Your Future **Graphics** Journey beyond CS3451

Bo Zhu

School of Interactive Computing

Georgia Institute of Technology

About Awards Events Inside SIGGRAPH SIGGRAPH 365

Join SIGGRAPH

ACM SIGGRAPH

Your global community for innovation and application

The ACM SIGGRAPH community is a global nonprofit organization serving the evolution of computer graphics and interactive techniques. With thousands of members across the world, the researchers, artists, developers, filmmakers, scientists, and business professionals of ACM SIGGRAPH are building the future of digital art and interactive design.

Join Us

Technical Paper Fast Forward in SIGGRAPH

Let’s take a random walk for SIGGRAPH 2023 Technical Paper Trailer

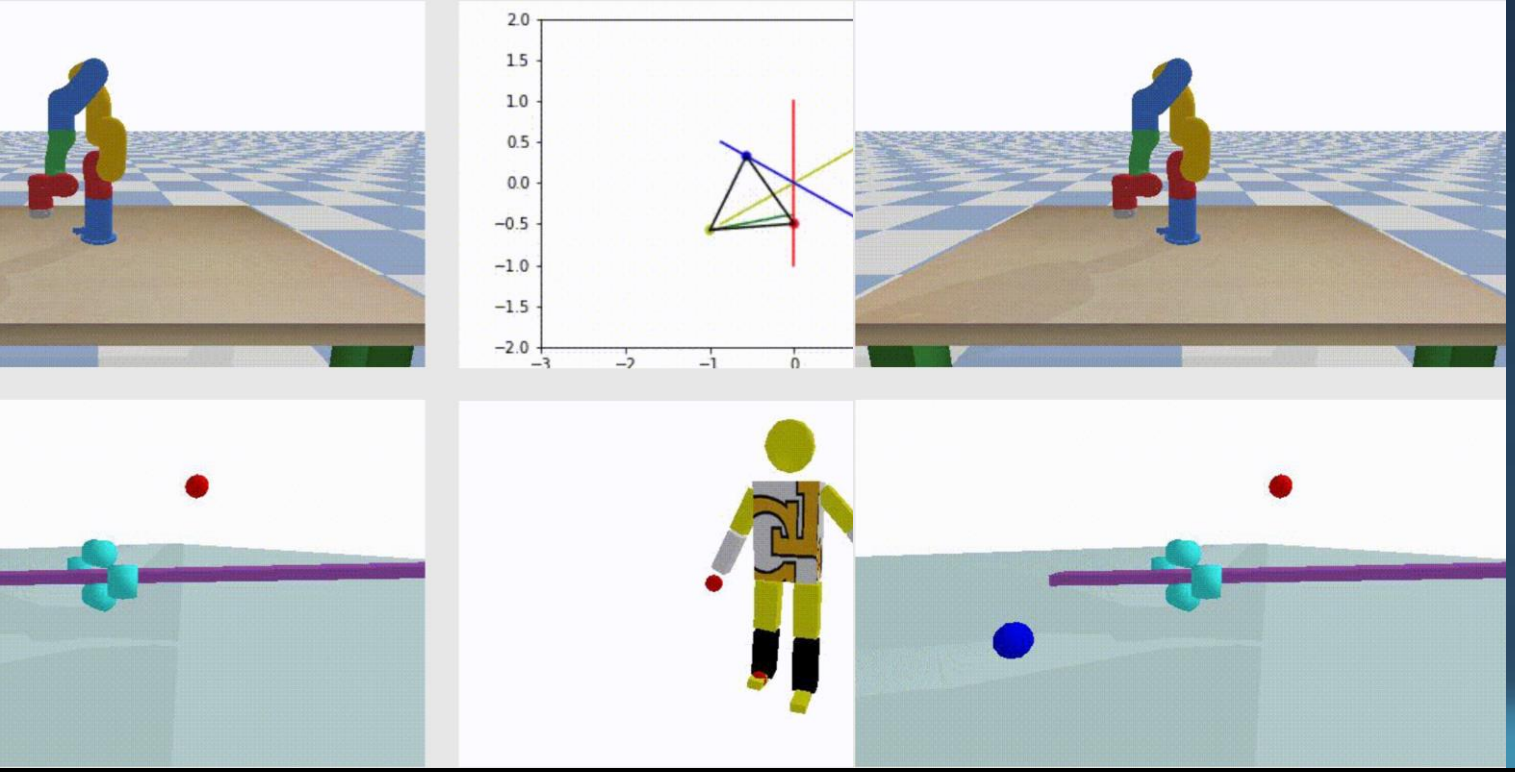

What are the next steps for your graphics journey after taking 3451?

If you take future courses at GT …

- **CS 3451 Computer Graphics (Turk, Ha, Zhu)**
- CS 4455 Video Game Design (Wilson)
- CS 4460 Information Visualization (Stasko, Endert)
- CS 4475 Computational Photography (Essa, Hays)
- CS 4496 Computer Animation (Ha)
- CS 4590 Computer Audio (Gandy)
- CS 4803 Procedural Content Generation (Turk)
- A New Course I Plan to Teach in 2025S

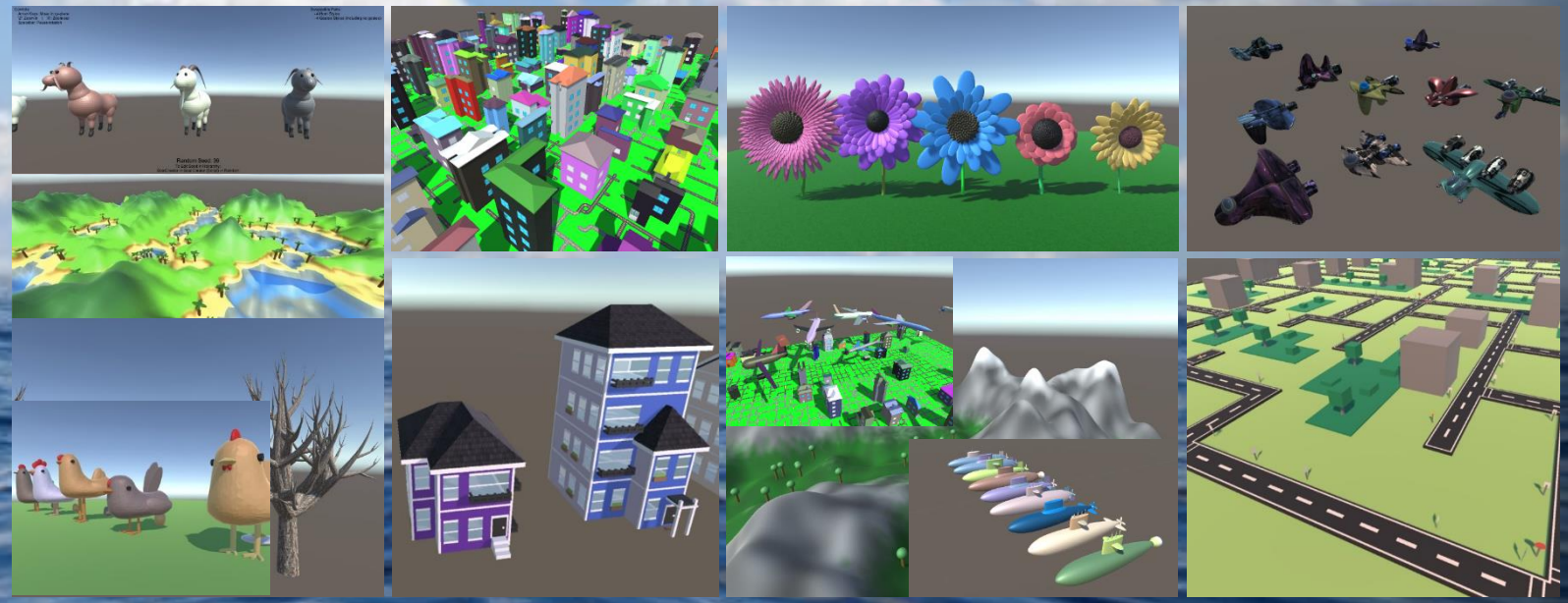
CS 4455 - Video Game Design

- Course Intro
- Game Engines
- Animation in Games
- Character Control with Animation
- Game Feel
- Game Controllers
- Physics simulation
- Artificial Intelligence
- Elements of Fun



CS 4496 - Computer Animation

- Keyframe animation
- Particle dynamics
- Rigid body simulation
- Motion capture
- Physics based animation
- Deep reinforcement learning



CS 4590 - Procedural Content Generation

- Use programming to create game environments
- Geometry + random numbers
- Natural environments
- Human made environments (cities)
- Behaviors (humans, animals, vehicles)
- Four projects, two options each time

A New Course I Plan to Teach in 2025S

- **Computer Graphics in the Age of AI** (Tentative Name)
- I plan to teach a new computer graphics course in 2025S
- The course is designed for both undergraduates and graduates
- It will focus on Modern Computer Graphics and its connections to AI
- I hope this course will be the natural next course you can take in computer graphics (from classical graphics to modern graphics)

If you decide to go to graduate school to further study computer graphics …

- Or decide to become a Ph.D. student in graphics …
- At some point, you will need to choose a research topic that you want to further explore, or even take it as your future career path

There are four main sub-areas in computer graphics that you can explore

Some Future Trends in Computer Graphics Research

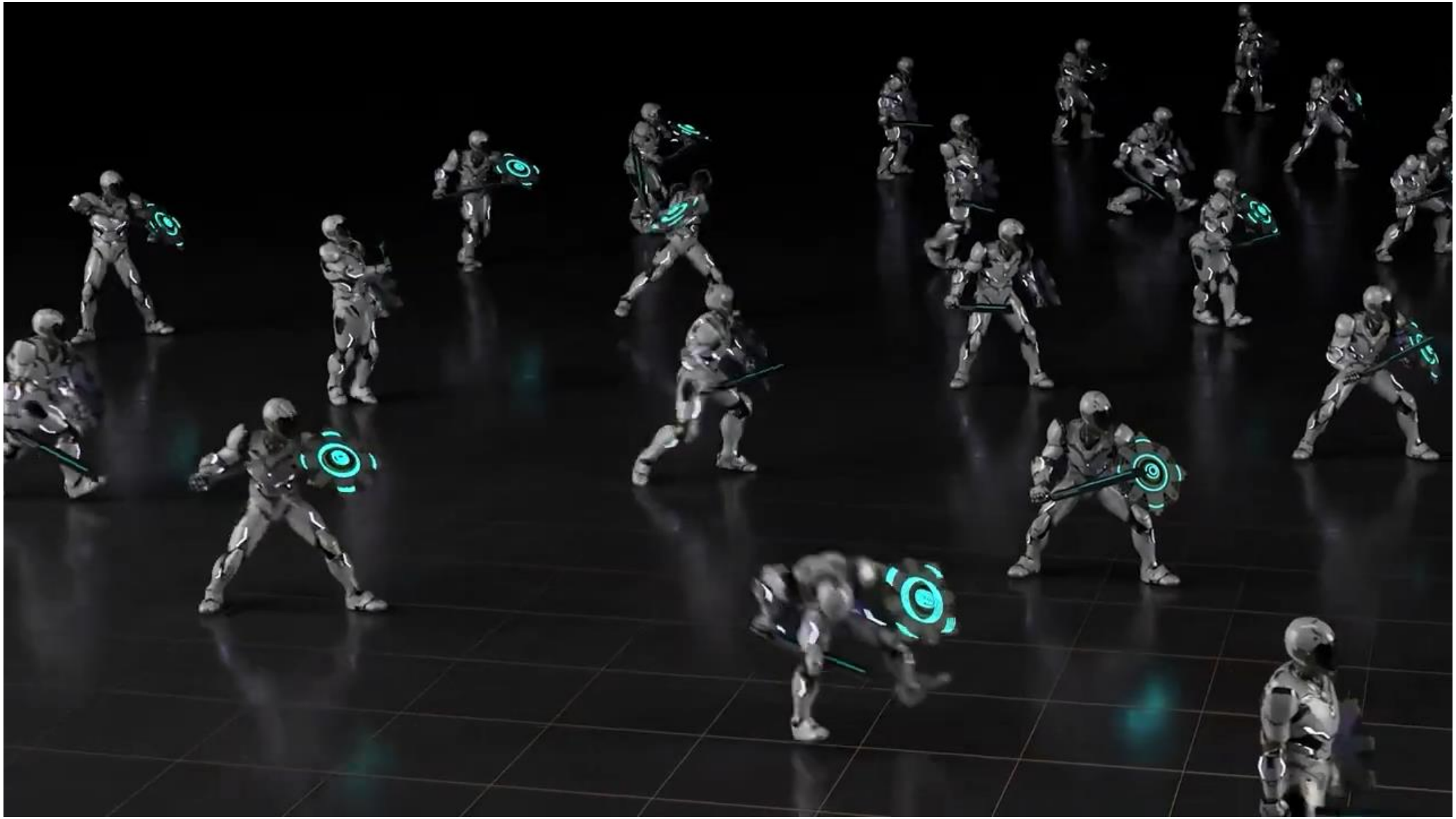
- **Unprecedented realism:** Computer graphics researchers are advancing algorithms to achieve faster performance, manage larger-scale scenes, and create more realistic visual effects
- **AI-powered architecture:** Computer graphics applications are more and more connected to AI techniques and ML frameworks
- **Real-world data connection:** Computer graphics interfaces with real-world data inputs, including images, videos, and 3D point clouds
- **Forward v.s. inverse:** Computer graphics research place equal emphasis on both forward and inverse computation processes

Virtual Human and Character Animation

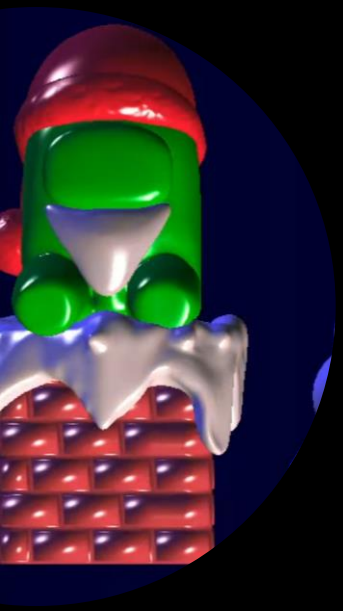
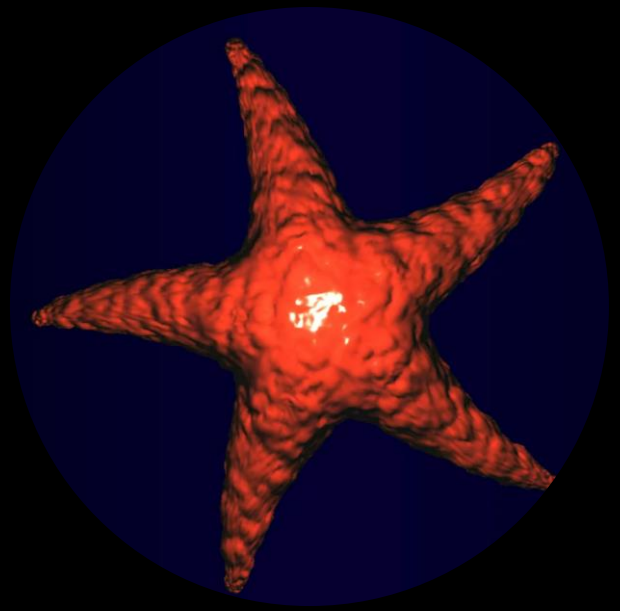
- Nowadays, virtual human research in computer graphics is crossing the “Uncanny Valley”
- Graphics algorithms can model a realistic virtual human in almost all aspects: face, body, hair, cloth, hand, skin, facial expression, etc.
- These algorithms can run in real-time to perform various kinds of vivid and engaging character-human interactions

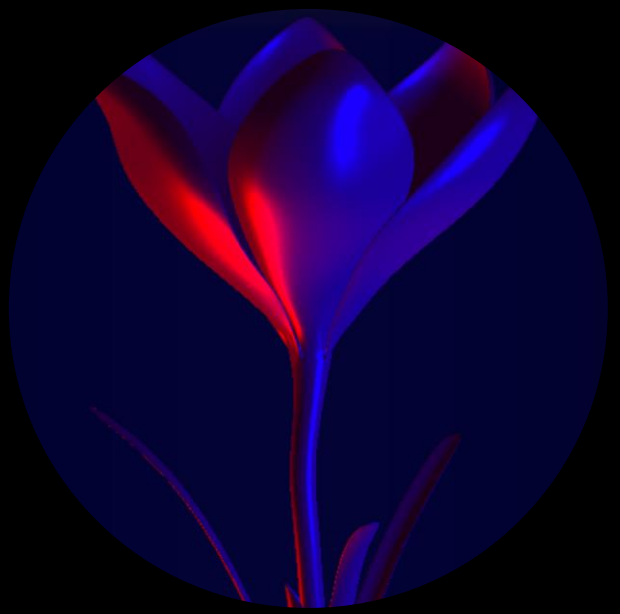
UE5 Virtual Human Demo

Virtual Human Animation: Metahuman Creator

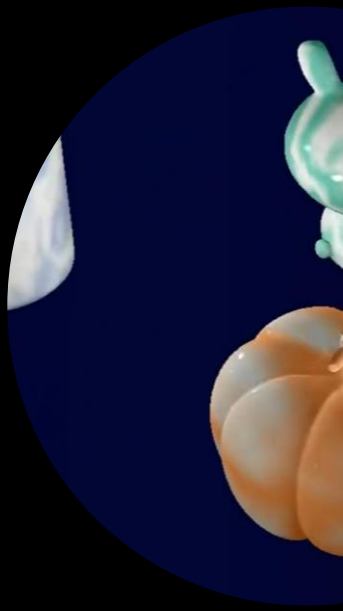


NVIDIA AI-Driven Character Animation



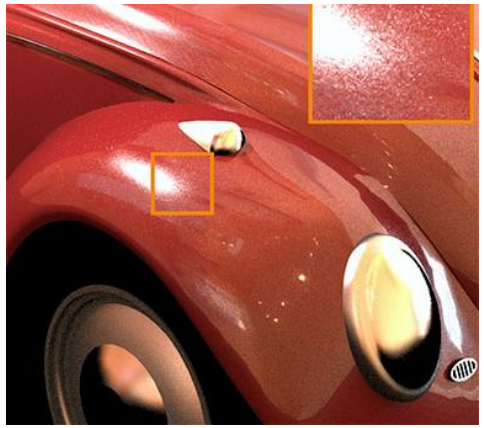
In 3451, we have studied Phong shading model to simulate the lighting effects on object surface and used it to render many different lighting and shading effects

Are there any more accurate lighting models that we can further study to enhance the rendering effects of complex materials and surfaces?

Physically-based Rendering

- By solving accurate light-surface interaction equations, computer graphics researchers can realistically render all kinds of surfaces and materials
- These equations are typically solved and integrated in an offline ray-tracing framework
- Many acceleration algorithms emerge over the past years to accelerate these rendering frameworks on GPU pipelines



Physically-based Rendering (PBR)

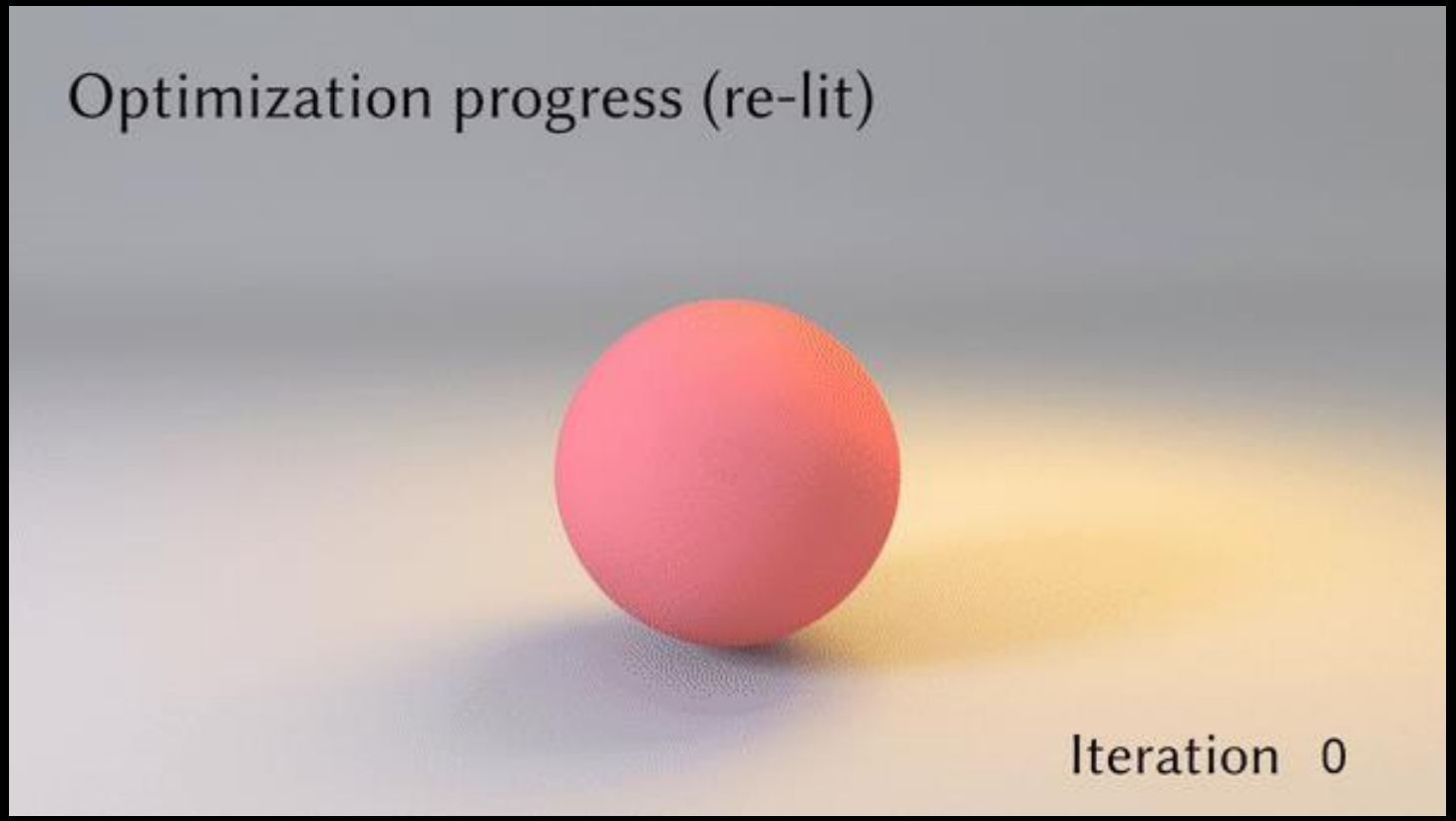
Forward Ray Tracing: **Scene -> Image**

- In 3451, we have studied the ray tracing algorithm as a forward process: we setup the scene by placing objects and lights, specifying camera parameters, materials, and loading textures, and the algorithm will produce a ray traced image for us

Can we reverse this process by figuring out rendering parameters based on images?

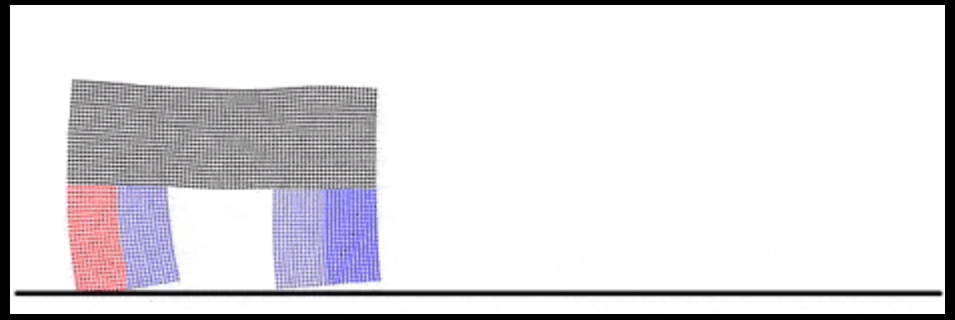
Differentiable Rendering

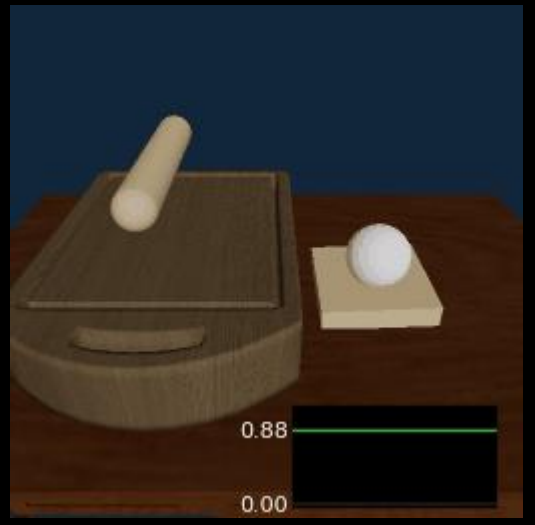
- Graphics researchers study the **inverse** process of ray tracing – to figure out the scene setup (e.g., object shape, camera position, lighting information, etc.) based on observing a few ray-traced images

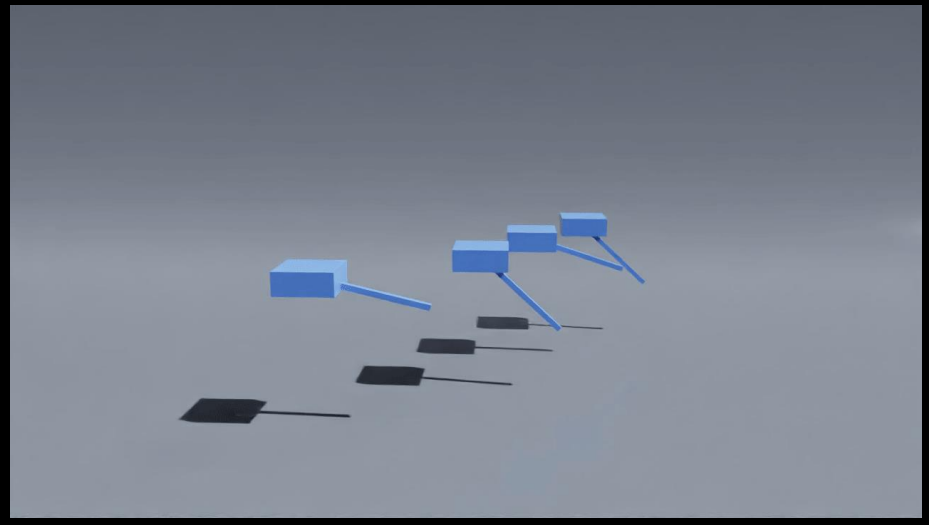


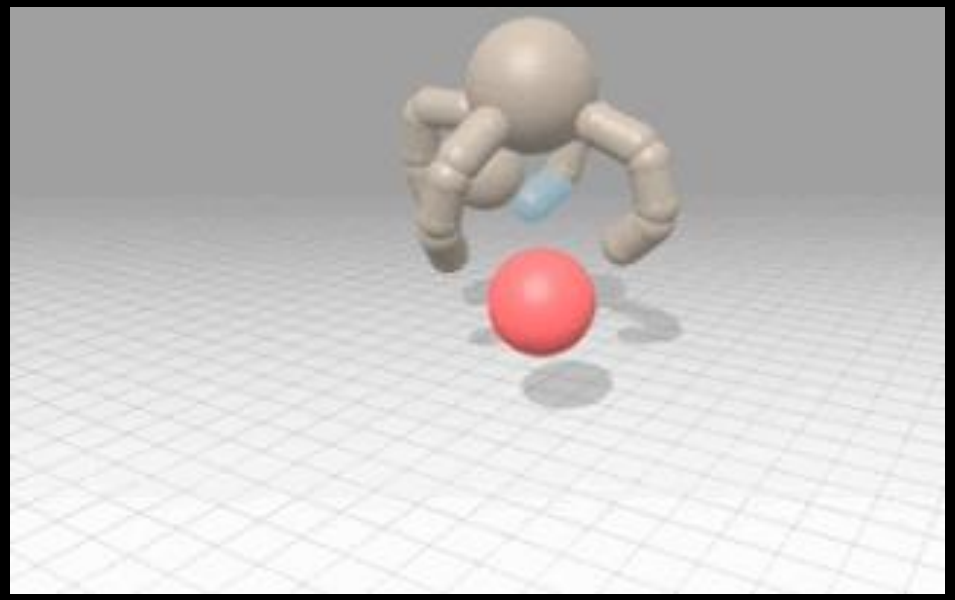
Example: Retrieve the 3D shape from 2D ray-traced images

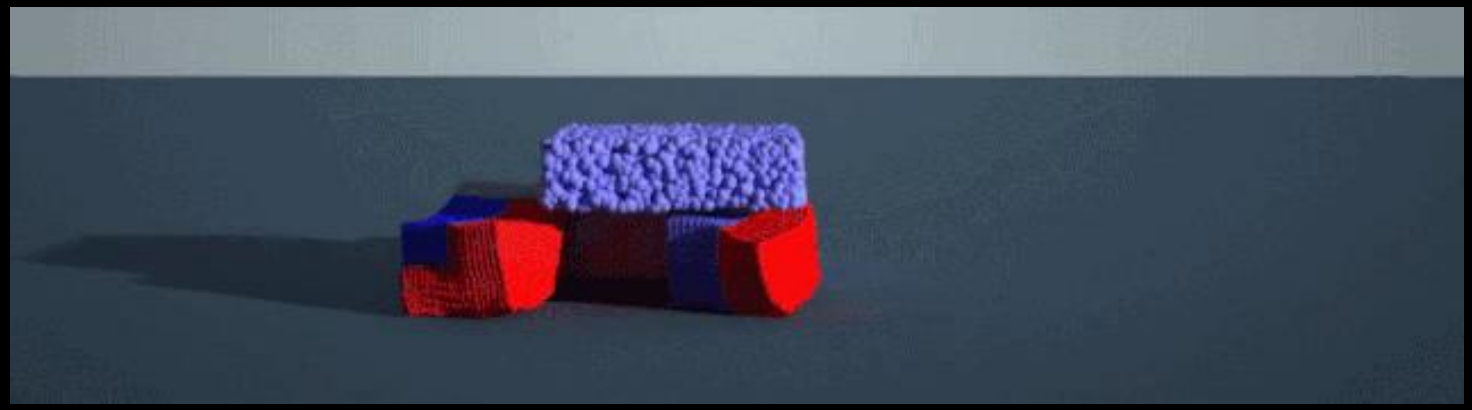
Differentiable Physics Simulation



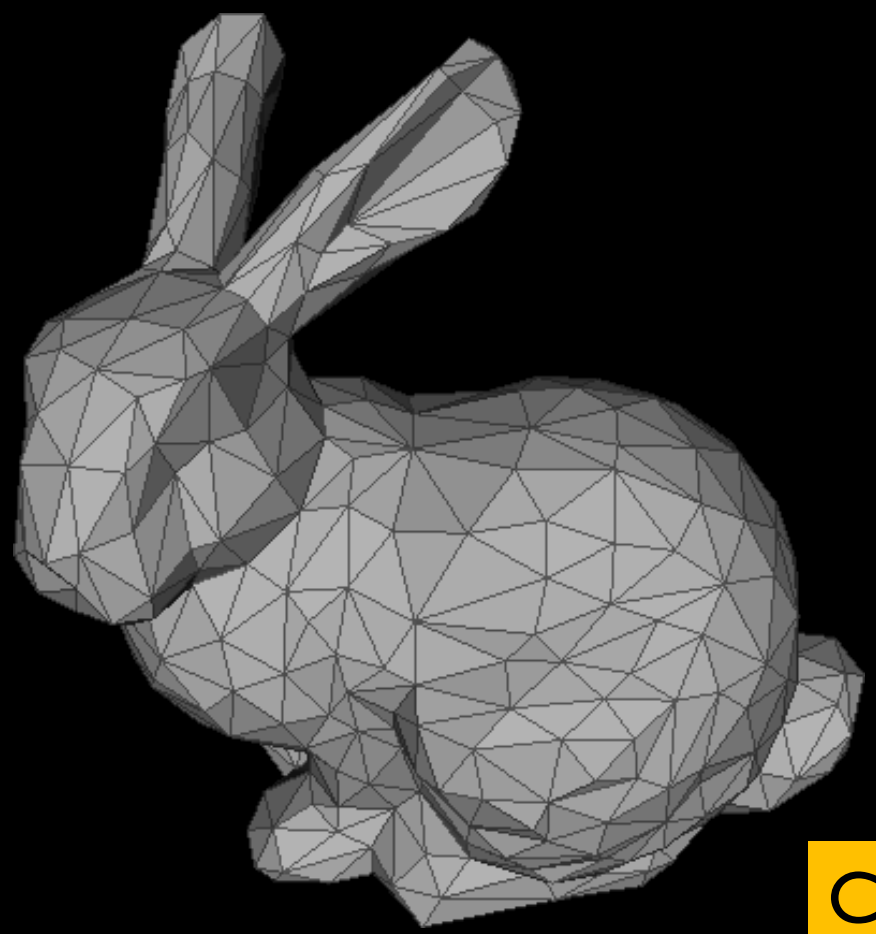








- Similar ideas have been used in physics simulation: by calculating the derivatives of physical equations, researchers can optimize design parameters and learn control policies with graphical simulations



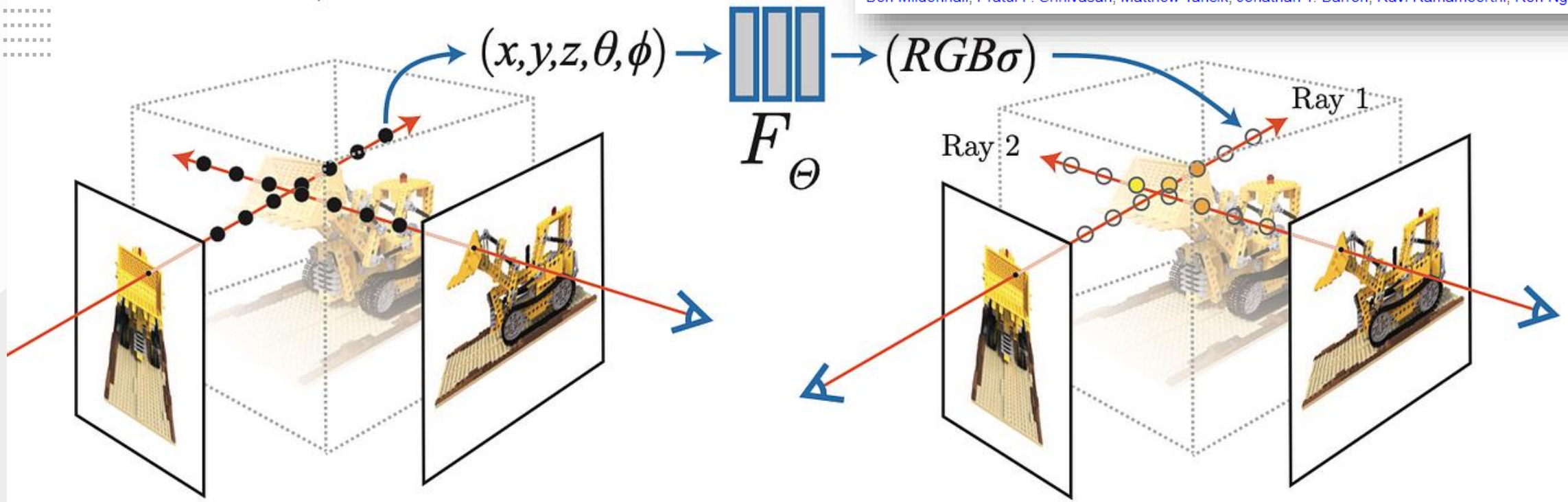
Forward Mesh Modeling: **Mesh -> Image**

- In 3451, we have studied various mesh data structures and subdivision algorithm as a forward process: we create mesh triangles and connectivities toward rendering some nice shapes on screen

Can we reverse this process to model the mesh or other shape representations by looking at its rendered appearance as images?

NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis

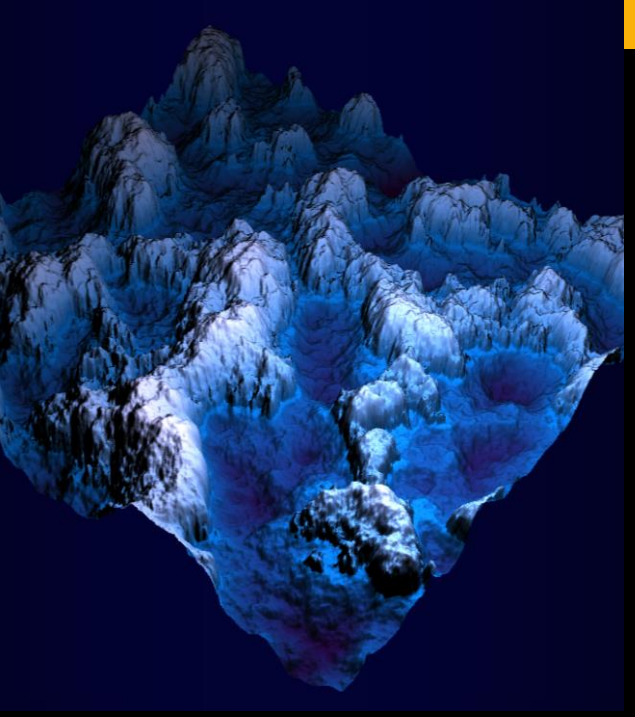
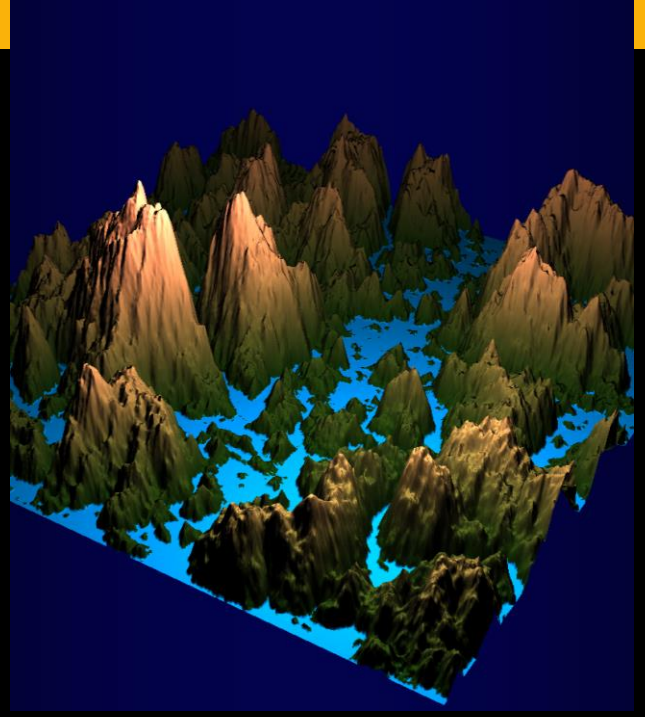
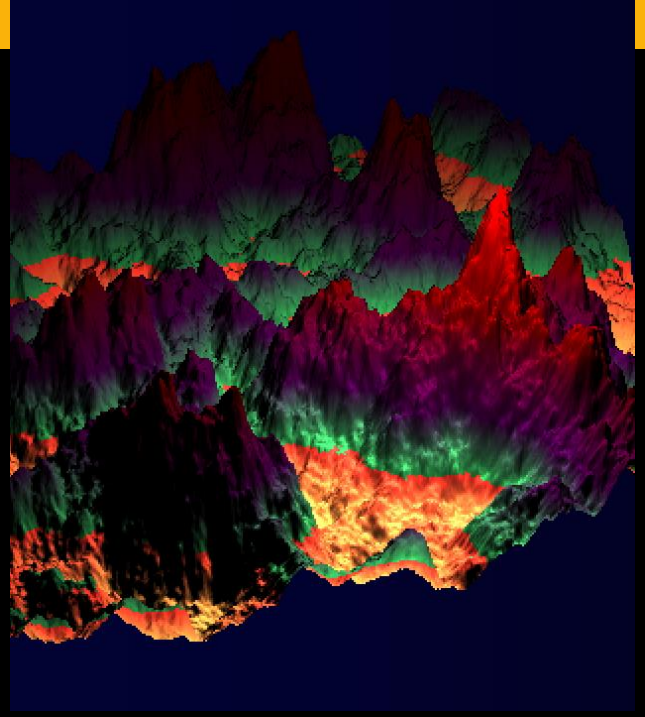
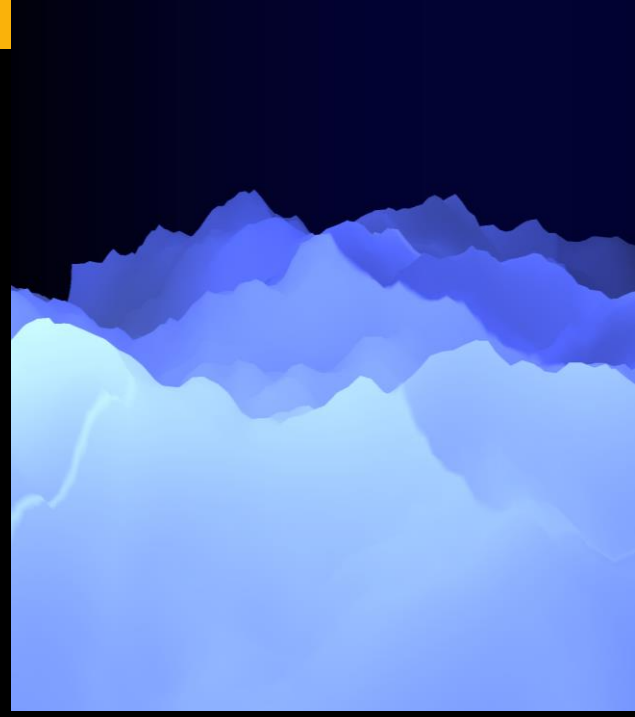
Ben Mildenhall, Pratul P. Srinivasan, Matthew Tancik, Jonathan T. Barron, Ravi Ramamoorthi, Ren Ng

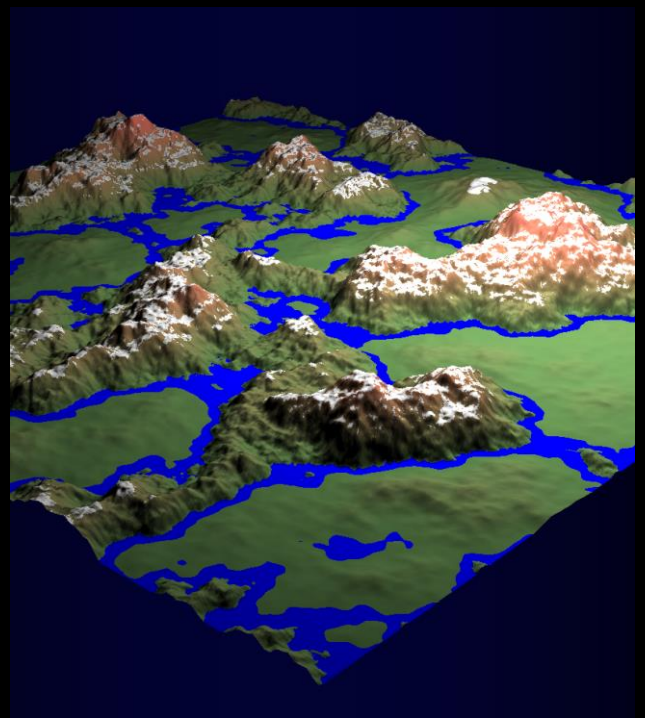


Neural Radiance Field (**NeRF**)

Image->Representation

- NeRF utilizes a neural network to synthesize photorealistic 3D scenes from sparse sets of 2D images.
- It represents scenes as continuous volumetric fields of radiance and density, which the NNlearns to model.
- NeRF can produce high-quality results that include complex lighting effects like reflections, refractions, and shadows.
- NeRF is also an inverse graphics model, by learning a hidden radiance field based on input images.



In 3451, we have studied how to model complex shapes and surfaces with noise functions and procedural modeling techniques.

Can we retrieval a complex object from the real world?

Gaussian Splatting

- Gaussian splatting is the most advanced neural representation model published in SIGGRAPH 2023
- It uses a large number of small “splats” to replace the previous neural fields for object representation
- It can capture very intricate surface details that NeRF cannot

Let's stop here and say goodbye

Here is the last question I want to ask you in this class ☺

Why do we read and write poetry?

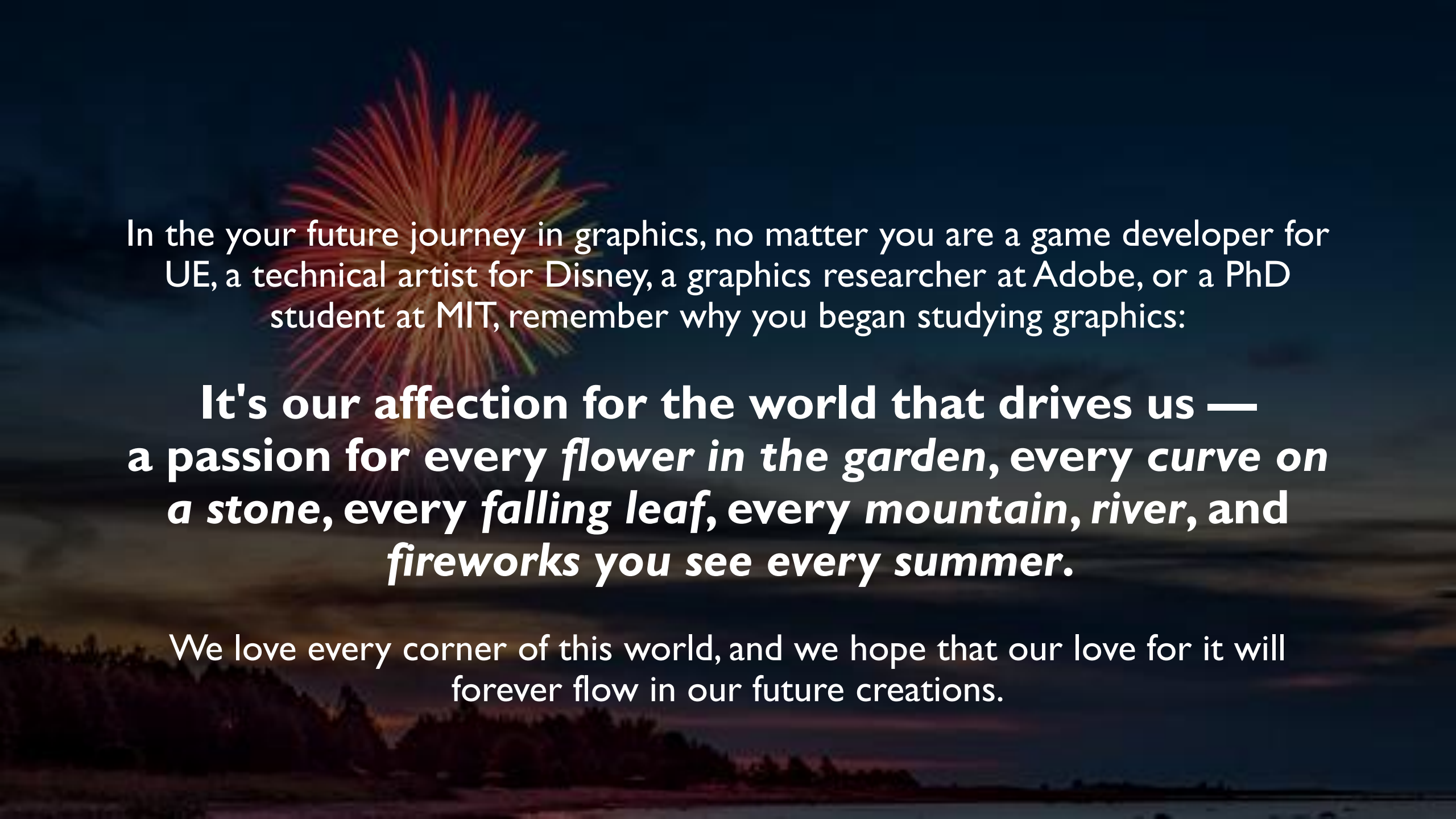
- *"We don't read and write poetry because it's cute. We read and write poetry because we are members of the human race. And the human race is filled with passion. And medicine, law, business, engineering, these are noble pursuits and necessary to sustain life. But poetry, beauty, romance, love, these are what we stay alive for."*

-- Dead Poets Society, 1989

What drives us to engage in painting, sculpting, and designing graphics?

- To make our emotion **vivid** and **real**
- To translate **intangible** into **tangible**
- To bring the richness of human experience into **a form that can be seen and felt**

Computer graphics is the poetry with math and code



In the your future journey in graphics, no matter you are a game developer for UE, a technical artist for Disney, a graphics researcher at Adobe, or a PhD student at MIT, remember why you began studying graphics:

It's our affection for the world that drives us — a passion for every *flower in the garden*, every *curve on a stone*, every *falling leaf*, every *mountain*, *river*, and *fireworks you see every summer.*

We love every corner of this world, and we hope that our love for it will forever flow in our future creations.

Thank you for the great term!

I am very proud of you all.

Best of luck for your future journey in graphics! ☺