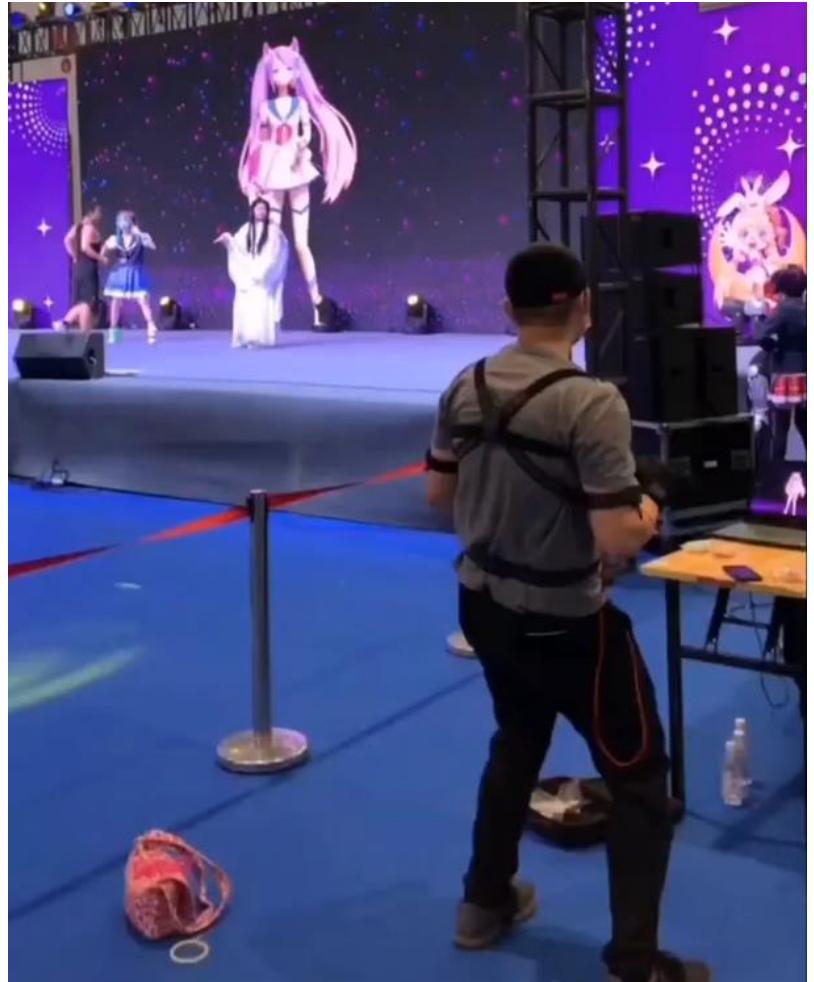
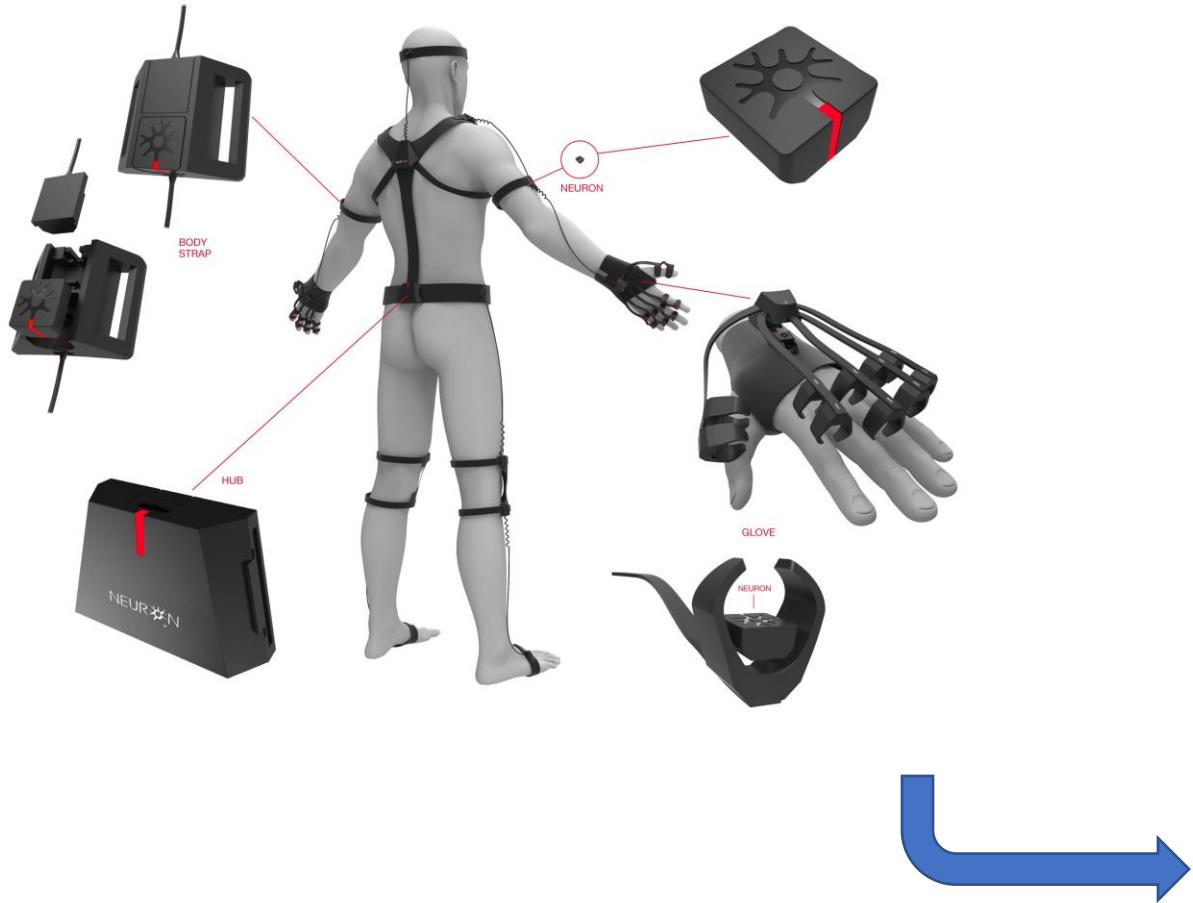


Behind the Scenes - God of War PS5 | Mocap Footage
<https://www.youtube.com/watch?v=HVXoOK4R8M0>



Motion Capture

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Source: douyin

33

Motion Capture

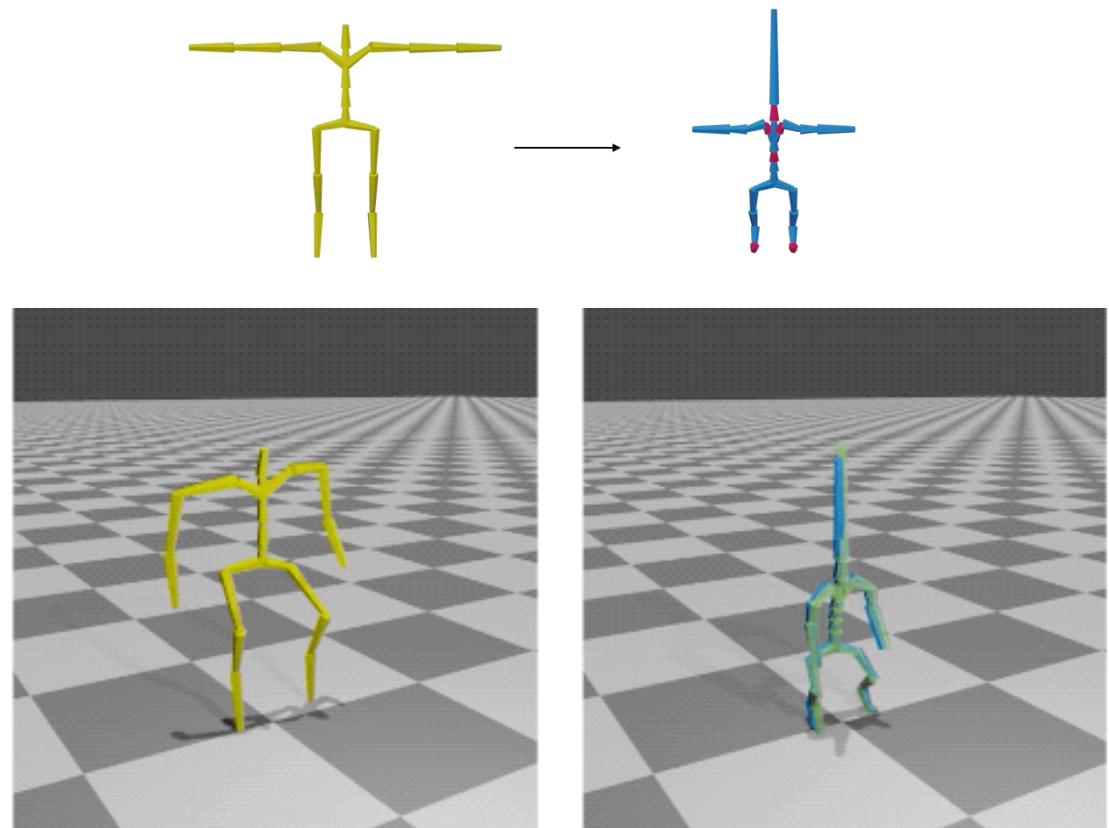


[OpenPose, 2D Pose estimation]



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

Motion Retargeting

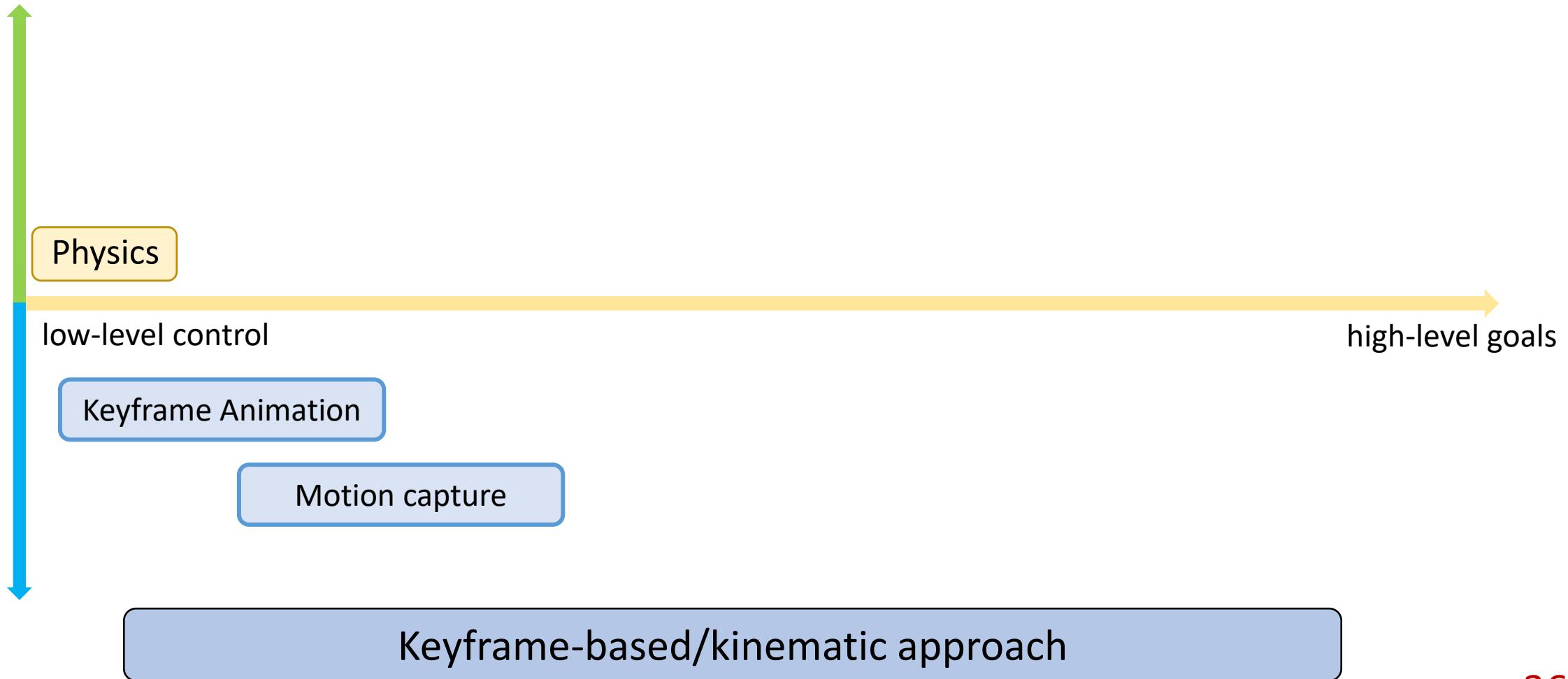


[Aberman et al. 2020 SIGGRAPH]

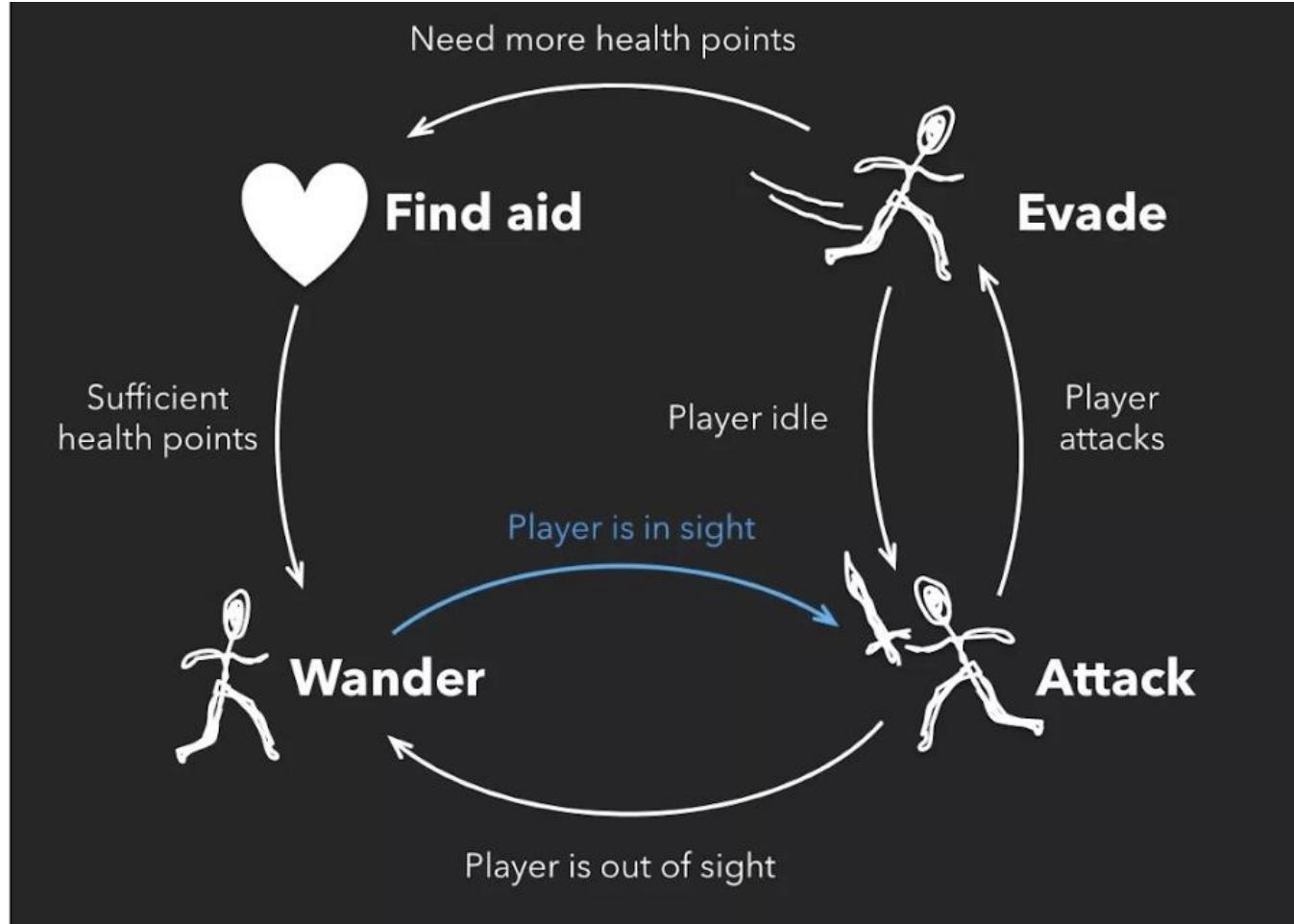
Given motions of a source character
Compute motions for target characters with

- different skeleton sizes
- different number of bones
- different topologies
-

Character Animation Methods



Motion Graphs / State Machines



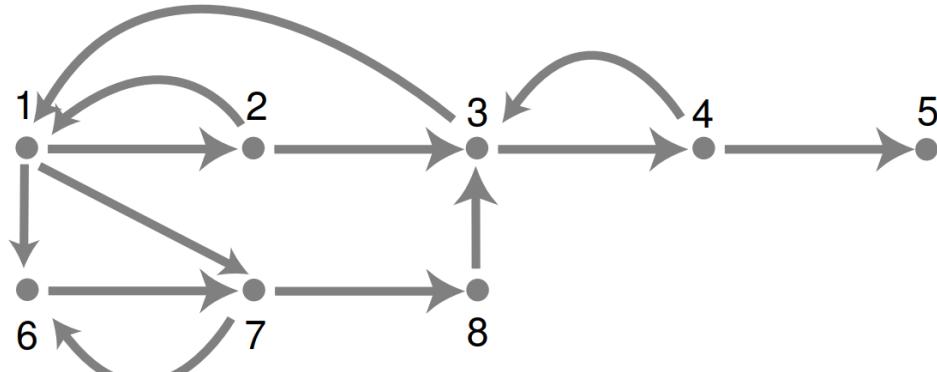
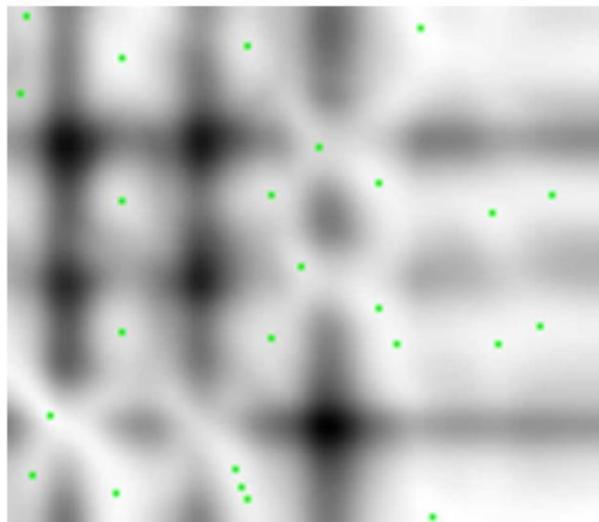
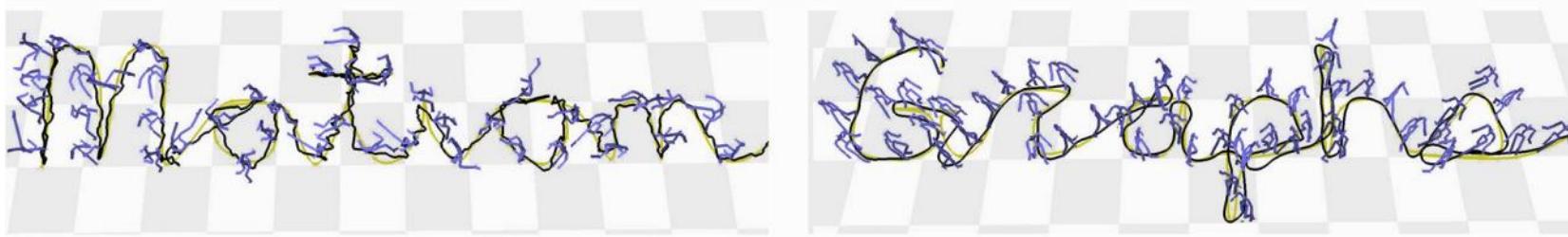
Motion Graphs / State Machines

Motion Graphs

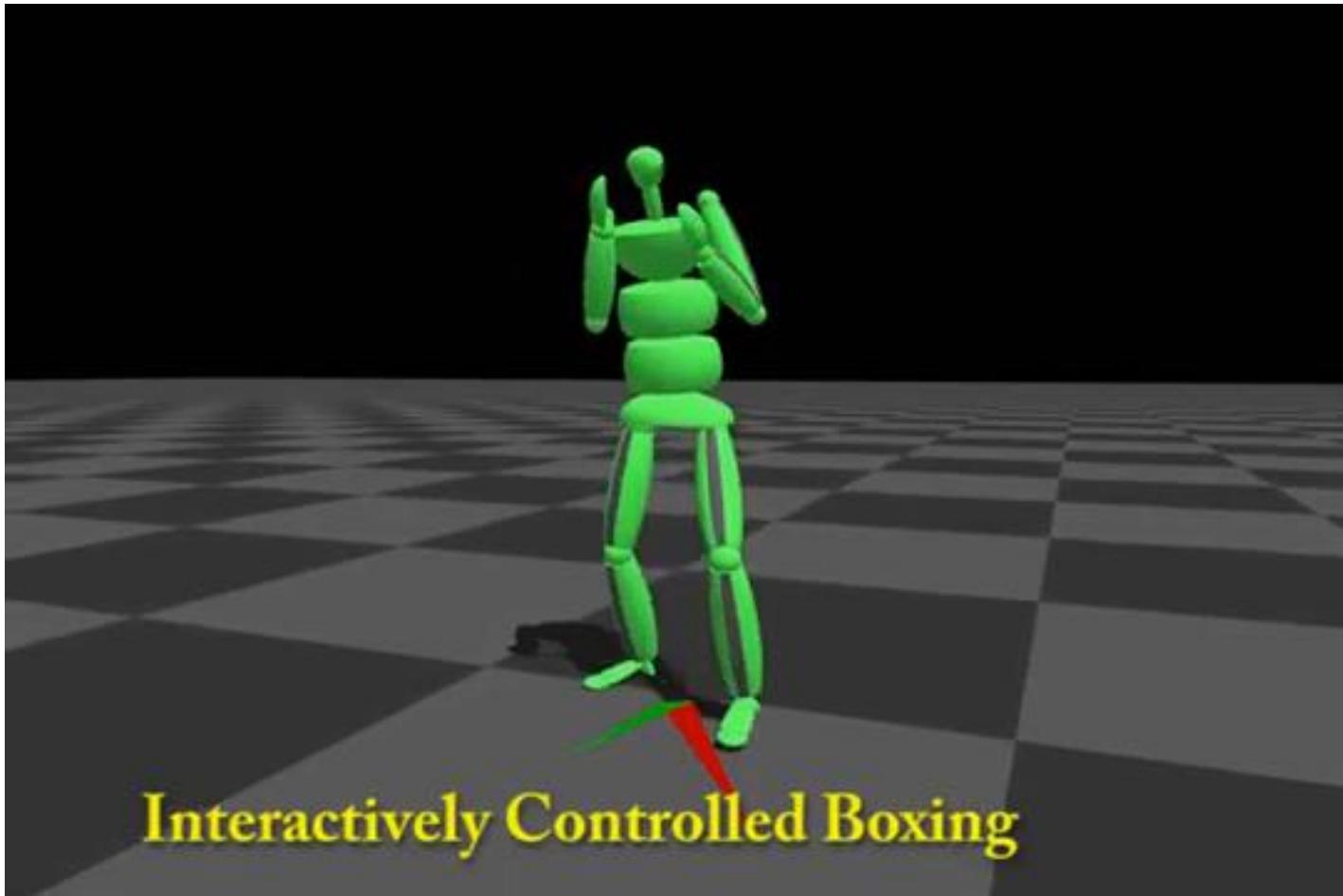
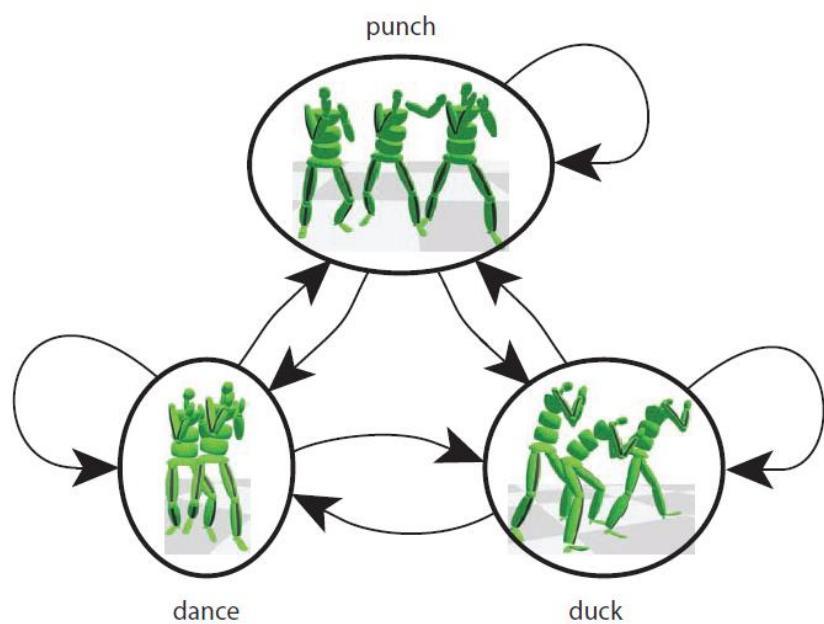
Lucas Kovar
University of Wisconsin-Madison

Michael Gleicher*
University of Wisconsin-Madison

Frédéric Pighin†
University of Southern California
Institute for Creative Technologies

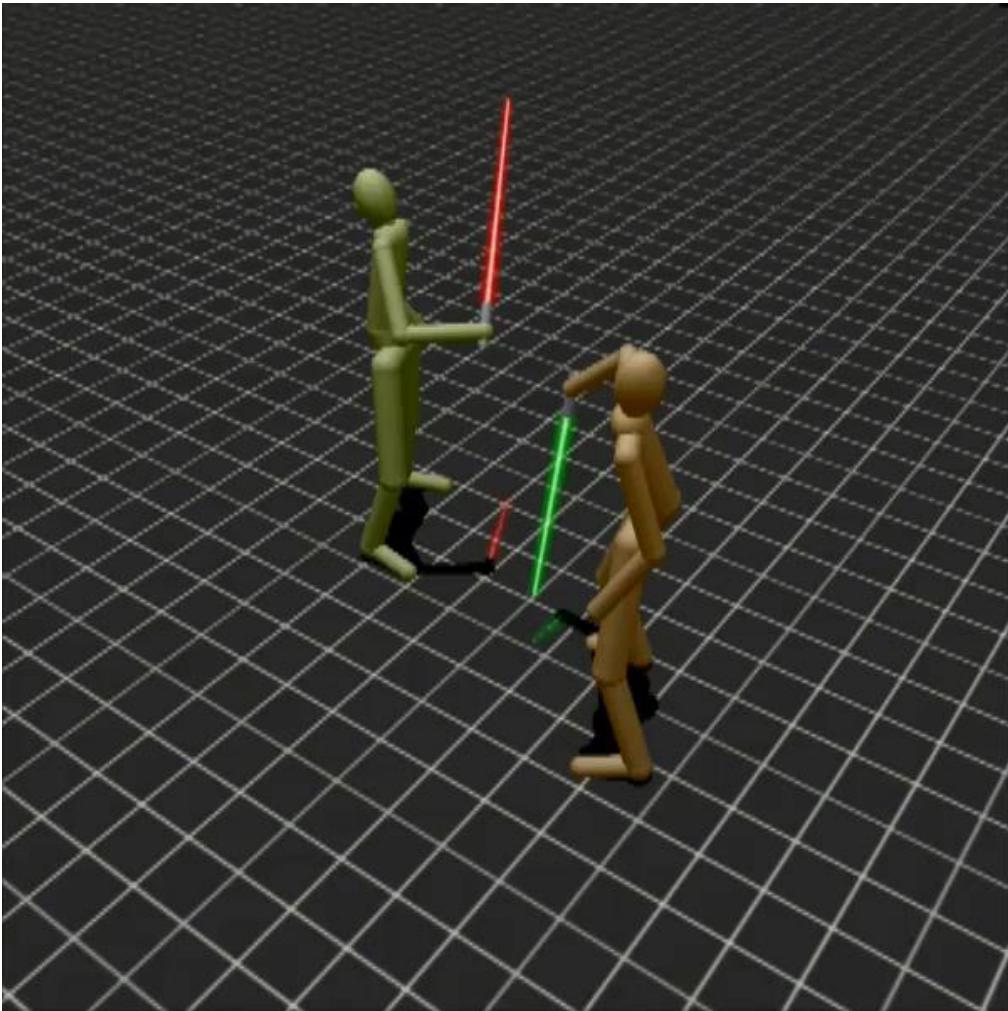


Motion Graphs / State Machines



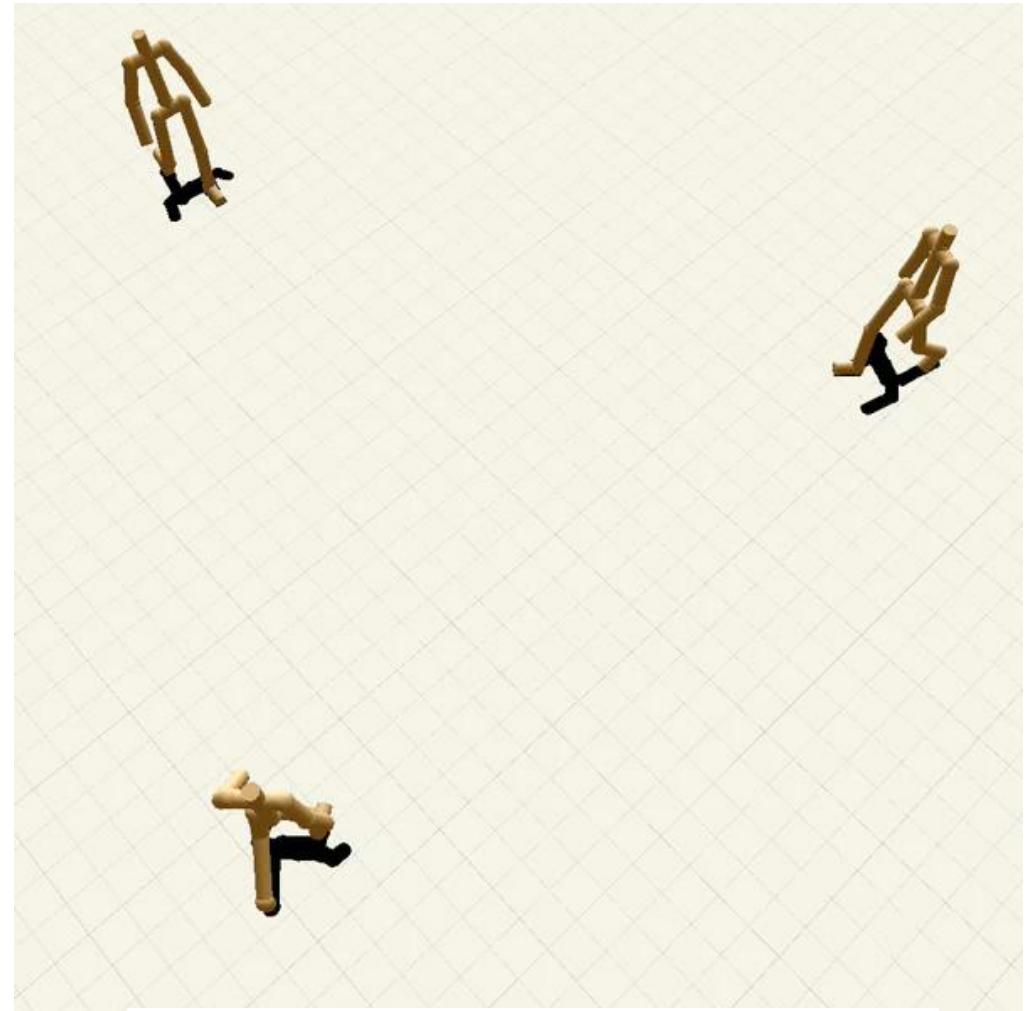
[Heck and Gleicher 2007, Parametric Motion Graphs]

Motion Graphs / State Machines



Character Animation in Two-Player Adversarial Games

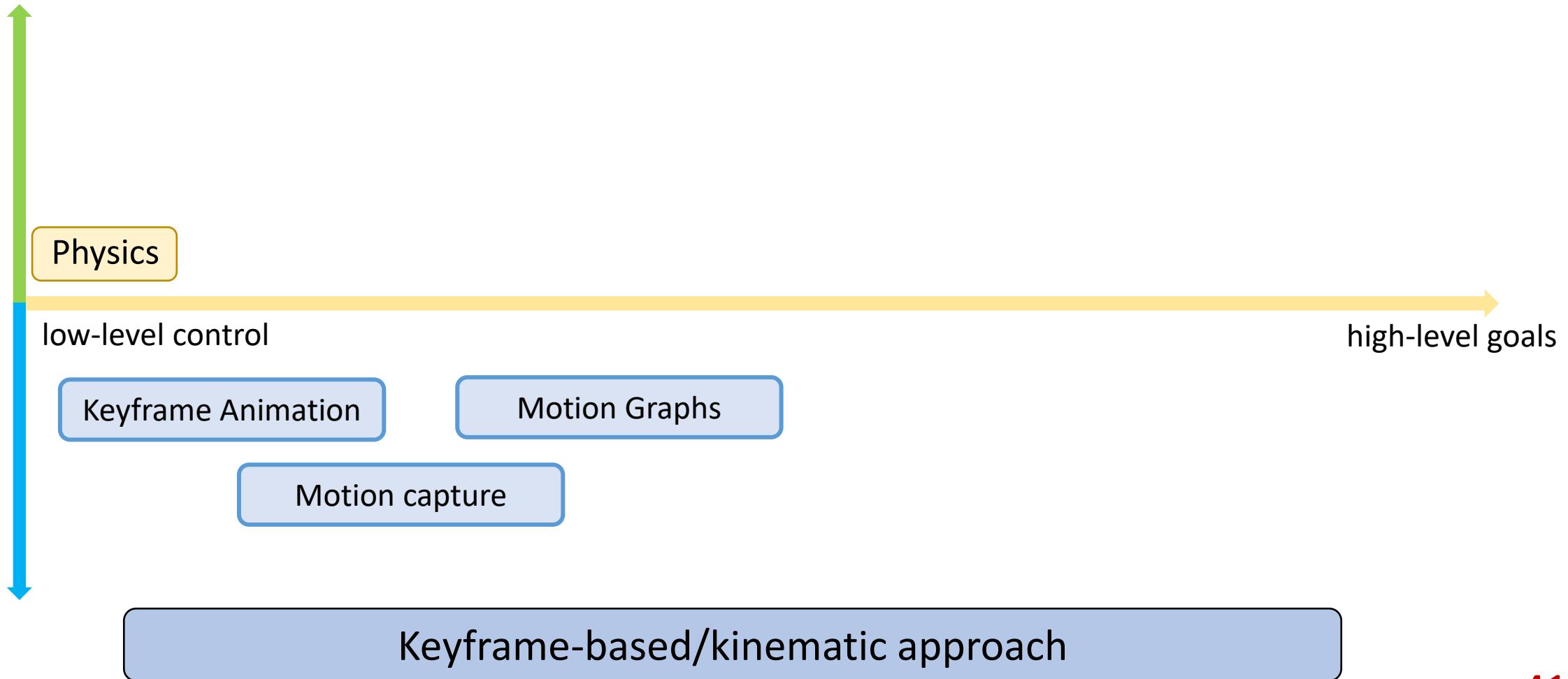
KEVIN WAMPLER, ERIK ANDERSEN, EVAN HERBST, YONGJOON LEE, and ZORAN POPOVIĆ
University of Washington



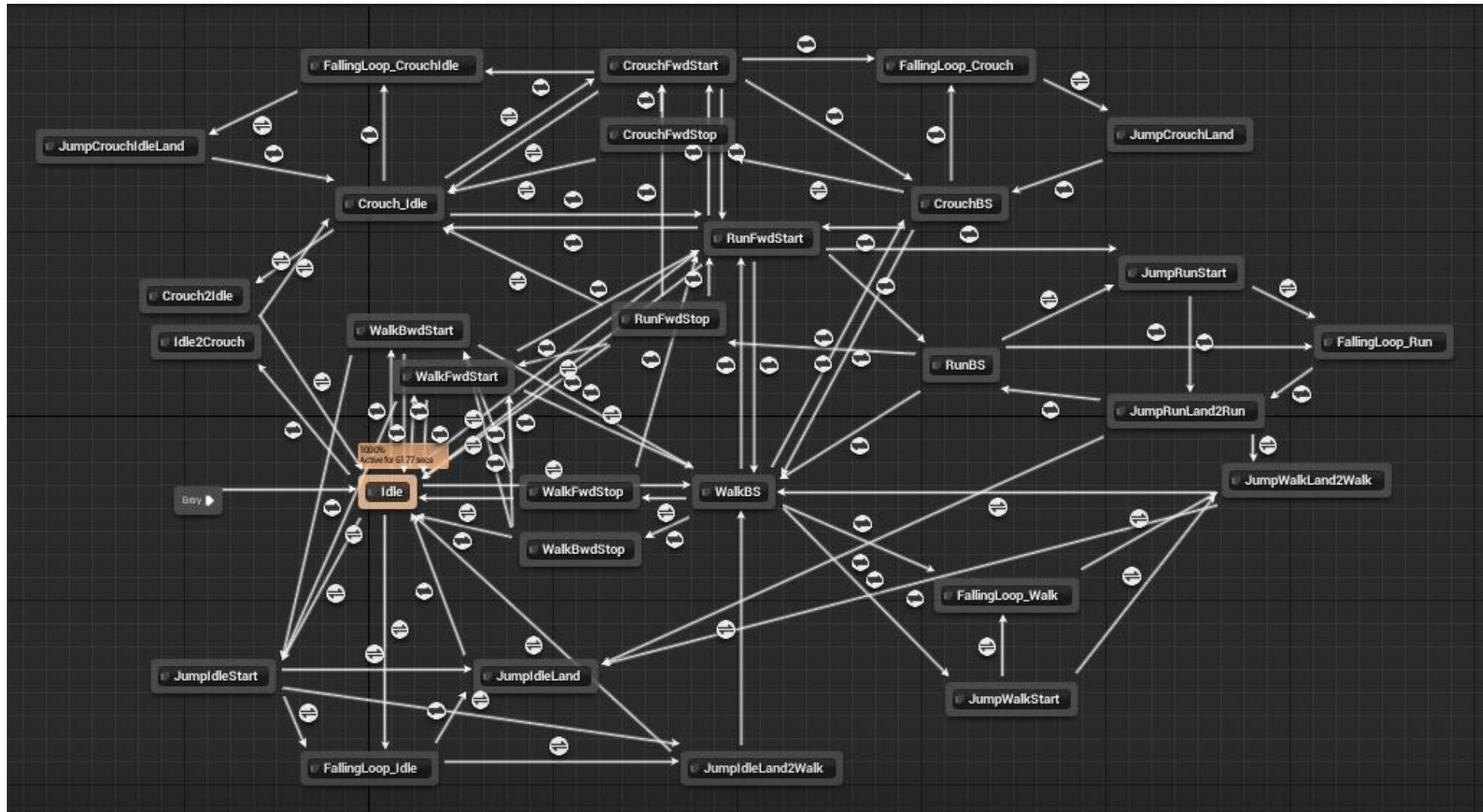
Near-optimal Character Animation with Continuous Control

Adrien Treuille Yongjoon Lee Zoran Popović
University of Washington

Character Animation Methods

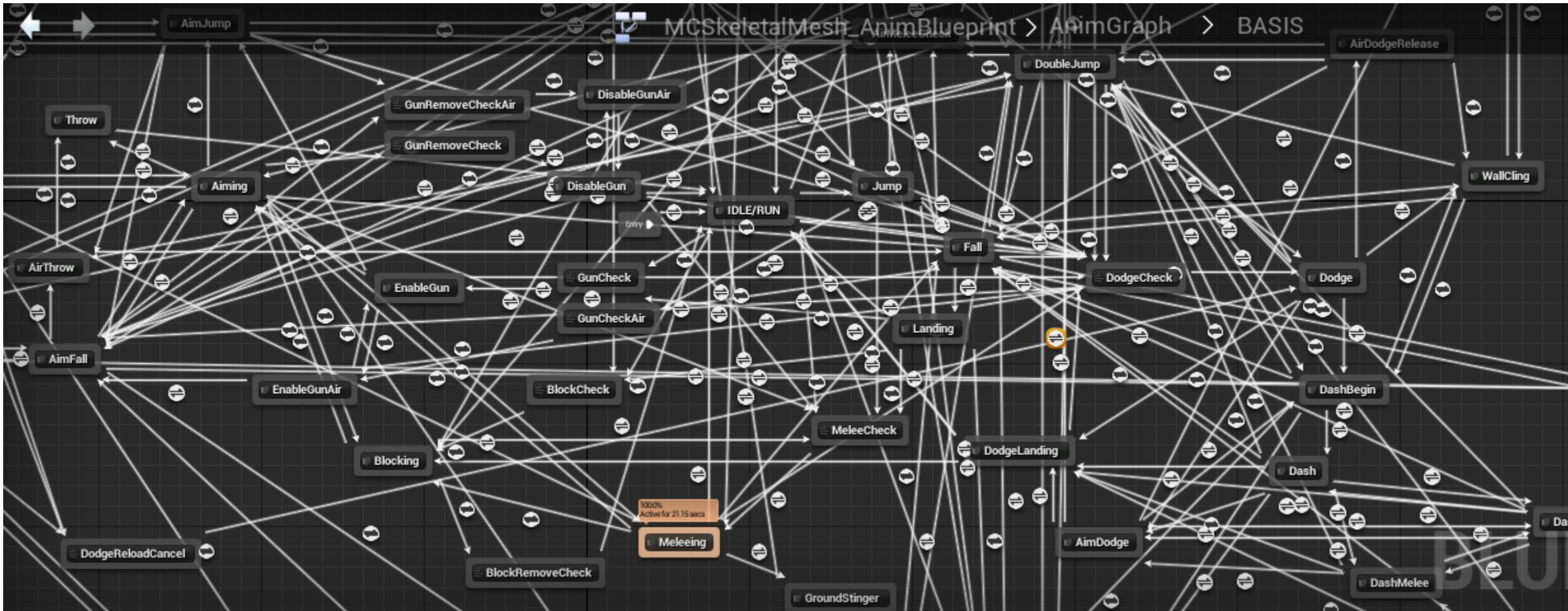


Complex Motion Graphs



<https://forums.unrealengine.com/t/cleaning-up-state-machine-spaghetti/>

Complex Motion Graphs

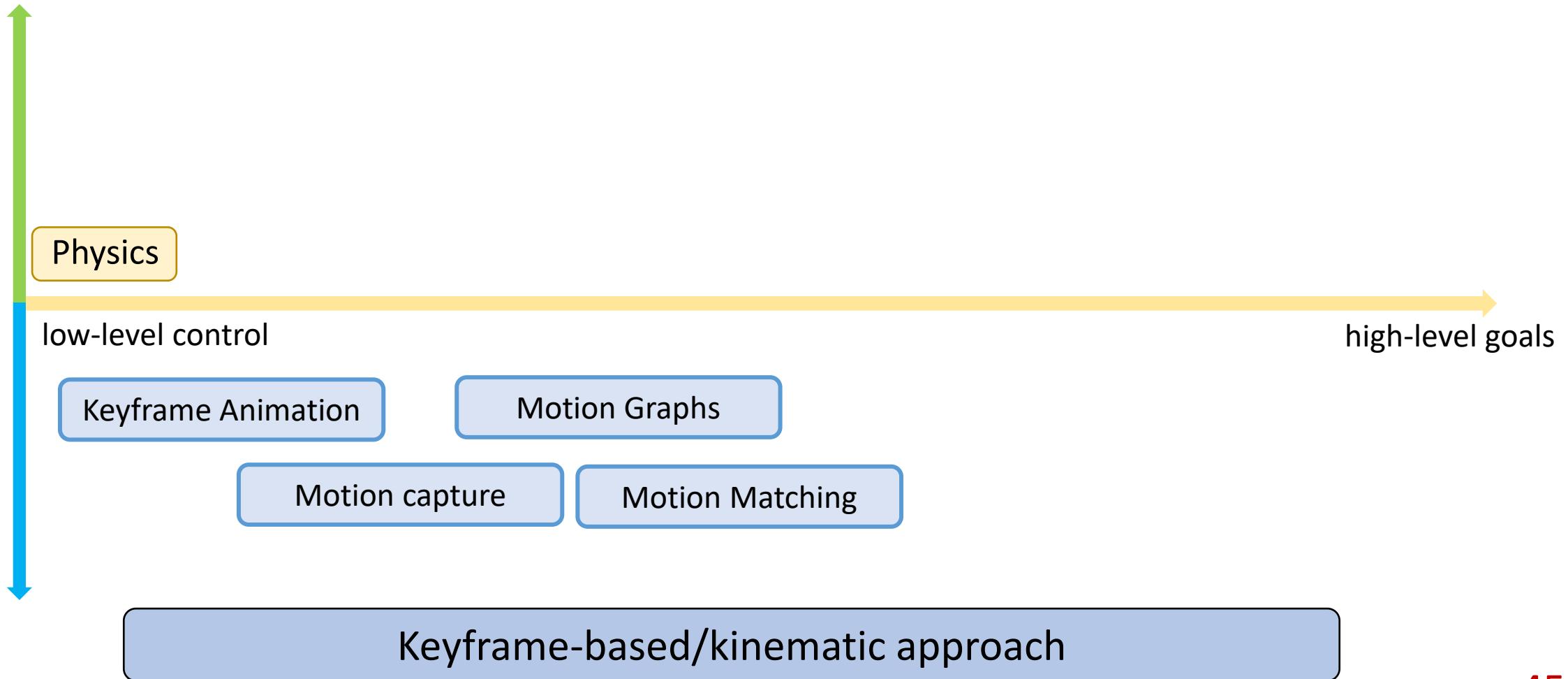


<https://forums.unrealengine.com/t/cleaning-up-state-machine-spaghetti/>

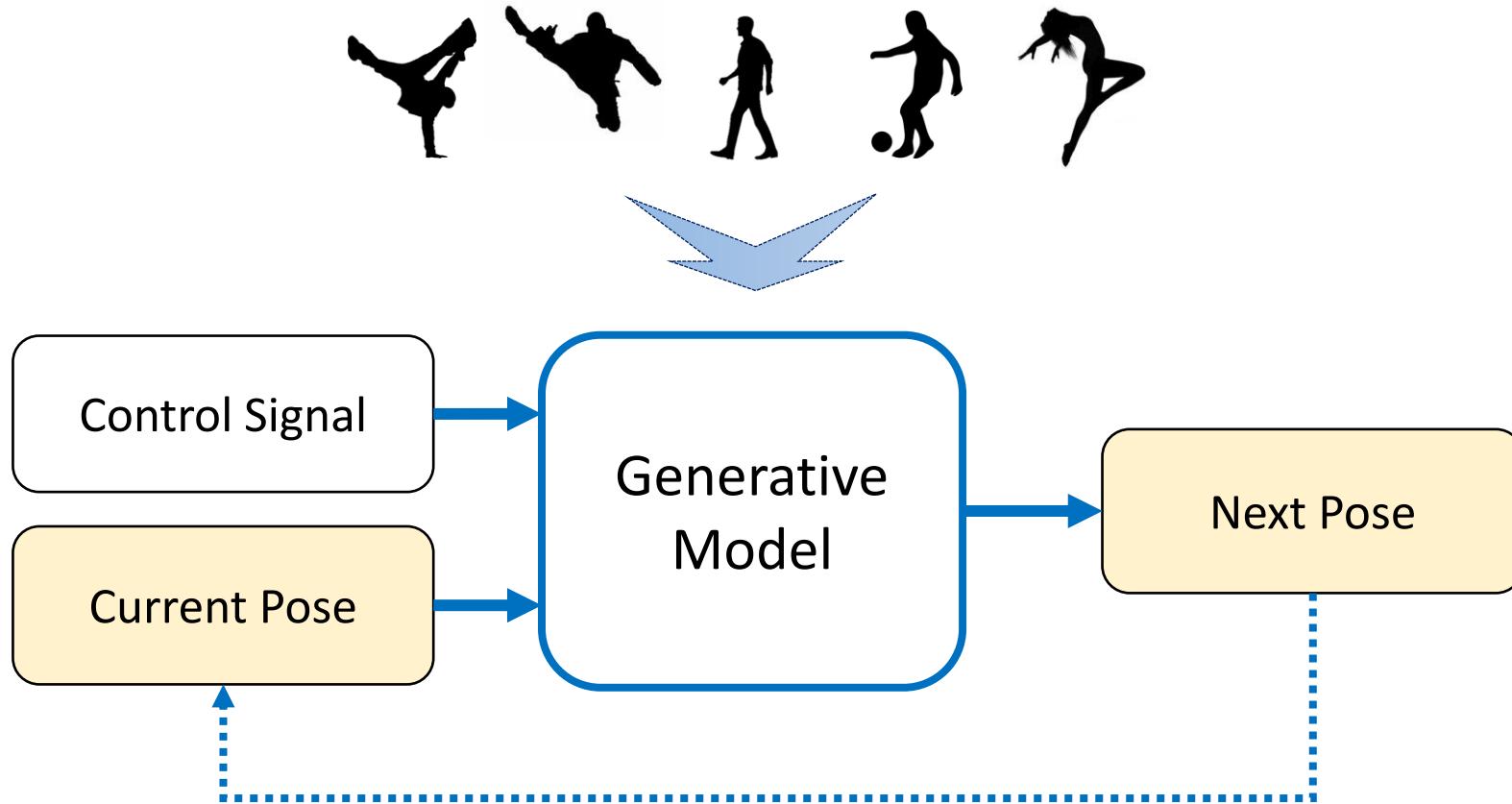
Motion Matching



Character Animation Methods



Learning-based Approaches



Learning-based Approaches

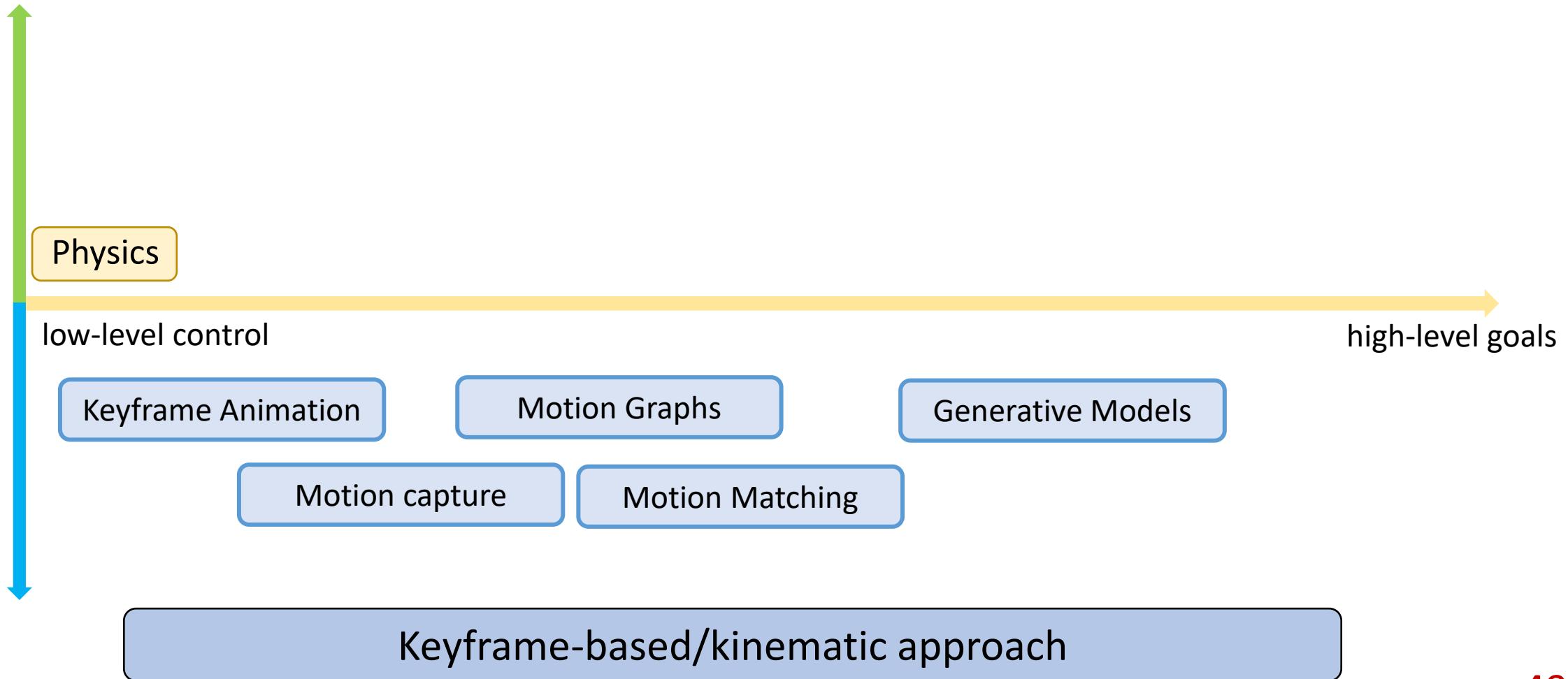


Motion Generative Models



[Ling et al. 2021 Character Controllers Using Motion VAEs]

Character Animation Methods



Cross-Modal Motion Synthesis

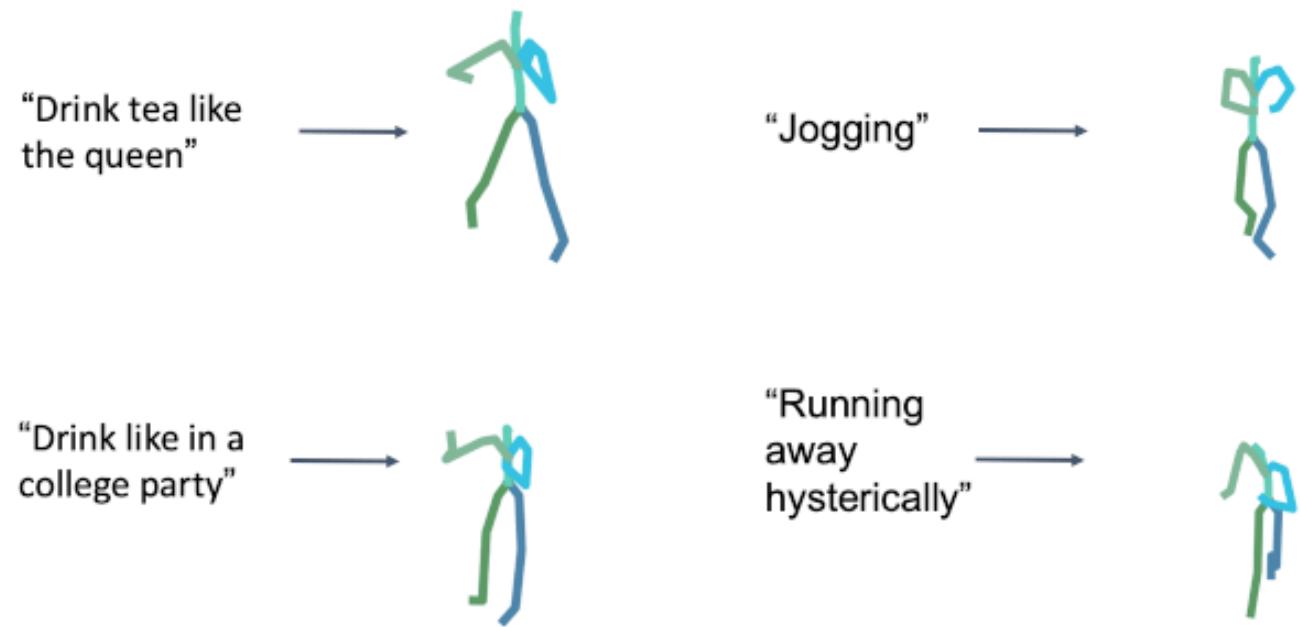
- Audio-driven animation
 - Music to dance
 - Co-speech gesture
 -



[Ao et al. 2022. Rhythmic Gesticulator.
SIGGRAPH Asia 2022]

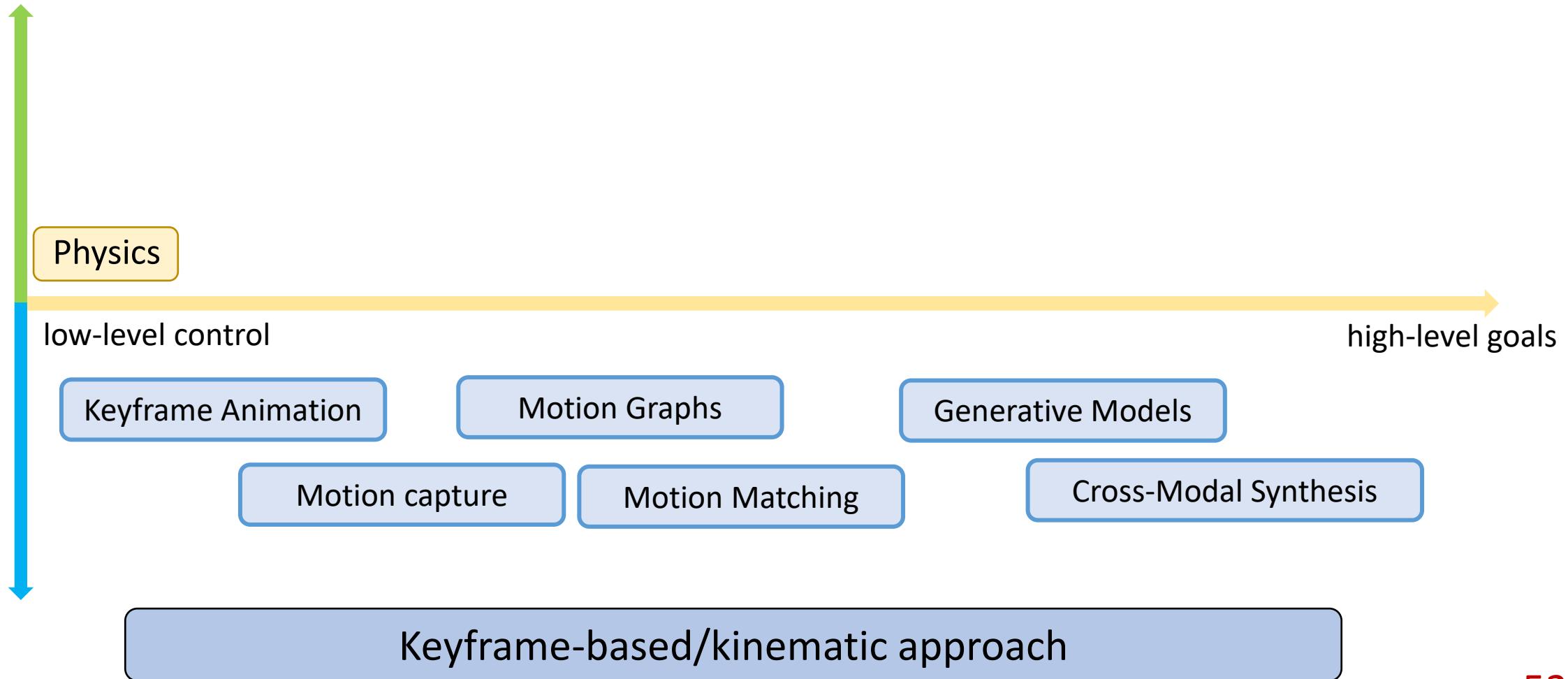
Cross-Modal Motion Synthesis

- Natural language to animation
 - Descriptions to actions
 - Scripts to performance
 -

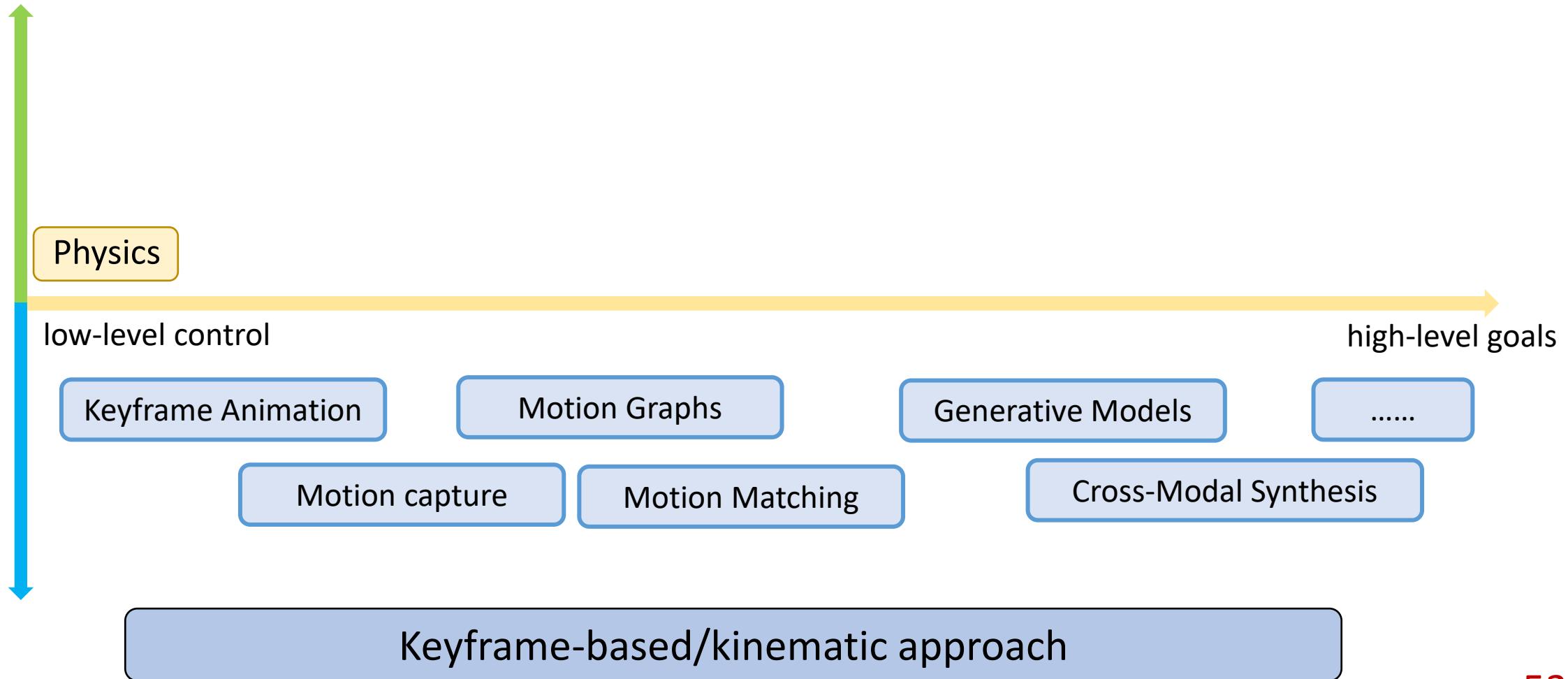


[Tevet et al. 2022. MotionCLIP]

Character Animation Methods

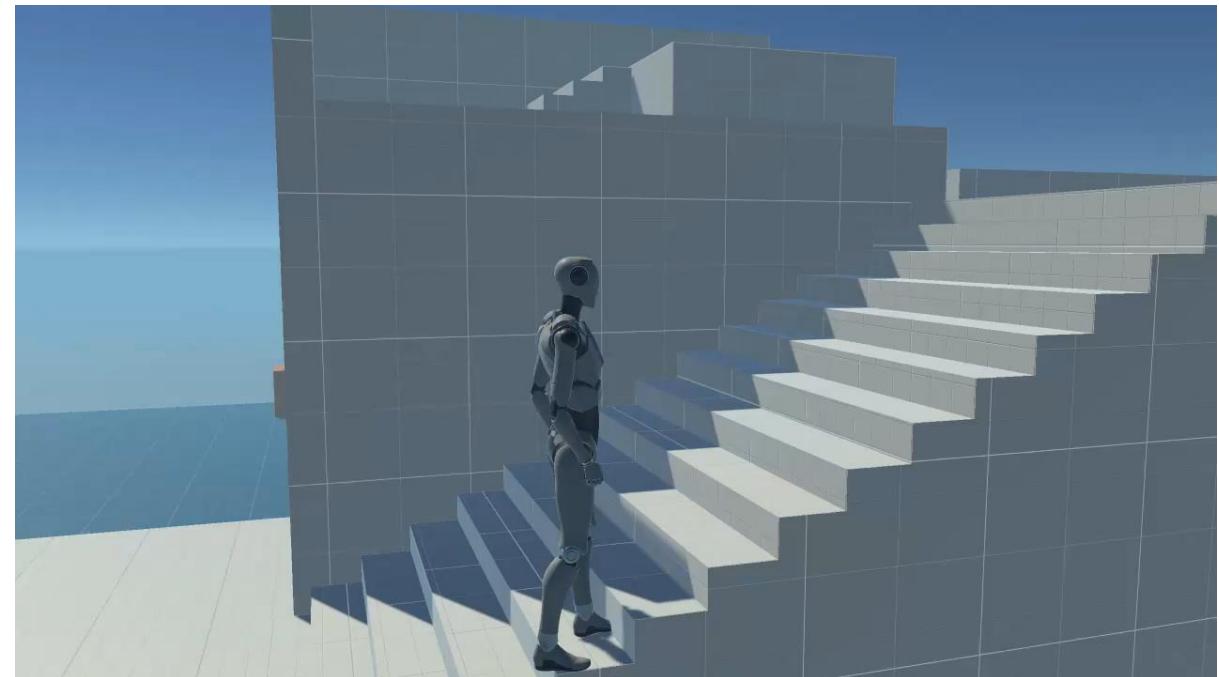
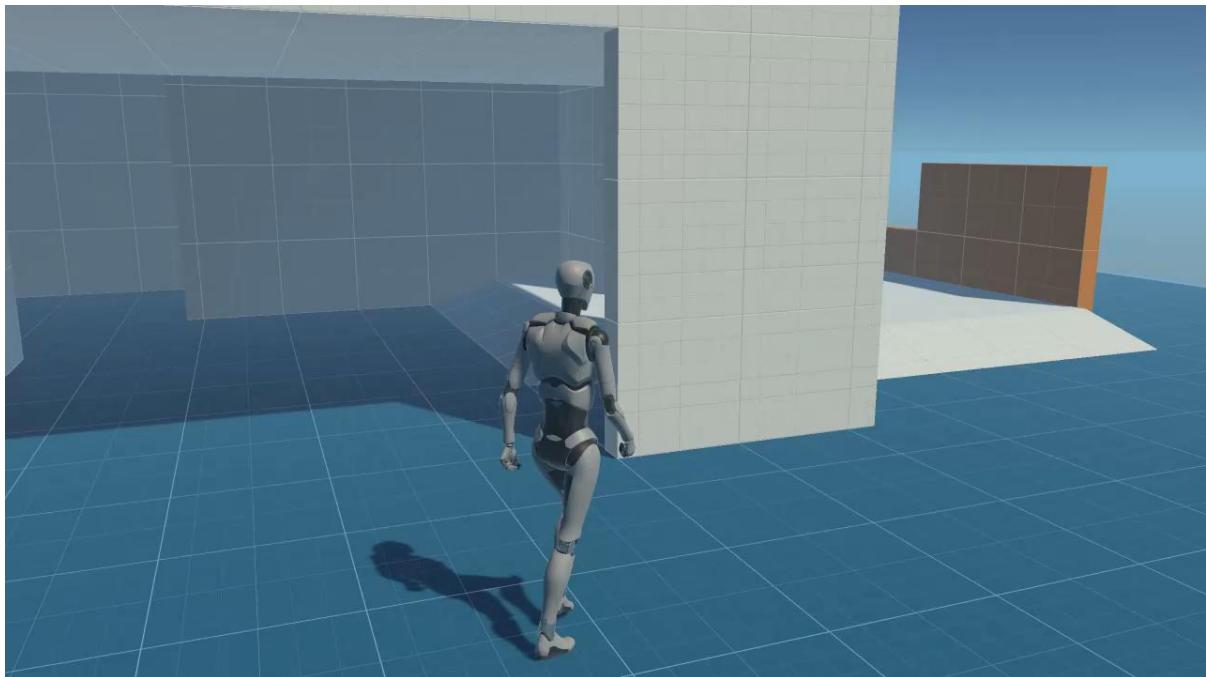


Character Animation Methods



Problems of Kinematic Methods

- Physical plausibility

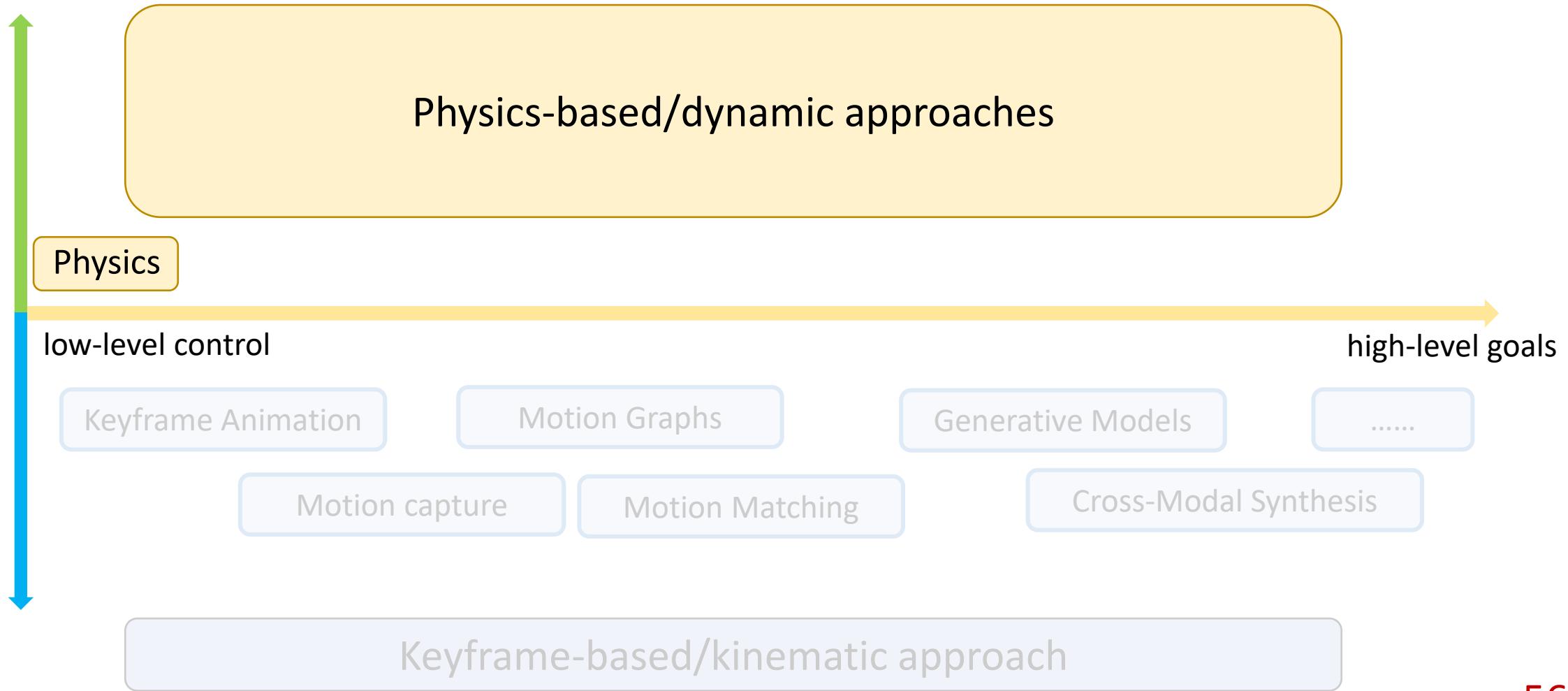


Problems of Kinematic Methods

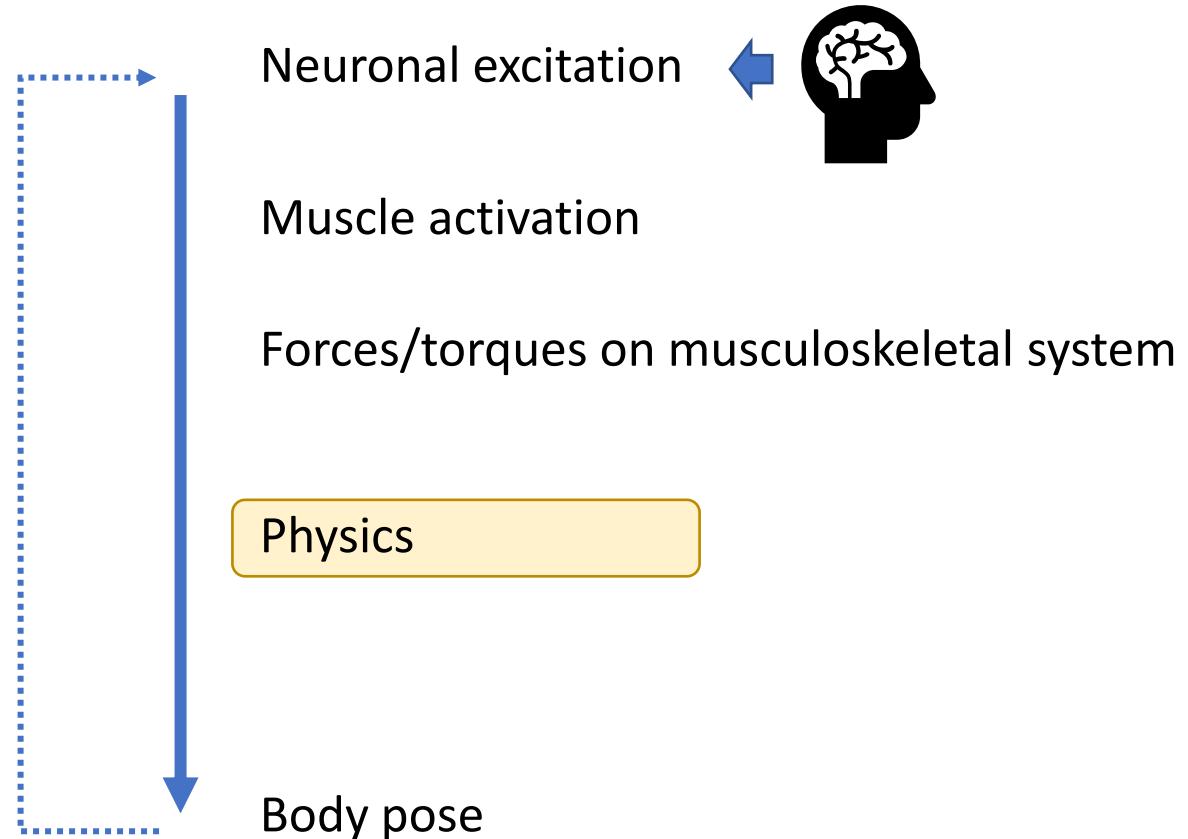
- Interaction with the environment



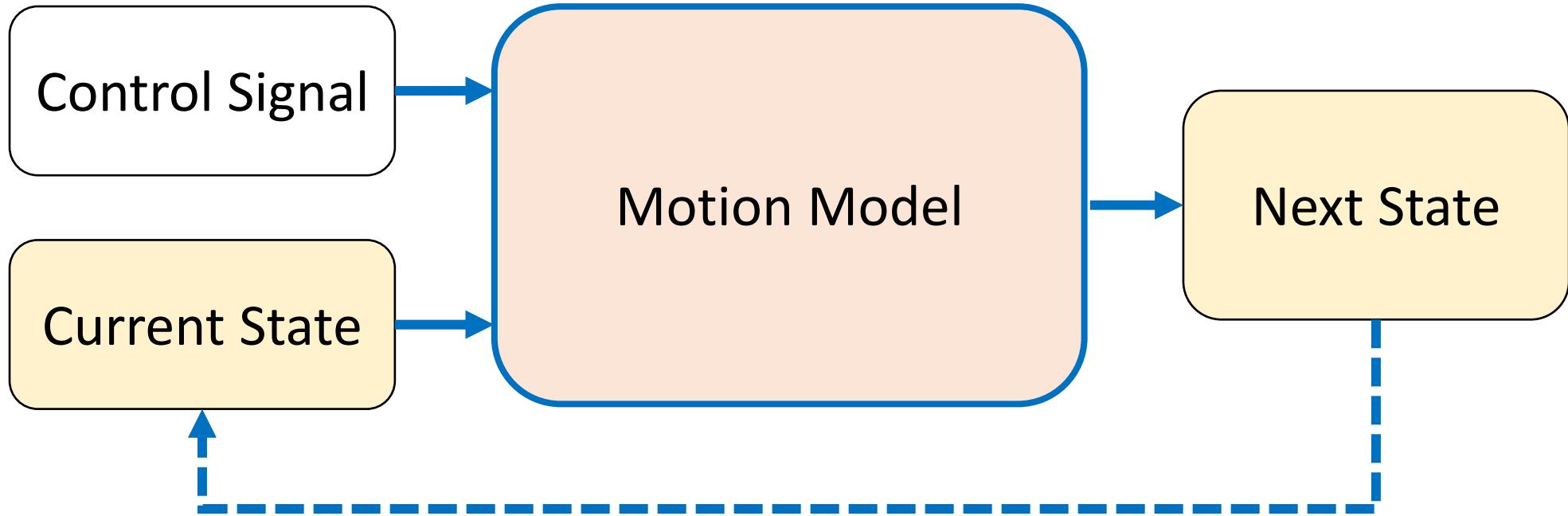
Character Animation Methods



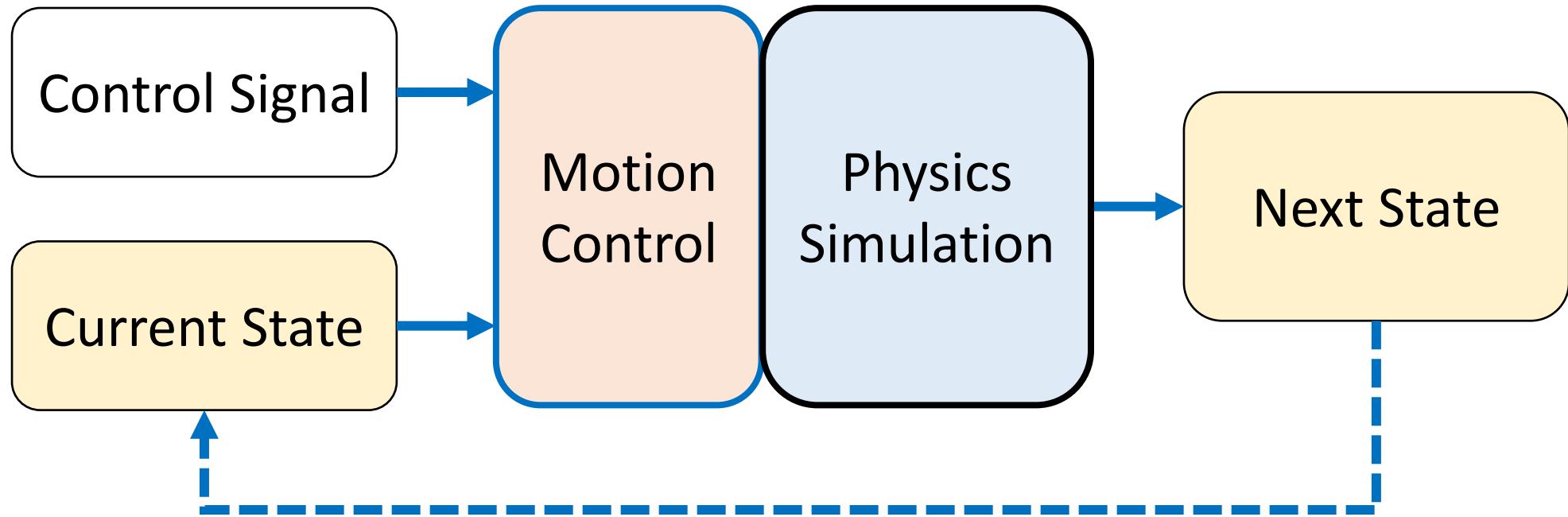
Physics-based/Dynamic Approaches



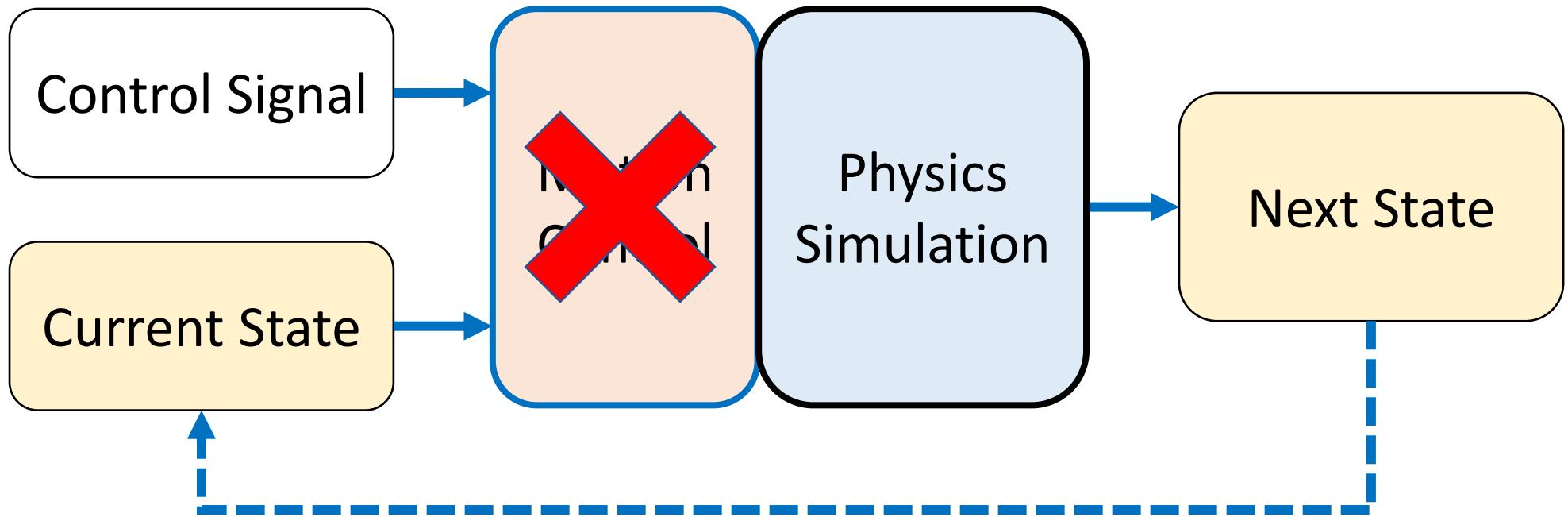
Kinematic Approaches



Physics-based Character Animation



Ragdoll Simulation

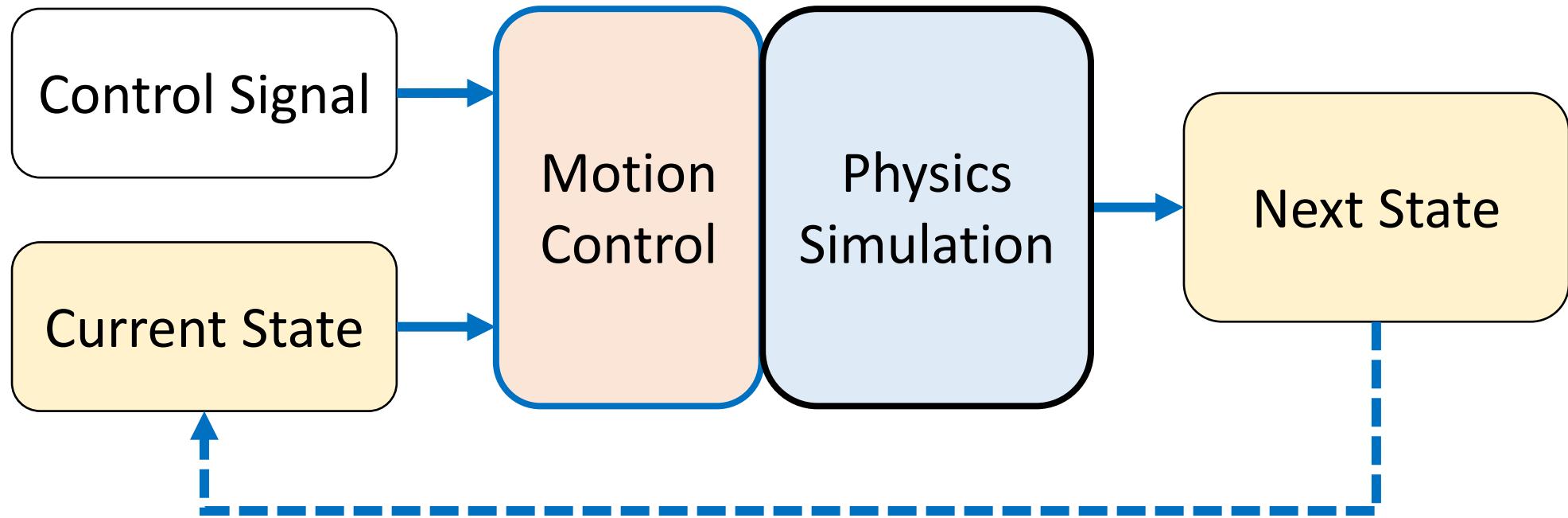


Ragdoll Simulation



Ivan Elizarov - **RagDoll Realistic - Unreal engine 4**
<https://www.youtube.com/watch?v=4pWBtoGzwwE>

Physics-based Character Animation



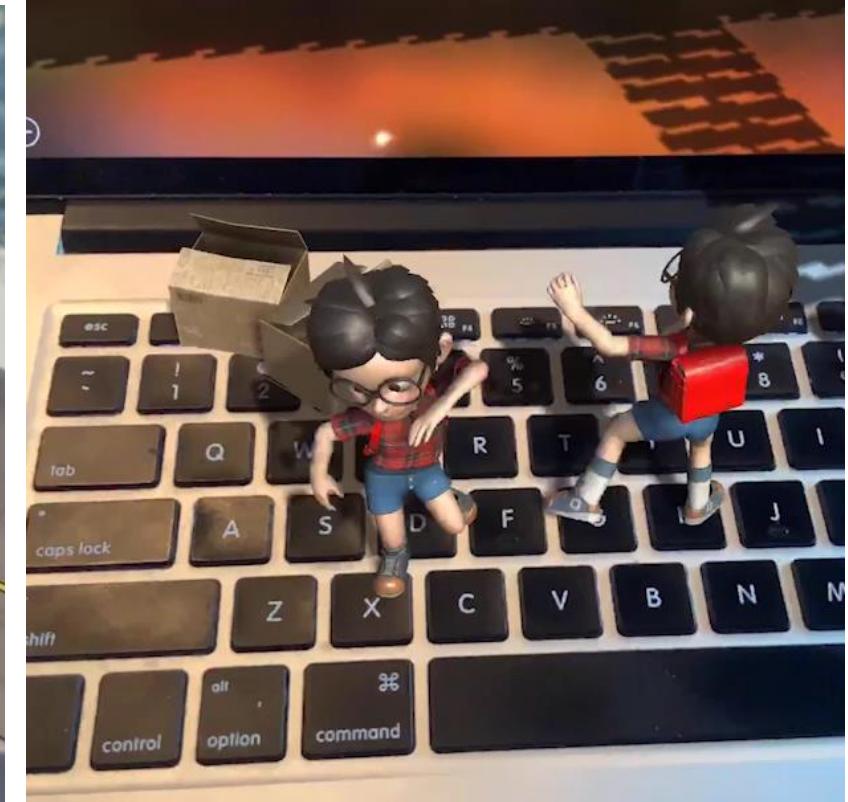
Physics-based Character Animation



Clumsy Ninja

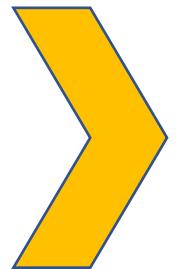


Party Animals

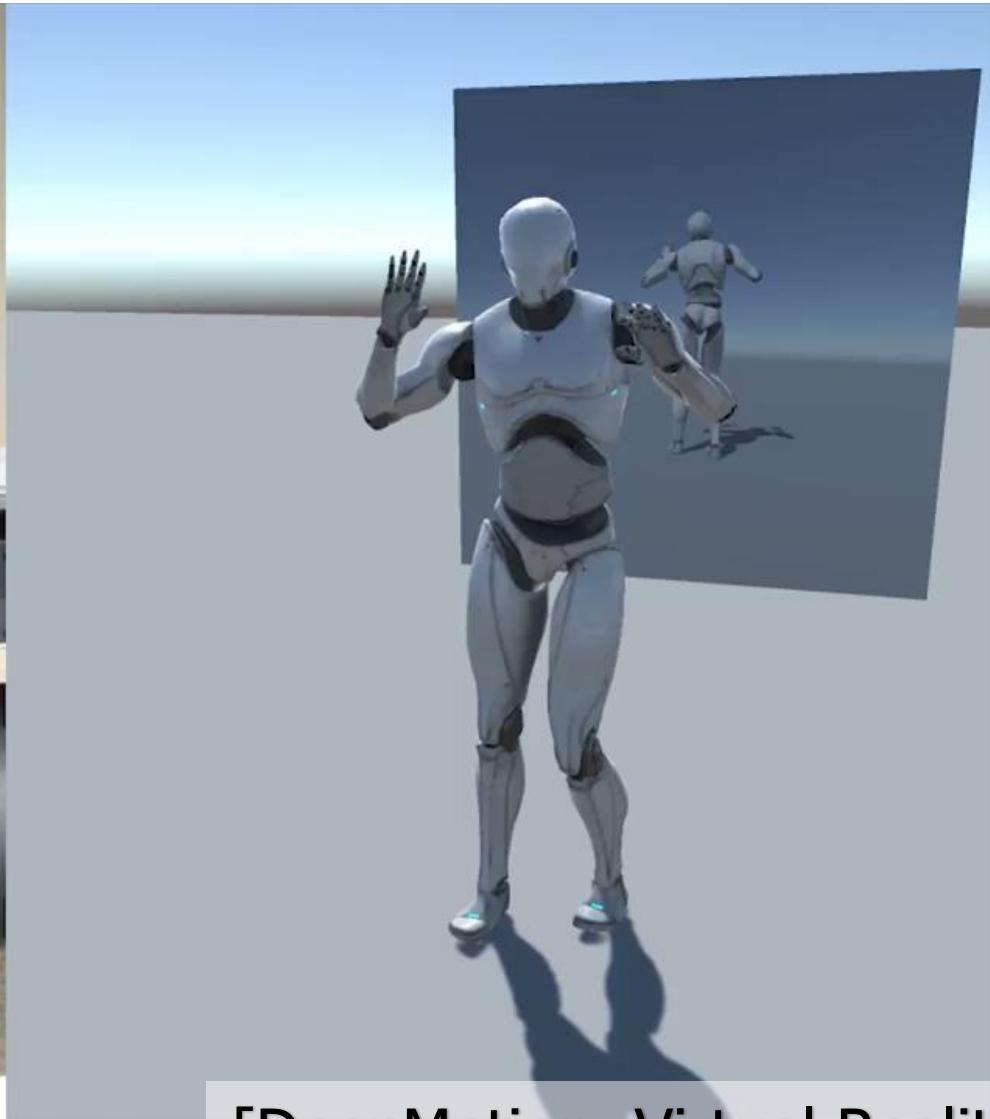


DeepMotion Brain

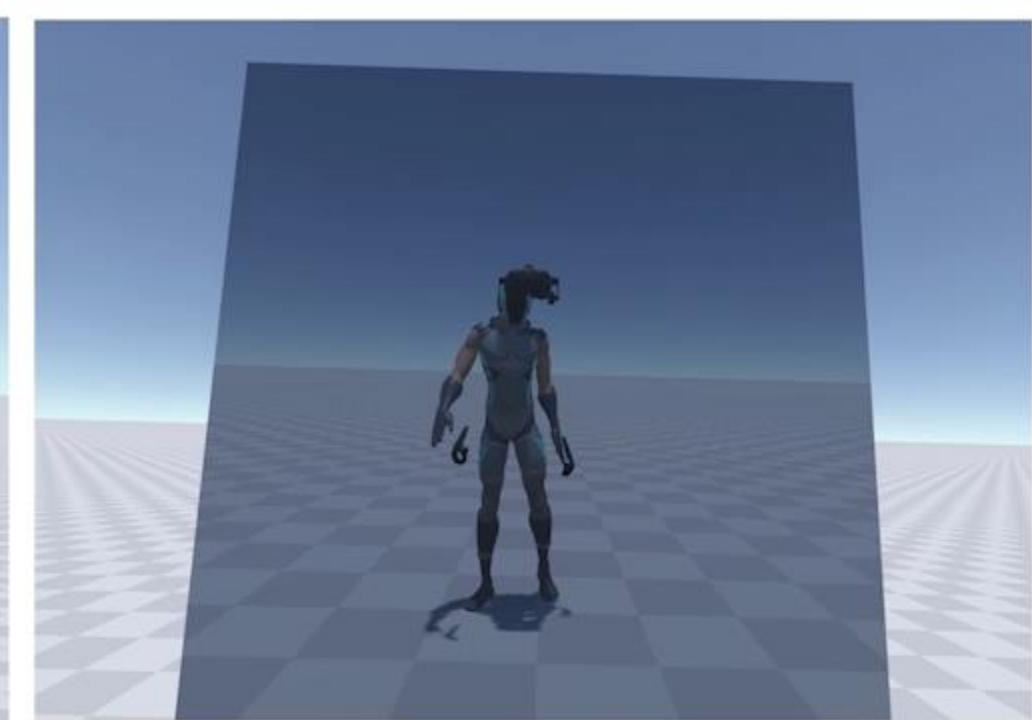
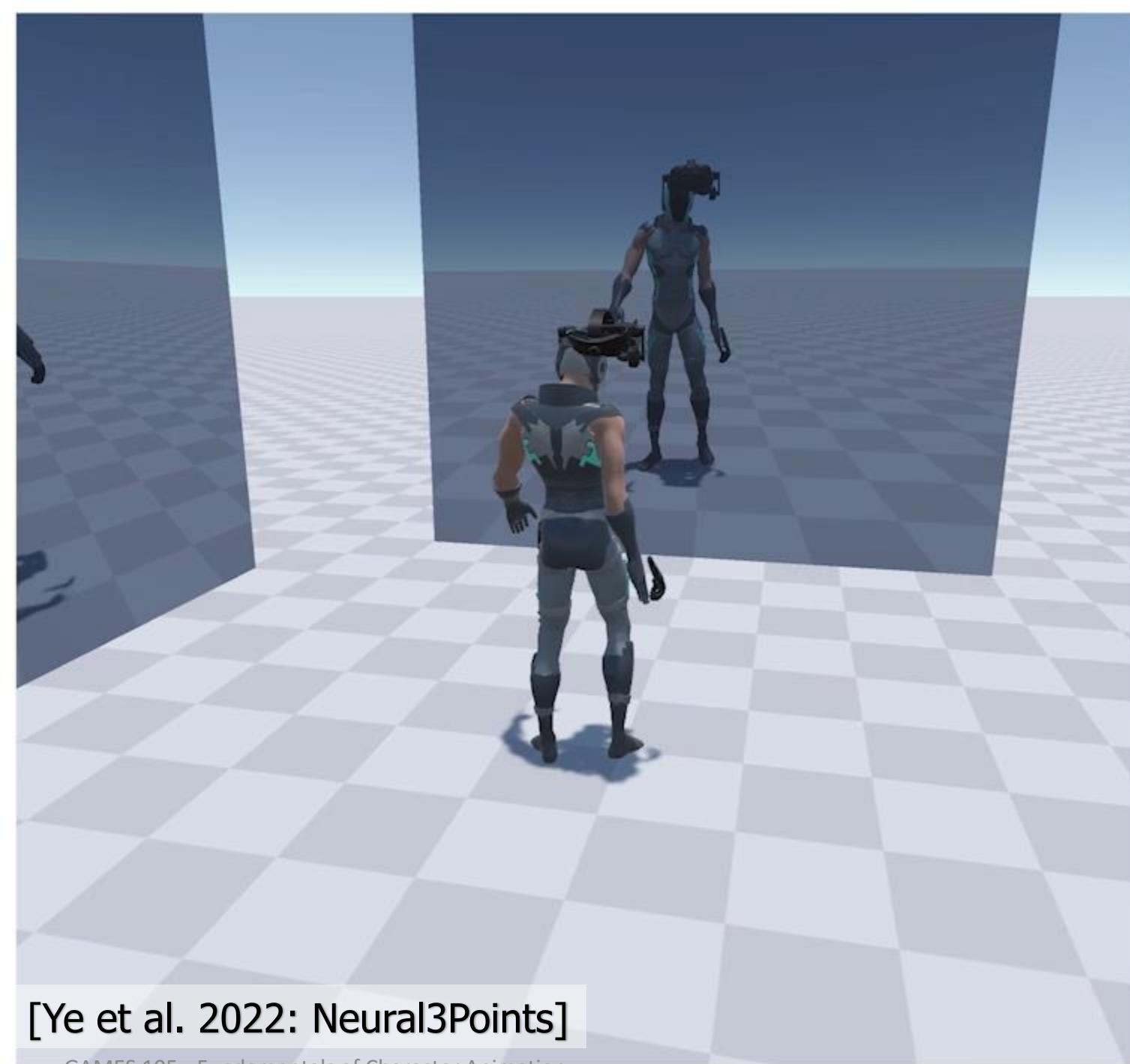
Motion Reconstruction with Sparse Sensors



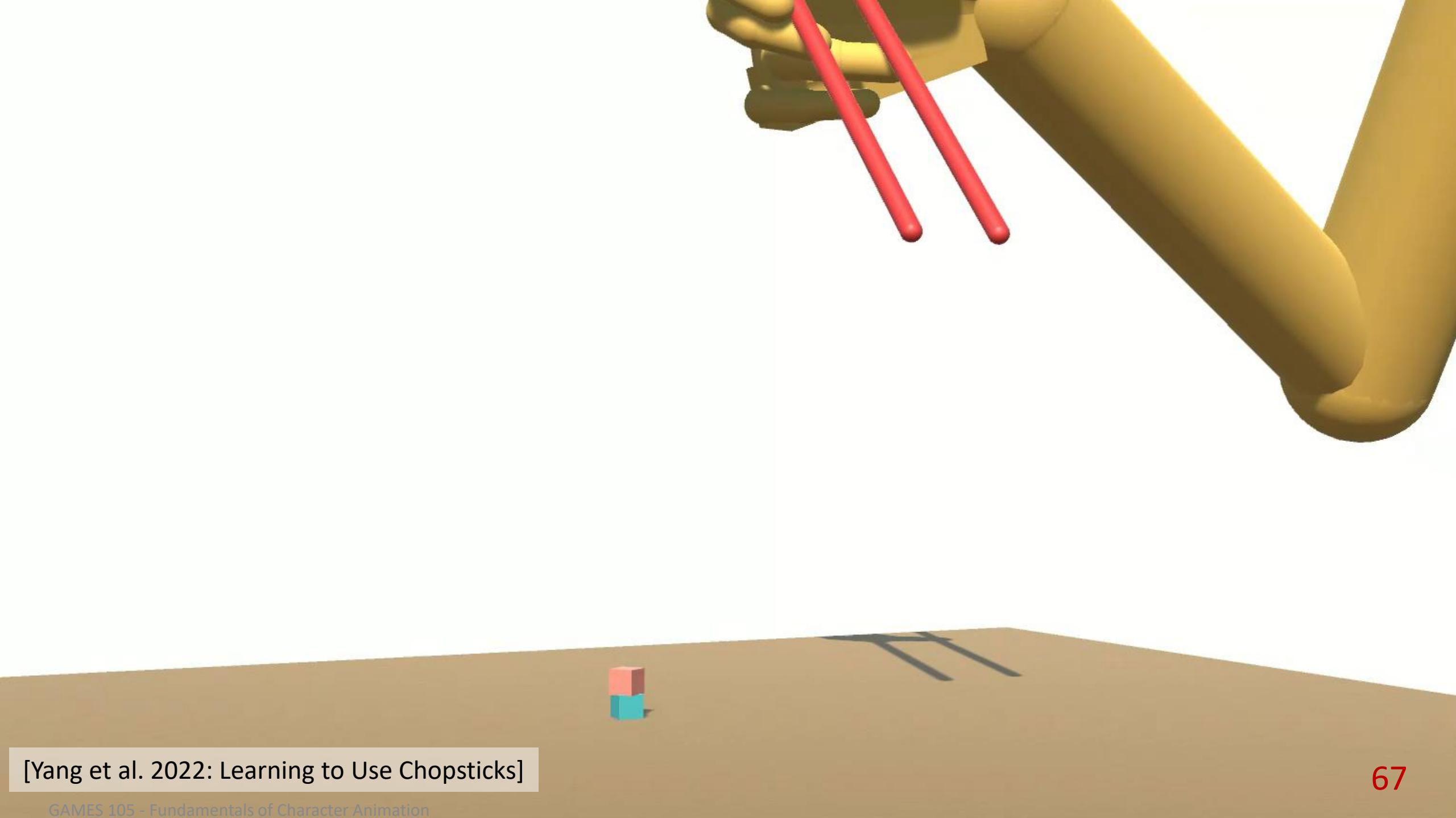
Motion Reconstruction with Sparse Sensors



[DeepMotion: Virtual Reality Tracking ^{SE}]

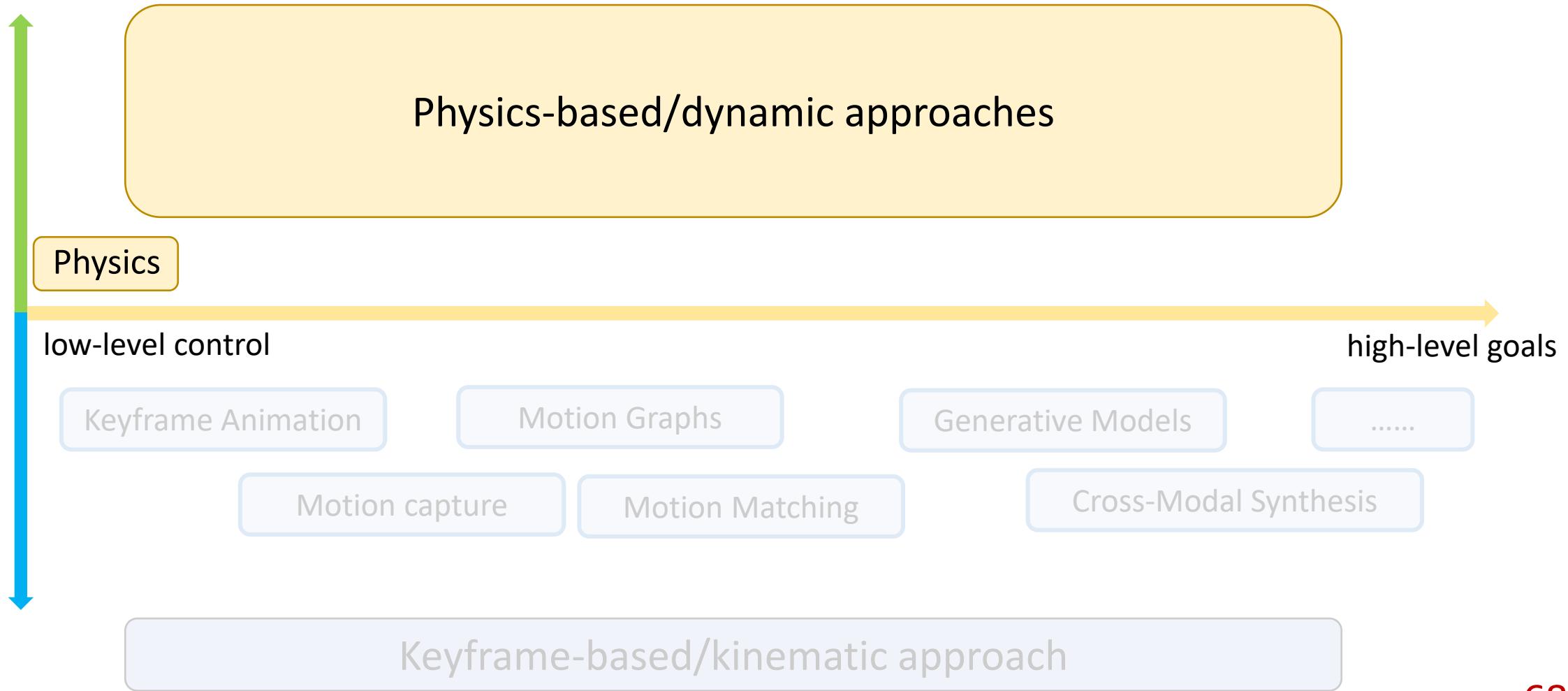


[Ye et al. 2022: Neural3Points]

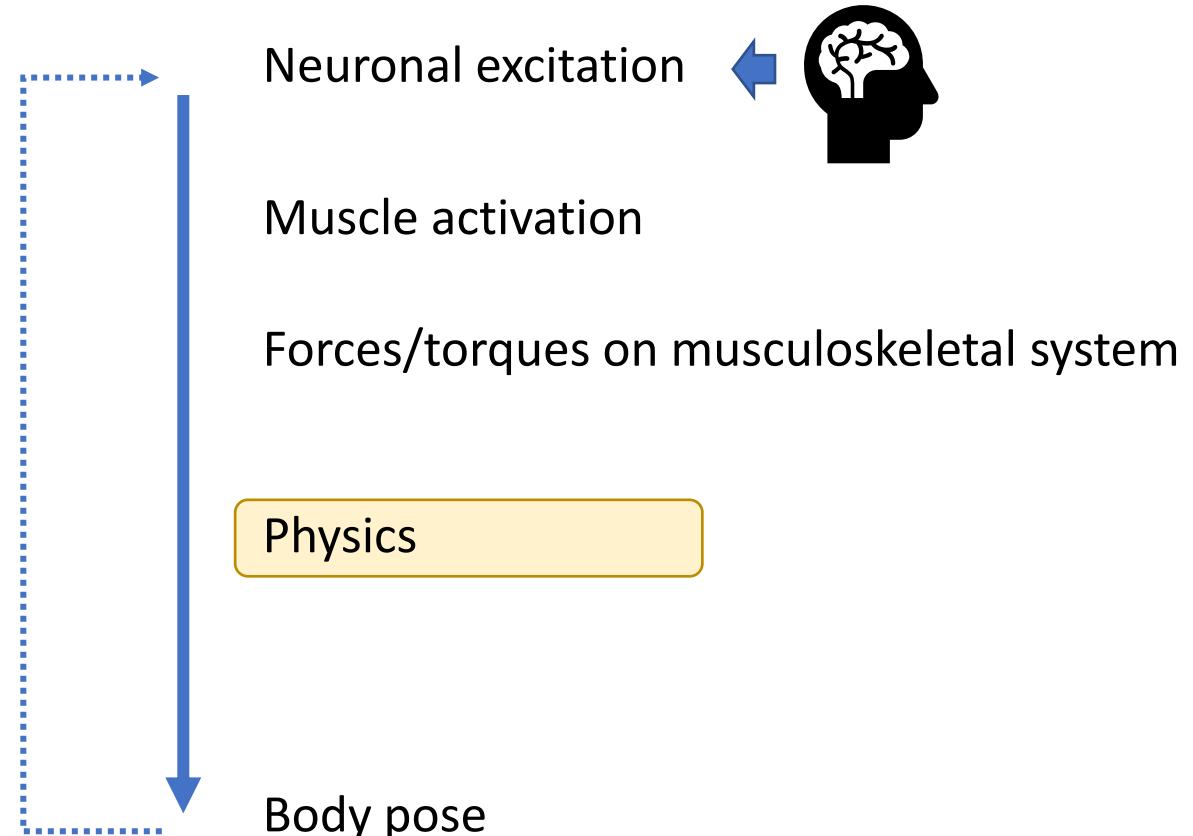
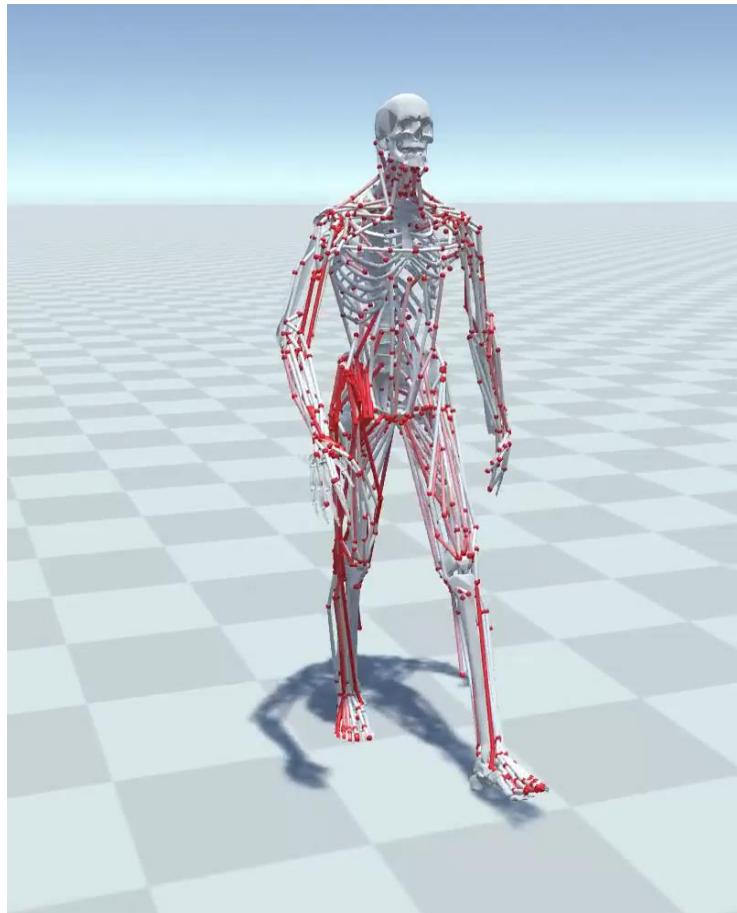


[Yang et al. 2022: Learning to Use Chopsticks]

Character Animation Methods

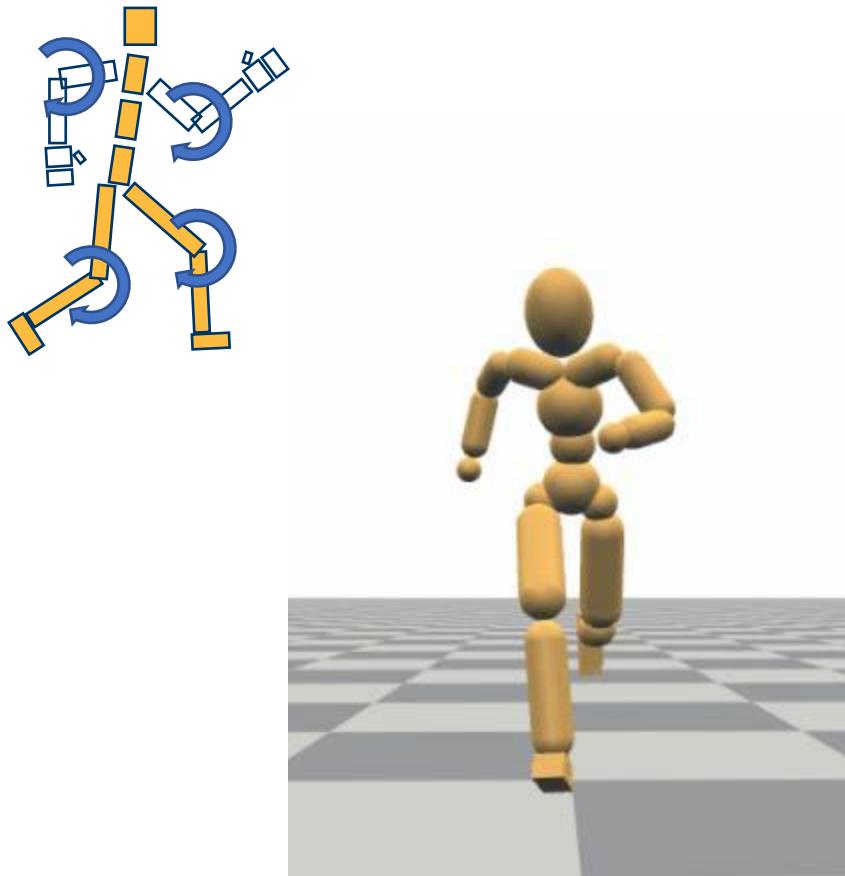


Physics-based/Dynamic Approaches



Physics-based/Dynamic Approaches

Simplified control & physics



Neuronal excitation

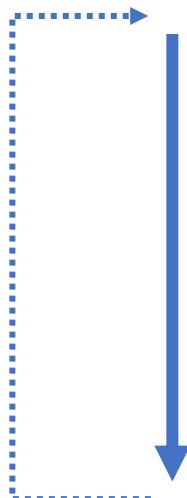
Muscle activation

Forces/torques on skeleton

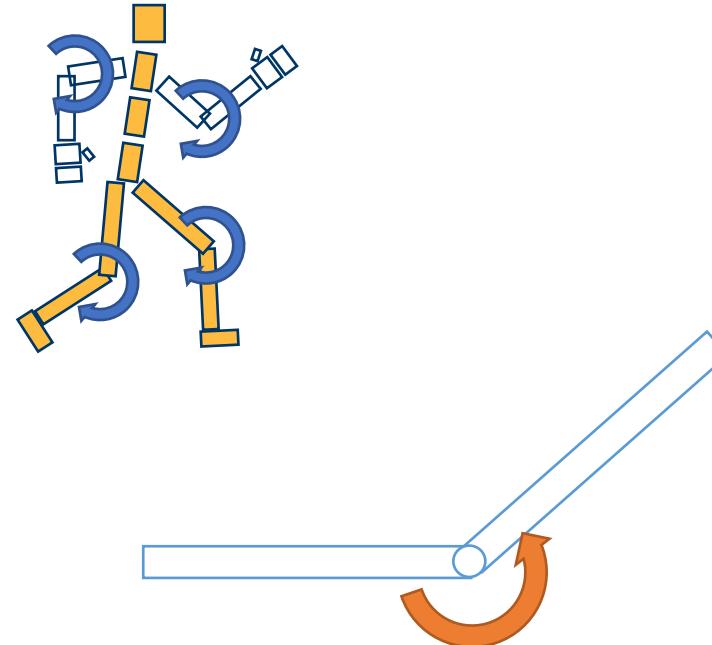
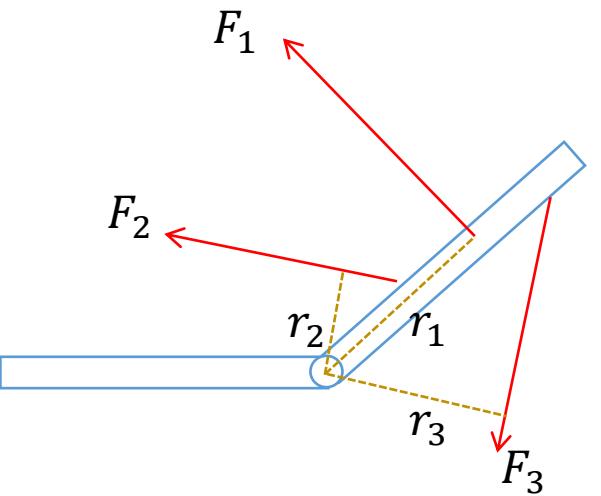
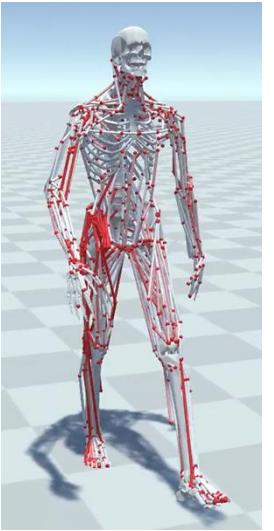


Physics

Body pose

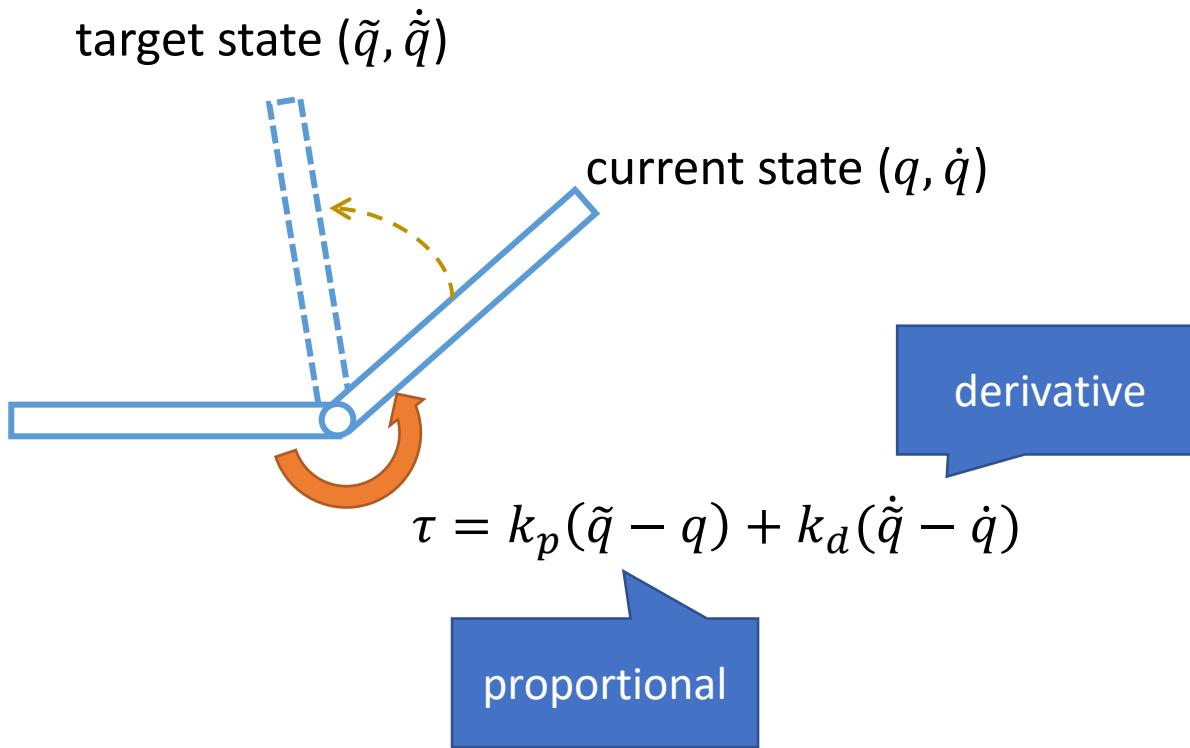


Force & Torque

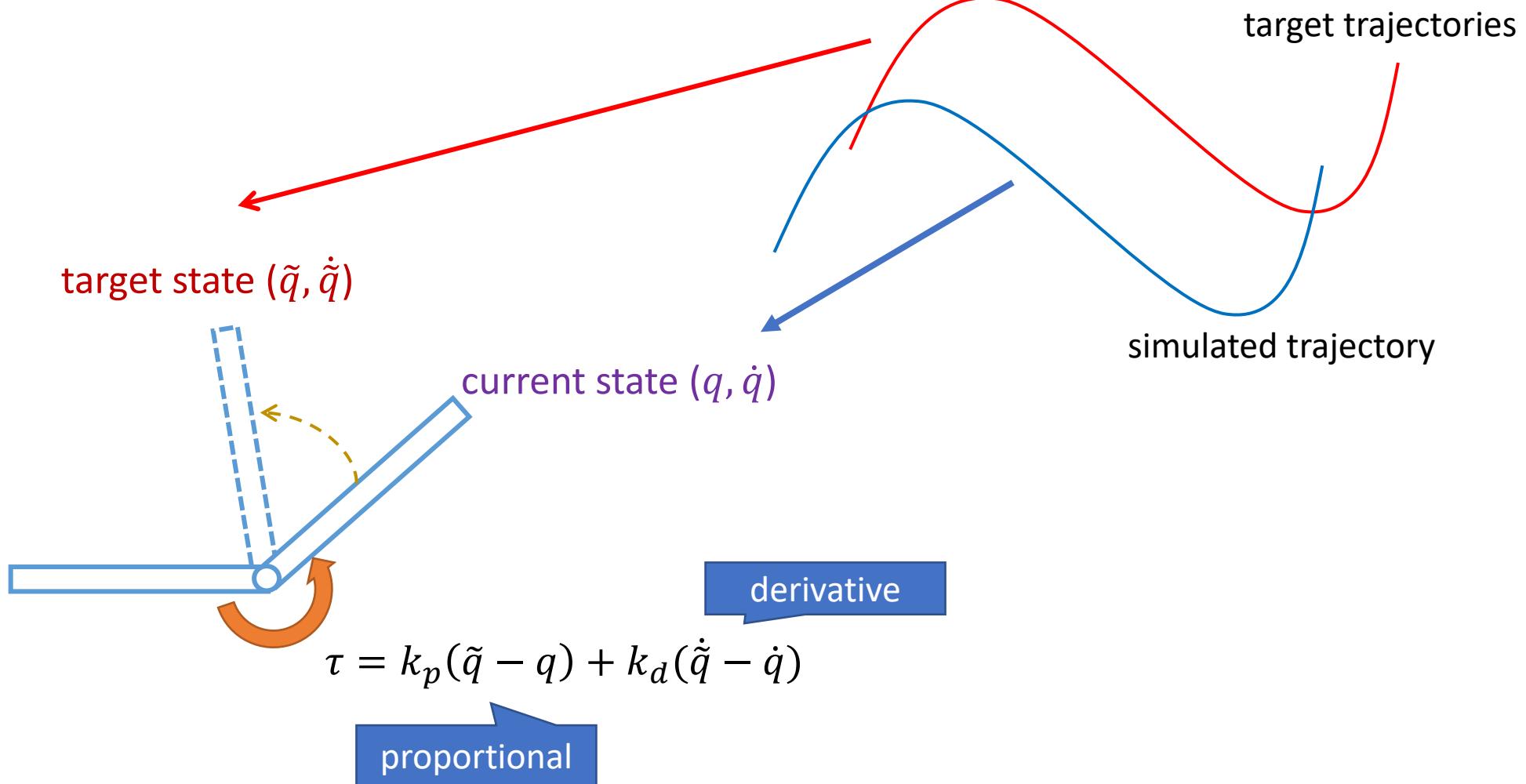


$$\tau = \sum r_i \times F_i$$

Proportional-Derivative (PD) Control



Tracking Controllers



Tracking Controllers



[Hodgins and Wooten 1995,
Animating Human Athletics]

Control is Hard

[QWOP - http://www.foddy.net/Athletics.html](http://www.foddy.net/Athletics.html)



Control is Hard

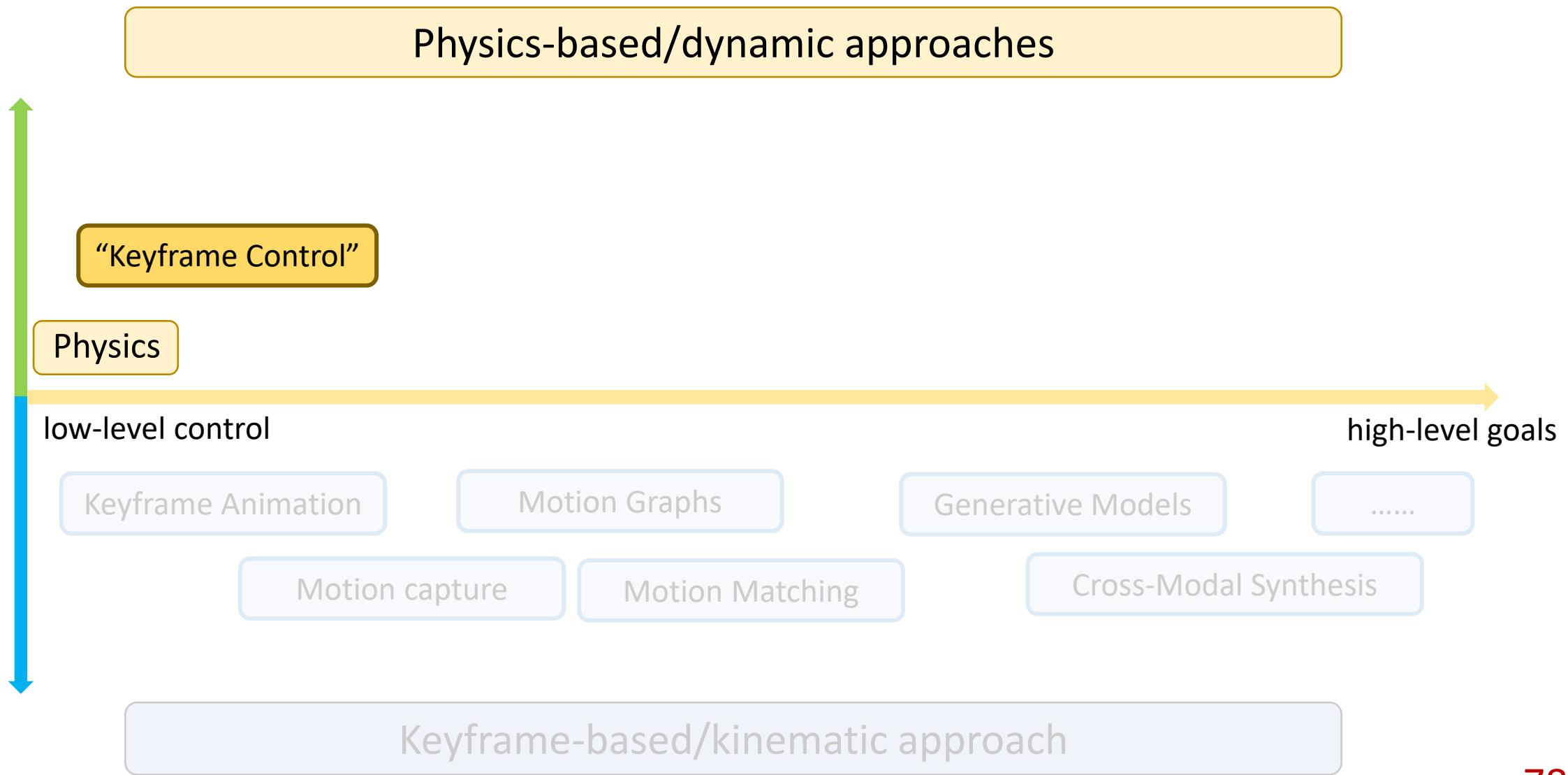


QWOP Cosplay At Anime North 2013 <https://www.youtube.com/watch?v=Mflgs3rH-Y8>

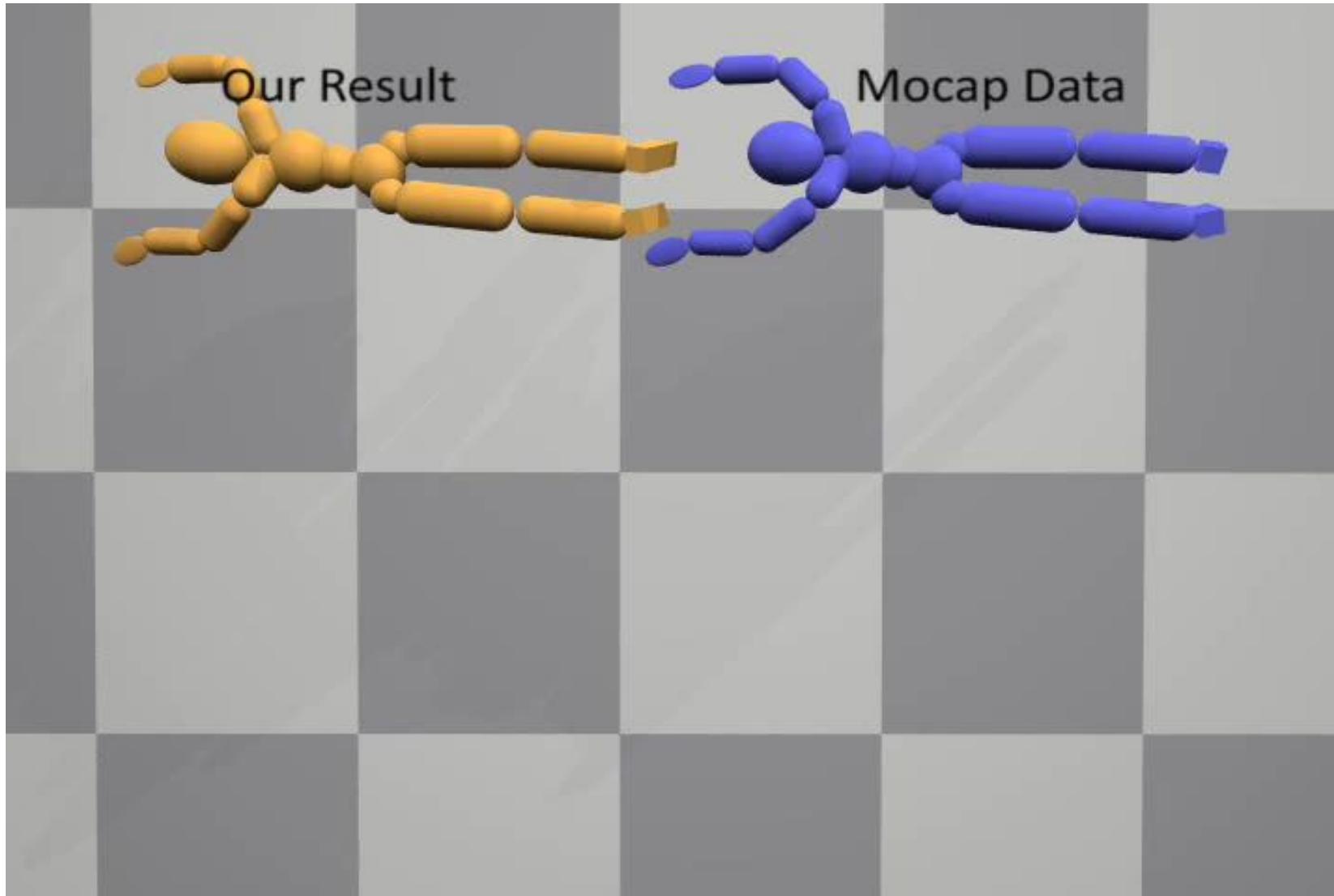
Trajectory Crafting



Character Animation Methods

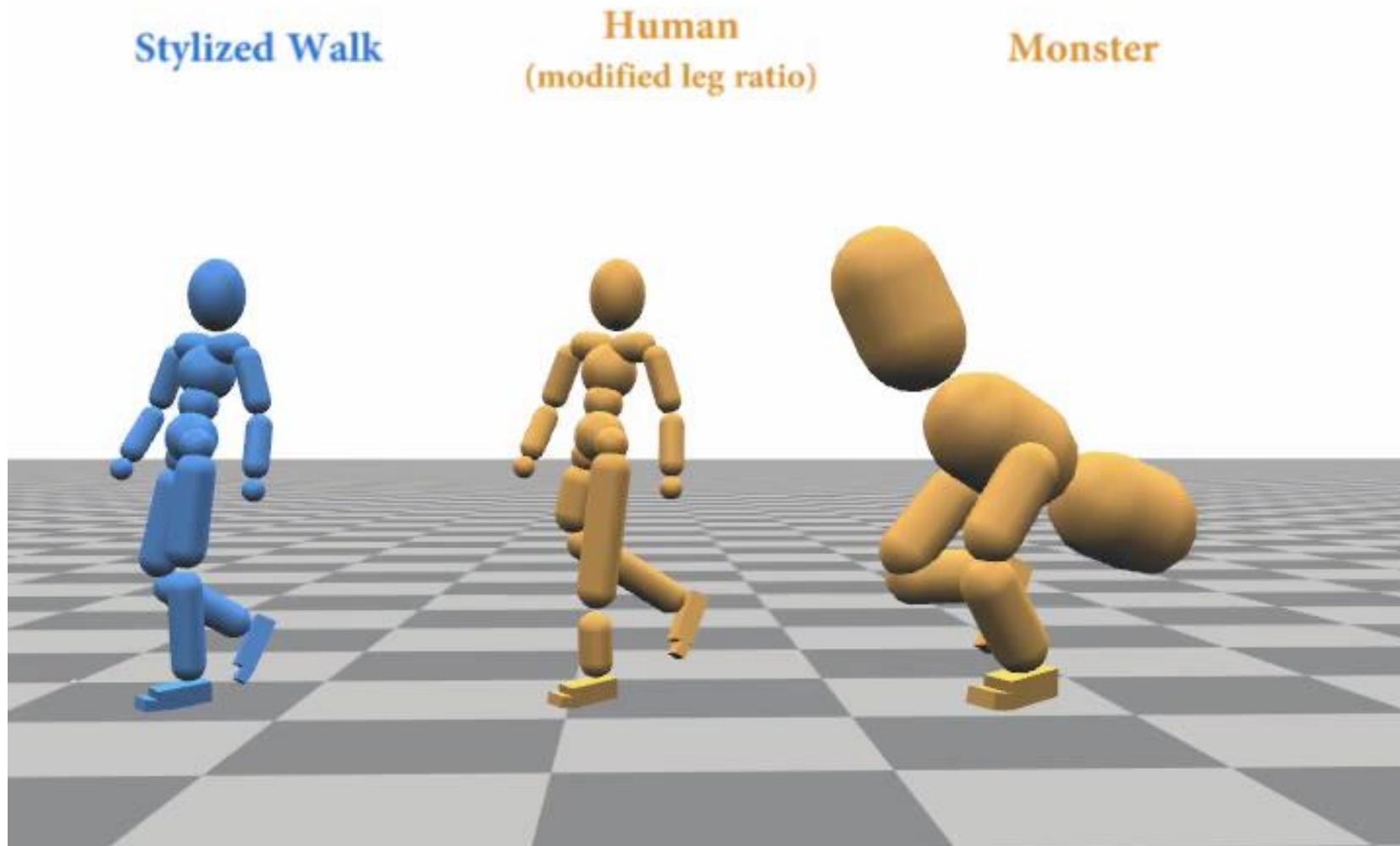


Spacetime/Trajectory Optimization



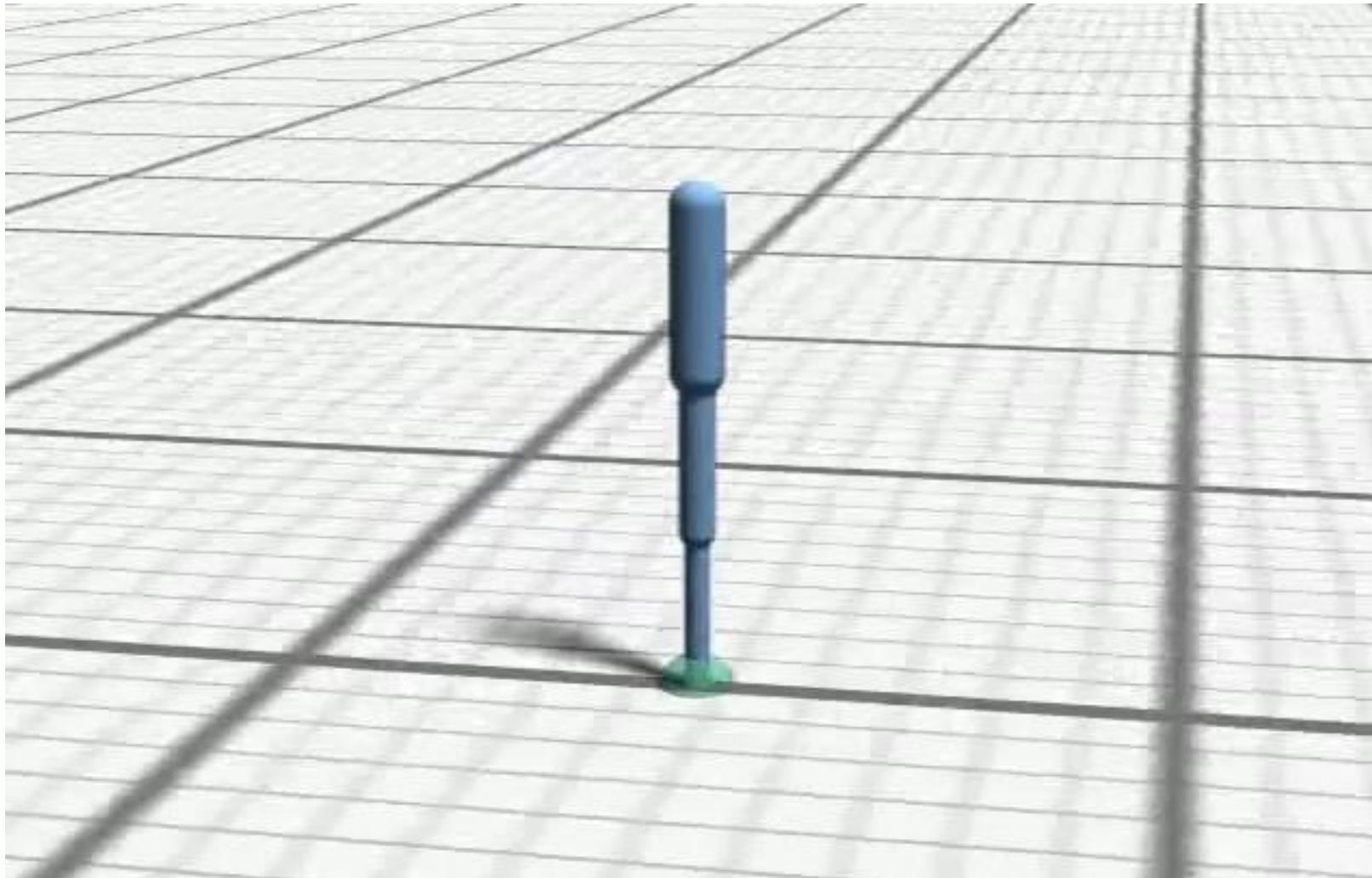
[Liu et al 2010. SAMCON]

Spacetime/Trajectory Optimization



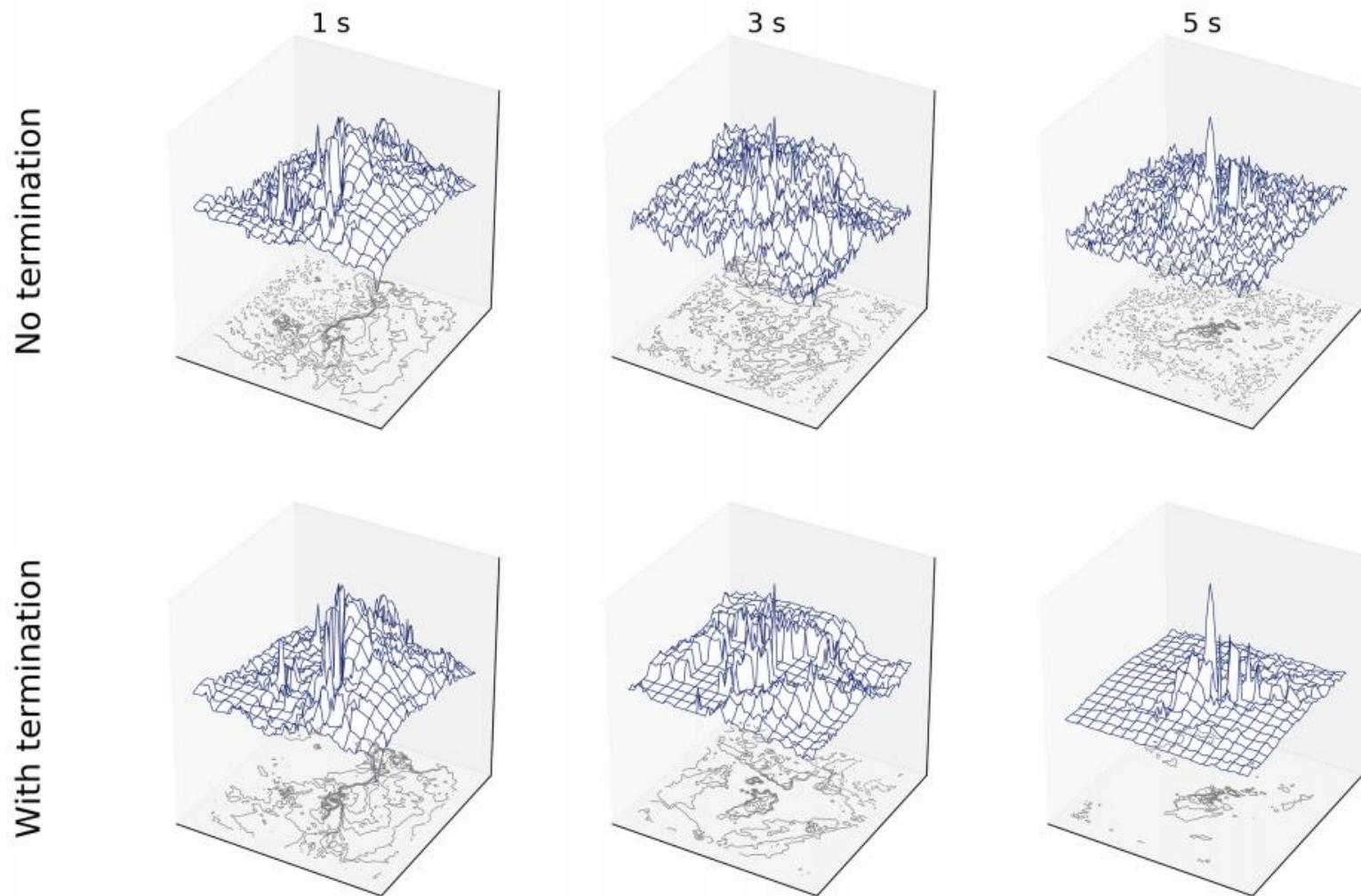
[Liu et al 2010. SAMCON]

Spacetime/Trajectory Optimization



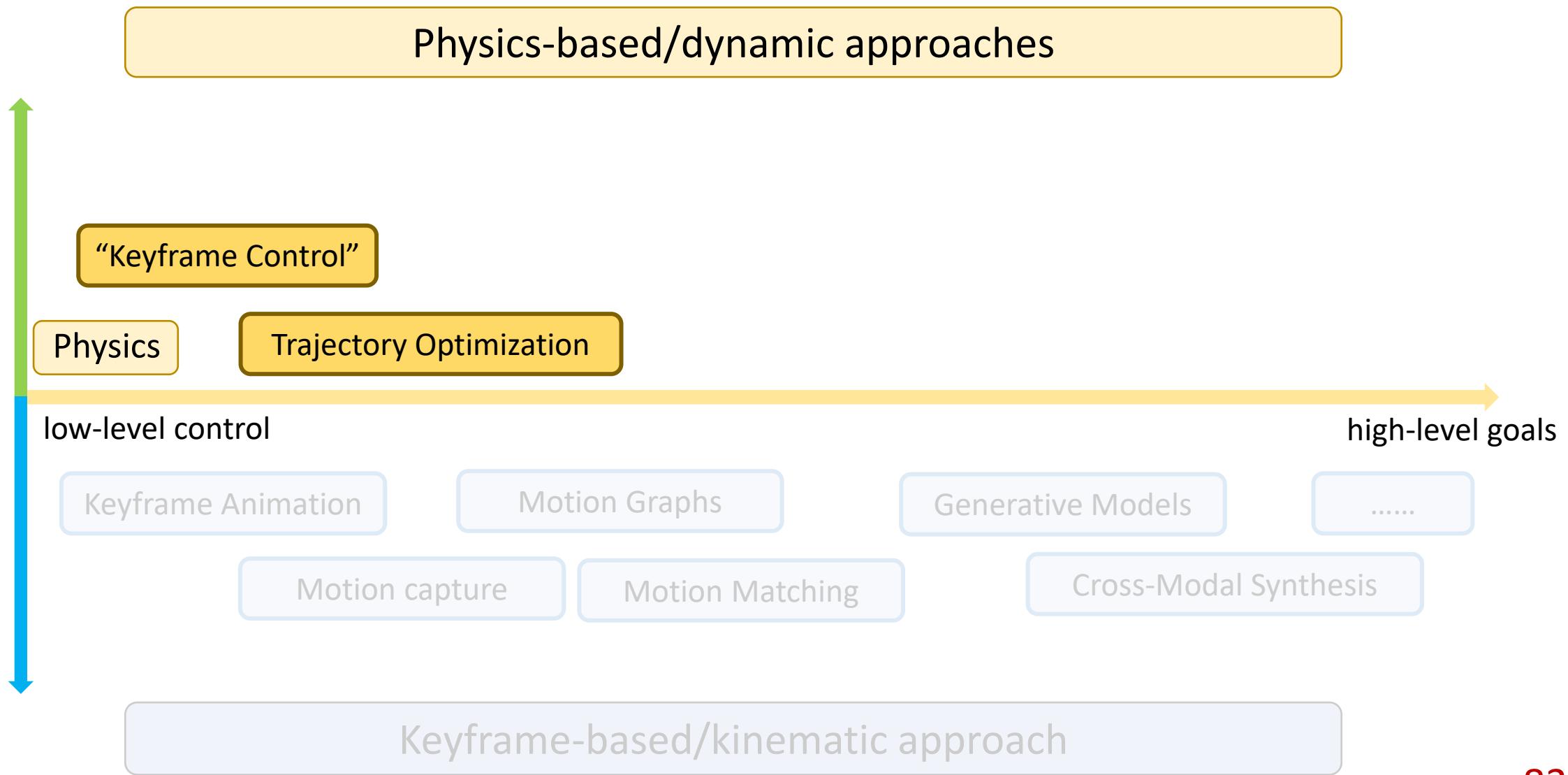
[Wampler and Popović. 2009. Optimal gait and form for animal locomotion]

Spacetime/Trajectory Optimization

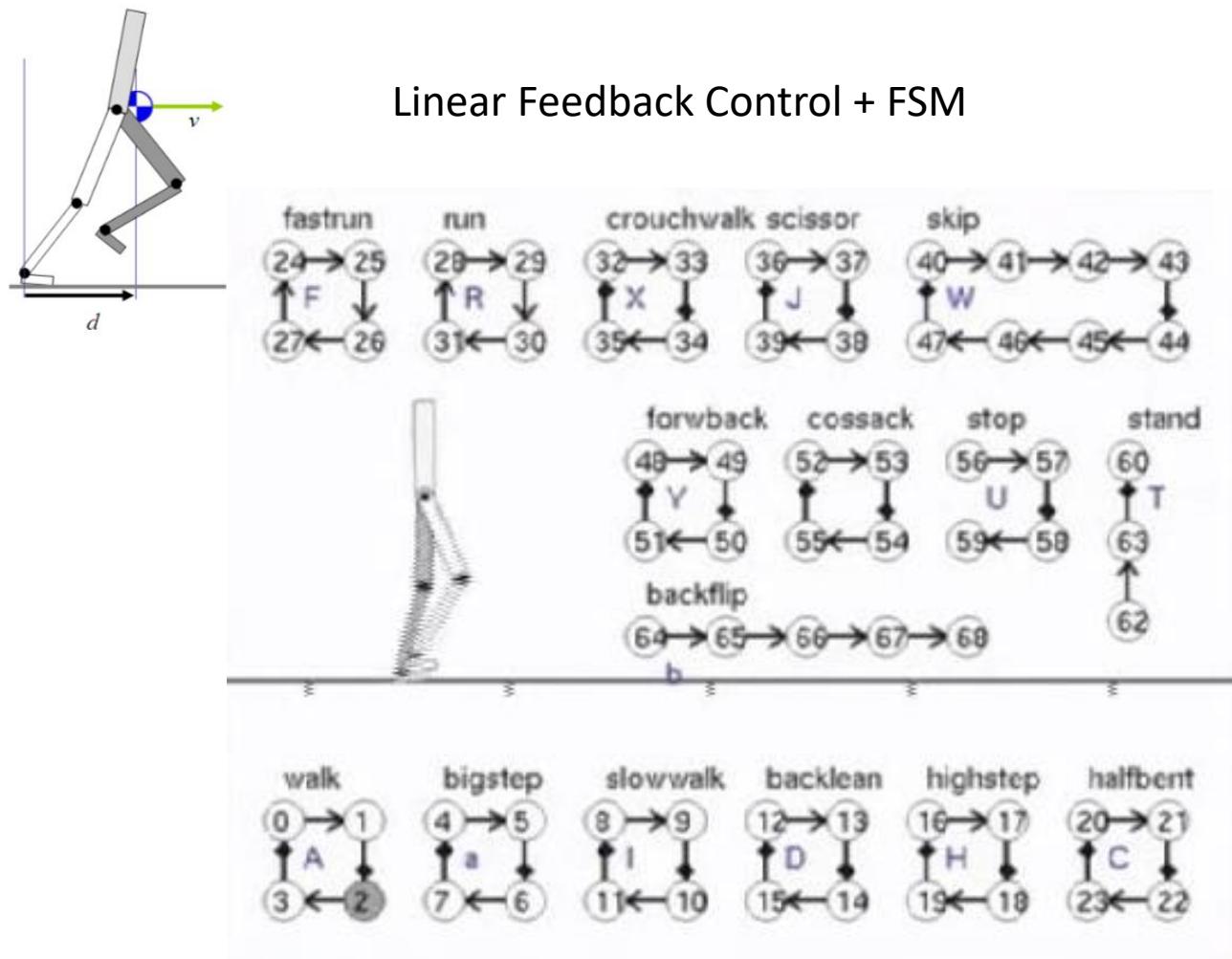


[Hamalainen et al. 2020, Visualizing Movement Control Optimization Landscapes]

Character Animation Methods

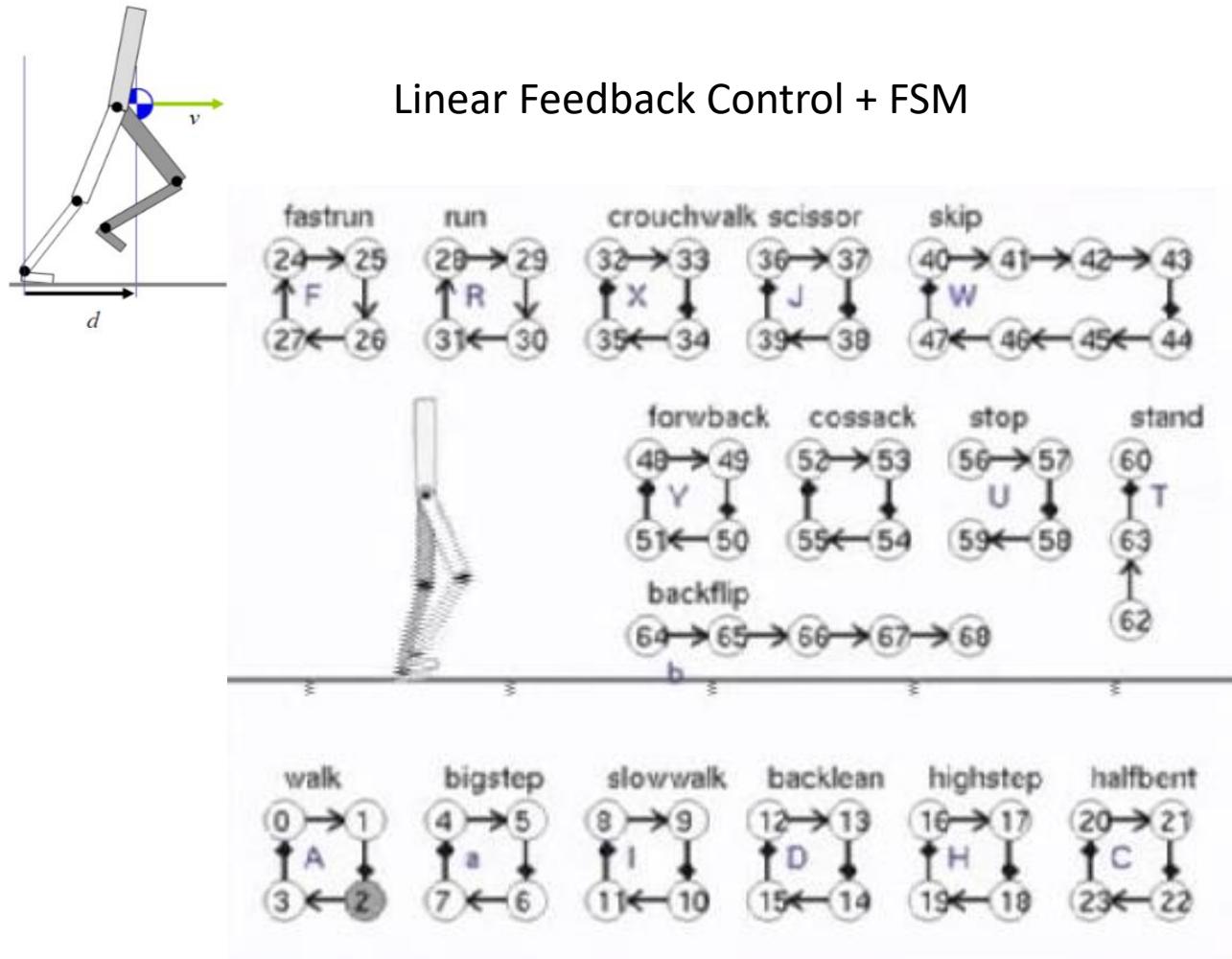


Abstract Models

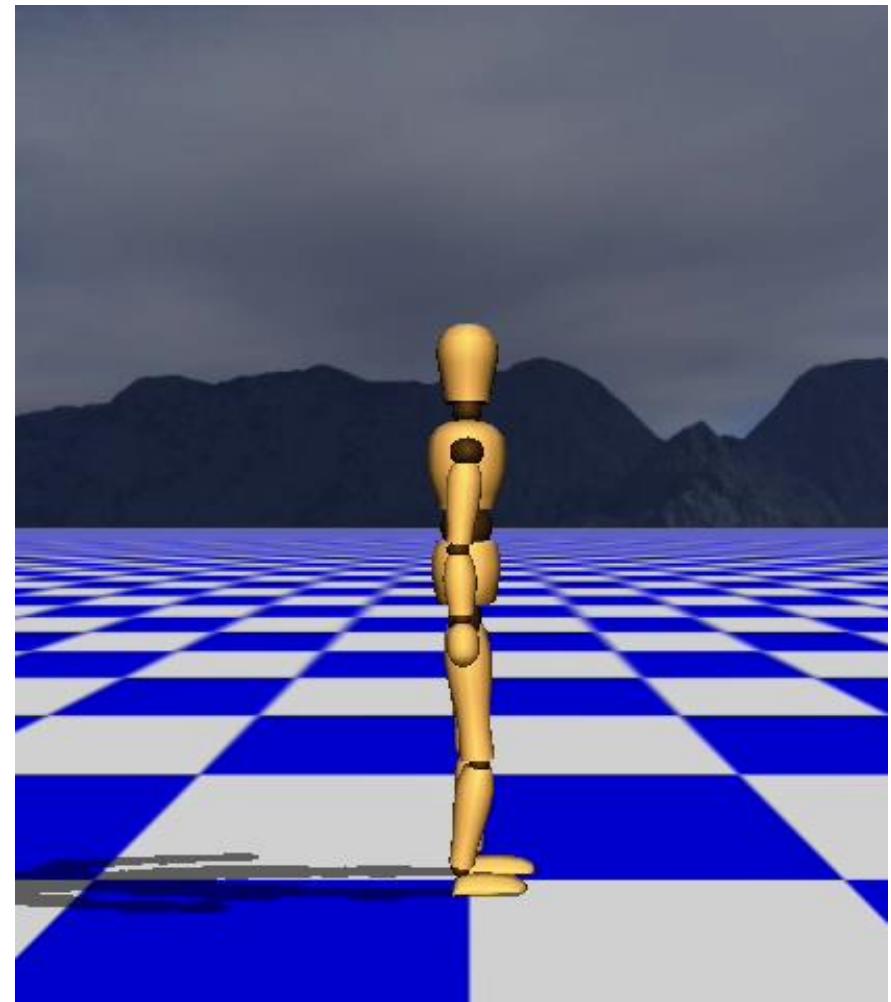


[Yin et al. 2007, SIMBICON]

Abstract Models

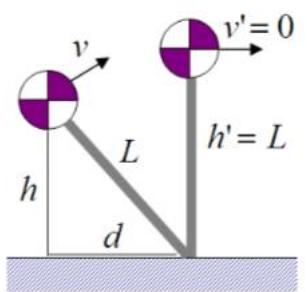


[Yin et al. 2007, SIMBICON]

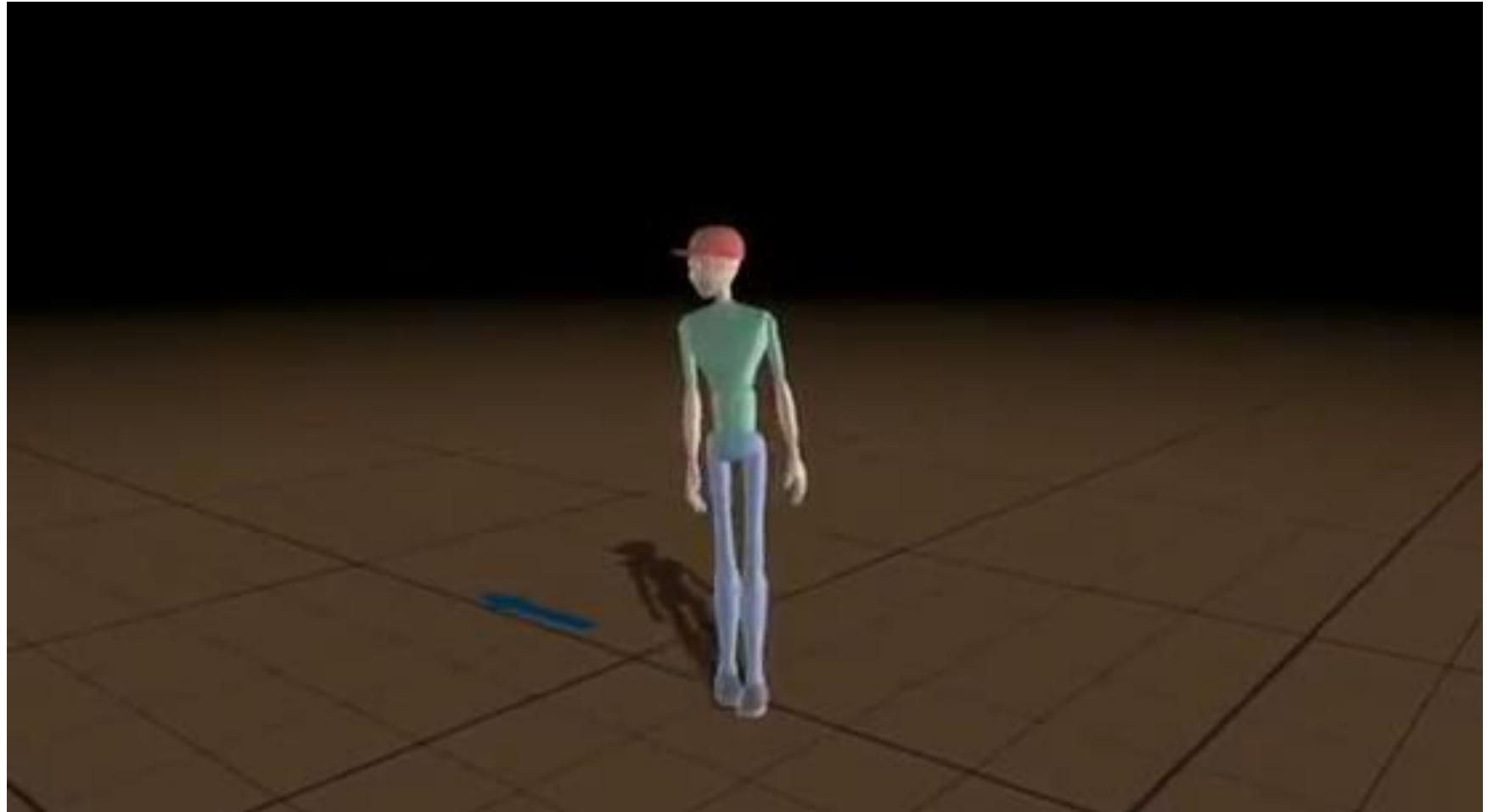


Abstract Models

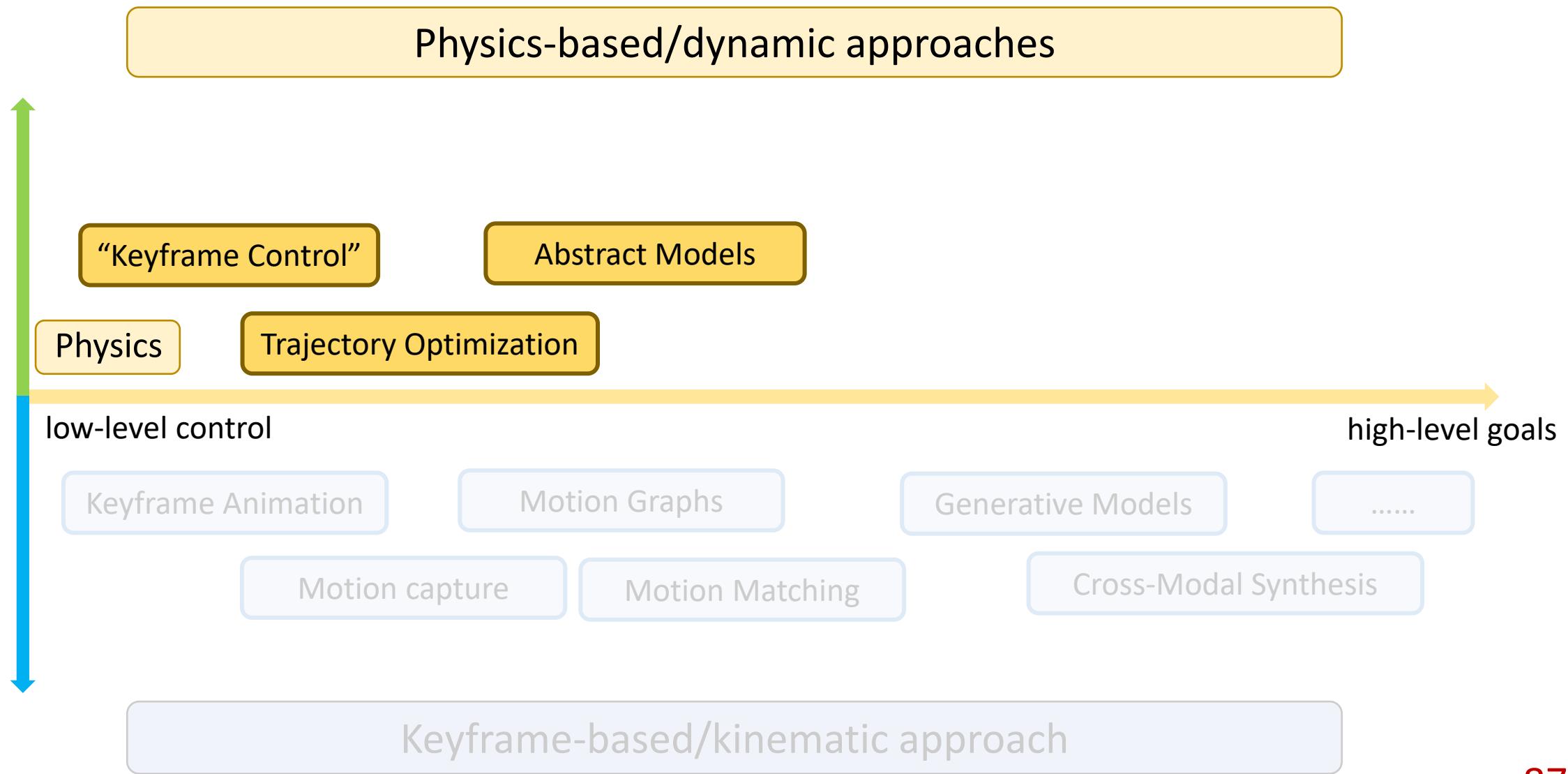
Inverted Pendulum Model



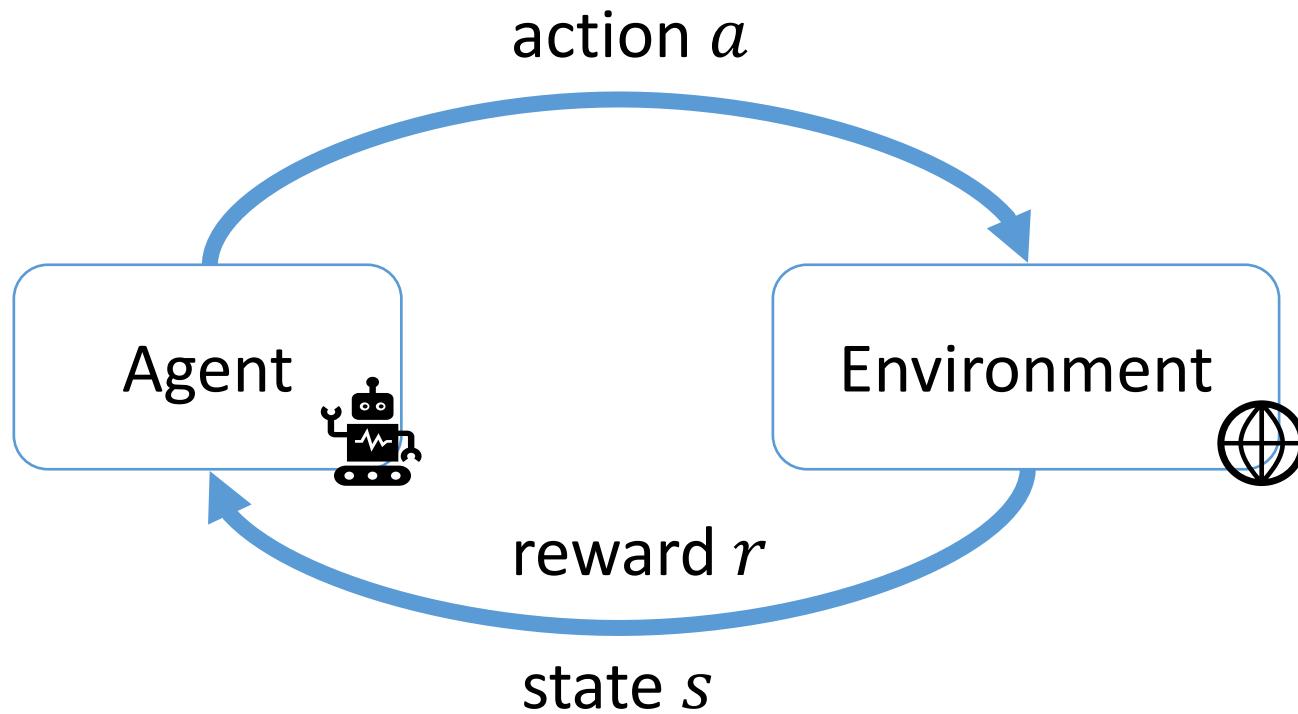
[Coros et al. 2010]



Character Animation Methods



Reinforcement Learning



Deep Reinforcement Learning



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Published: 25 February 2015

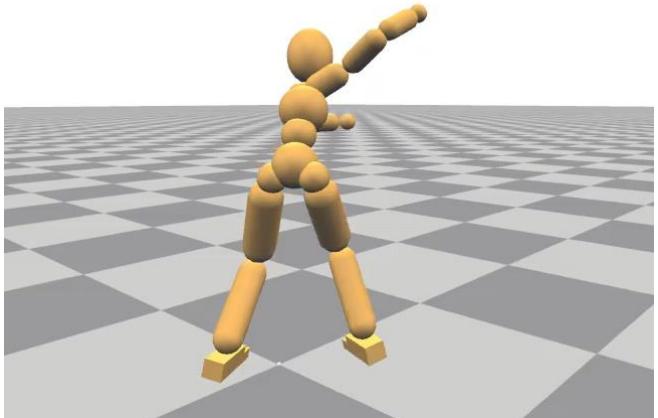
Human-level control through deep reinforcement learning

Volodymyr Mnih, Koray Kavukcuoglu, David Silver, Andrei A. Rusu, Joel Veness, Marc G. Bellemare, Alex Graves, Martin Riedmiller, Andreas K. Fidjeland, Georg Ostrovski, Stig Petersen, Charles Beattie, Amir Sadik, Ioannis Antonoglou, Helen King, Dharshan Kumaran, Daan Wierstra, Shane Legg & Demis Hassabis

[Nature](#) 518, 529–533 (2015) | [Cite this article](#)

412k Accesses | 8860 Citations | 1562 Altmetric | [Metrics](#)

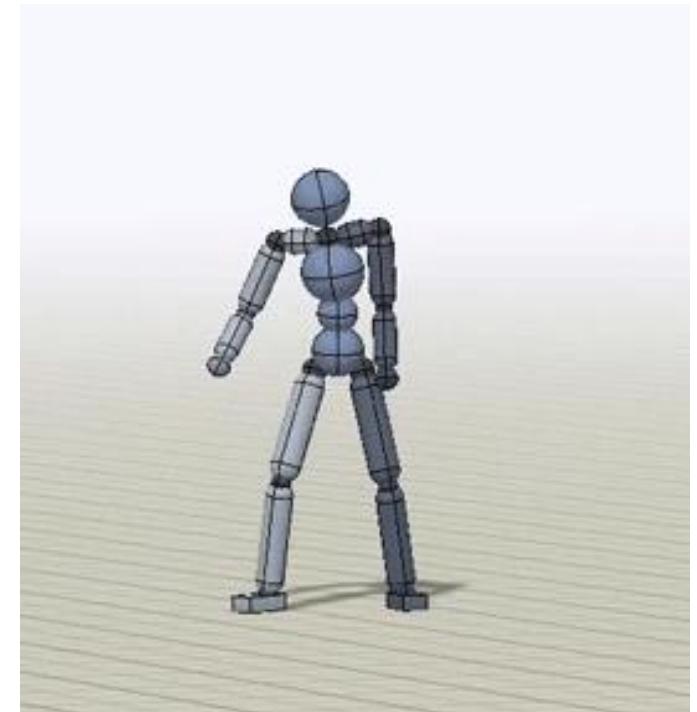
DRL-based Tracking Controllers



[Liu et al. 2016. ControlGraphs]



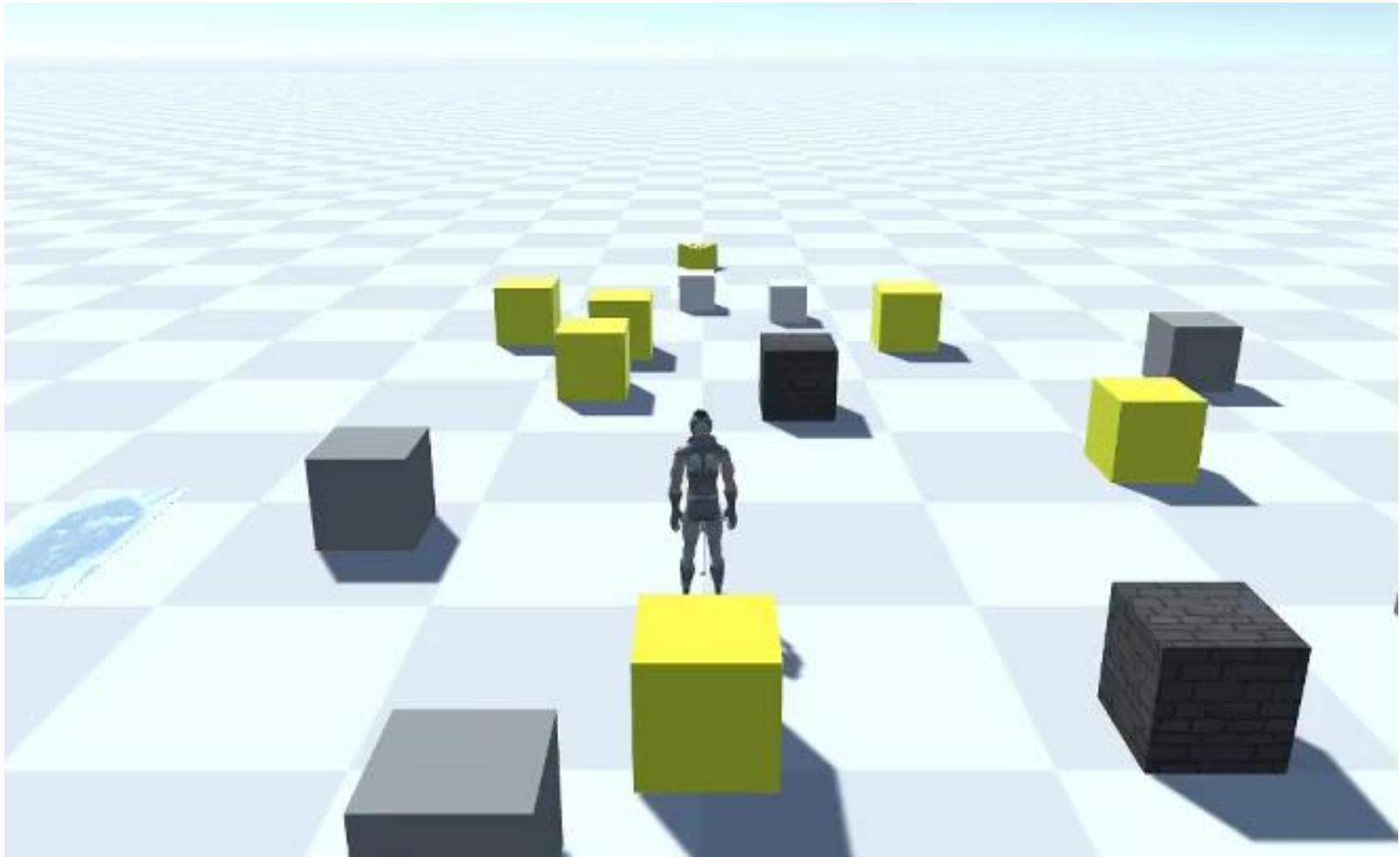
[Liu et al. 2018]



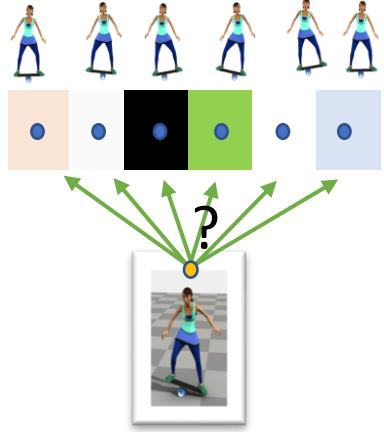
[Peng et al. 2018. DeepMimic]

Multi-skill Characters

State Machines of
Tracking Controllers

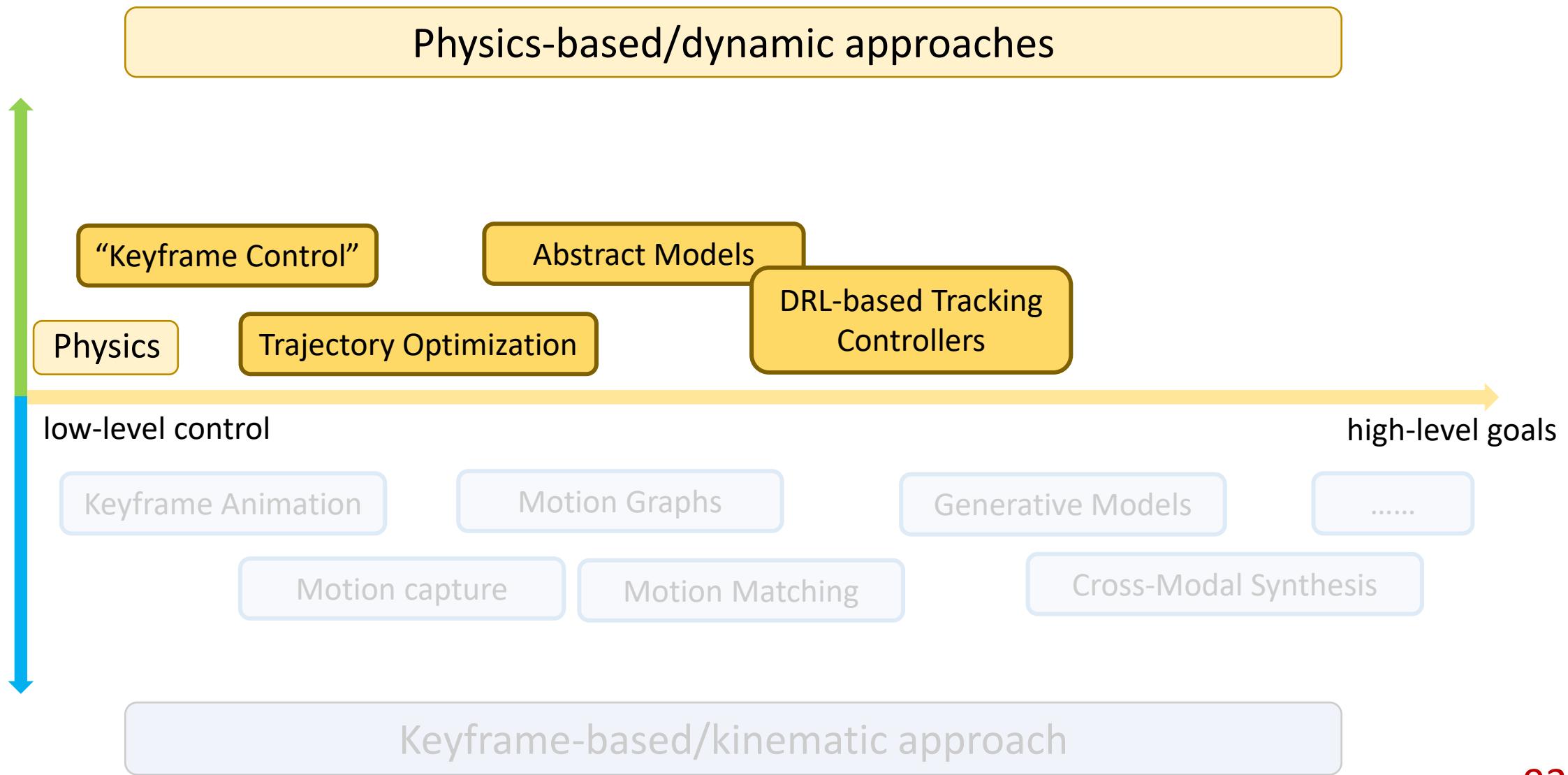


Multi-skill Characters

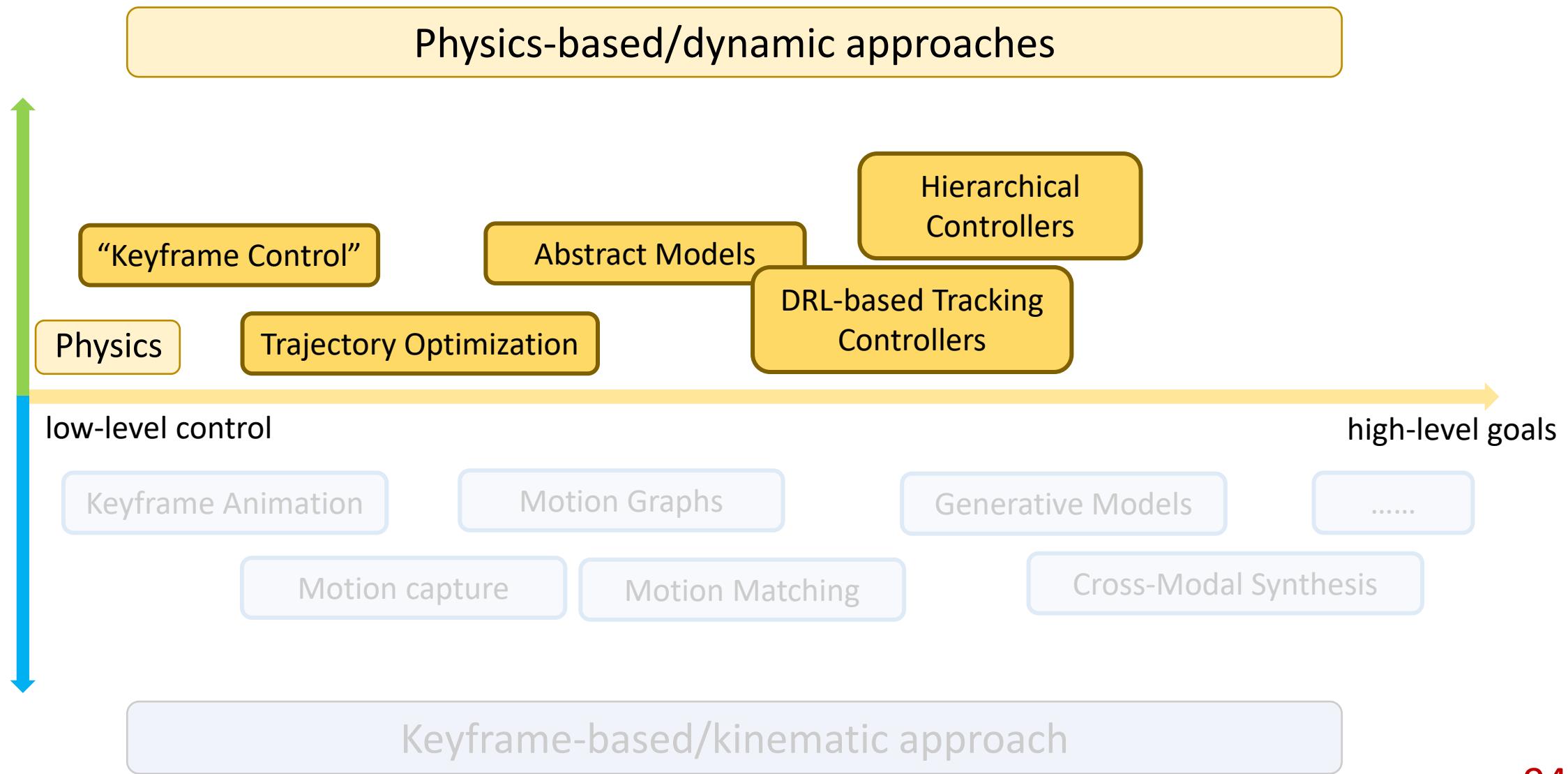


[Liu et al. 2017: Learning to Schedule Control Fragments]

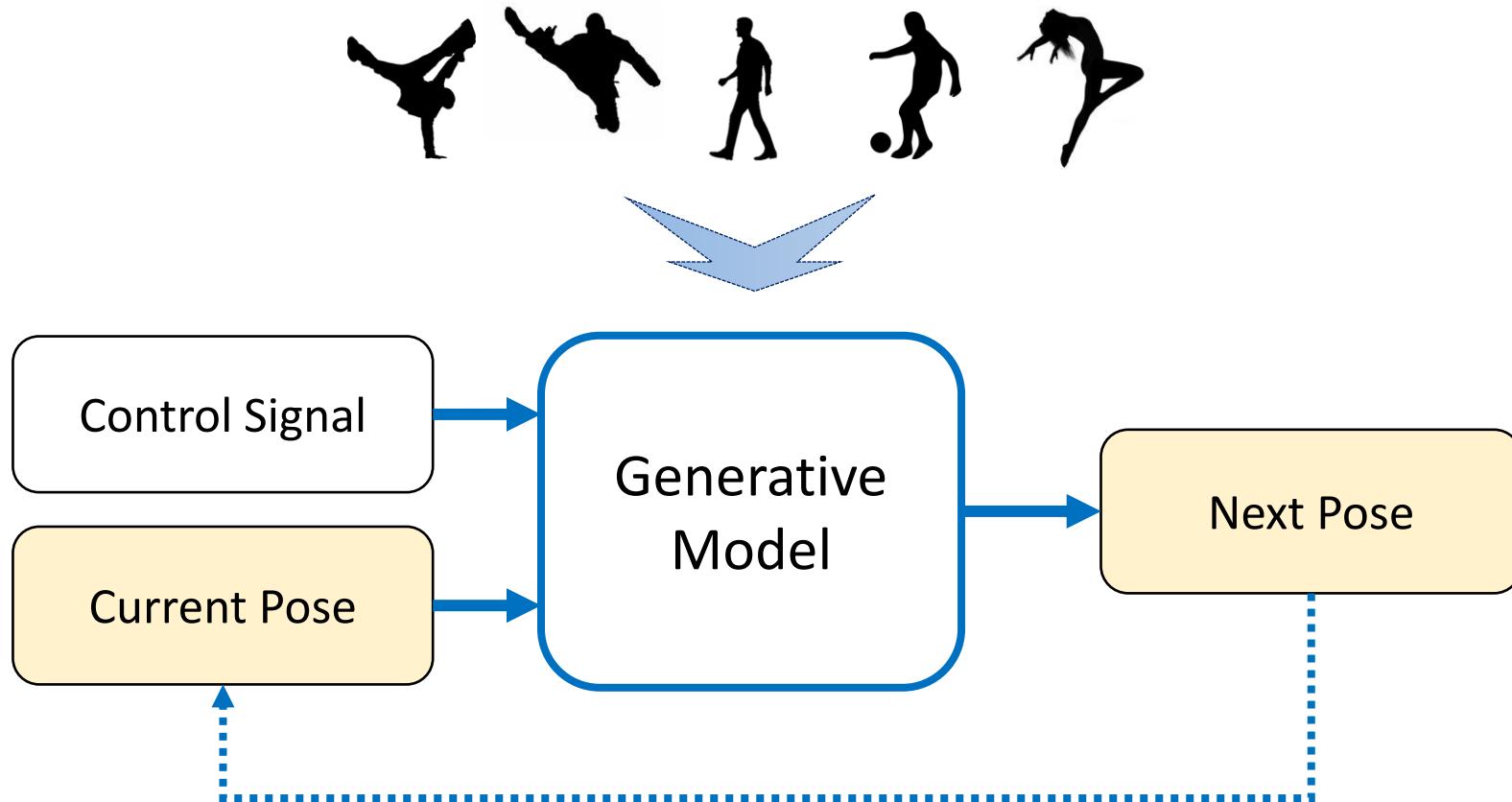
Character Animation Methods



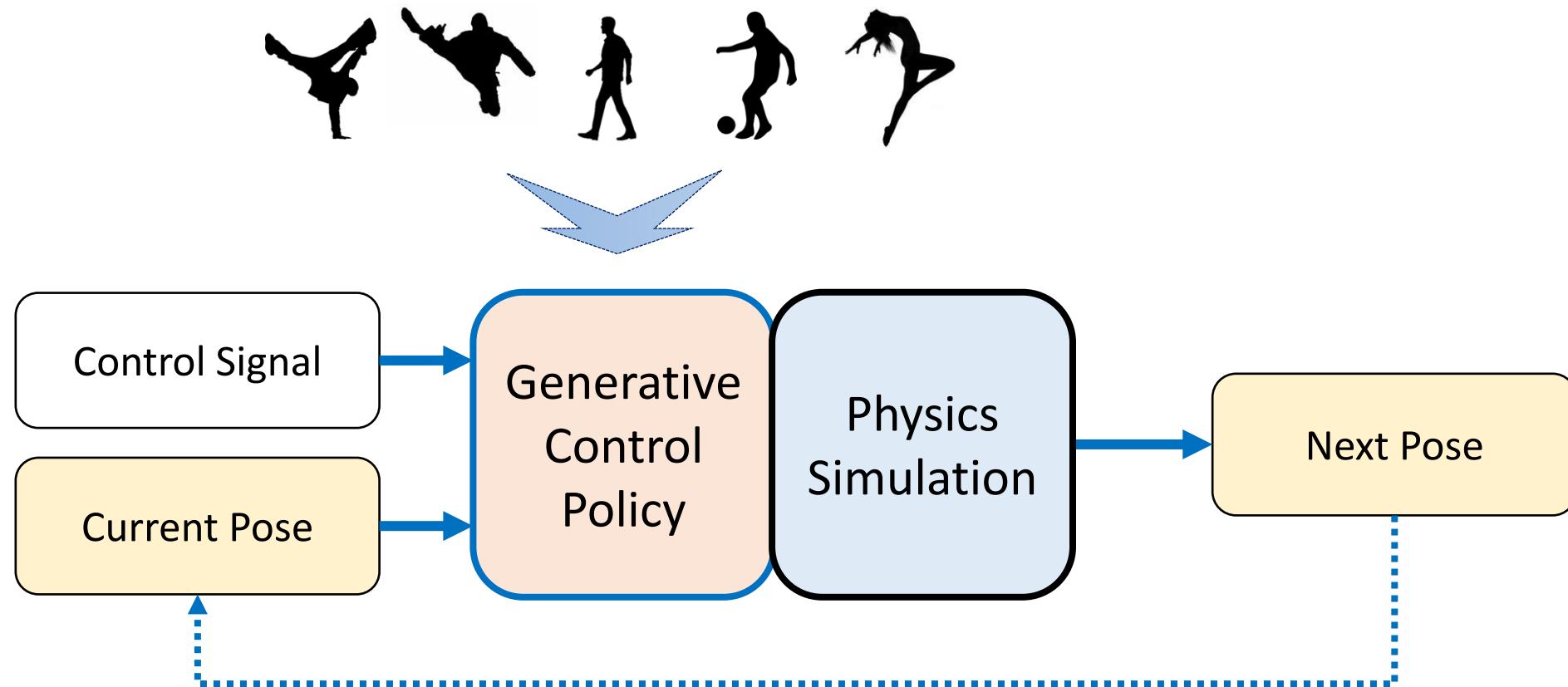
Character Animation Methods



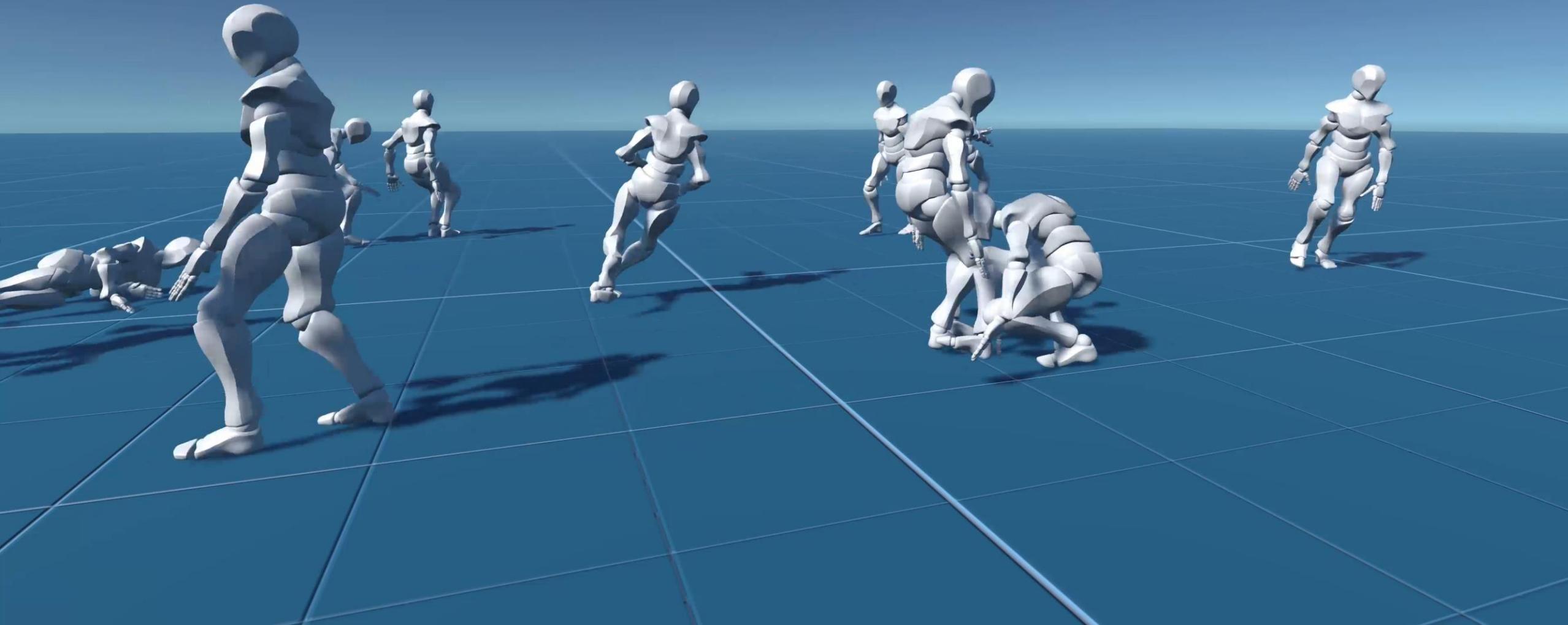
Generative Control Policies



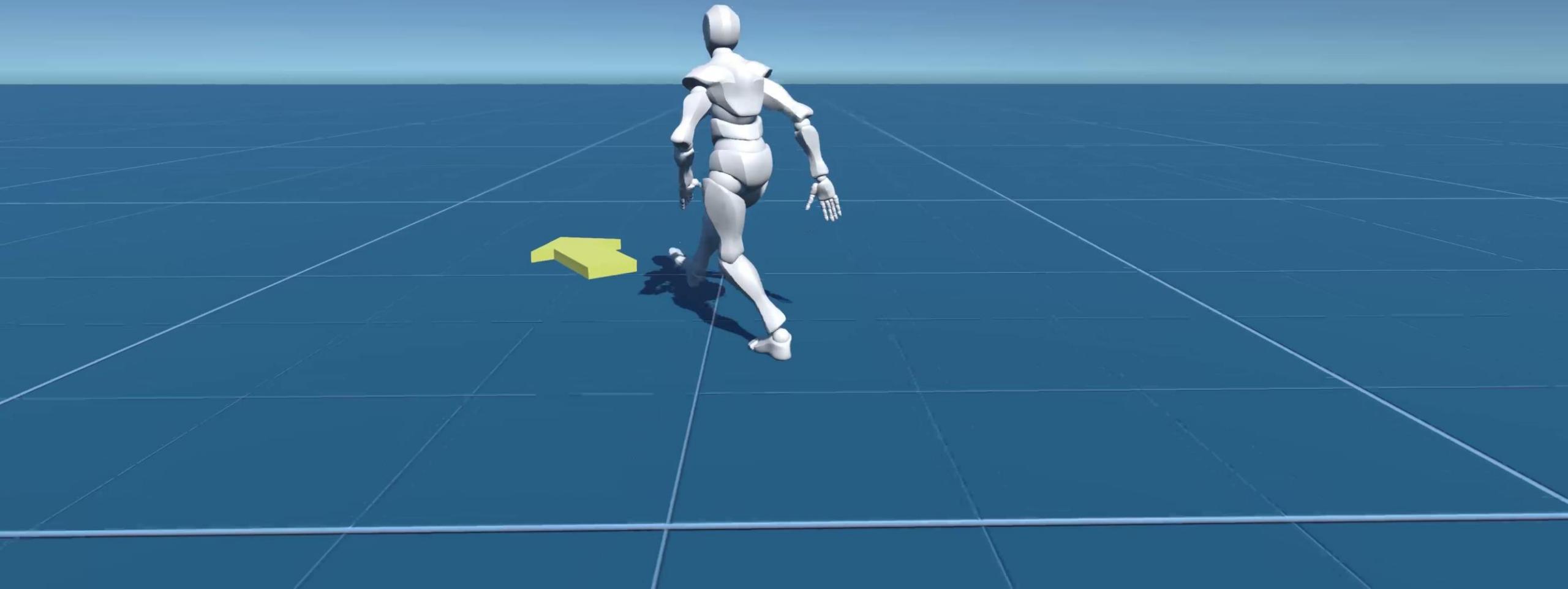
Generative Control Policies



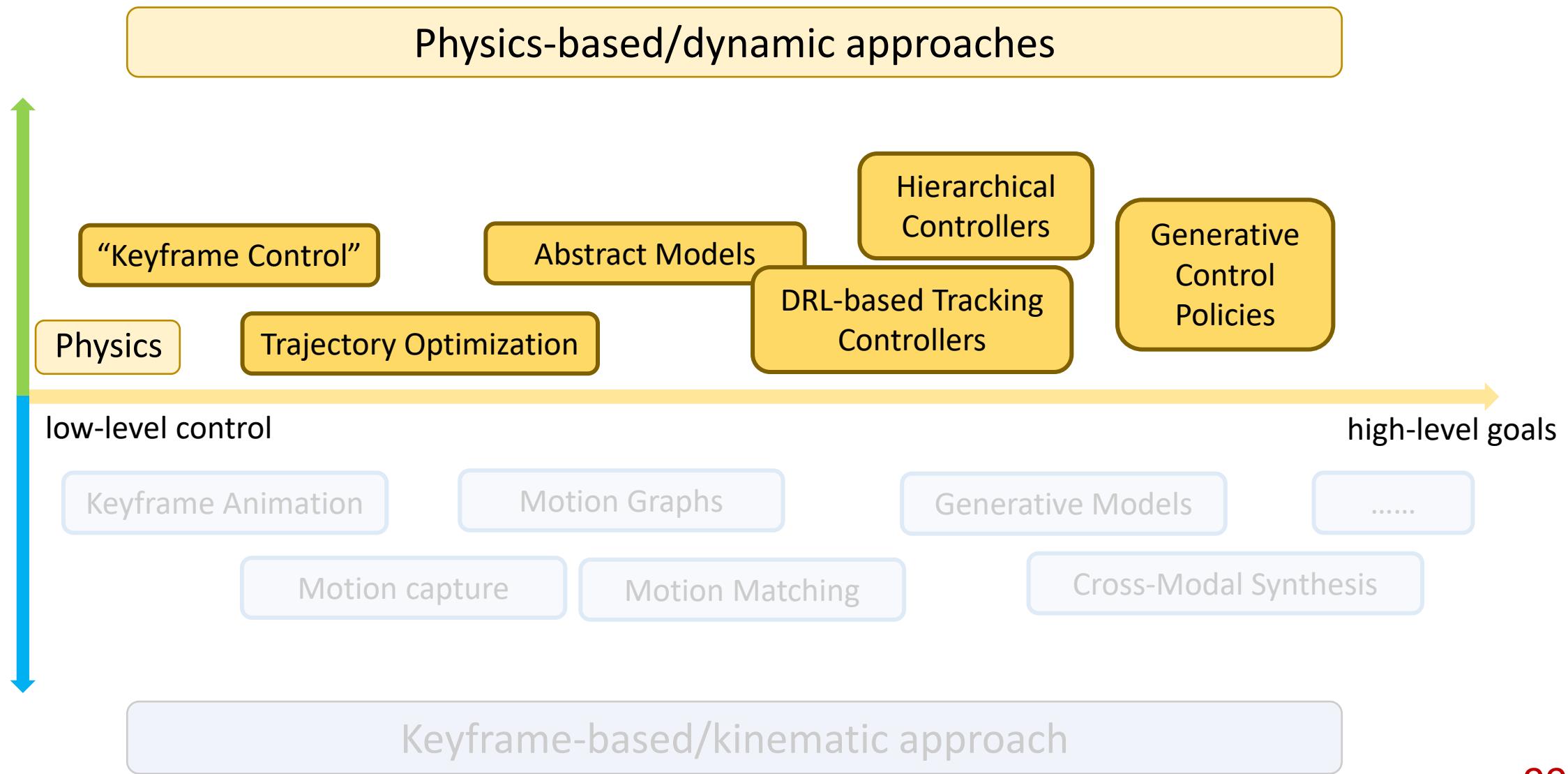
Random sample in latent space



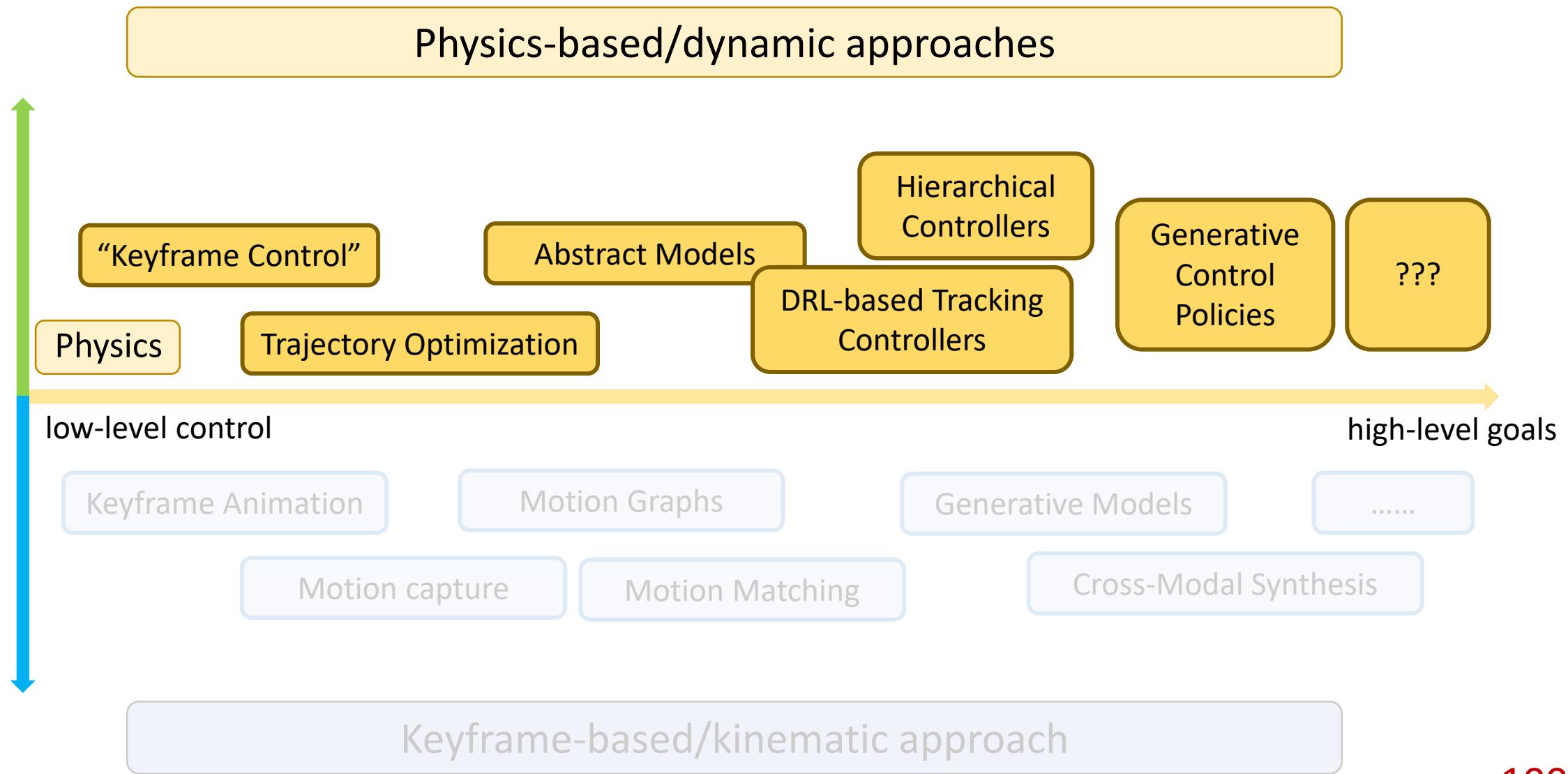
Switch heading and skills



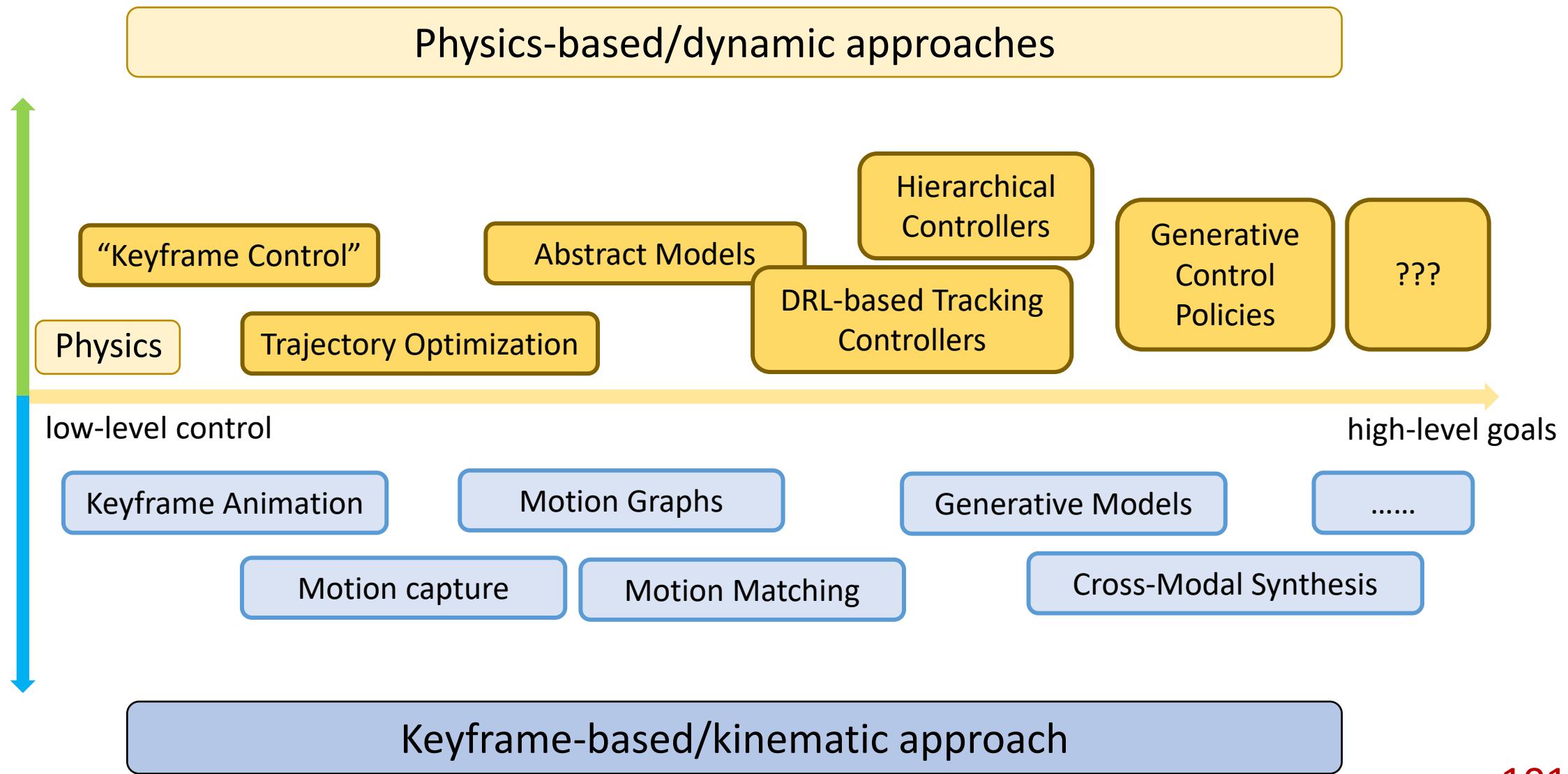
Character Animation Methods



Character Animation Methods



Character Animation Methods



About This Course



About This Course

- 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

Welcome & Course Information

- Instructor: Libin Liu (<http://libliu.info>)
- Website: <https://games-105.github.io/>
- Lecture: Monday 8:00PM to 9:00PM (12 Weeks)
- Prerequisites: linear algebra, calculus, programming skills (python), probability theory, mechanics, ML, RL...
- Exercise:
 - Codebase: <https://github.com/GAMES-105/GAMES-105>
 - Submission: <http://cn.ces-alpha.org/course/register/GAMES-105-Animation-2022/>
 - Register code: **GAMES-FCA-2022**
- BBS: <https://github.com/GAMES-105/GAMES-105/discussions>
- QQ Group: 533469817



群名称:GAME105课程交流群
群号:533469817

Lectures

2022年10月10日	Introduction to Character Animation	
2022年10月17日	Rotation, Transformation, and Forward Kinematics	
2022年10月24日	Inverse Kinematics	Proj1
2022年10月31日	Keyframe Character Animation	
2022年11月07日	Data-driven Character Animation	
2022年11月14日	Learning-based Character Animation	Proj2
2022年11月21日	Skinning and Facial Animation	Proj S
2022年11月28日	Physics-based Simulation and Articulated Rigid Bodies	
2022年12月05日	Actuating Character and Feedback Control	Proj3
2022年12月12日	Learning to Walk with Simplified Models	
2022年12月19日	Optimal Control and Trajectory Optimization	Proj4
2022年12月26日	Reinforcement Learning and Multiskilled Characters	

may change according to course progress

Exercise

- Instruction to be announced
- Program in Python, with physics engine (pybullet/ode/...)
- Five projects
 - Project 1: FK/IK, play with motion data
 - Project 2: Interactive character
 - Project S: Skinning
 - Project 3: Simulation and Ragdoll
 - Project 4: A simulated walking character

Relationship to Other GAMES “1” Courses

- This source is designed to be self-contained, but it is good to also learn:



Questions?





That's all for today.
See you next week!

abandon [ə'band(ə)n]

adj. 常看常新

