Data-Driven Computer Animation

Lecture 1

Introduction

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Teaching Staff

- Lecturer:
  - Taku Komura (me), Professor in Computer Science
- Teaching Assistant:
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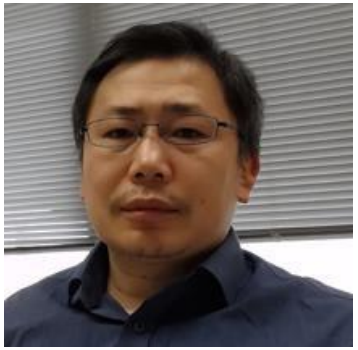


Today's topics

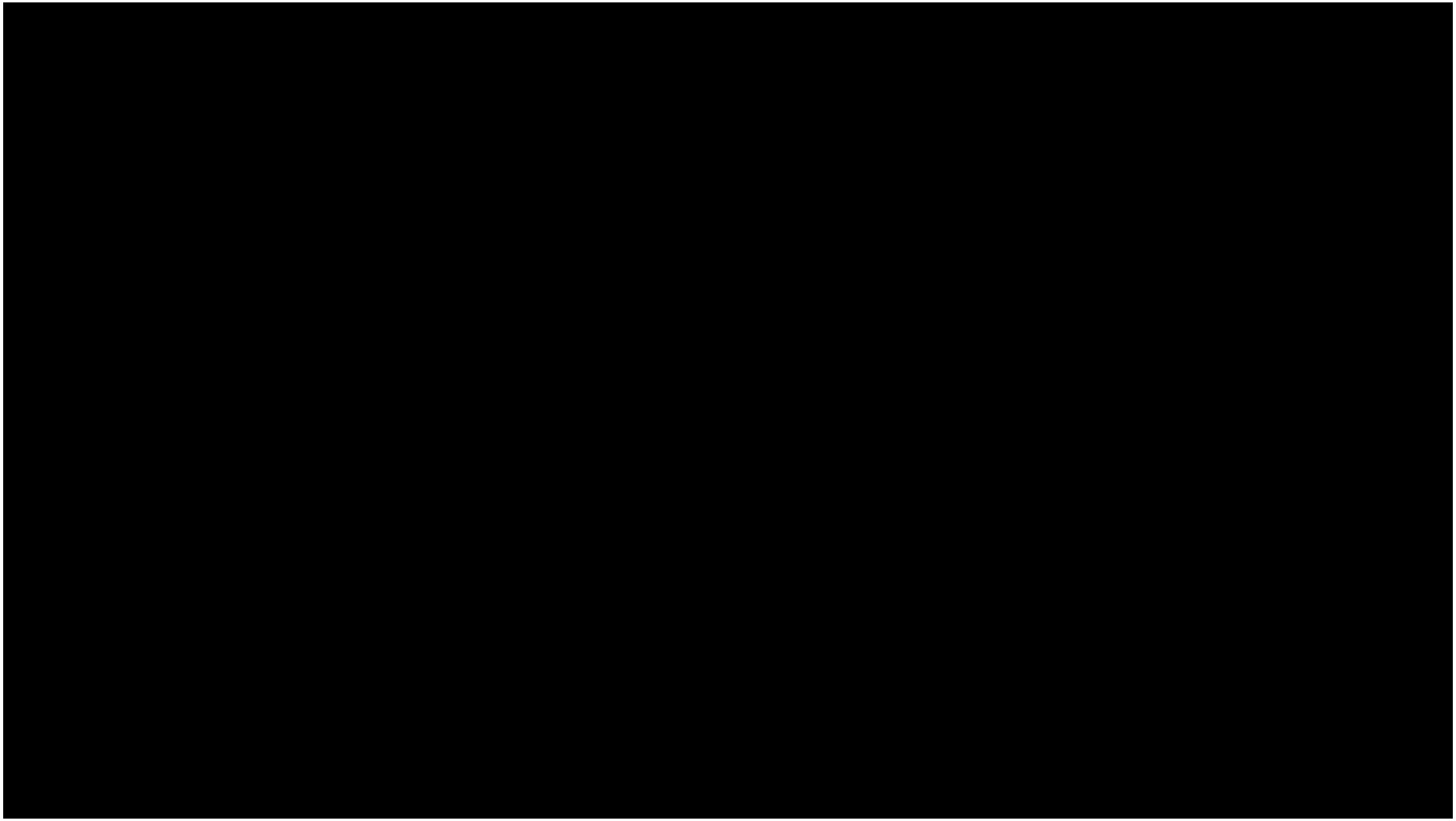
Overview of the lecture

- Introduction to computer animation
- Topics covered in the lecture
- Motivation / Group research
- Other applications of computer animation

What is computer animation?

- Creating moving images via the use of computers.
- Subfield of computer graphics
- Applications :
  - Films & Special Effects
  - TV Programs
  - Computer Games
  - Web Contents
  - VR and AR
  - Prepare training data for machine learning
  - Design of buildings, environment etc.

Demo Animation



Topics of computer animation

- Character animation (3D animation)
  - Keyframe animation, motion capture
  - Skinning, facial animation
  - Motion synthesis by machine learning
  - Crowd simulation
- Physically-based animation
  - Rigid objects
  - Cloth, strands, deformable objects
  - Fluids (fire, water, smoke)
  - Finite Element Method (soft materials)
- Geometry modelling (2D, 3D)
- Computer animation (2D)

Character Animation

- Controlling characters
  - Different body structures (humans / cartoon characters / animals / ...)
  - using real human movements (MoCap)
  - manually creating the movements (KeyFrame)

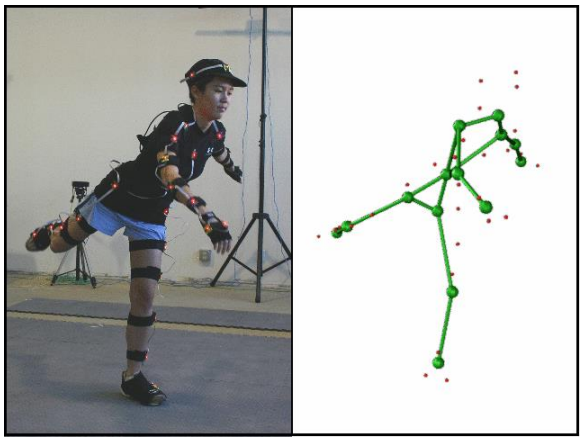


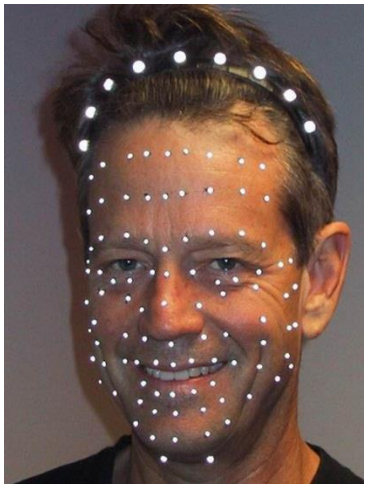
Keyframe Animation

- The keyframe postures are designed by the animator
- The inbetween motion is created by interpolation

Motion capture

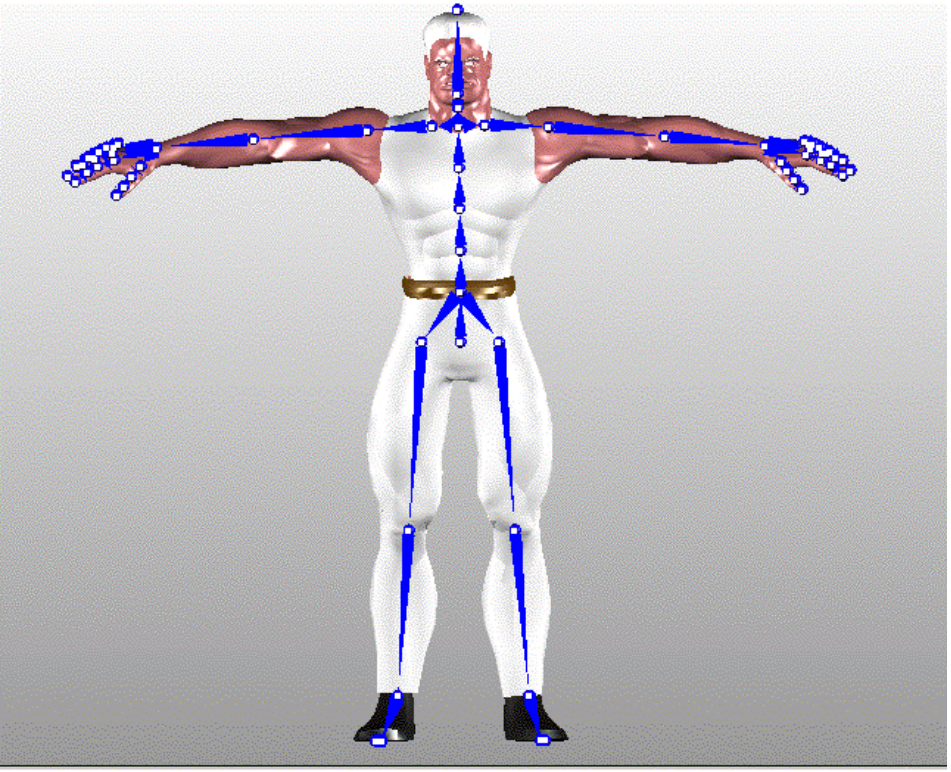
- Digitizing the human movements
- Tracking the movements of the markers
- Apply them to virtual characters





Skinning

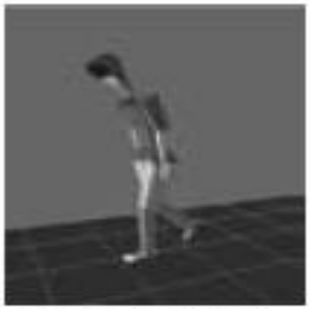
- Need to decide how the surface deforms according to the movements of the skeletal bones



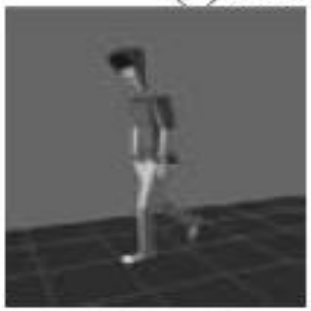
Motion Editing

- Making use of the captured motions for different scenes
- Adjust the movements so that they satisfy constraints

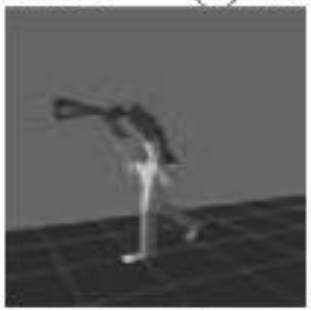
(a) Normal walk



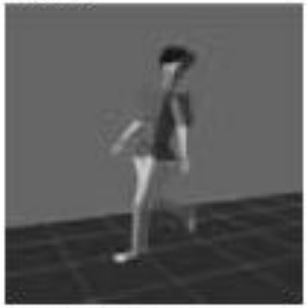
(b) Tired walk



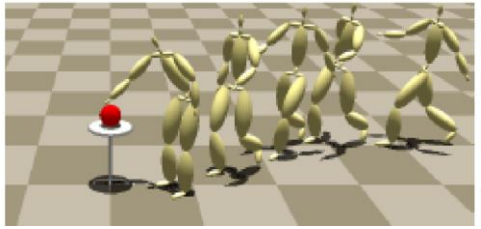
(c) $s = 0.5$

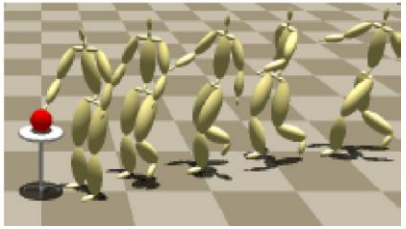


(d) $s = 2.0$



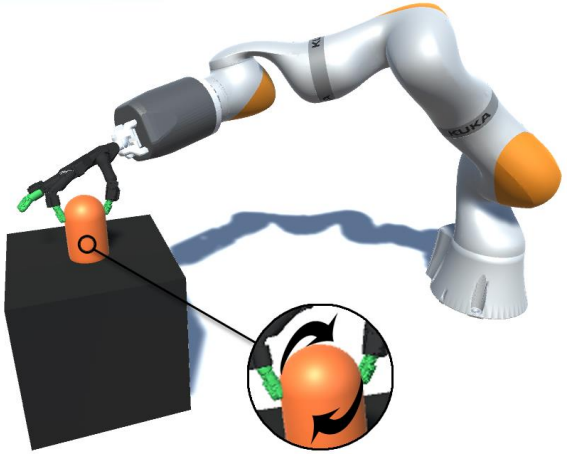
(e) $s = -0.5$

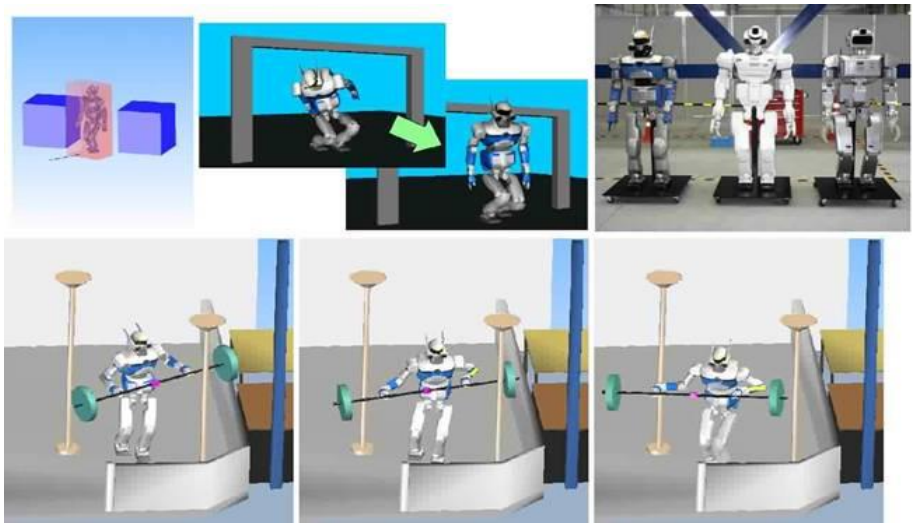


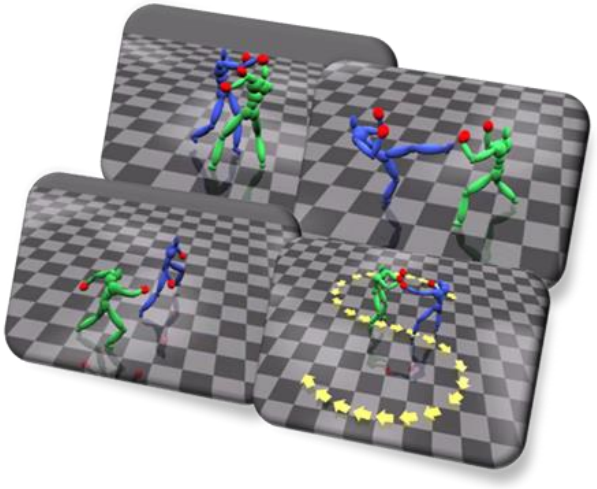


Motion Planning

- How to switch from one posture to another without colliding with other objects / characters
- How to control characters so that they behave smartly

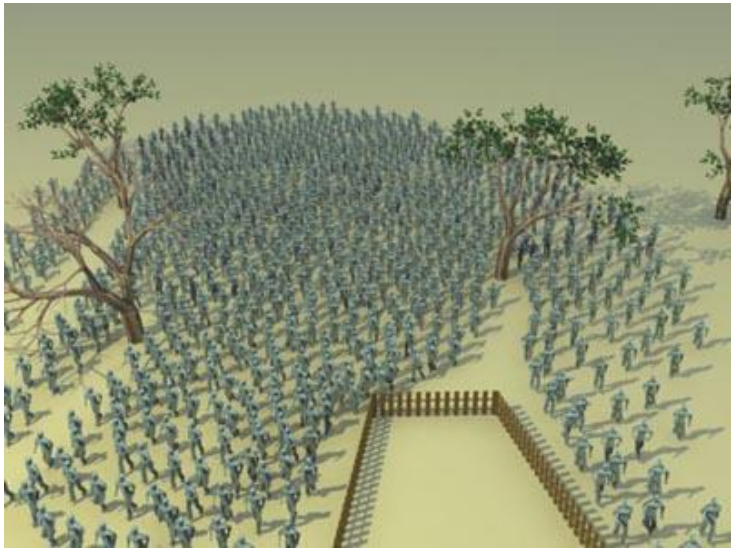






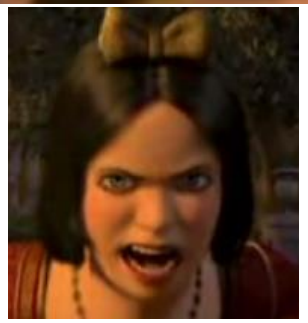
Crowd simulation

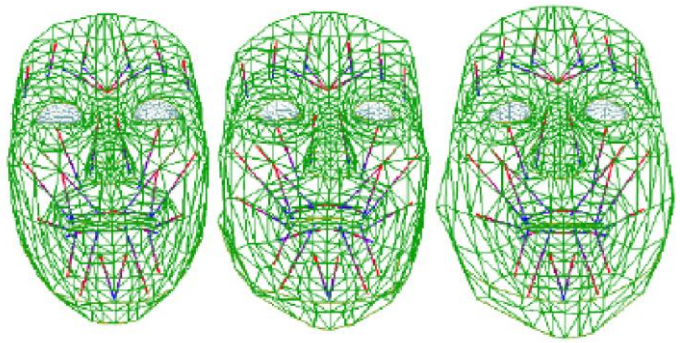
- Simulating the pedestrians in the streets, the audience of a concert, soldiers in the battlefield, etc.
- How does one's movement affect those of the others



Facial animation

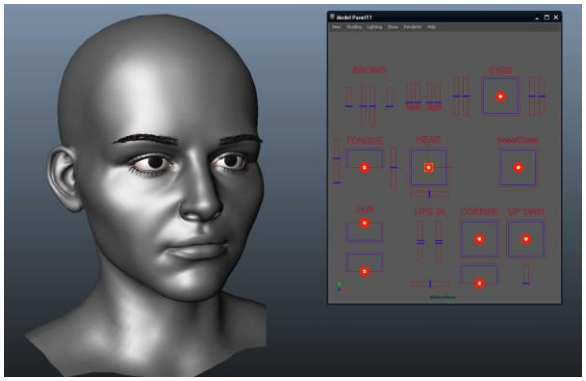
- Animating the face by
  - Motion capture data
  - Using musculoskeletal models

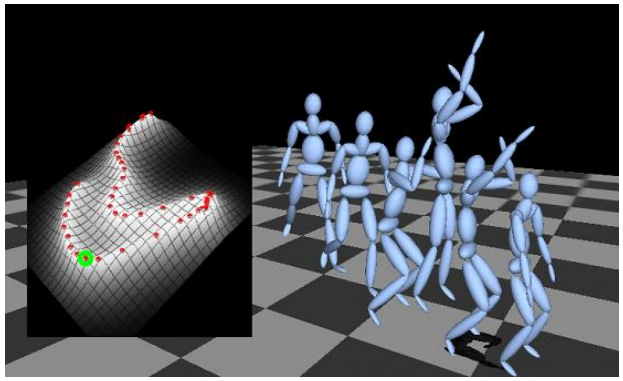




AI/Machine Learning Techniques for Character Animation

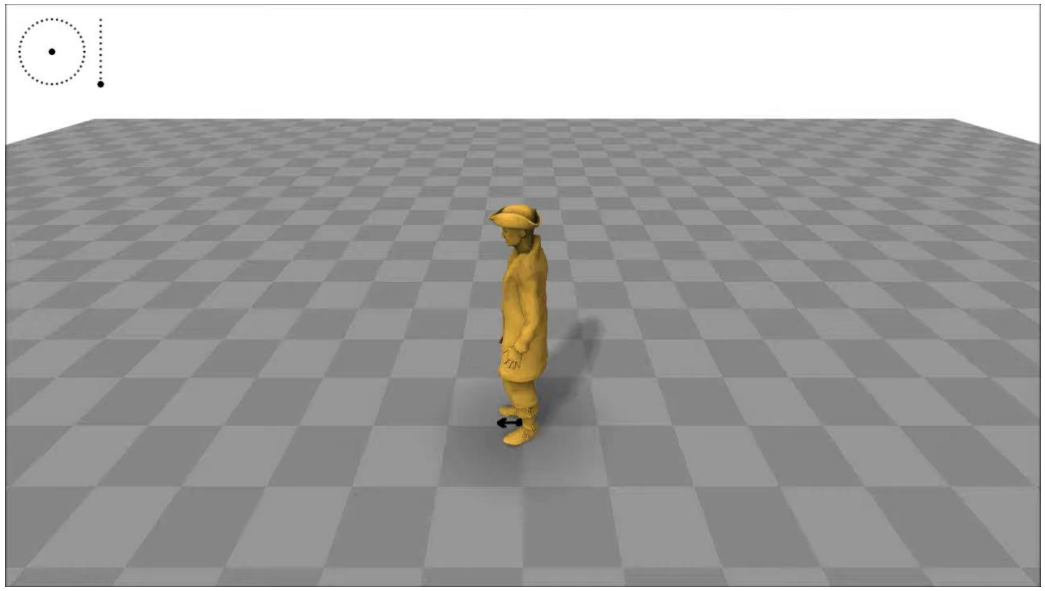
- Learn how the humans move using the motion capture data
- Apply them for character motion synthesis
- Controlling high dimensional models (face, skin, high DOF articulated characters) with low dimensional control signals





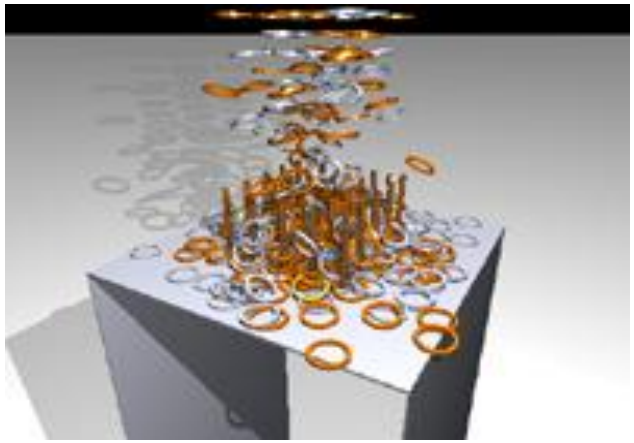
Deep Learning Techniques for Character Animation

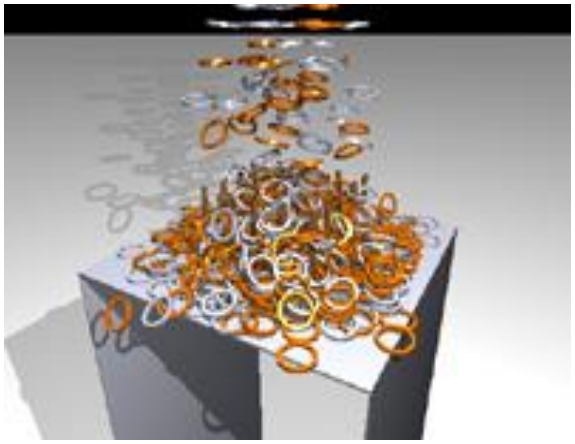
- Neural network-based time series models are often used nowadays to produce character movements that follow the user instructions.
- Neural networks are useful as they can compress the data a lot. Also relatively fast to compute at runtime.

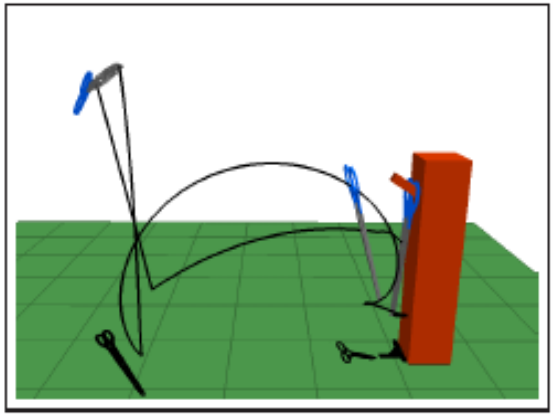


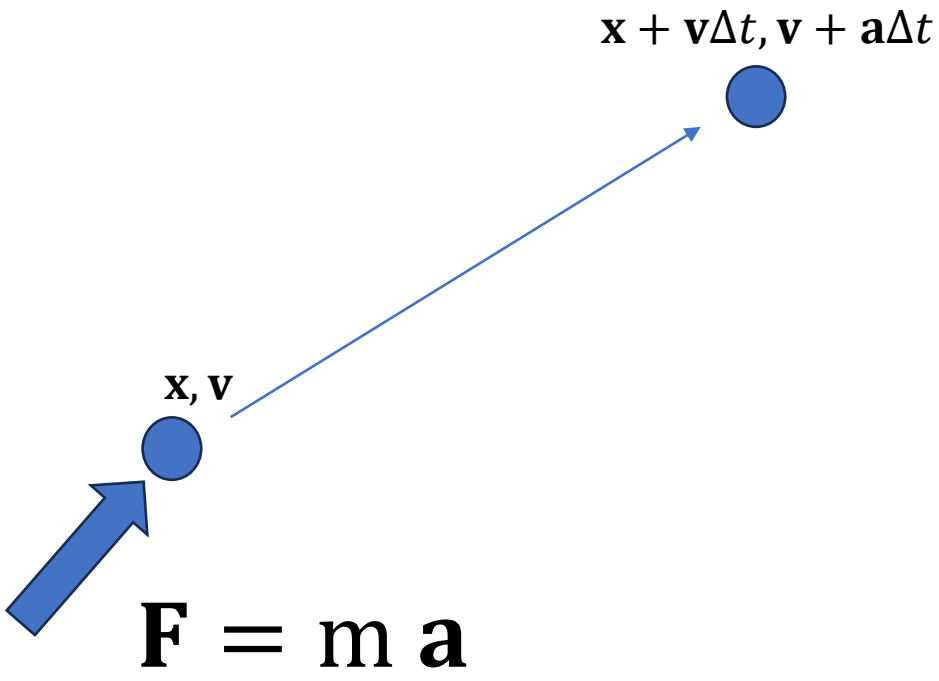
Physically-based Animation: Rigid Objects

- Simulating rigid objects flying, colliding, and bouncing
- Technical issues
  - Collision detection, response
  - Computing the contact forces, friction forces





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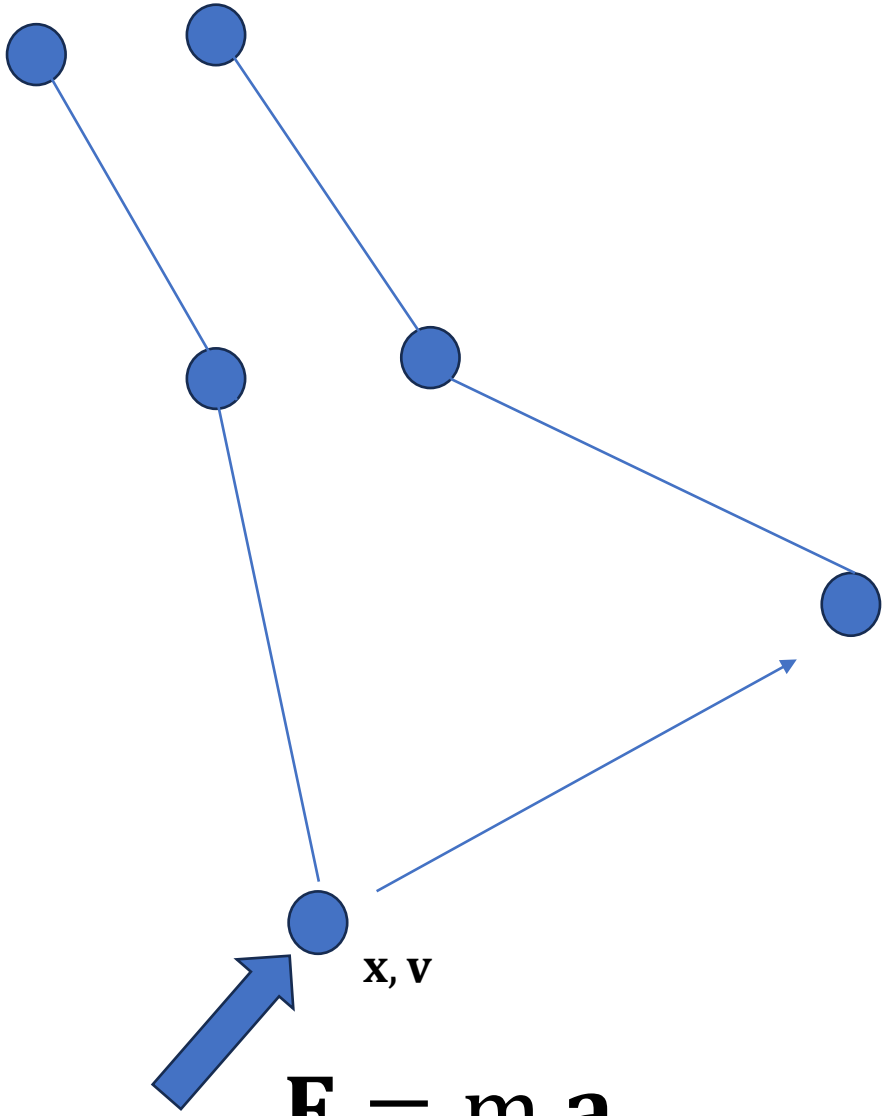
$\mathbf{x}, \mathbf{v}$
$\mathbf{F} = \mathrm{m}\,\mathbf{a}$

Physically-based animation: Hair

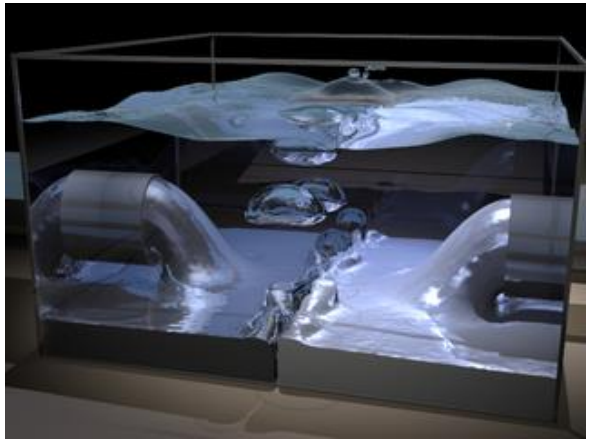
- How the hair moves when the wind blows
- Need to take into account
  - the physical properties of the hair,
  - Collisions between the hair

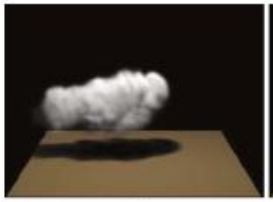
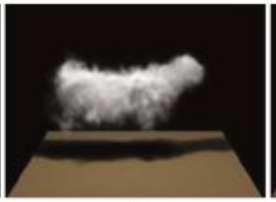
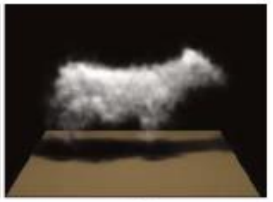


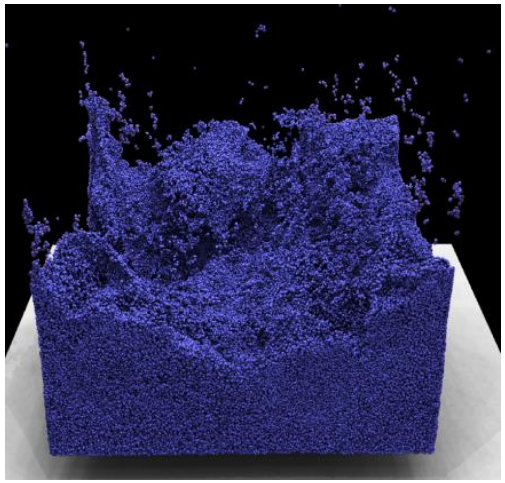
$$\mathbf{F} = \mathrm{m}\,\mathbf{a}$$

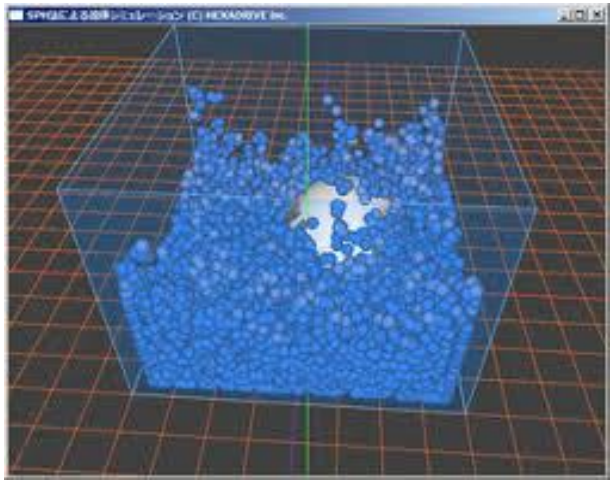
Physically-based animation: Fluids

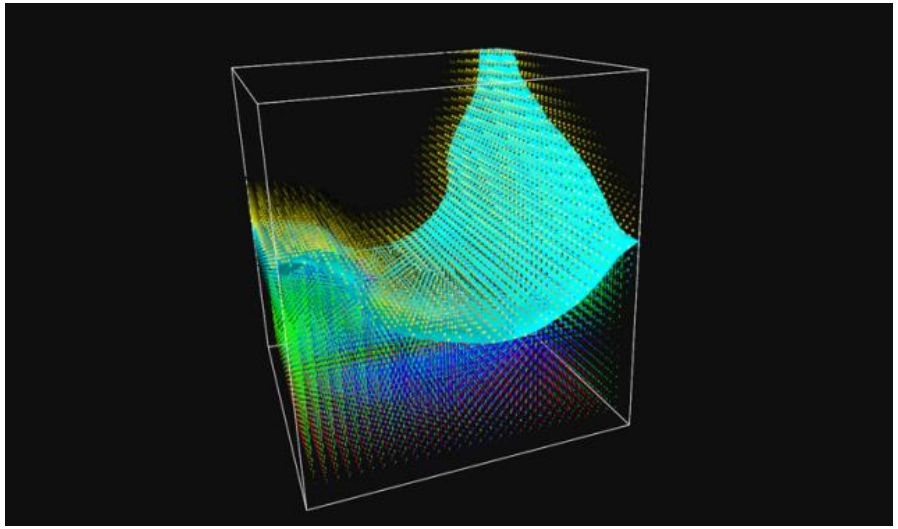
- Simulating liquid, mud, fire, bubbles
- How to efficiently simulate the motion of the fluids
- How to control the fluids so that the animator can get what s/he wants

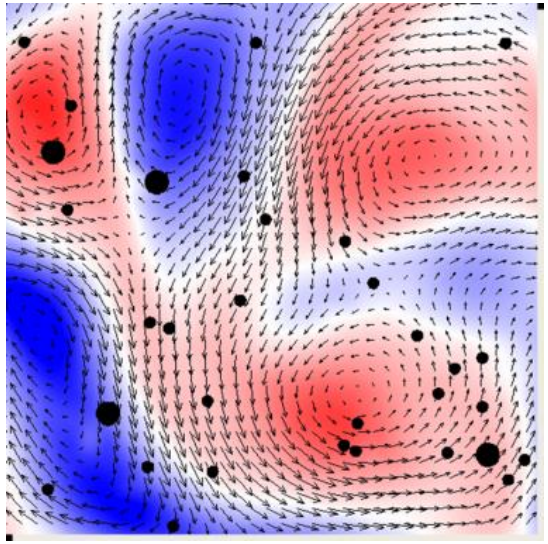




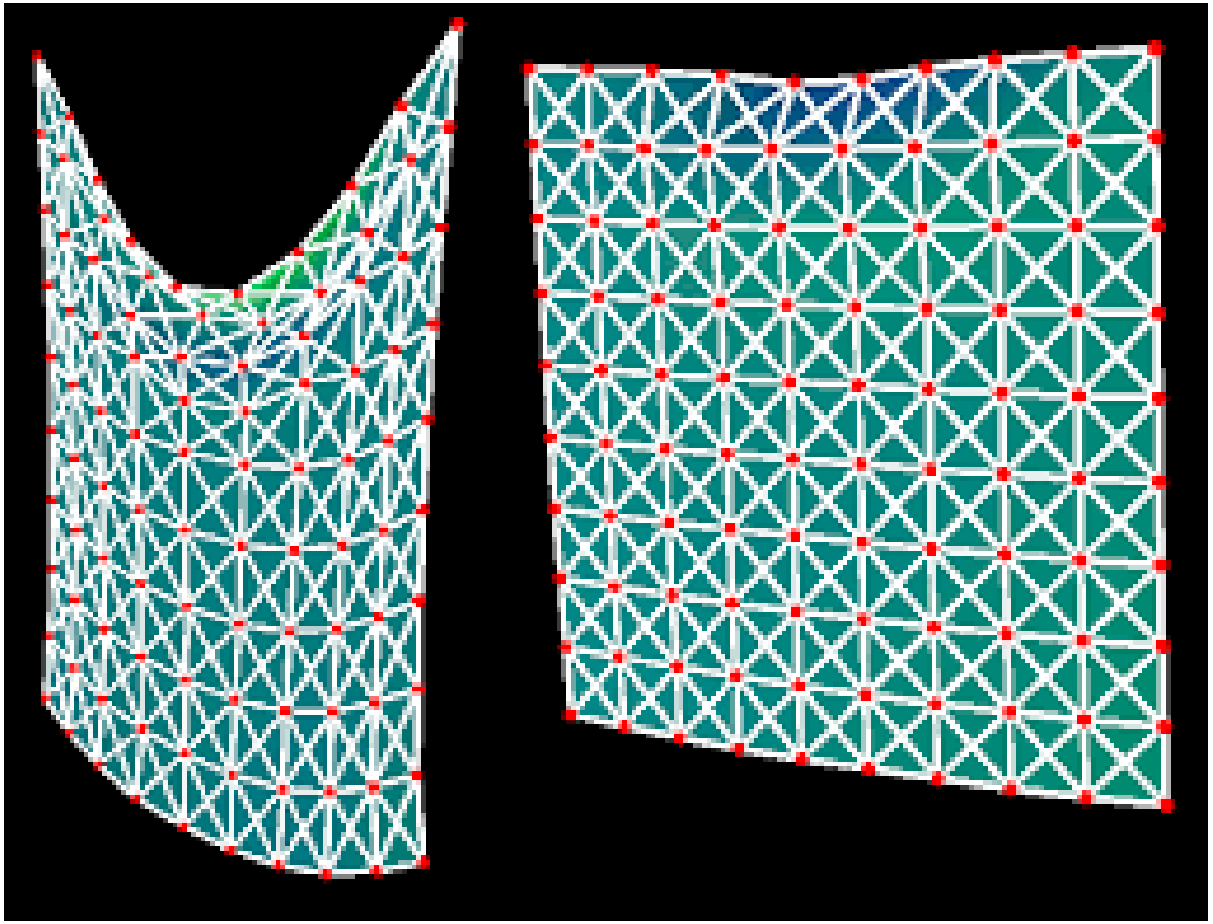






Physically-based Animation: Cloth simulation

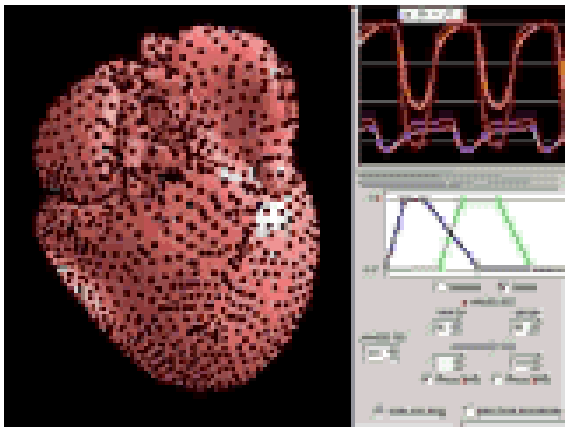
- Simulating the movements of clothes when the body moves
- How the wind affects the deformation of a cloth

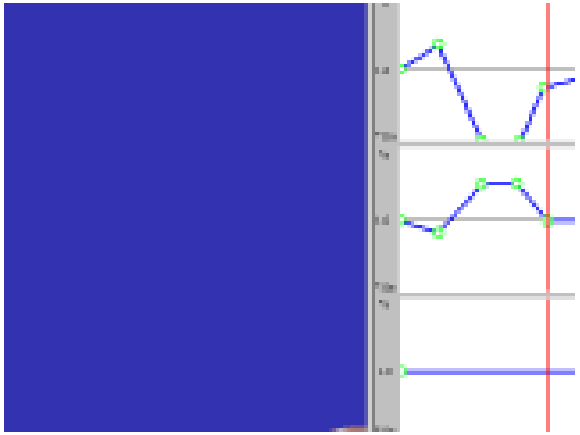


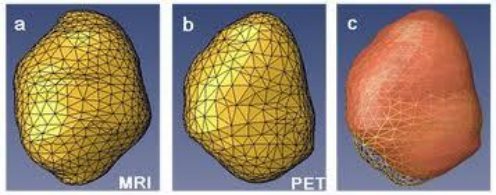
Finite Element Method

Needed to simulate soft materials like jelly fish, human heart

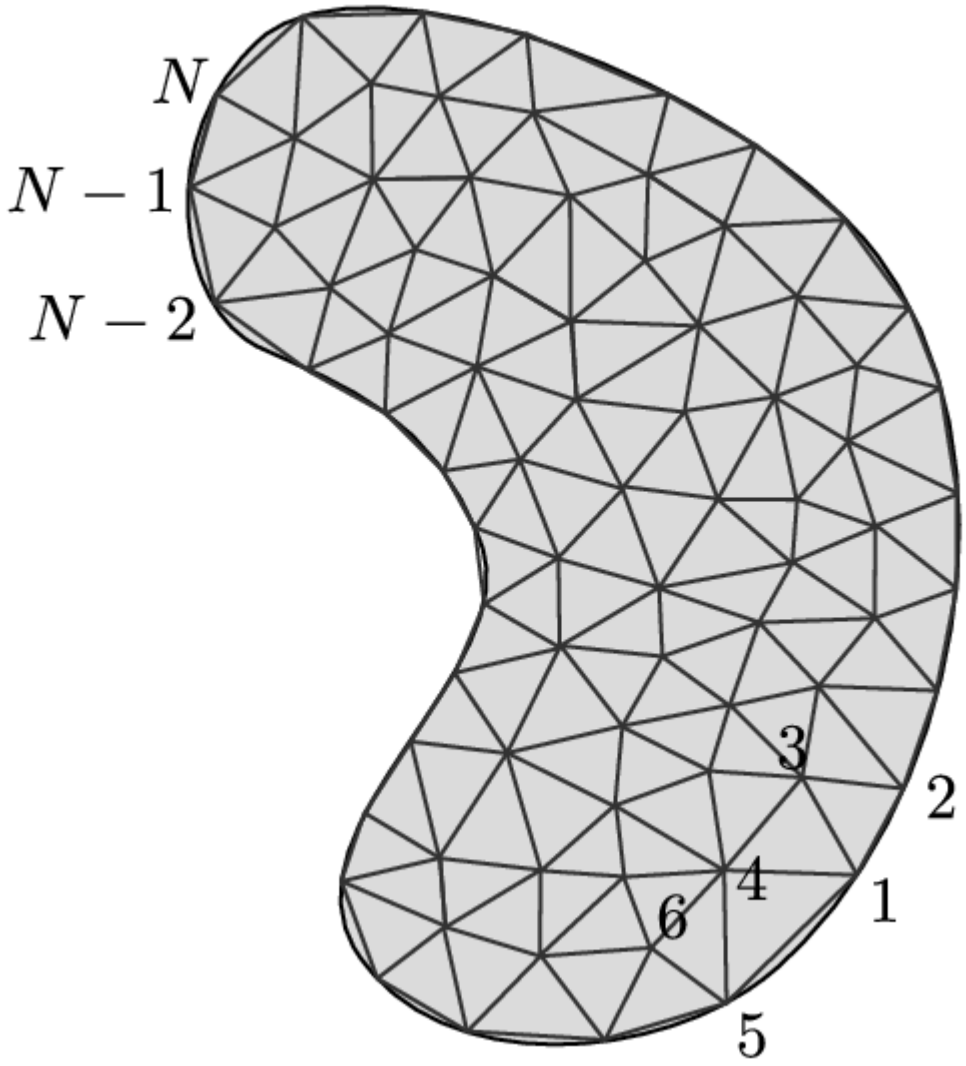
FEM is also used for the analysis of hard objects like buildings, bridges, aircrafts etc







On courtesy of Dr. Takashi Ijiri


N
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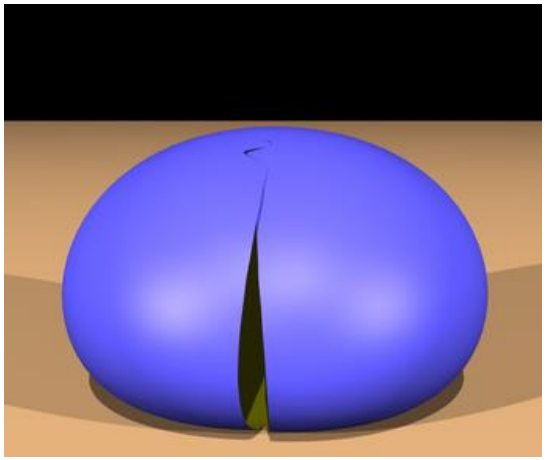
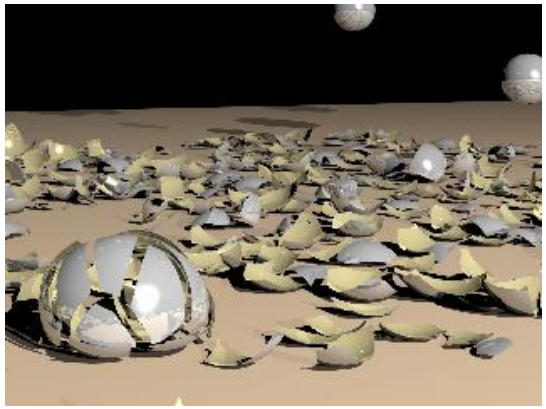
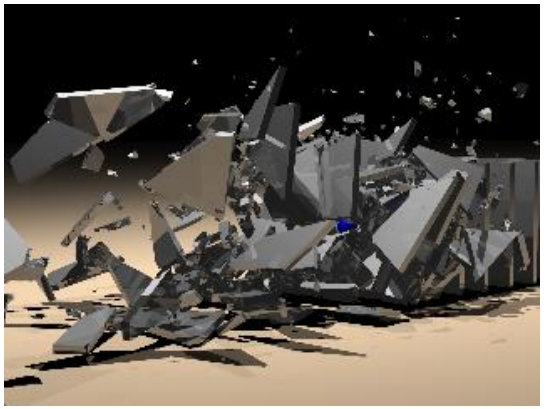
Wrecks/Crashes/Destruction

- Simulate how / where the destruction starts and expands







Physically-based Animation: Forward Dynamics

- Simulating the body as articulated objects connected at the joints
- Easy to simulate ragdoll motion
- Difficult to simulate voluntary motion

Physically-based Animation: Forward Dynamics

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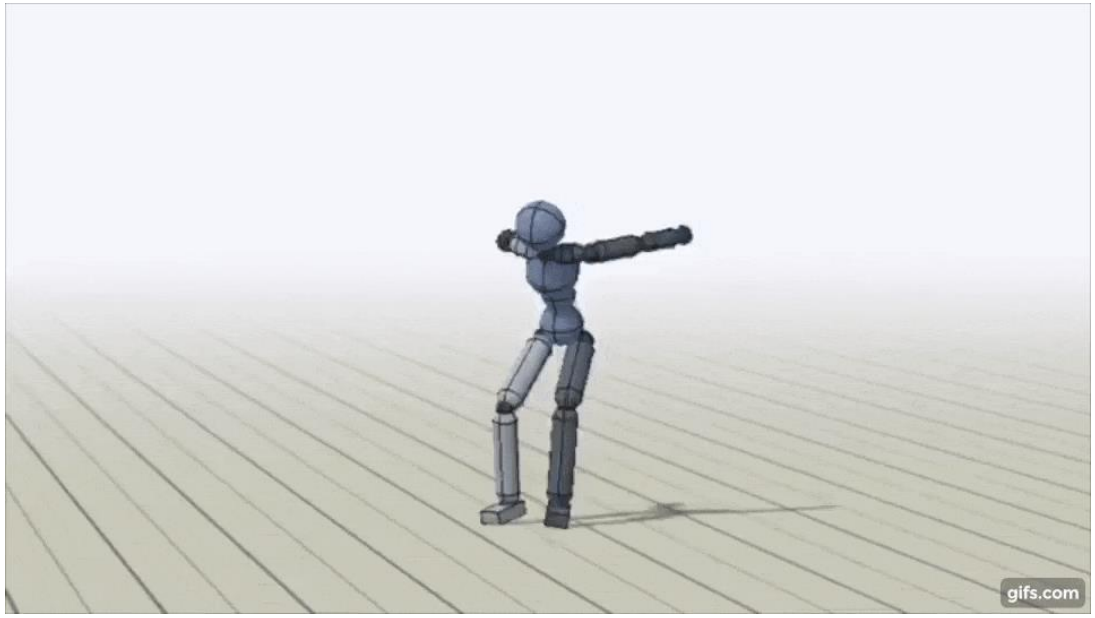
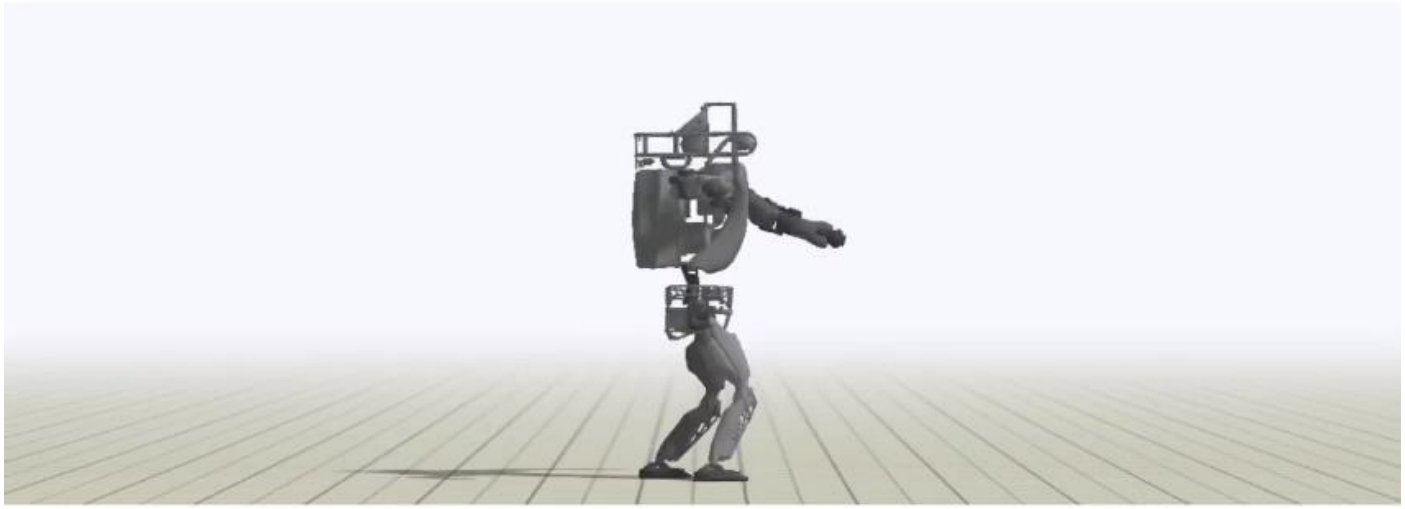
Deep Reinforcement Learning for Tracking Human Motion

- In forward simulation of articulated humans, it is difficult to compute the joint torques to track some motion, especially when the perturbation is very random.
- Researchers propose to use deep reinforcement learning to track a reference motion



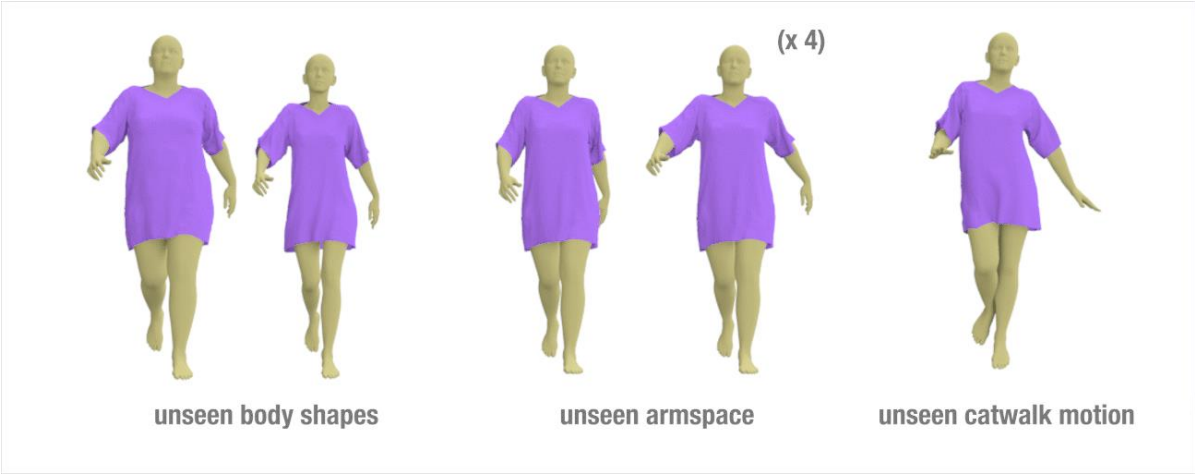
Deep Reinforcement Learning for Tracking Human Motion

Atlas: Spinkick



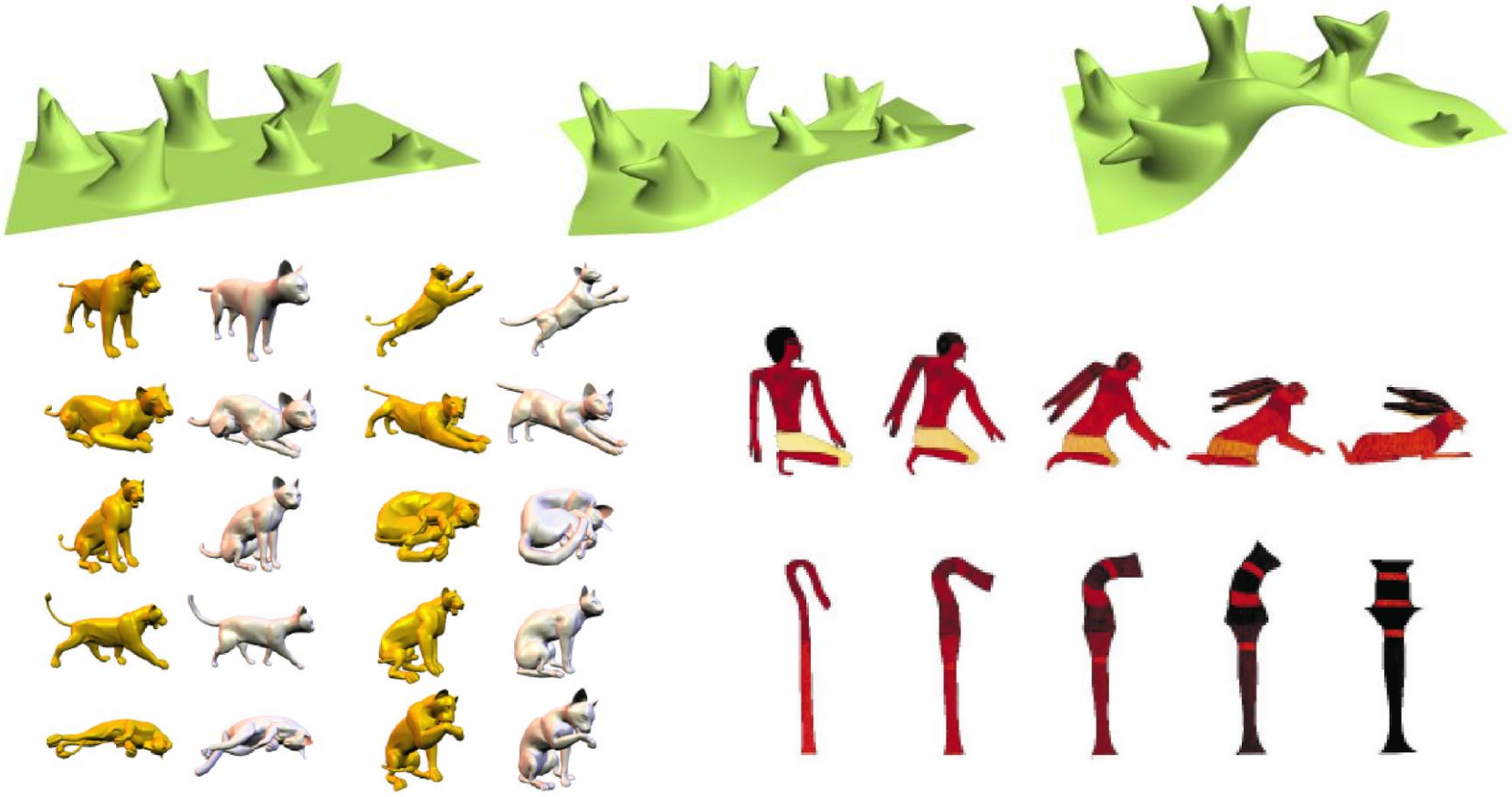
Data Driven Physics Simulation

- Instead of simulating the response of the objects by physics rules, some researchers propose techniques to learn the updates of the state.
- Using the simulated results for supervised learning



Shape Modelling and Editing

Designing shapes, editing shapes



2D Cell animation

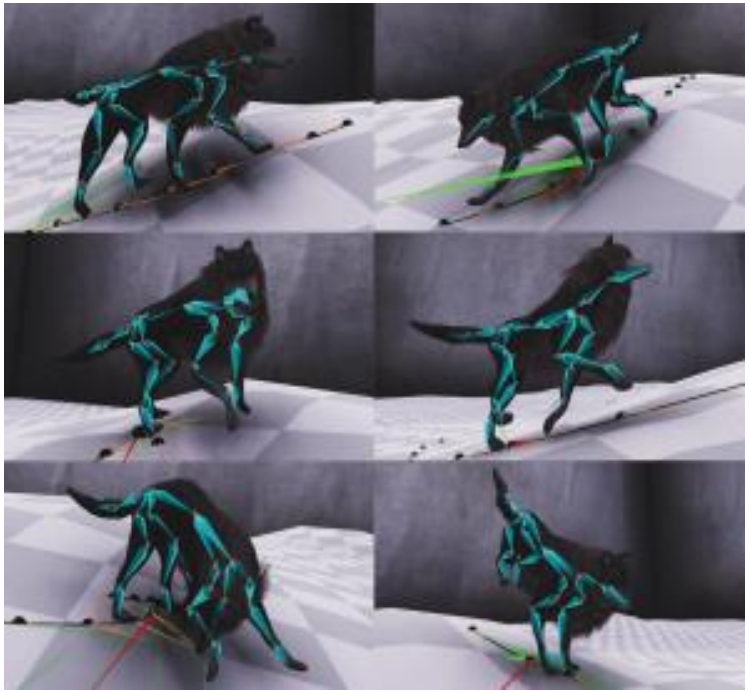
- For a 30 minute cartoon, 3000 cell pictures are needed
- This requires a month labour of 50 professional drawers
- How to create 2D Cell animation efficiently
  - Using 3D graphics and render in a 2D cell animation fashion
  - lighting, shadows, deformation

Today’s topics

- Introduction to Computer Animation
- Topics covered in this course
- **Motivation / Group Research**
- Other applications of computer animation

Motivation of Research

- Improving the realism of the character movements, simulated scenes
- Improving the efficiency of animation (faster, less memory)

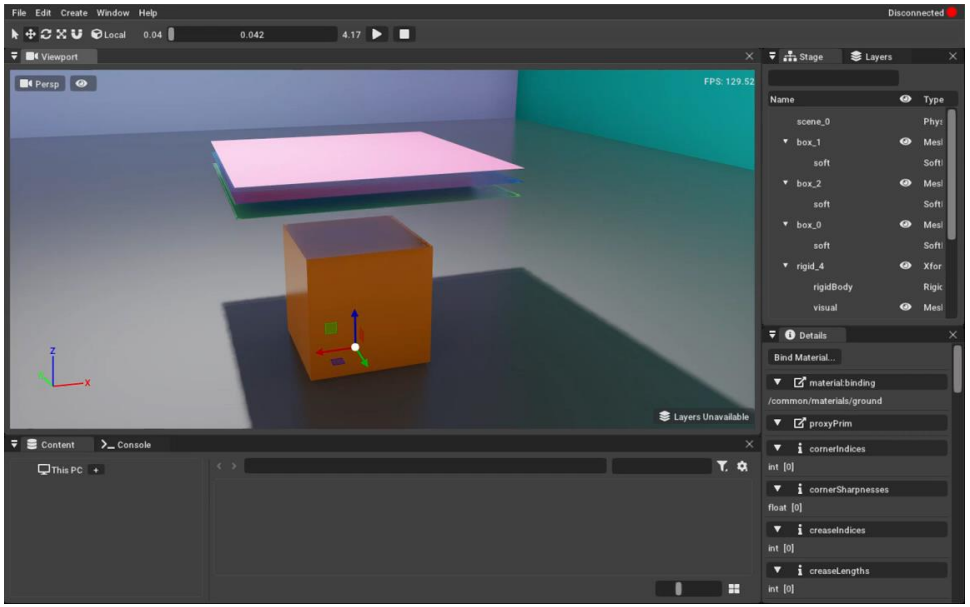


Offline vs. Real-time

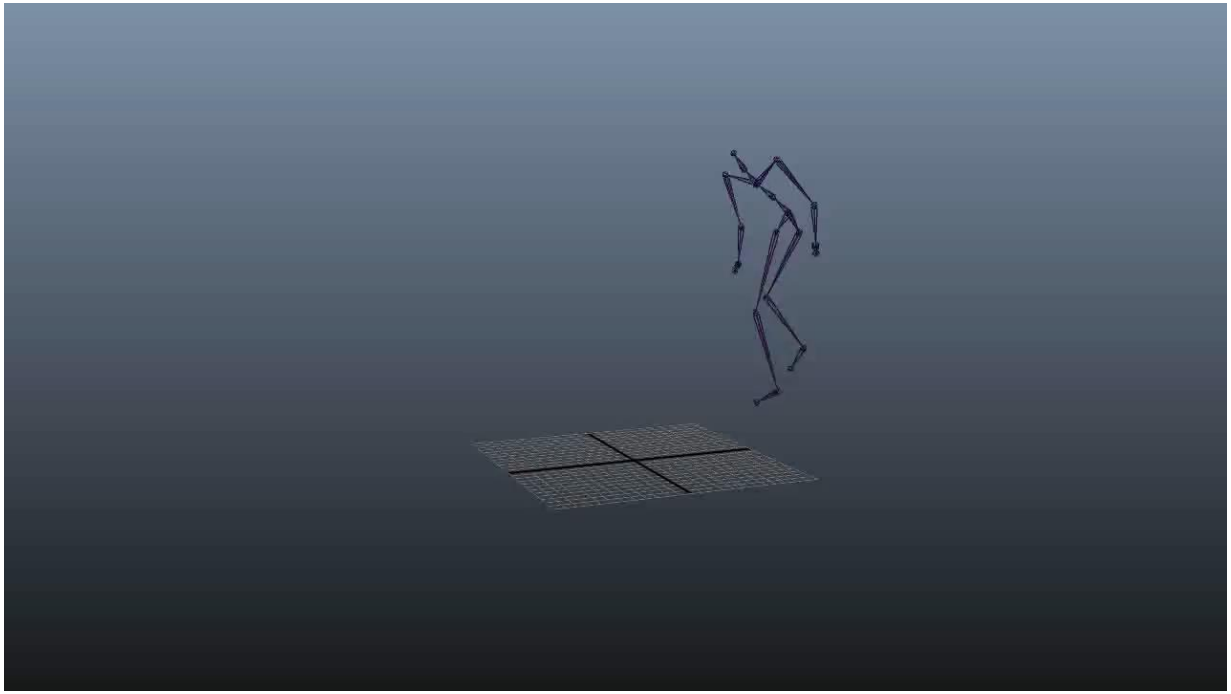
- Computer animation techniques are often very expensive
  - Physical simulation may require a lot of memory and mathematical operations
  - Many techniques require optimization with many variables
  - This is fine for applications such as movie production
  - The animators can generate the scene, fix the parameters if they don't like the results and render the results again – can repeat such cycles

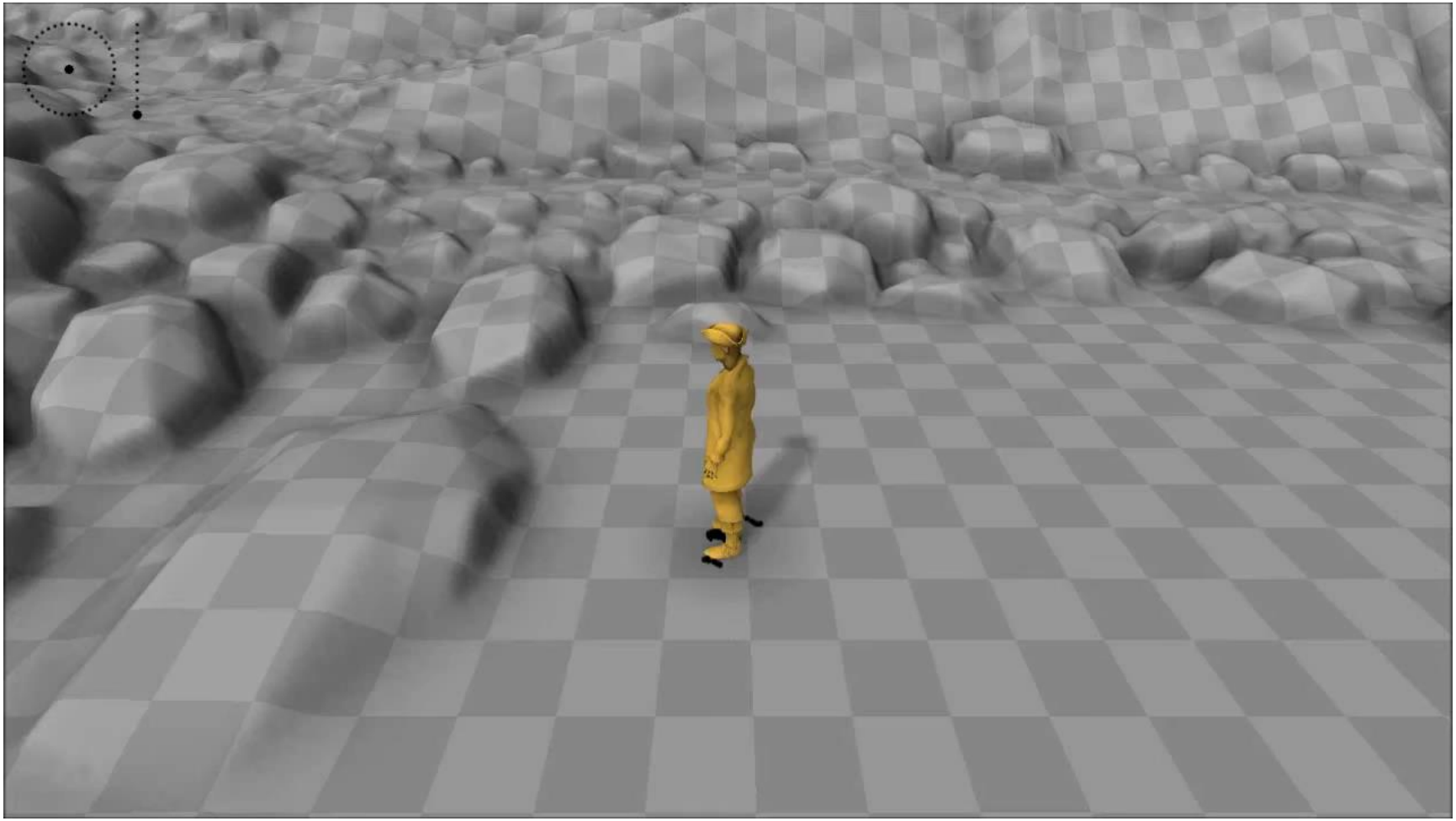
Offline vs. Real-time

- On the other hand, real-time applications such as computer games and virtual reality require quick response (30 frames per second)
- It is often the case that techniques are first developed for offline animation and then improved such that they can run in real-time later.

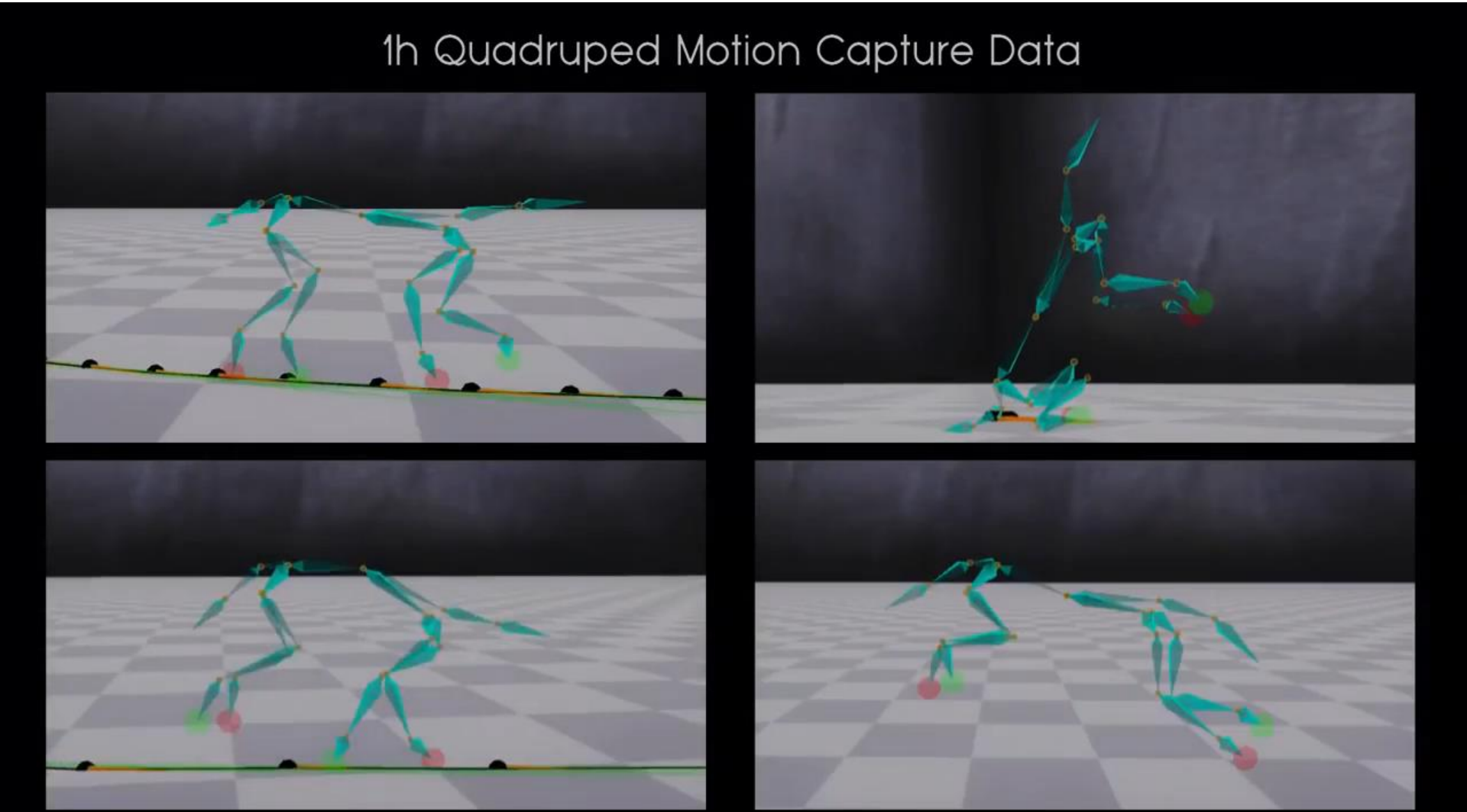


Phase-Functioned Neural Networks



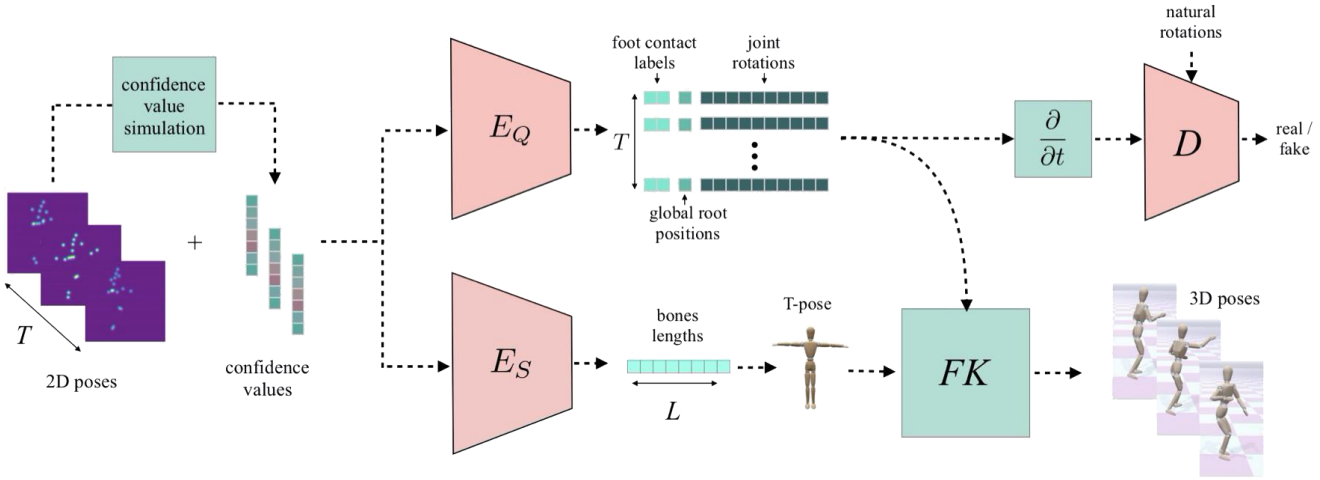


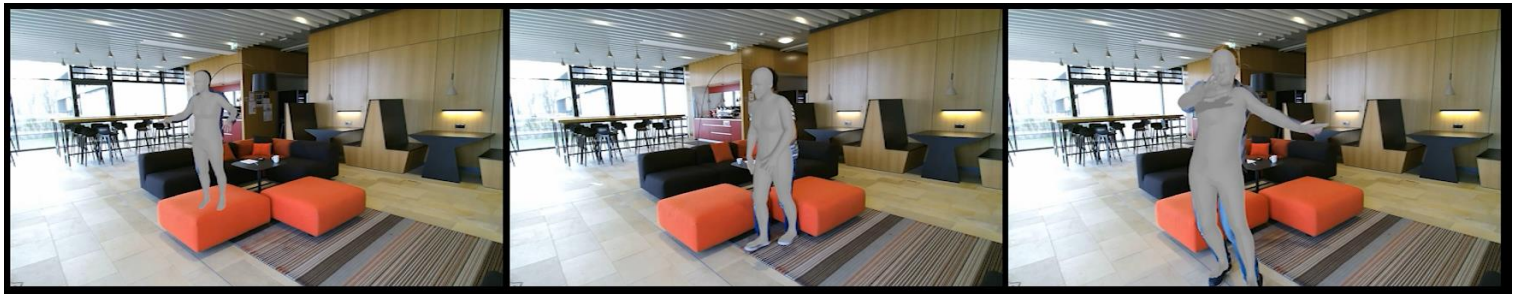
Mode Adaptive Neural Networks



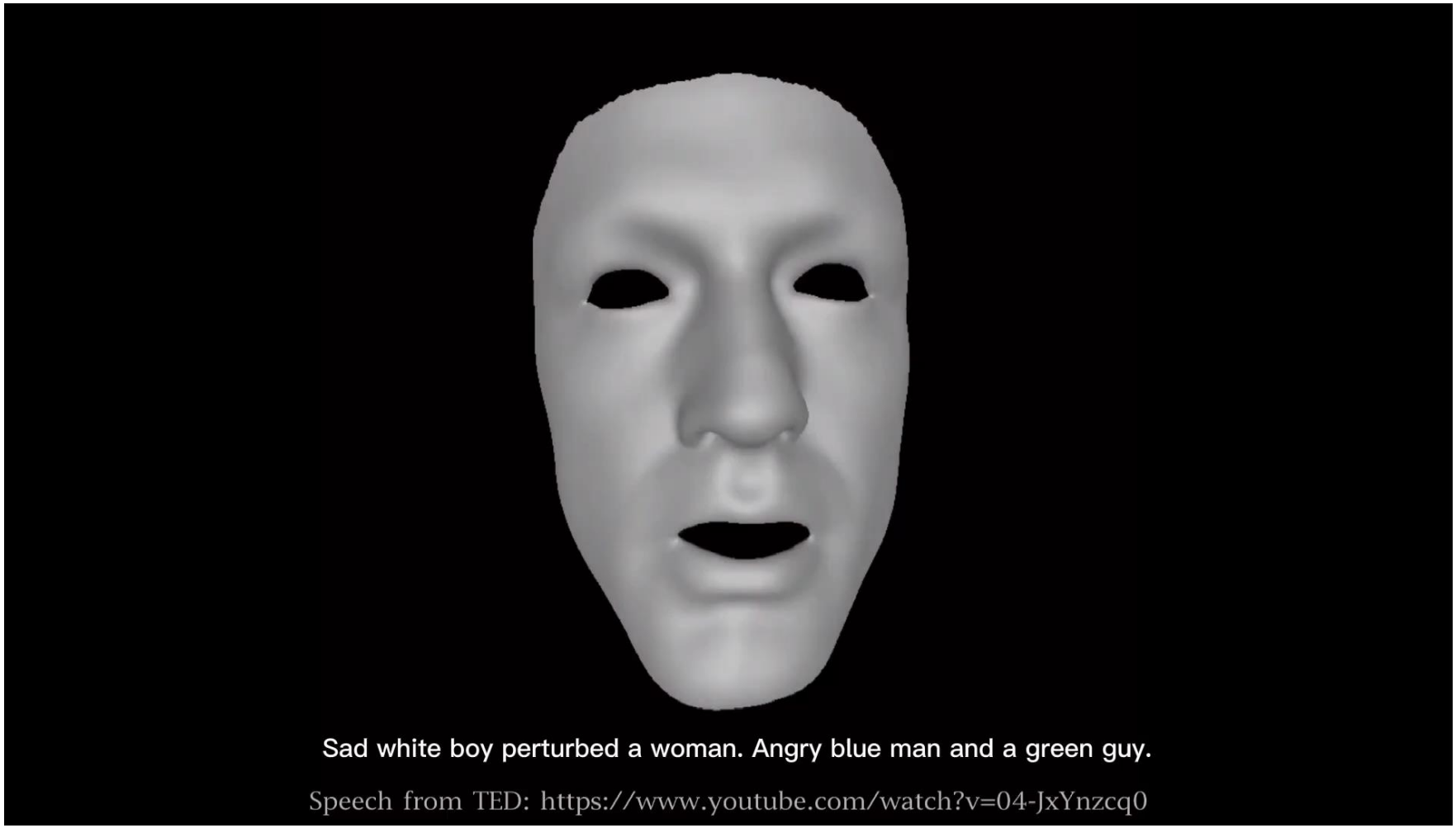
Local Motion Phase

Video-based Motion Capture





Face animation from speech



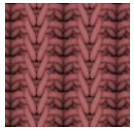
Face retargeting

Physical Simulation

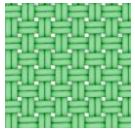
We can also simulate various yarn-level woven fabric types by adjusting the anisotropic parameters.

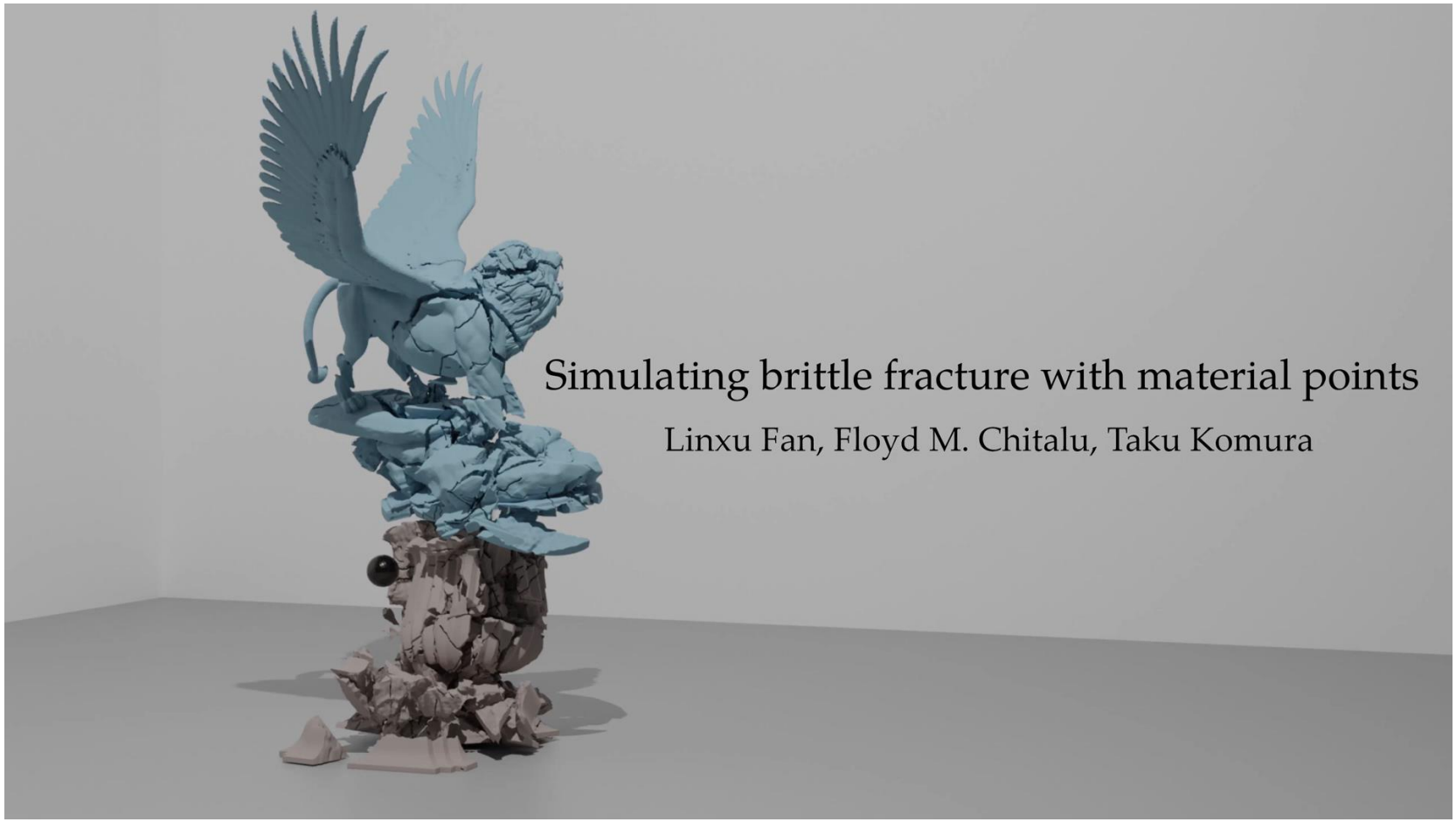
Satin

Ribs



Basket




Simulating brittle fracture with material points
Linxu Fan, Floyd M. Chitalu, Taku Komura

Other Applications

In addition to films and computer games, applications of computer animation include

- AR/VR
- Creating data for machine learning
- Evaluation of buildings/environment

AR/VR applications

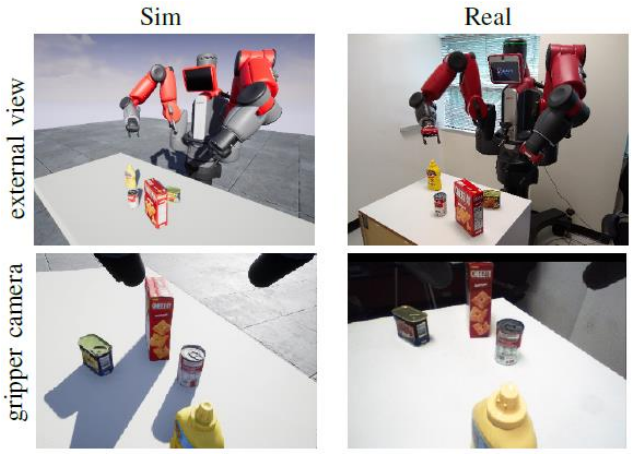
Preparing Training Data for Machine Learning

Applications like self-driving car require a lot of training data

- People start to use data created by computer animation for the training
  - Some researchers used GTA-5 animation for training their self-driving system
- Same concept applies to human motion tracking, facial expression tracking, etc.

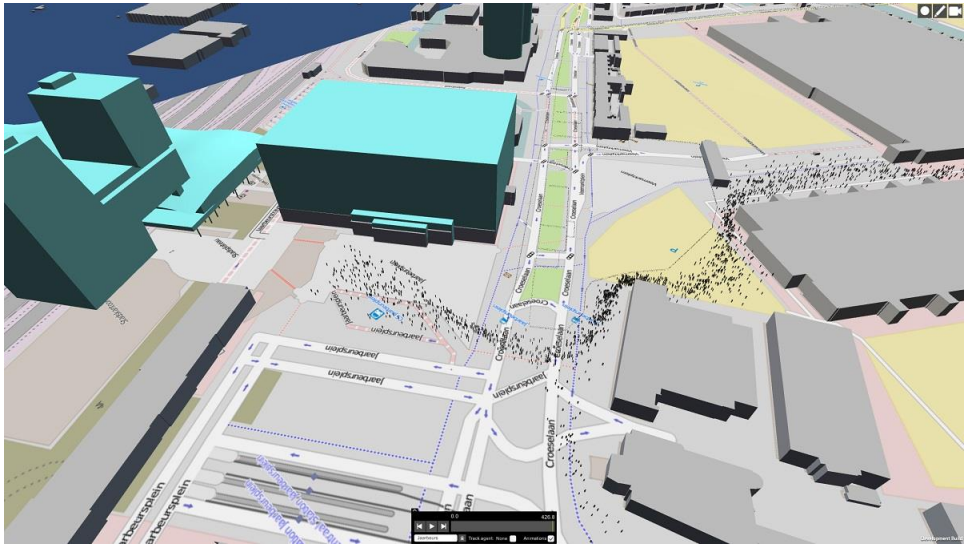
Sim2Real

- Machine learning is also used a lot for robot control
- Controlling the robot to collect data is time consuming
- That can also cause damage to the robot
- Instead, people simulate the robot in virtual environments and collect the data
- These are applied for the real robot for the control
- Usually there is a gap between simulation and the real robots – people use domain transfer techniques for filling in the gap.



Building/Environment Design

- The flow of people is an important factor when designing buildings or facilities like airports
- So that we know if the building is comfortable to live, or people can evacuate well in case of fire etc.
- Crowd simulation is used for such purposes.



Course Outline

- **30 Lectures**
  - Roughly half about character animation, half about physical simulation
- **6 tutorials**
  - Related to the assignments
- **4 Assessed Practicals (Python)**
  - 2 for character animation
  - 2 for physical simulation

- **Assessment**
  - Examination (50%)
  - Practical assignments (50%)

Teaching Hours

- **Thursday 7:00-10:00PM,**
- **Office Hours**
  - Taku Komura: Tuesday 4:30-5:30PM, CYC,CB407
  - Mingyi Shi: Monday 2:30-4:30PM, CYC, CB416
  - Zhouingchen Liao: Monday 2:30-4:30PM, CYC, CB416

Q&A