

Highlights of Deep RL

CS 8803 RLR

Agenda

- We will fast-forward a few important highlights of deep RL / robotics / animation research.
- The curation is very subjective: focused on my research field, while a lot of impactful papers are missing.

What is the most popular example of deep RL?

AlphaGo



Fun Call Centre at YouTube, “Lee Sedol Hand of God Move 78 Reaction and Analysis”

Deep Q Learning



Disclaimer: I was not part of this research project, I am merely providing commentary on this work.

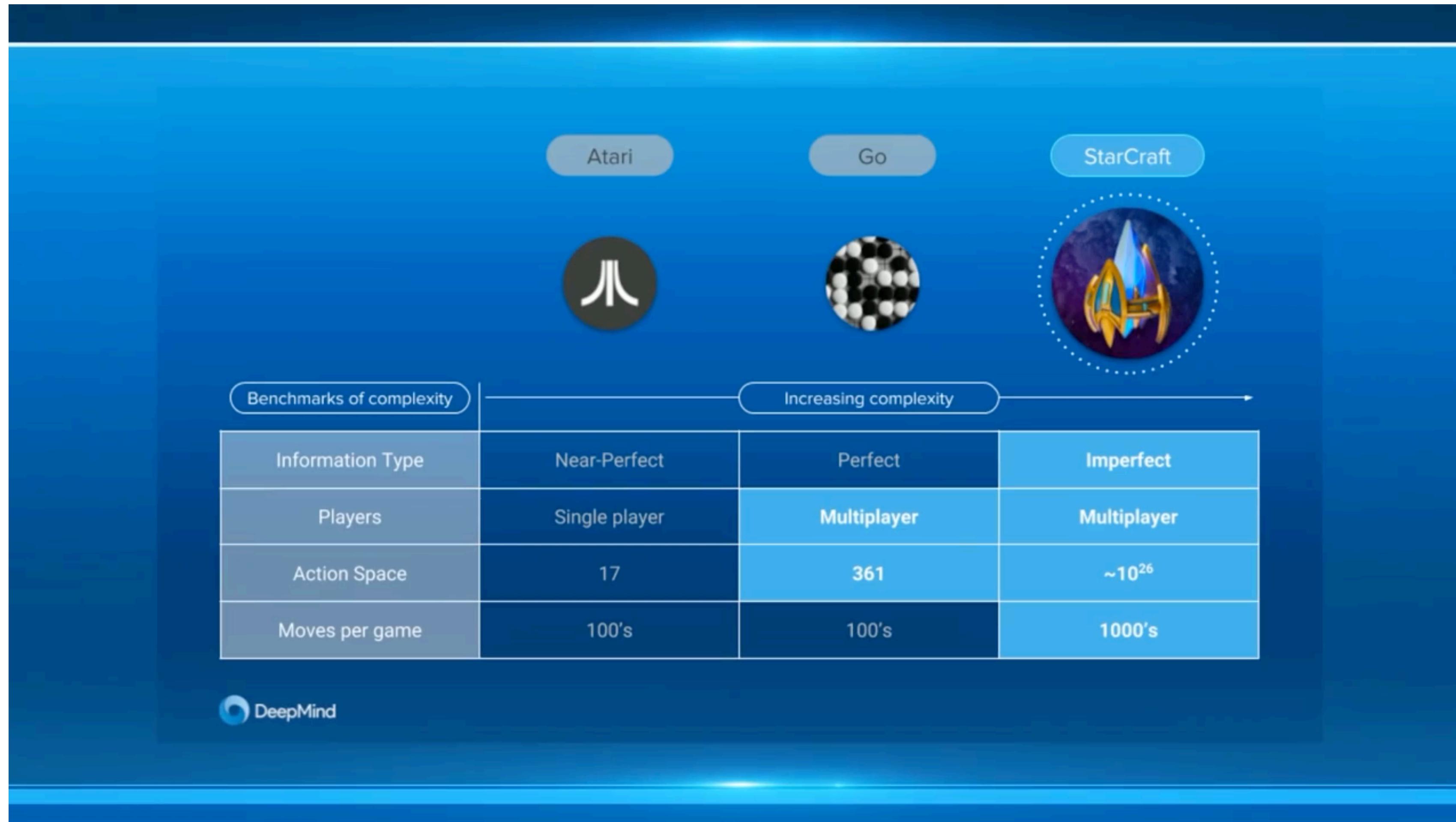
Mnih et al. "Human Level Control Through Deep Reinforcement Learning"
The video from "Two Minutes Papers" at YouTube

OpenAI Gym



Brockman et al. "Openai gym."
The video from "Two Minutes Papers" at YouTube

Starcraft II



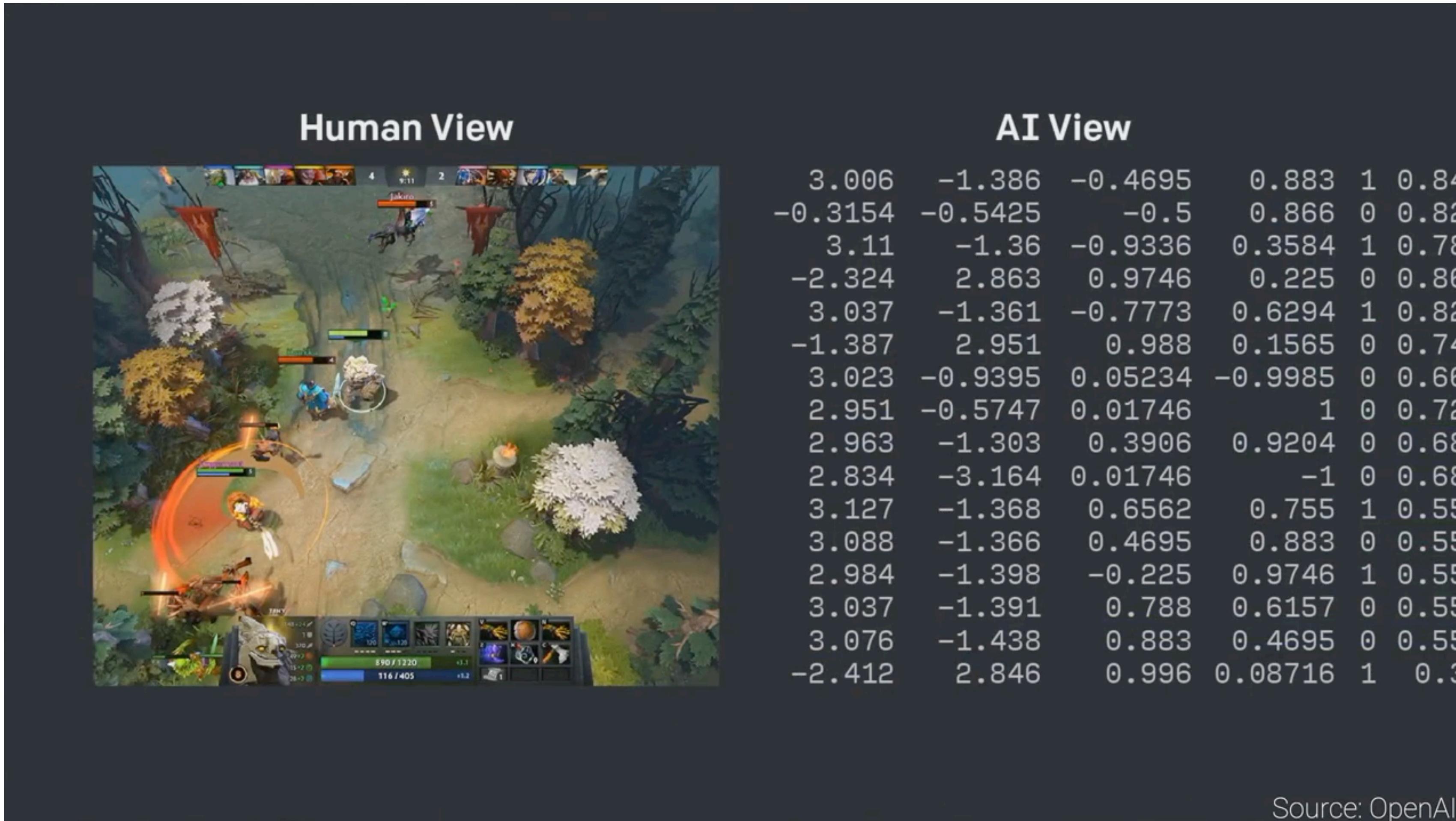
Vinyals et al. "Grandmaster level in StarCraft II using multi-agent reinforcement learning"
The video from "SC2HL" at YouTube

Starcraft II



Vinyals et al. “Grandmaster level in StarCraft II using multi-agent reinforcement learning”
The video from “SC2HL” at YouTube

DoTA



Berner et al. "Dota 2 with large scale deep reinforcement learning"
The video from "Two Minutes Papers" at YouTube

Gran Turismo

**Super-Human Performance in
Gran Turismo Sport
Using Deep Reinforcement Learning**

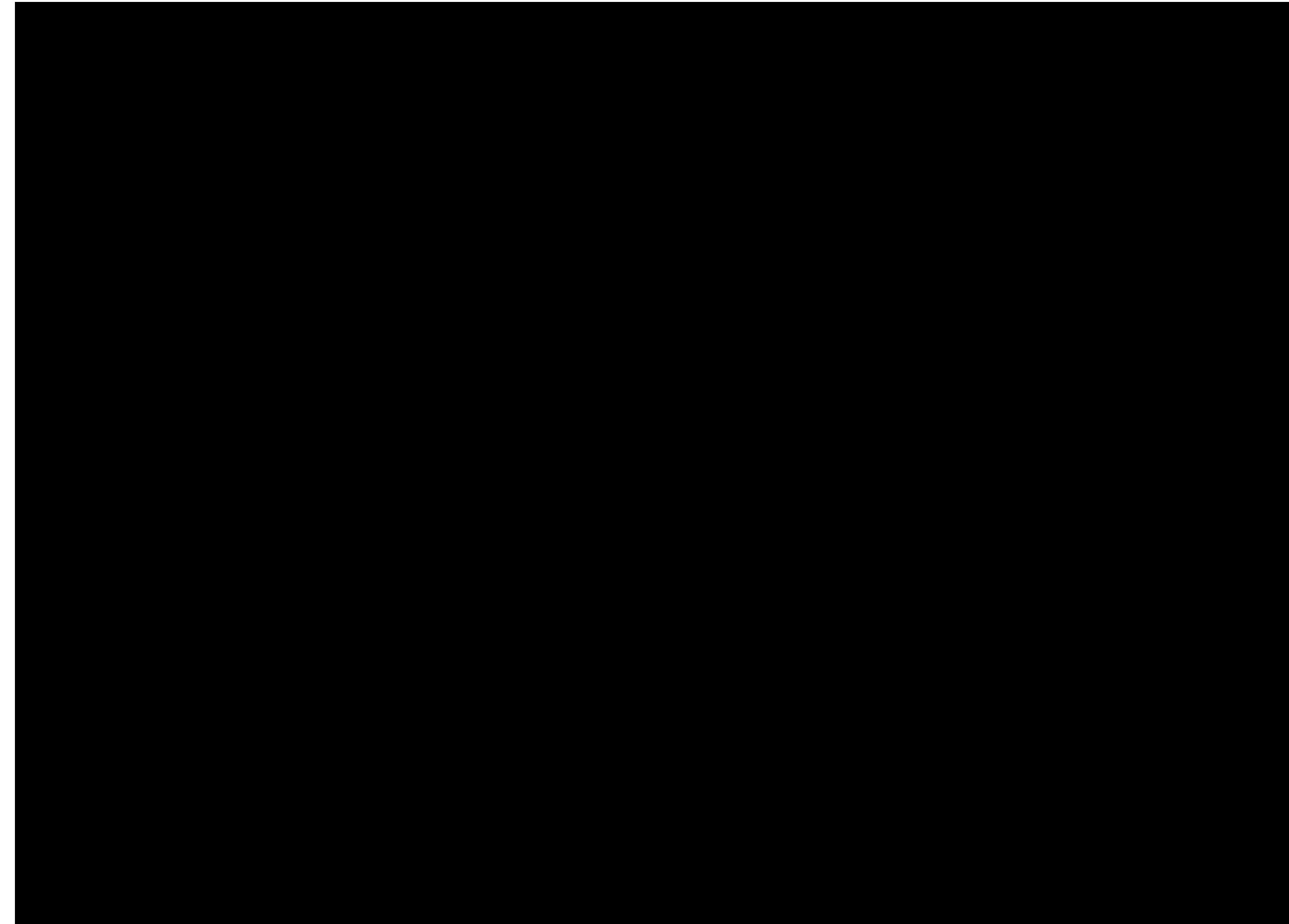
**Florian Fuchs, Yunlong Song, Elia Kaufmann,
Davide Scaramuzza, Peter Dürr**



**University of
Zurich UZH**

SONY

Simulated Human



Heess et al. "Emergence of Locomotion Behaviours in Rich Environments"

Simulated Human

**Learning to Schedule Control Fragments
for Physics-based Characters
Using Deep Q-Learning**

Libin Liu¹ Jessica Hodgins^{1,2}

¹Disney Research

²Carnegie Mellon University

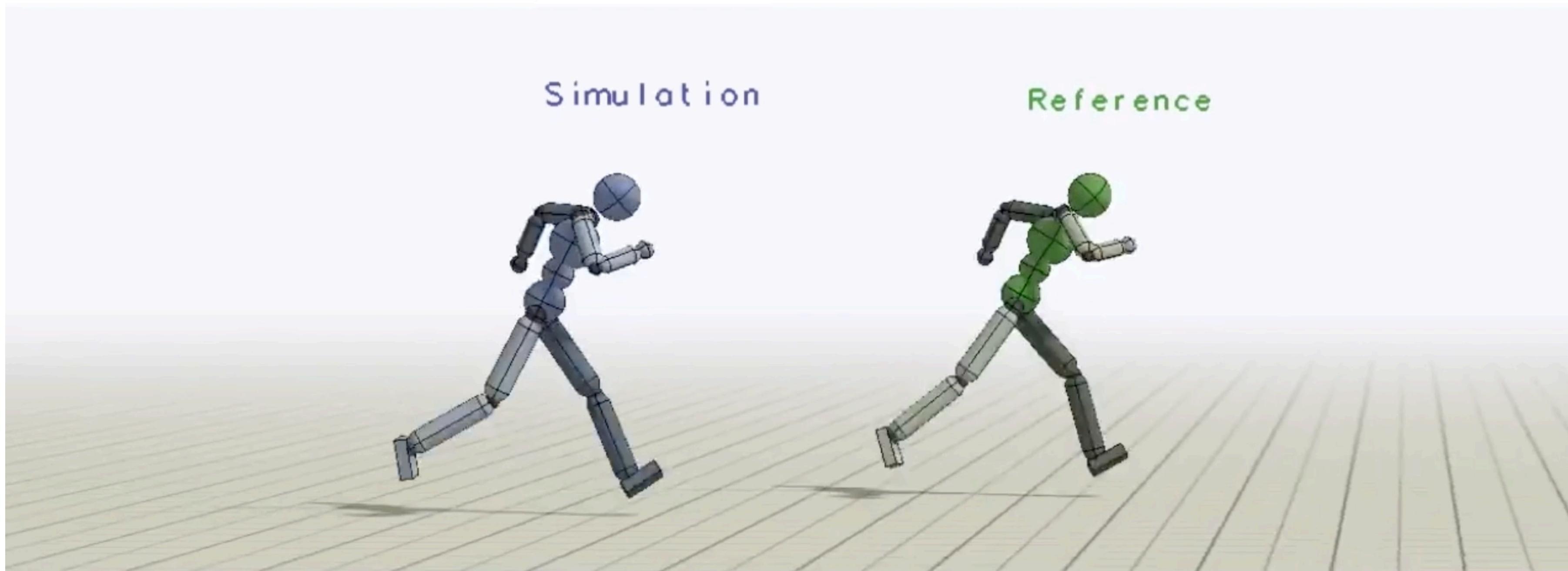
(with audio)



Disney Research

Mimicking Mocaps

Humanoid: Run



Policy trained to imitate a running clip.

Mimicking Videos

SFV: Reinforcement Learning of Physical Skills from Videos (with audio)

Xue Bin Peng, Angjoo Kanazawa, Jitendra Malik,
Pieter Abbeel, Sergey Levine

UC Berkeley

Mimicking Many Mocaps

DReCon

Data-Driven Responsive Control of Physics-Based Characters

Kevin Bergamin, Simon Clavet, Daniel Holden, James Richard Forbes

UBISOFT
LA FORGE



Muscle-Actuated Character

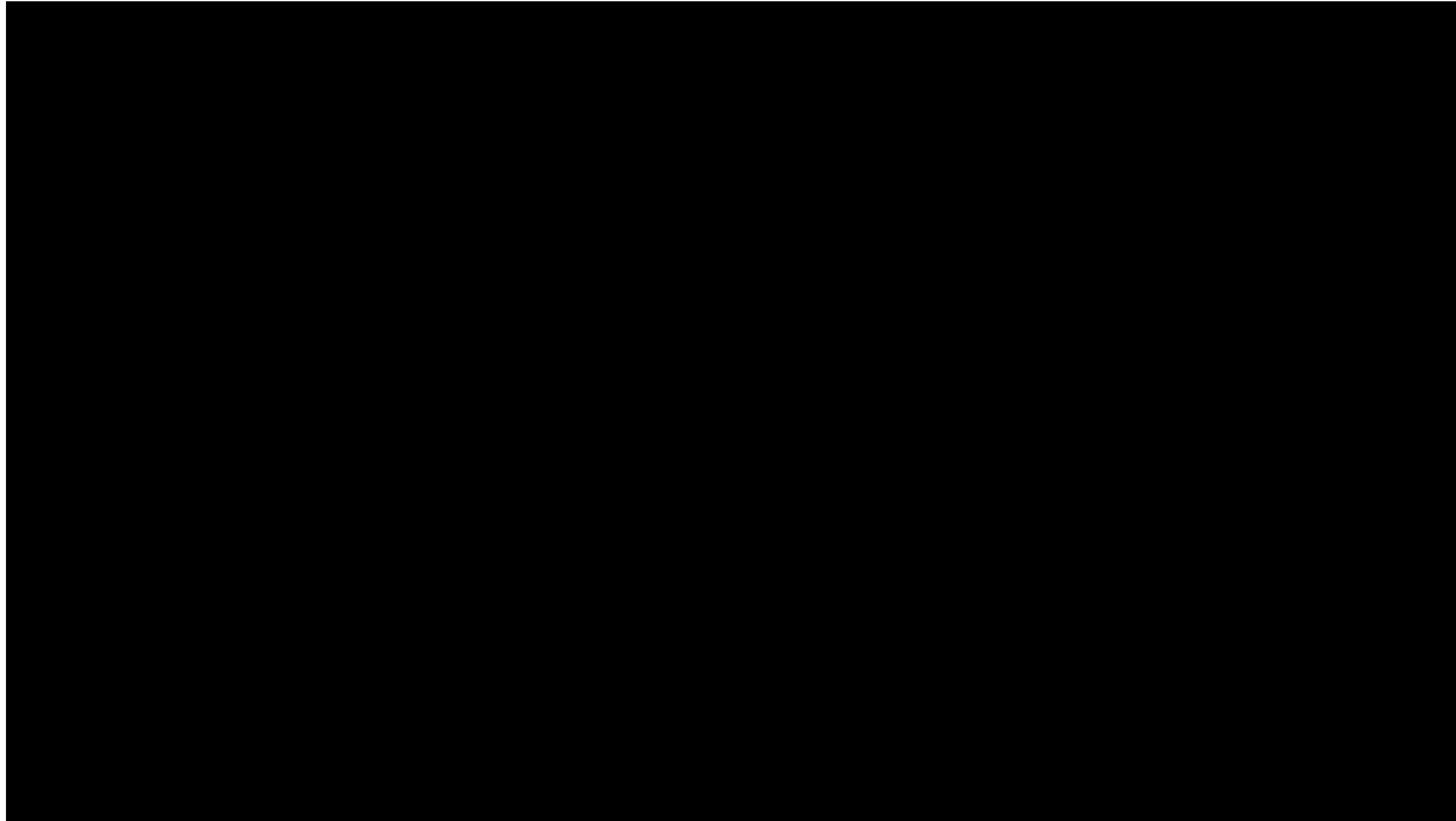
Scalable Muscle-Actuated
Human Simulation and Control



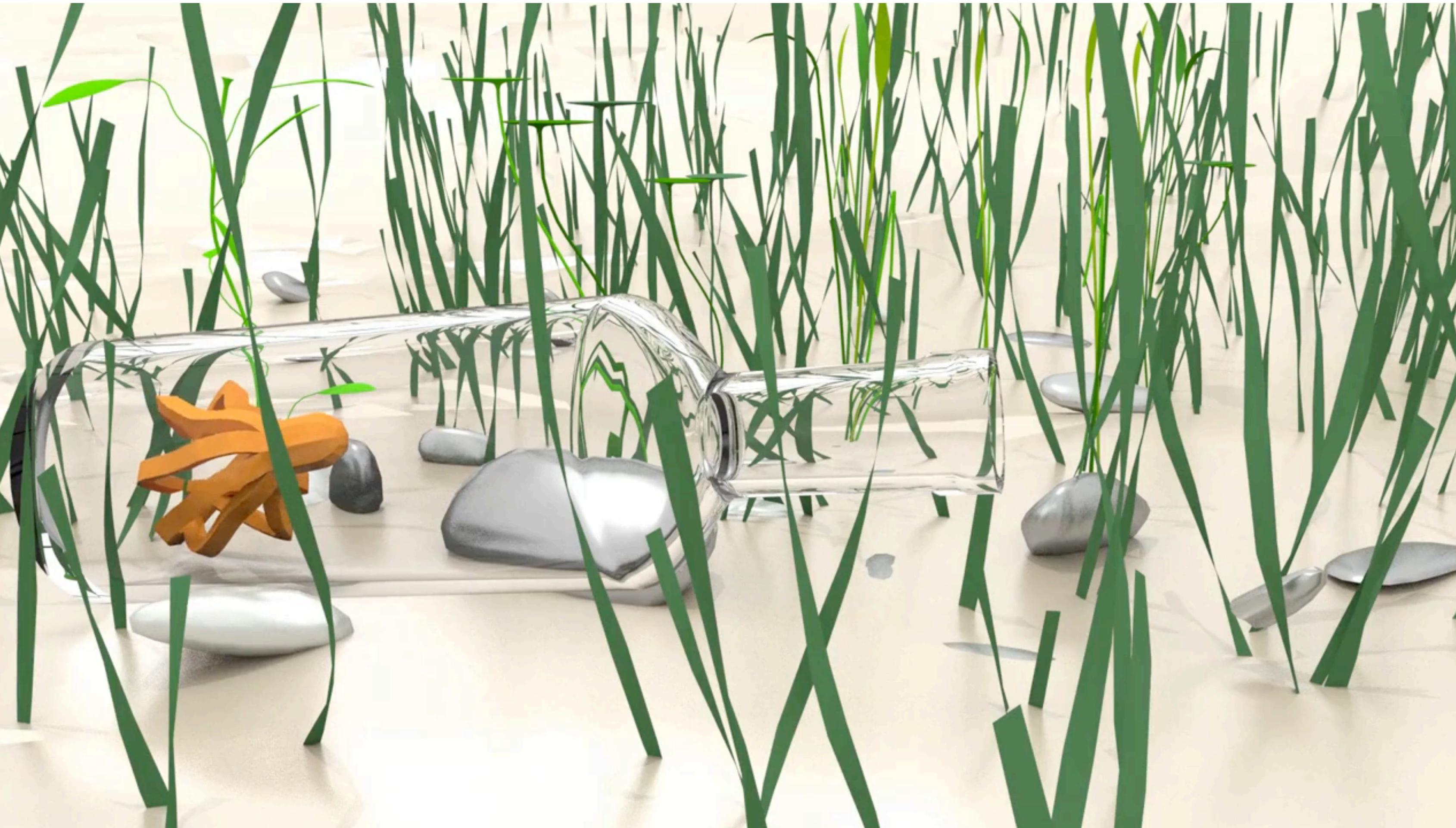
Seunghwan Lee⁽¹⁾, Kyoungmin Lee⁽²⁾, Moonseok Park⁽²⁾, and Jehee Lee⁽¹⁾
Seoul National University⁽¹⁾, Seoul National University Bundang Hospital⁽²⁾

Lee et al. “Scalable muscle-actuated human simulation and control”

Multi-player Sports



Soft Creatures



Min et al. "Softcon: Simulation and control of soft-bodied animals with biomimetic actuators"

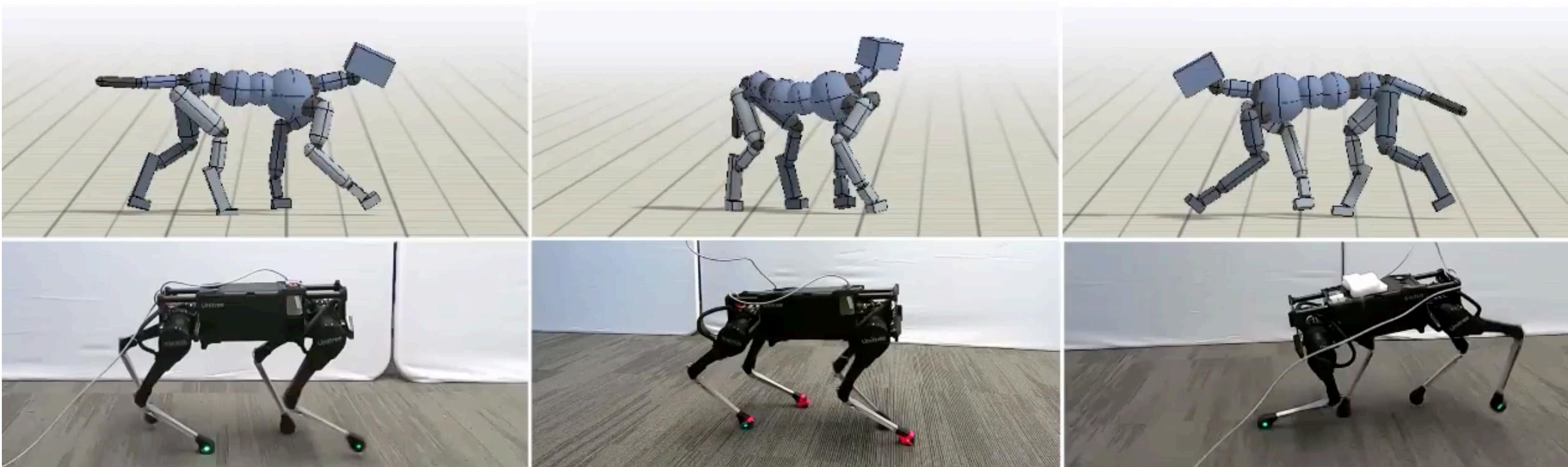
Quadrupedal Character



Luo et al. "CARL: Controllable Agent with Reinforcement Learning for Quadruped Locomotion"

Quadrupedal Robot

Learning Agile Robotic Locomotion
Skills by Imitating Animals



Xue Bin Peng^{1,2}

Tsang-Wei Lee¹

Erwin Coumans¹

Jie Tan¹

Tingnan Zhang¹

Sergey Levine^{1,2}

¹ Google Research

² University of California, Berkeley



Sim-to-real #1: Randomization

Sim-to-Real: Learning Agile Locomotion For Quadruped Robots

Jie Tan¹, Tingnan Zhang¹, Erwin Coumans¹, Atil Iscen¹,
Yunfei Bai², Danijar Hafner¹, Steven Bohez³, Vincent Vanhoucke¹

¹Google Brain
²X

³Google Deepmind

Sim-to-real #2: System ID

Science Robotics, Special Issue on Learning-Beyond Immitation

Learning Agile and Dynamic Motor Skills for Legged Robots

Jemin Hwangbo¹, Joonho Lee¹, Alexey Dosovitskiy²,
Dario Bellicoso¹, Vassilios Tsounis¹, Vladlen Koltun², Marco Hutter¹

2018/08/16

¹ Robotic Systems Lab, ETH Zurich, Switzerland

² Intelligent Systems Lab, Intel

ETHzürich



www.rsl.ethz.ch



Intelligent Systems Lab

Sim-to-real #3: Adaptation

Rapid Motor Adaptation for Legged Robots

Ashish Kumar
UC Berkeley

Zipeng Fu
CMU

Deepak Pathak
CMU

Jitendra Malik
UC Berkeley/FAIR

Robotics: Science and Systems 2021

Learning on Real Robots

Learning to Walk in the Real World with Minimal Human Effort

Sehoon Ha^{12*}, Peng Xu², Zhenyu Tan², Sergey Levine²³, and Jie Tan²

¹Georgia Institute of Technology

²Robotics at Google

³University of California, Berkeley

*The research was conducted when the author was at Google

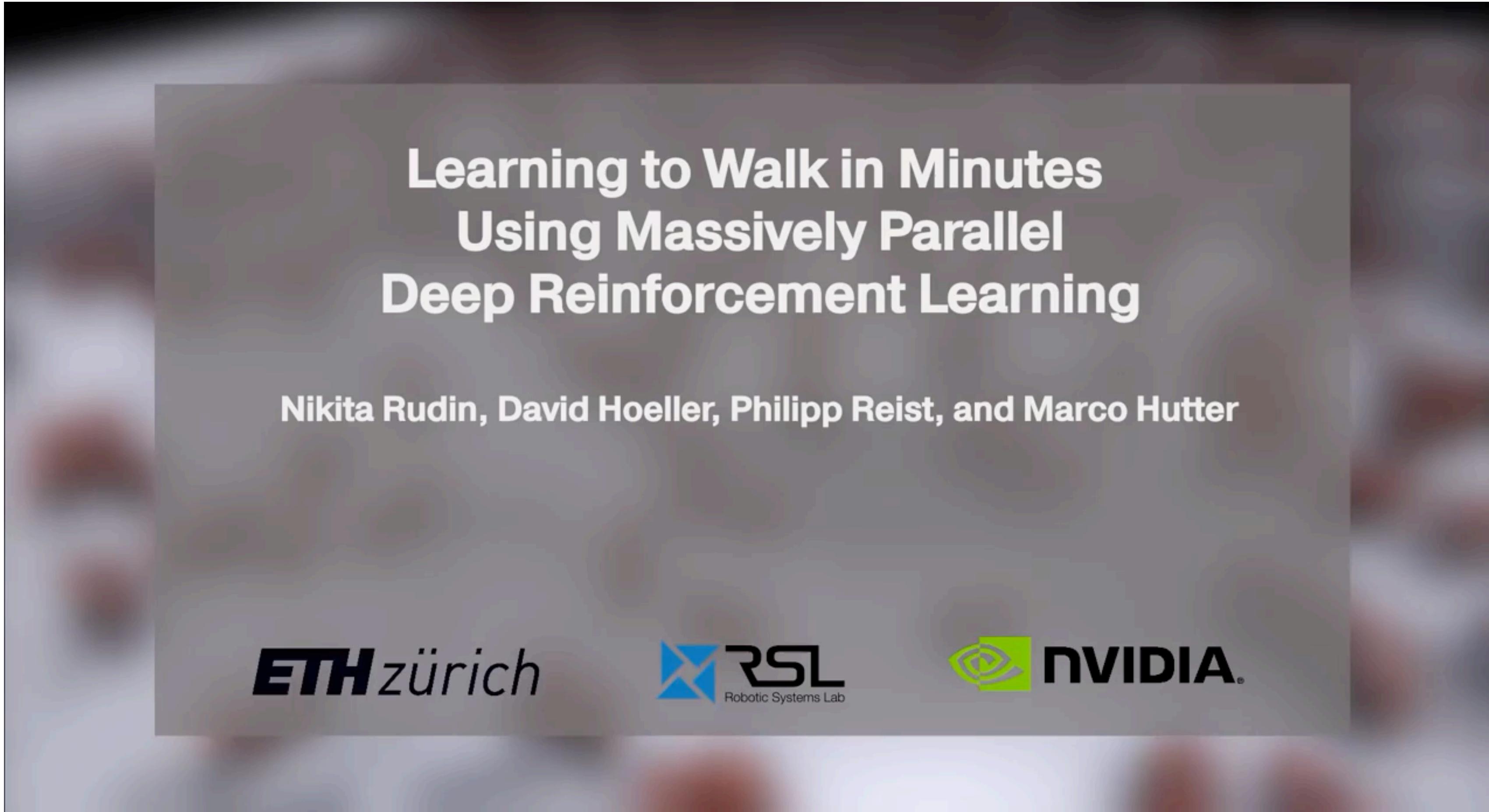


Learning on Real Robots

Legged Robots that Keep on Learning:
Fine-Tuning Locomotion Policies in the Real World

Smith et al. “Legged Robots that Keep on Learning:
Fine-Tuning Locomotion Policies in the Real World”

Scalability



Rudin et al. "Learning to Walk in Minutes using Massively Parallel Deep Reinforcement Learning"

Learning + Model-based Control

GLiDE: Generalizable Quadrupedal Locomotion in
Diverse Environments with a Centroidal Model

Xie et al. “GLiDE: Generalizable Quadrupedal Locomotion in Diverse Environments with a Centroidal Model”

Visual Locomotion

Visual-Locomotion: Learning to Walk on Complex Terrains with Vision

Wenhai Yu¹, Deepali Jain¹, Alejandro Escontrela¹, Atil Iscen¹,
Peng Xu¹, Erwin Coumans¹, Sehoon Ha^{1,2}, Jie Tan¹, Tingnan Zhang¹

¹.Robotics at Google

². Georgia Institute of Technology

Navigation

Learning to Navigate Sidewalks in Outdoor Environments

Maks Sorokin¹ Jie Tan² C. Karen Liu³ Sehoon Ha¹²

¹Georgia Institute of Technology ²Robotics at Google ³Stanford University

Sorokin et al. “Learning to Navigate Sidewalks in Outdoor Environments”

Navigation

Learning Navigation Behaviors
End to End with AutoRL



Hao-Tien Lewis Chiang*, Aleksandra Faust*,
Marek Fiser, Anthony Francis

* Equal contribution

Scalability

Decentralized Distributed PPO: Solving PointGoal Navigation



Erik Wijmans



Abhishek Kadian



Ari Morcos



Stefan Lee



Irfan Essa



Devi Parikh



Manolis Savva



Dhruv Batra

facebook
Artificial Intelligence Research

Georgia Tech

SFU

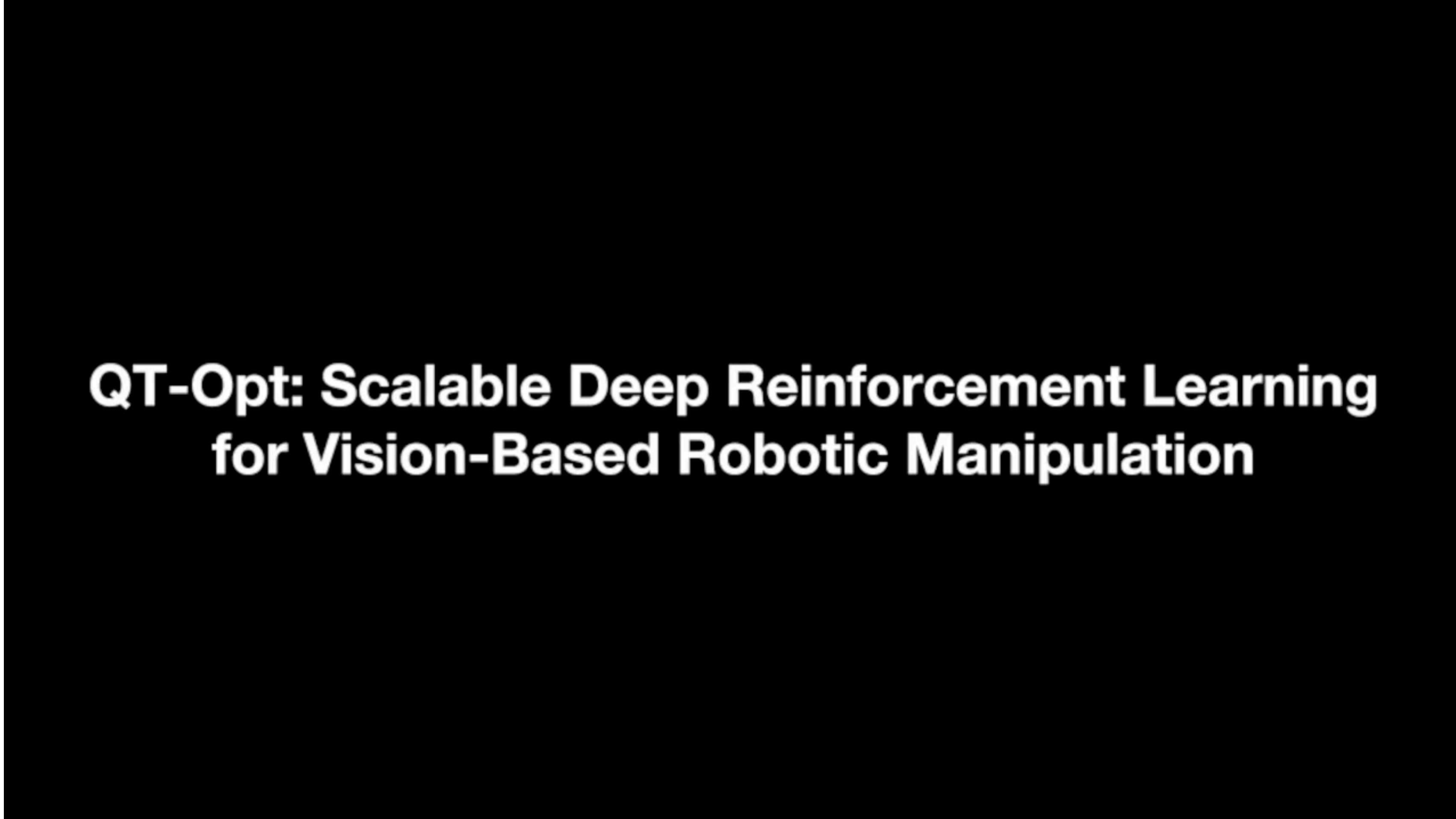
 **Oregon State
University**

Autonomous Driving



Dosovitskiy et al. “CARLA: An open urban driving simulator”

Manipulation



**QT-Opt: Scalable Deep Reinforcement Learning
for Vision-Based Robotic Manipulation**

Kalashnikov et al. “QT-Opt: Scalable Deep Reinforcement Learning for Vision-Based Robotic Manipulation”

Sensor Fusion

Making Sense of Vision and Touch:
Self-Supervised Learning of Multimodal Representations
for Contact-Rich Tasks

ICRA 2019 Submission

Michelle A. Lee*, Yuke Zhu*, Krishnan Srinivasan, Parth Shah,
Silvio Savarese, Li Fei-Fei, Animesh Garg, Jeannette Bohg



Stanford AI Lab

* equal contribution

In-hand Manipulation



Akkaya et al. "Solving rubik's cube with a robot hand"

Drone

Autonomous Drone Racing with Deep Reinforcement Learning

Yunlong Song*, Mats Steinweg*, Elia Kaufmann, Davide Scaramuzza



**University of
Zurich^{UZH}**

Department of Neuroinformatics

ETH zürich



**University of
Zurich^{UZH}**

Department of Informatics

What's next?

- We have watched the video of a few selected papers, focused on the applications.
- We will organize papers based on the topics and read them.