CS148:
Introduction to Computer Graphics and Imaging

Slides by Sarah Jobalia and Kevin Li, with modifications by Kate Baker

Course Staff

Kate Baker

CS B.S./M.S.

Computer & Network Security

Lvmin Zhang

CS Ph.D. Candidate

Computer Graphics

Nicole Garcia

CS B.S/M.S.

AI

Kate Baker

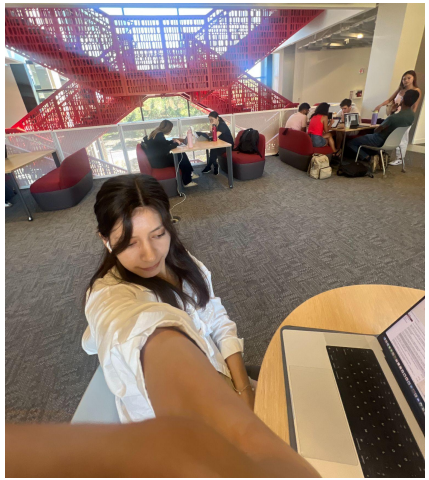
- Always loved art and gaming
  - Big Minecraft fan
- Xbox, Gaming AI team
- Stanford: focus in security and systems
  - Especially interested in parallel computing and GPUs
- Love teaching!

Lvmin Zhang

- From Maneesh lab
- Computer Graphics and Interactive Techniques
- Made some Unity Games many years ago
- Stanford: Image and video diffusion, large models

Nicole Garcia

- Grew up gaming which inspired my interest in graphics
  - Retired Roblox Obbyist and Skryim fan
- Infrastructure at AWS
- Stanford: AI track, focus on building applied AI systems (multi-agents, health-related image classification, etc.)
- Lots of love for the Minions and my cat niece and nephew



Lecture Outline

- Motivation and high level topics
- What makes a movie
- What you can do with computer graphics
- Course logistics

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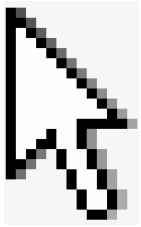
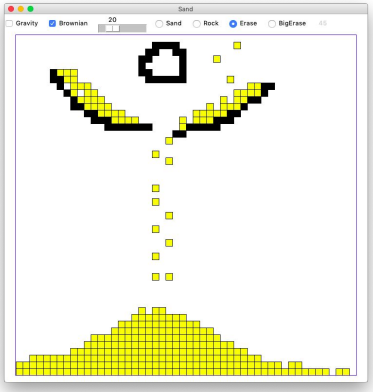
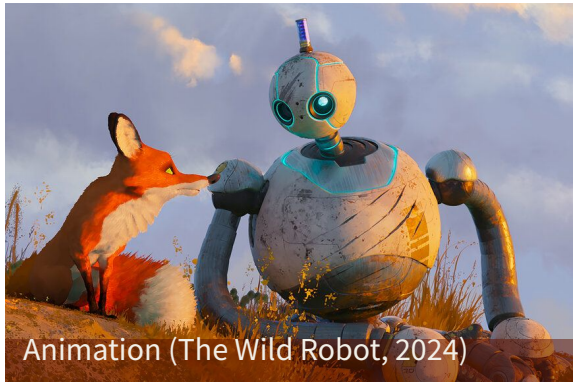
What is Computer Graphics?

- VFX
- Animation
- Gaming
- Anything that appears on a screen!




VFX (Last of Us, 2025)




Animation (The Wild Robot, 2024)


Gaming (Clair Obscur: Expedition 33, 2025)

What is Computer Graphics?

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Tiktok filter


Taylor Swift, Eras tour


Museums and Planetariums

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Graphics Hardware

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Educational Tools

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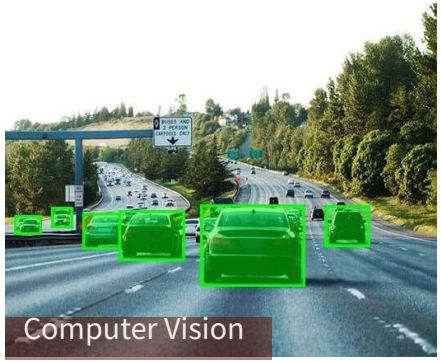

Computer Vision

What is Computer Graphics?

The study of computer-generated imagery

- Movies
- Games
- 2D & 3D Design
- Scientific Visualization
- Synthetic data for AI

Understanding the Pixel

Understanding the Pixel

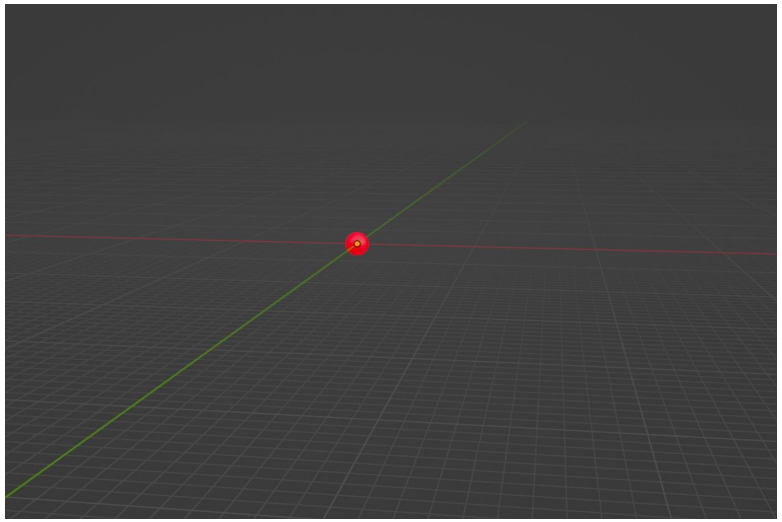
2D TEXT

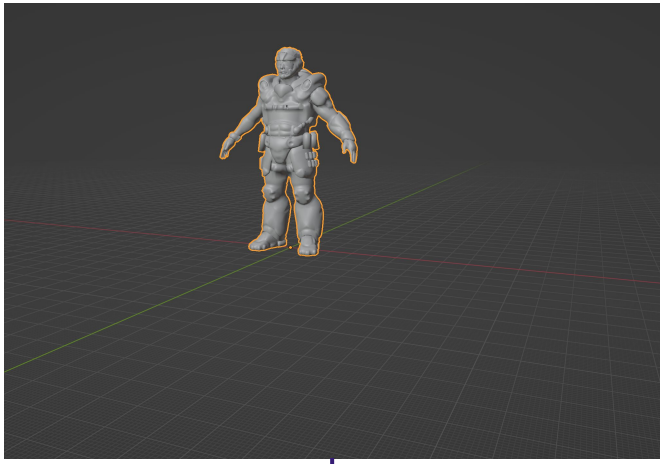
Understanding the Pixel

VFX (Avengers Infinity War, 2018)

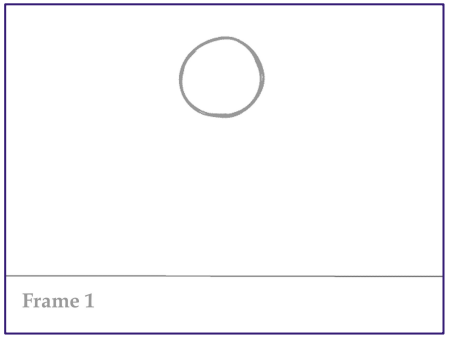
Virtual Space vs. Screen Space

- Put points in different spots in 3D space until you get a scene





Virtual Time



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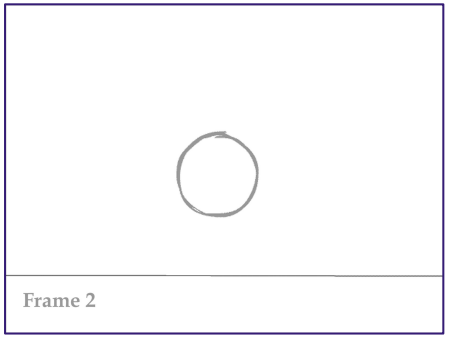

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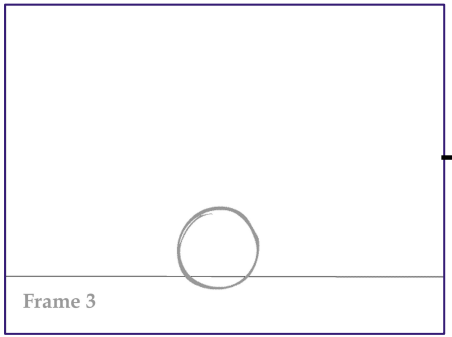

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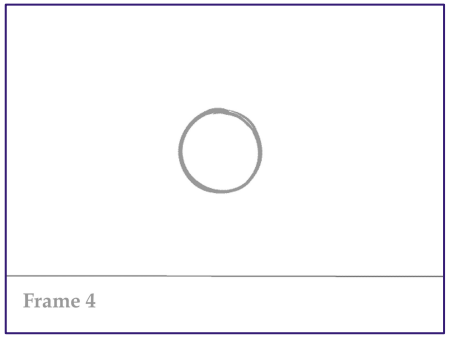

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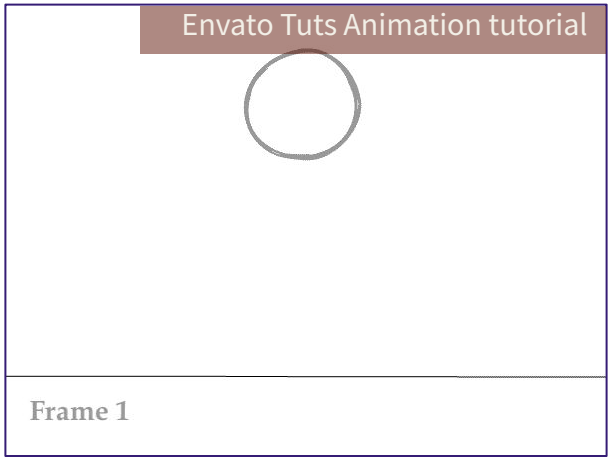

Virtual Time

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The Incredibles, (The Science Behind Pixar)

Lecture Outline

- Motivation and high level topics
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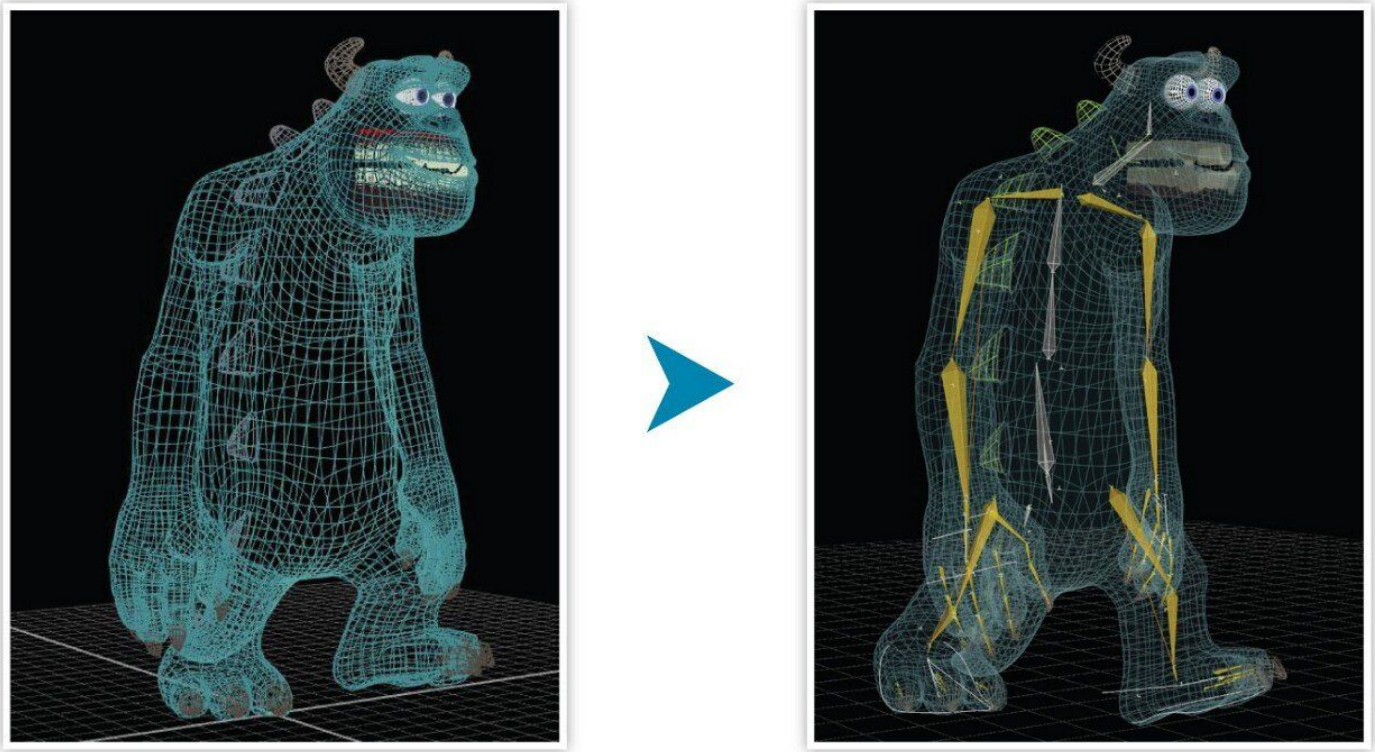
Luca Case Study

Luca Case Study: Storyboard

Luca Case Study: Modeling

Luca Case Study: Rigging

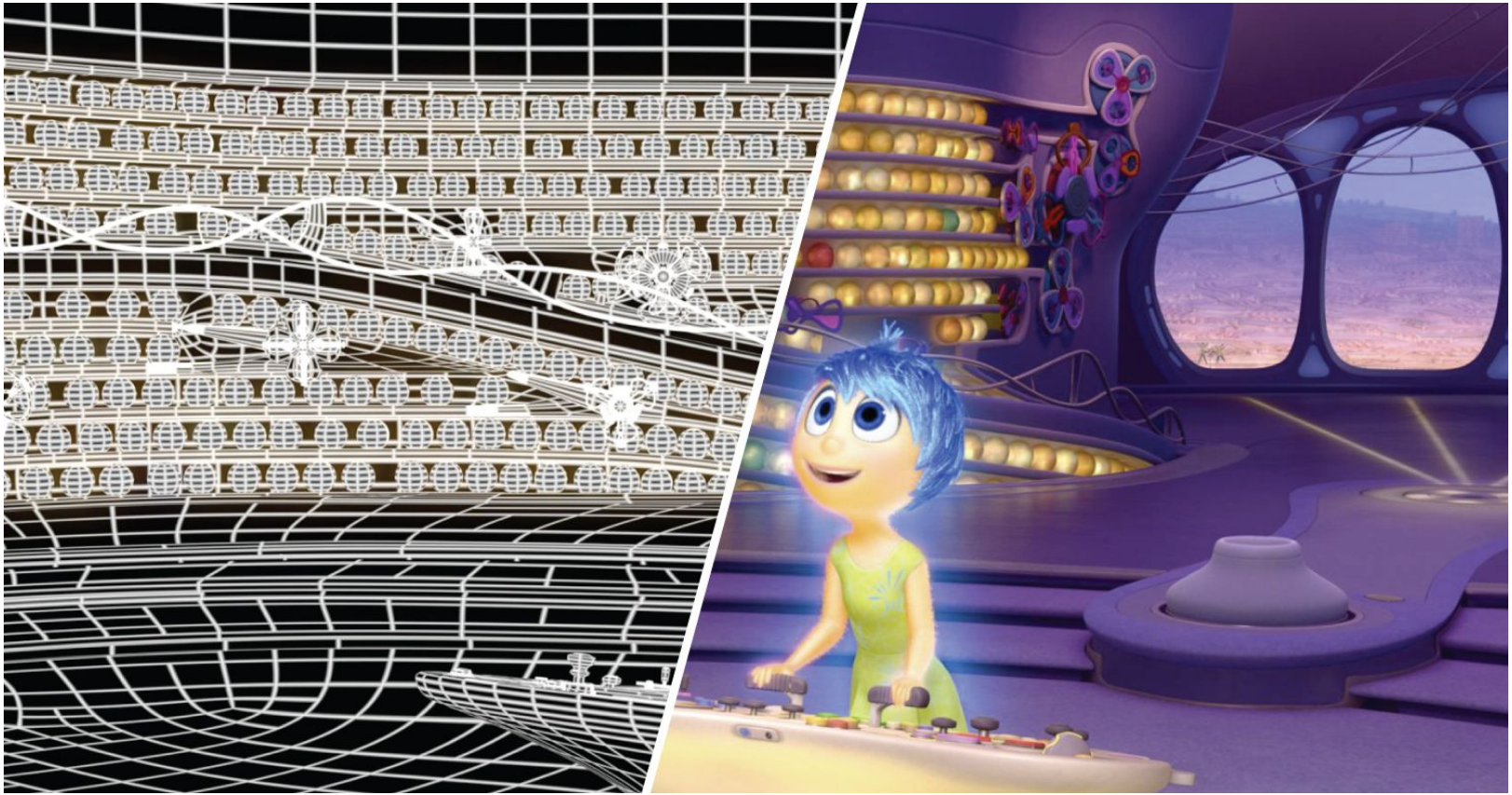
Luca Case Study: Rigging



Luca Case Study: Texturing

Luca Case Study: Sets and Layout

Luca Case Study: Sets and Layout



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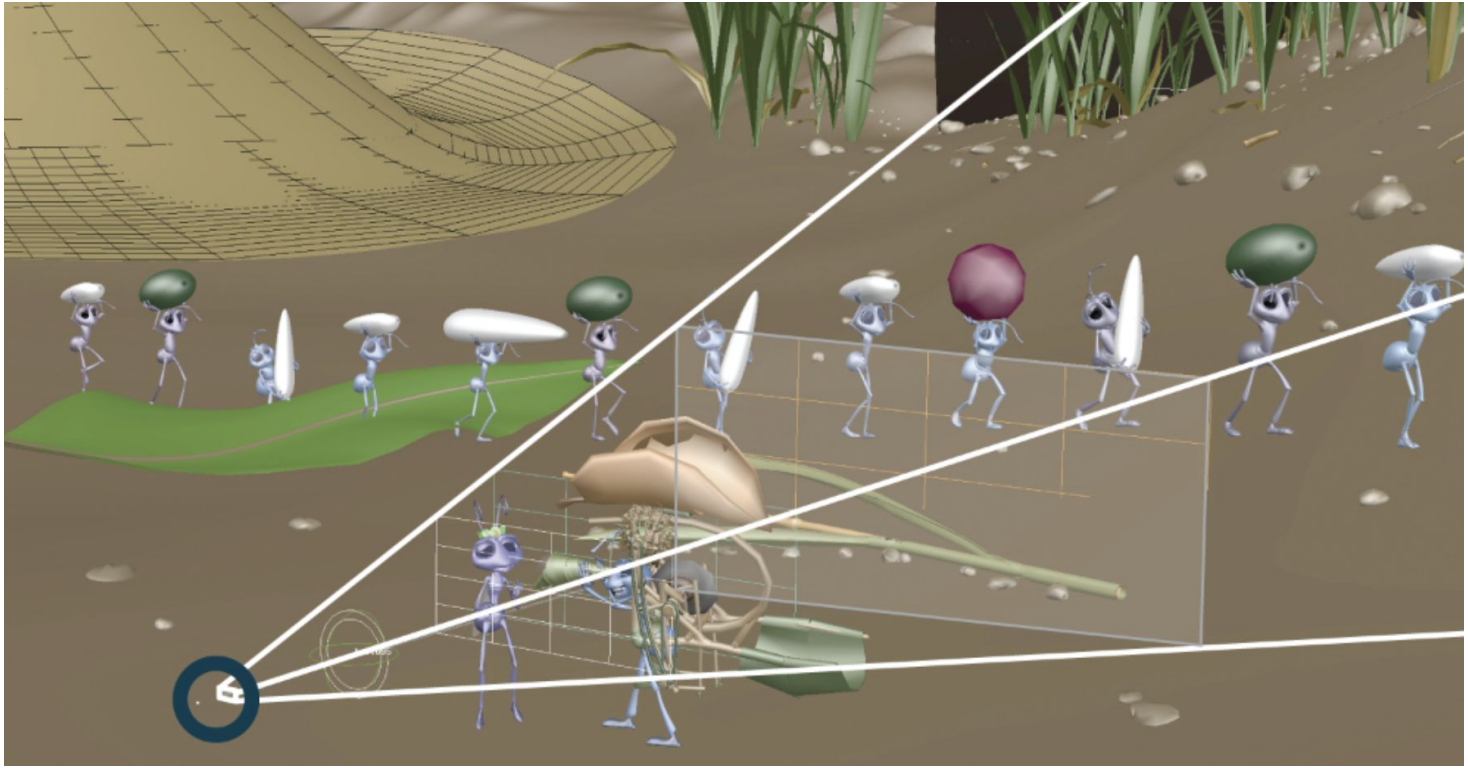


Luca Case Study: Animation

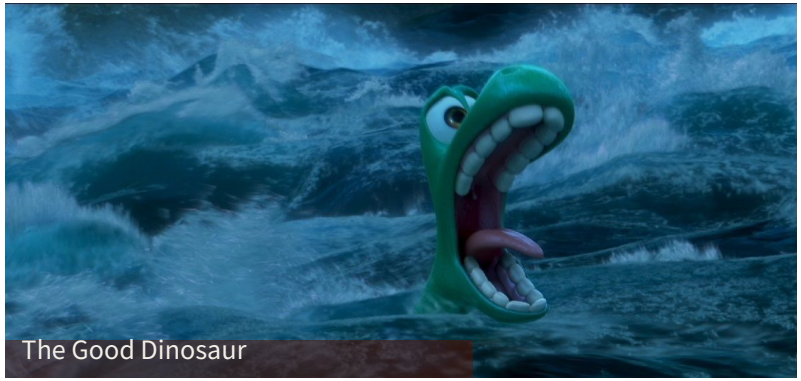
Luca Case Study: Animation

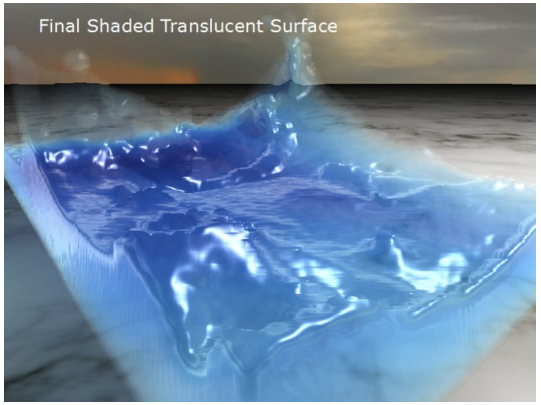
The Incredibles, (The Science Behind Pixar)

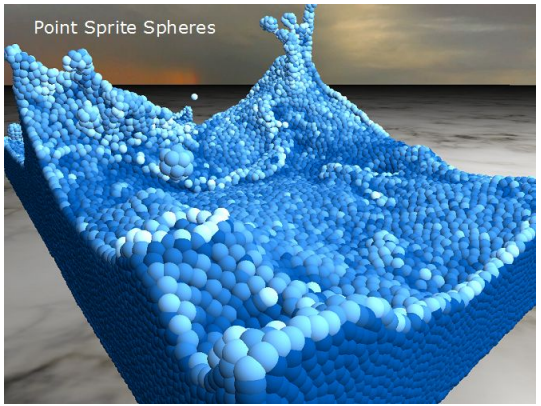
Toy Story 3

Luca Case Study: Simulation

Luca Case Study: Simulation







Luca Case Study: Lighting

Luca Case Study

What components make up this scene?

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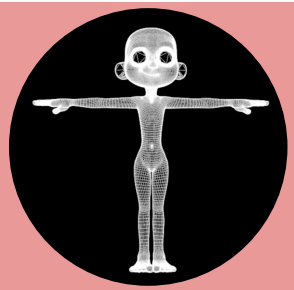
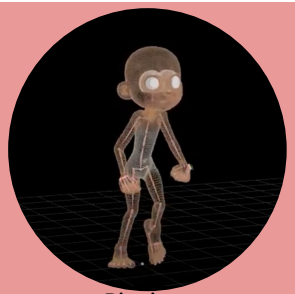
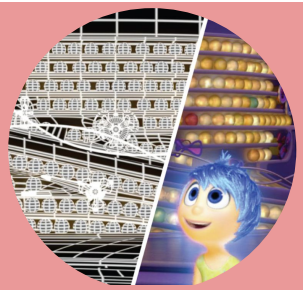
Luca Case Study: All Together!


Models


Textures


Rigging


Sets

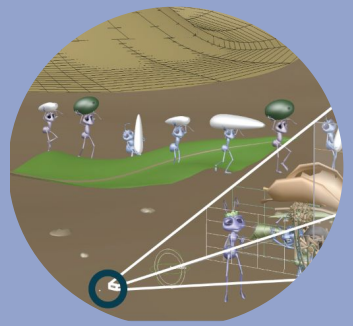

Lights

Placing objects in the scene

Moving objects over frames


Animation

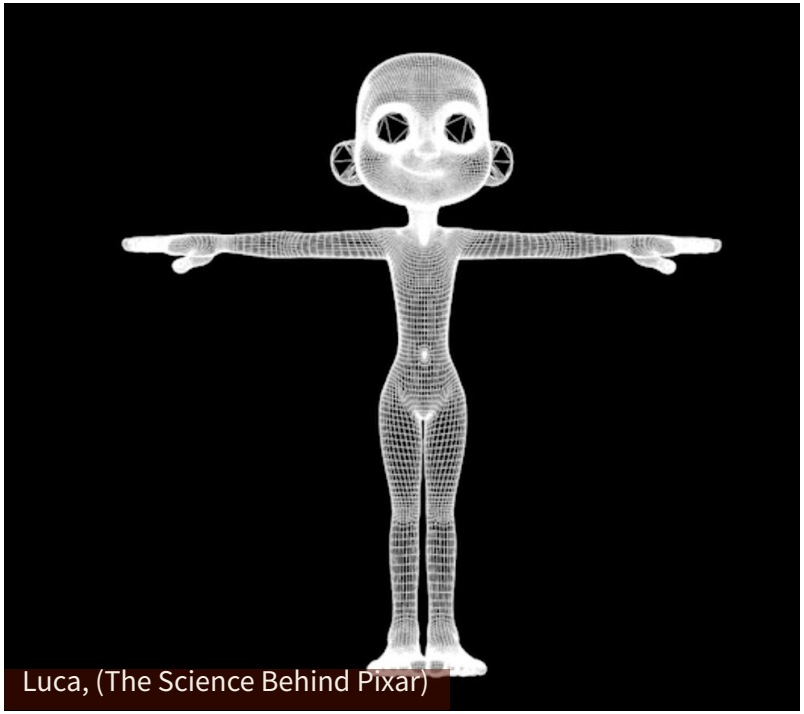

Simulation


Layout


Rendered Result

Where do you see yourself?

Building and animating objects?

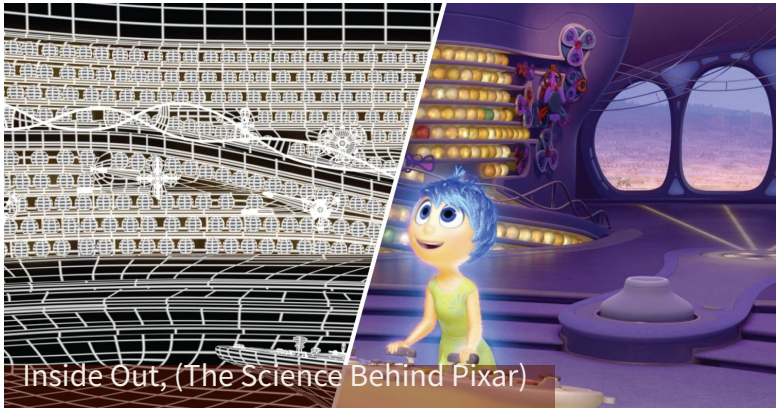


Luca, (The Science Behind Pixar)

The Incredibles, (The Science Behind Pixar)

Where do you see yourself?

Designing beautiful sets?



Inside Out, (The Science Behind Pixar)

Moana

Where do you see yourself?

Simulating natural phenomena?


Brave, (The Science Behind Pixar)


The Good Dinosaur

Visual Effects (VFX)

- Photorealistic simulation and rendering

San Andreas (Movie)

Visual Effects (VFX)

- Photorealistic simulation and rendering

Davy Jones Ship (Pirates of the Caribbean)

Visual Effects (VFX)

- Video Games


Elden Ring

Metaverse

Visual Effects (VFX)

- Video Games (+ optimization!)

Gollum Recreation (Lord of the Rings)

Visual Effects (VFX)

- Creature modeling, motion capture, animation


Dinosaurs (Jurassic Park, 1993)


Facial Capture in Avatar

Gollum (Lord of the Rings)


Davy Jones (Pirates of the Caribbean)

Visual Effects (VFX)

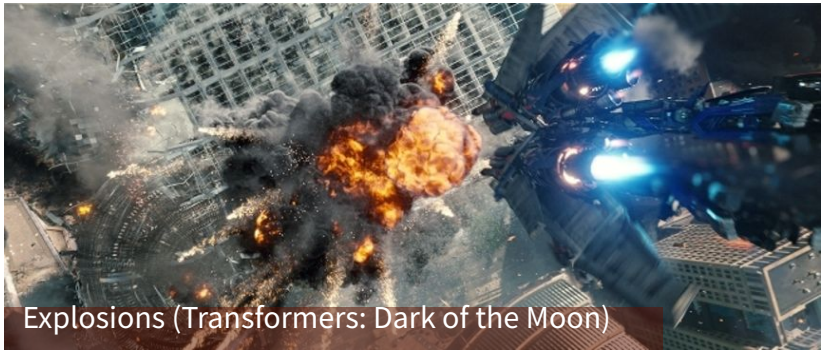
- Creature modeling, motion capture, animation

Visual Effects (VFX)

- Photorealistic simulation and rendering


Water (The Day After Tomorrow)


Fire (Harry Potter and The Goblet of Fire)

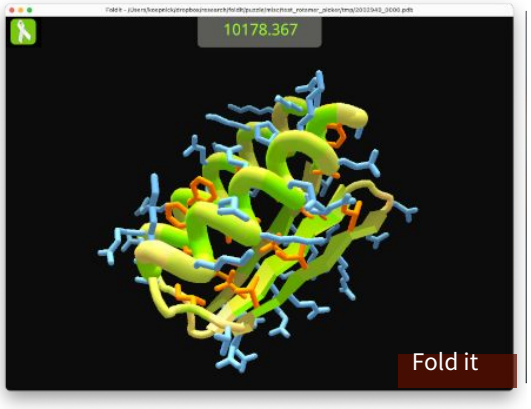

Explosions (Transformers: Dark of the Moon)

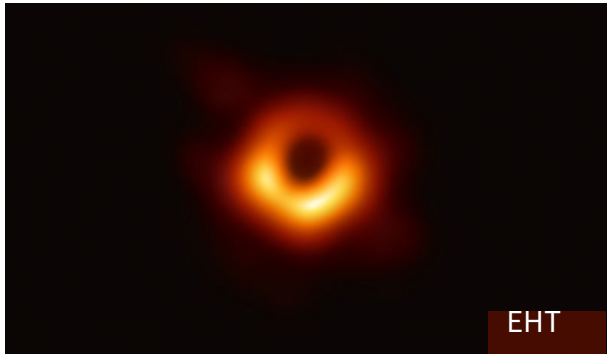

Cloth (Harry Potter and The Chamber of Secrets)

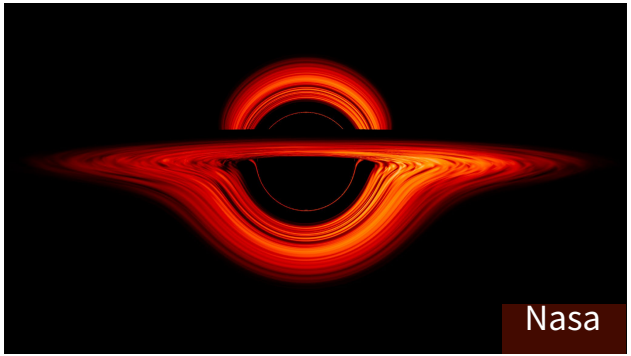
Where do you see yourself?

Visualizing scientific phenomena?

- Used to capture/visualize things that are inaccessible to the human eye







Where do you see yourself?

Bringing characters to life?

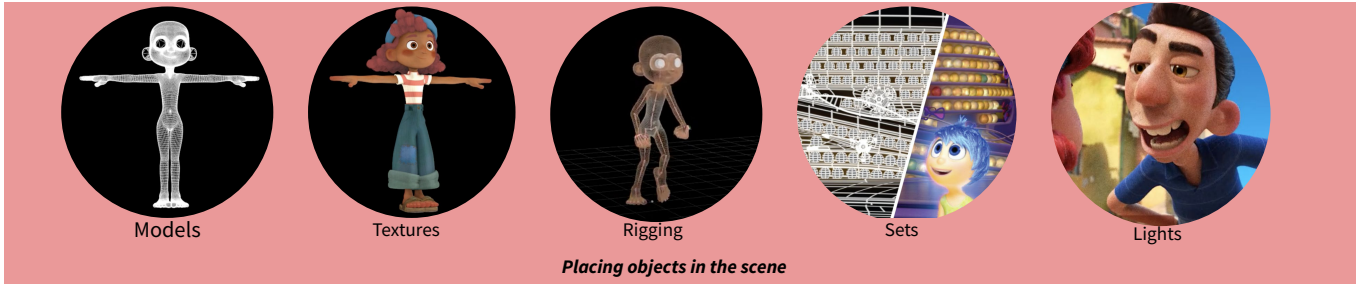

Luca, (The Science Behind Pixar)

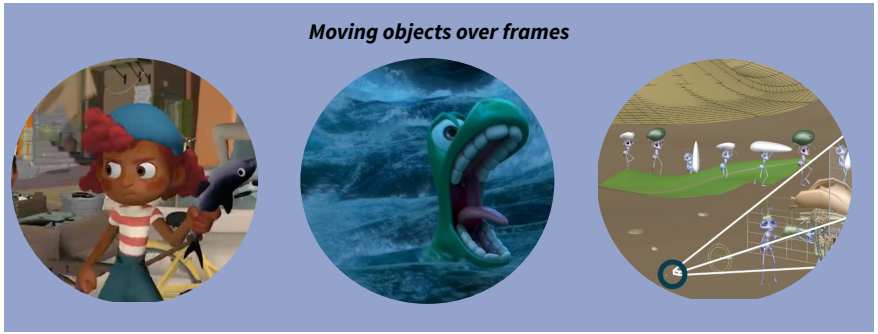

Frozen


Toy Story 3

Where do you see yourself?

Building platforms so everything can work together?

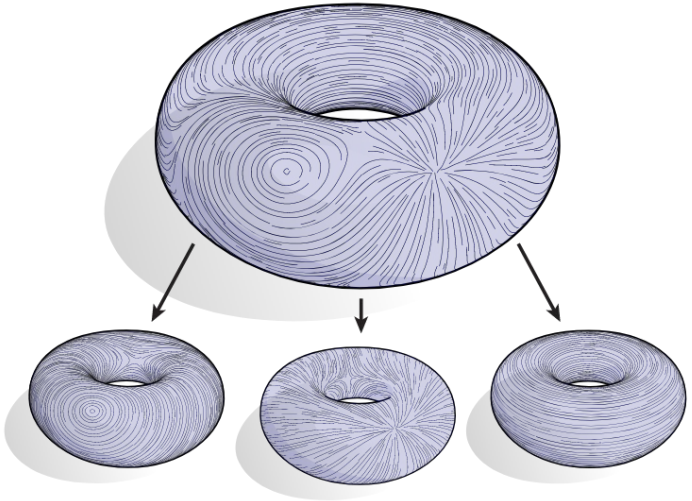


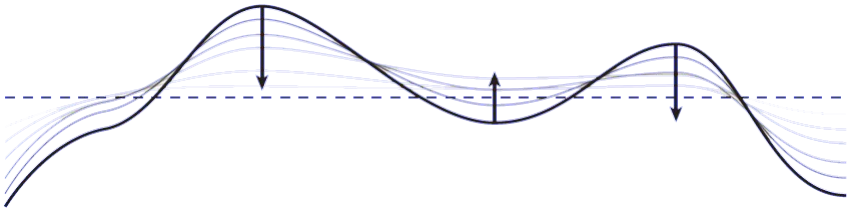


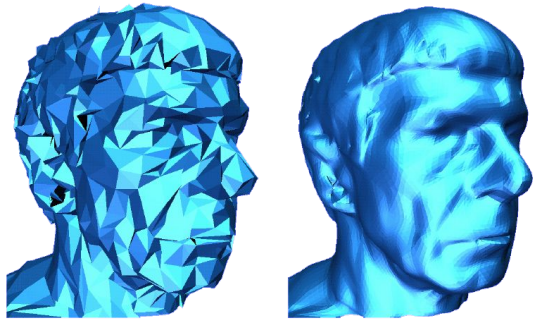
Rendered Result

Mathematics in Graphics

- Analyzing flows (e.g. fluid flows) across geometric surfaces
- Smoothing out high frequencies in noisy functions
- Any computations across space!
  - *Linear Algebra for navigating 3D space*
  - *Monte Carlo for rendering*



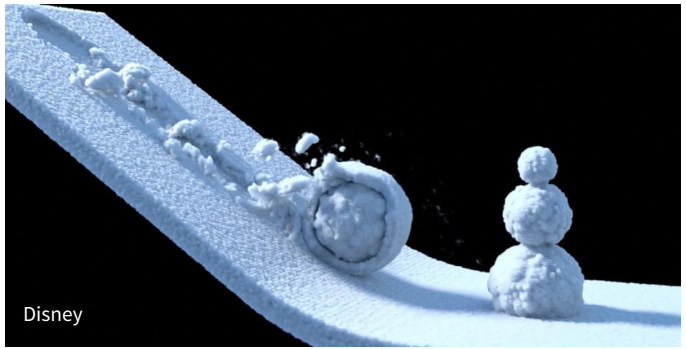


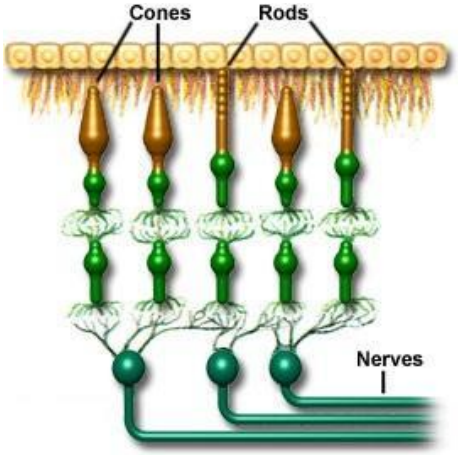


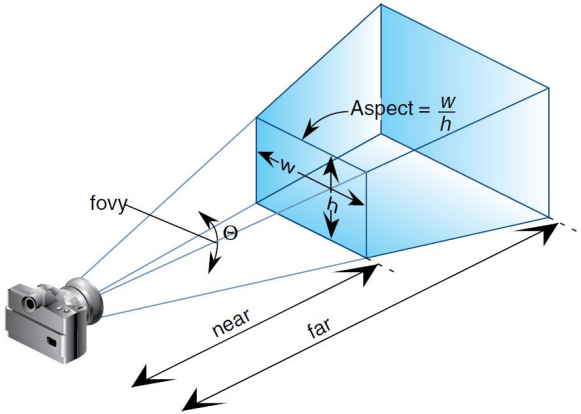
Natural Sciences in Graphics

Simulating and modeling the world!

- **Physics**
  - Simulations: *light, optics*
- **Biology**
  - Motion capture: *perceptual color*
- **Chemistry**
  - Modeling: *object materials*



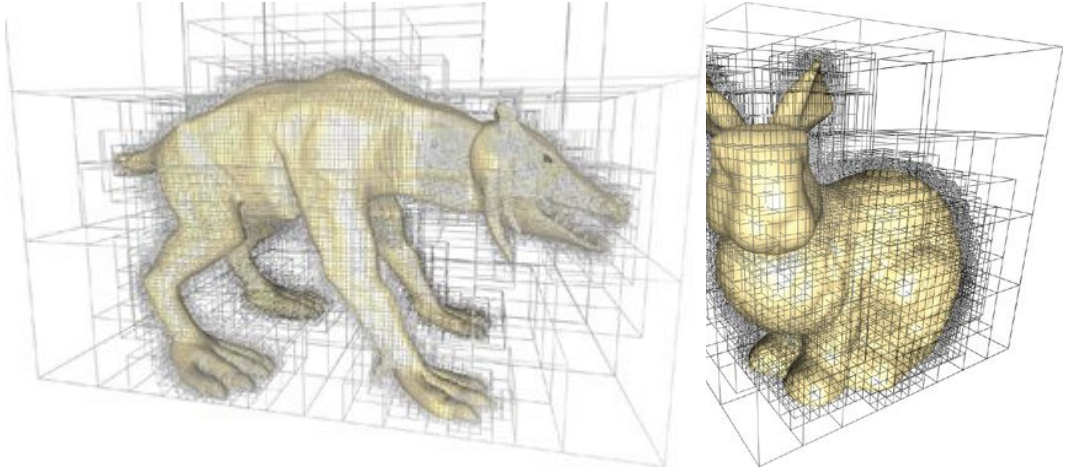




Engineering in Graphics

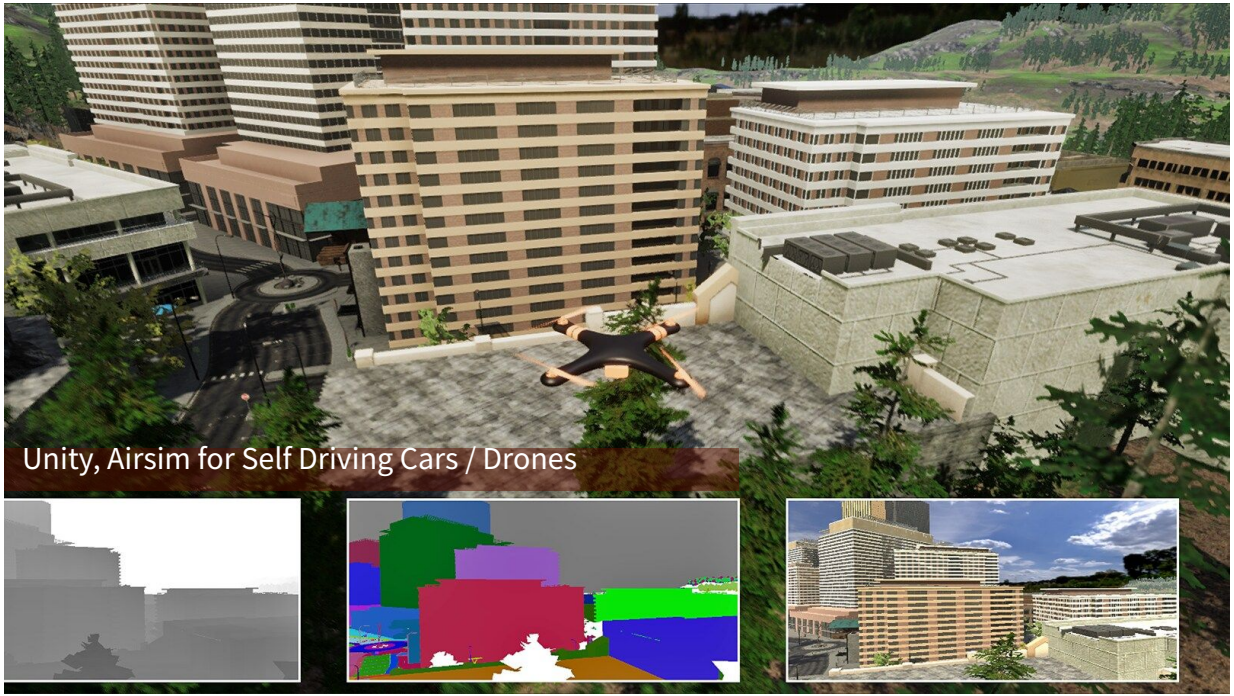
High performance computing

- **Aggressive approximations**
  - *Data structures for code acceleration*
- **Optimized hardware**
  - *GPUs, cameras*
- **Software systems**
  - *Data management*



Engineering in Graphics

- Synthetic data generation for AI/ML



Art in Graphics

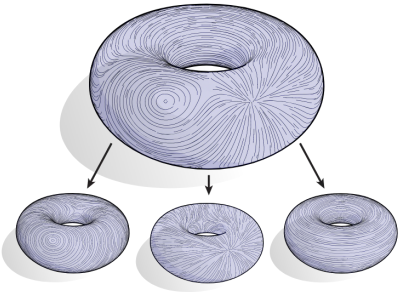
Making everything look good!

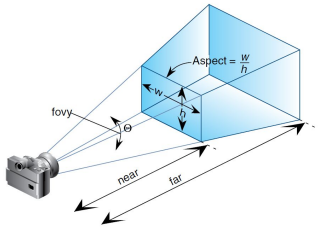
Kate Eselius and Jamie Ullman, Fall 2022

Yan (Mia) Miao, Summer 2022

What can you do with computer graphics?

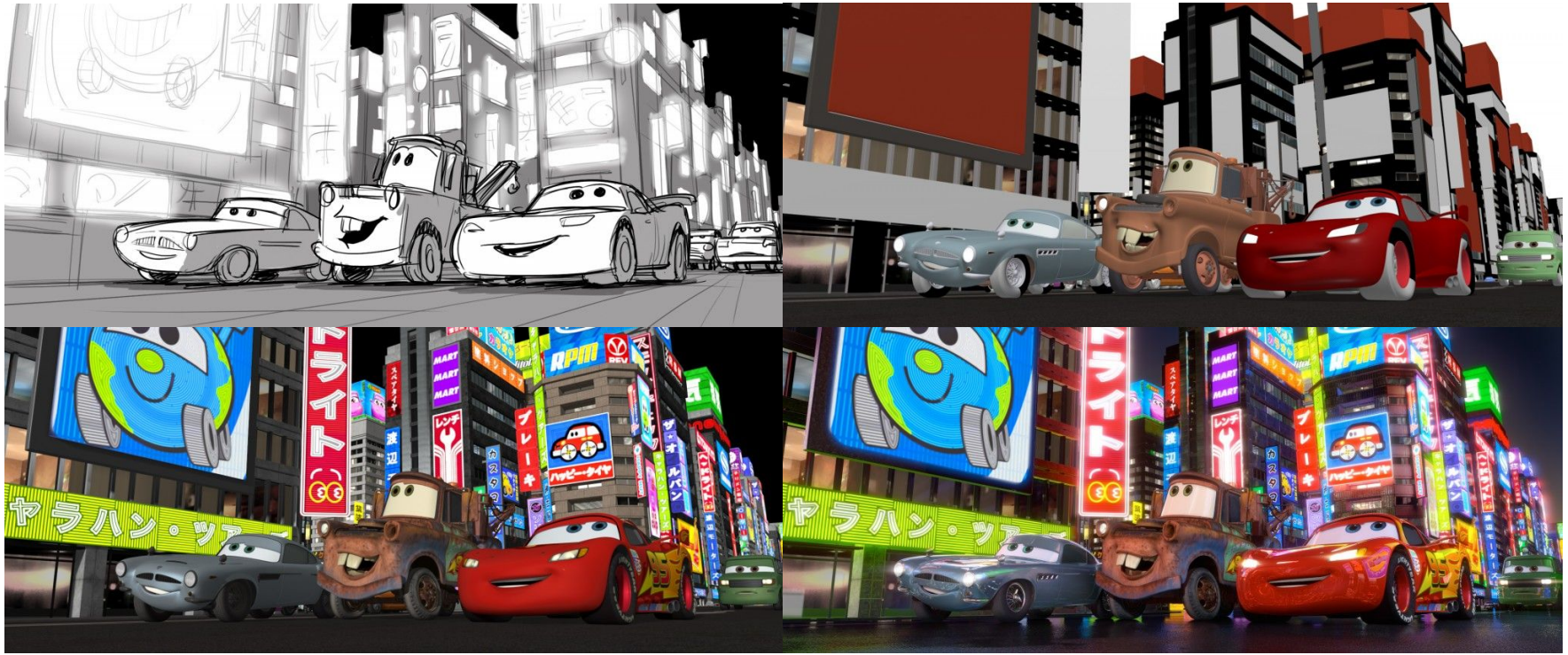
- Traditionally
  - Movies, Games, 2D & 3D Design, Scientific Visualization
- More recently
  - Synthetic data for AI applications
- Philosophically
  - **Learn how to use interdisciplinary knowledge spanning mathematics, natural sciences, engineering, art and more!**





What should you get out of this course?

Regardless of your major, graphics has something for everyone!



Lecture Outline

- Motivation and high level topics
- What makes a movie
- What you can do with computer graphics
- Course logistics

Graphics: Specific to Course

- Course focus:
  - Understanding what it takes to create a well-composed 3D virtual scene and rendering it as a 2D image

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- Out of scope of the course:
  - 2D graphic design
  - Systems-level graphics (e.g. CS 248)
  - Interactive Graphics / Video Game Design
  - Animated (short) films

Graphics: Specific to Course

- We only have 8 weeks so…
- We'll have breadth, limited depth
  - Gain **high level knowledge** on a broad set of topics
  - Implement **low level details** with simplifications and assumptions
  - **Learn how to use software** that has more complete implementations

- Equal emphasis on technical and practical knowledge

Graphics: How to Approach this Course

- Project-based course

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  - We highly recommend coming in with Python experience

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  - We highly recommend coming in with Python experience
- Sometimes difficult to explore creativity and artistry in CS courses… here you can! (It's a WAYS CE)
- Full of procedural methods (e.g. texture, geometry), which are good candidates for ML research topics

Syllabus

(Subject to change)

	Tuesday Lecture	Thursday Lecture	Homework due (Thursday)
Week 1	Introduction	Geometry & Transformations	*Installation & Setup* *
Week 2	Rasterization & Shading	Color, Images & Cameras	Geometry & Transformations
Week 3	Light & Optics	Raytracing I	Shading & Cameras
Week 4	Raytracing II	Sampling & Texturing	Raytracing
Week 5	Final Project Expectations	Simulation & Animation I	Lighting & Texturing
Week 6	Simulation & Animation II	Guest Lecture	Simulation & Advanced Rendering
Week 7	Advanced Topics	Final Project Workshop	
Week 8	Art of Images	Next Steps in Graphics	Project Submission

Stanford Graphics Faculty

Leo Guibas
Geometry/ML

Pat Hanrahan
Rendering/Viz

Ron Fedkiw
Physics/ML

Maneesh Agrawala
HCI/Media

Doug James
Simulation/Interactivity

Kayvon Fatahalian
Systems/ Scalability

Karen Liu
Animation/Robotics

Gordon Wetzstein
AR/VR

Practical Component

- We will use **Blender**

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- Ray tracing
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- We suggest getting familiar with Blender by watching a tutorial every 1-2 days

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- Assignments are meant to inspire you to explore more advanced topics and courses (CS x48)

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  - Both in-person and over Zoom
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- Let’s learn together!
  - Ask questions! I’ll bring my findings of things I don’t know to future lectures.

Grading Logistics

- 50% final project,
  50% assignment/quizzes

- Assignments and Quiz questions released each Thursday
- Live grading Thursday afternoon of the next week

Assignments (w/ quiz)	50%
Final Project Proposal	5%
Final Project	45%

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- Due via live grading on Thursdays (3-415pm or 6-8pm)
- Short mini presentation of your HW results (~5-7 min max)

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- **Homework 0 (Installation & Setup) is out on the course website!**
  - Graded on completion, due this Friday.
  - Submit on Gradescope
  - Needed for future assignments

Assignments (50%)

- Occurs during live grading
  - Quizzes are expected to take only a few minutes (~3 max)

- Not meant to be difficult
- All questions released ahead of time; one gets randomly asked!
- **If you're working in partners, then both partners get asked a different question that they have to answer individually**

- Reach out to us at least **a day in advance** for alternative arrangements if you cannot make the grading sessions!

Assignments (50%)

Missing assignments:

- You may miss **ONE grading session** (no questions asked)
  - This will account for extenuating circumstances
  - We will be less lenient with second missed sessions

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- 32 points = full credit
  - 5 homework assignments x 8 points each = 40 max points
  - Any points past 32 will count as extra credit

Lecture Attendance + Extra Credit

- Not required!! Will NOT impact your grade.
  - Lectures will be posted to Canvas

- We will have a **TINY** bit of extra credit for lecture attendance.
  - Sign your name at the end of each lecture
  - If you're on a grade boundary, we will consider bumping you up with demonstrated extra credit
  - Online / CGOE students can get extra credit through the homework point system

AI Policy

- OKAY
  - Clarifying course concepts
  - Debugging / navigating Blender tools
- NO
  - Generating code/scripts for Blender coding assignments
  - Answering live grading questions
  - Somehow using AI to generate your final project

Course Feedback

- Will be asked to provide feedback twice this quarter through automatic “HRCF” surveys

- Please fill these out! We really appreciate feedback early in the quarter to help us course correct if needed.

Final Project (50%)

- Can work with 1 partner
- See cs148.stanford.edu/showcase for past project writeups

Kate Eselius and Jamie Ullman, Fall 2022

Yan (Mia) Miao, Summer 2022

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Luna Yang and Xuelin Yang, Fall 2021

Grace Zhao and Le Yuan Chen Summer 2025

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Po-Ya Wu, Fall 2021

Lingjie Kong and Yanjia Li, Fall 2020

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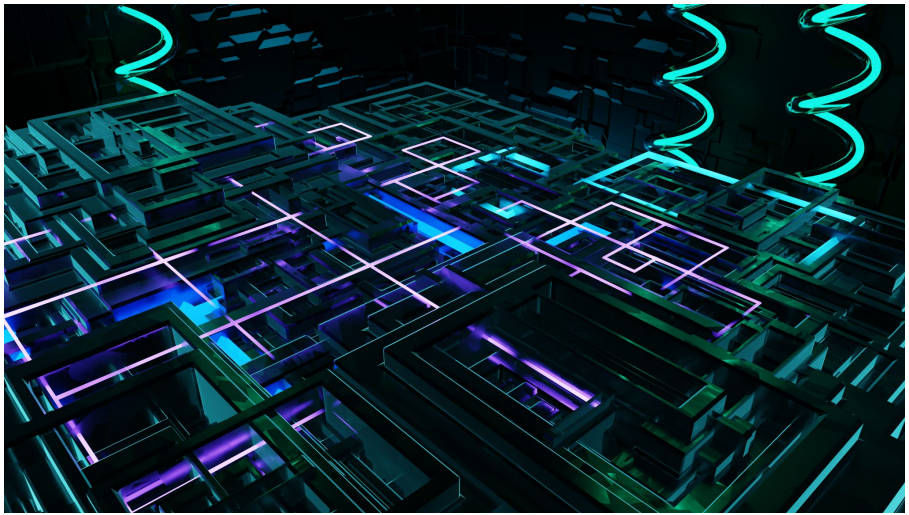

Anthony Xie, Fall 2021

Sisira Aarukapalli, Summer 2025

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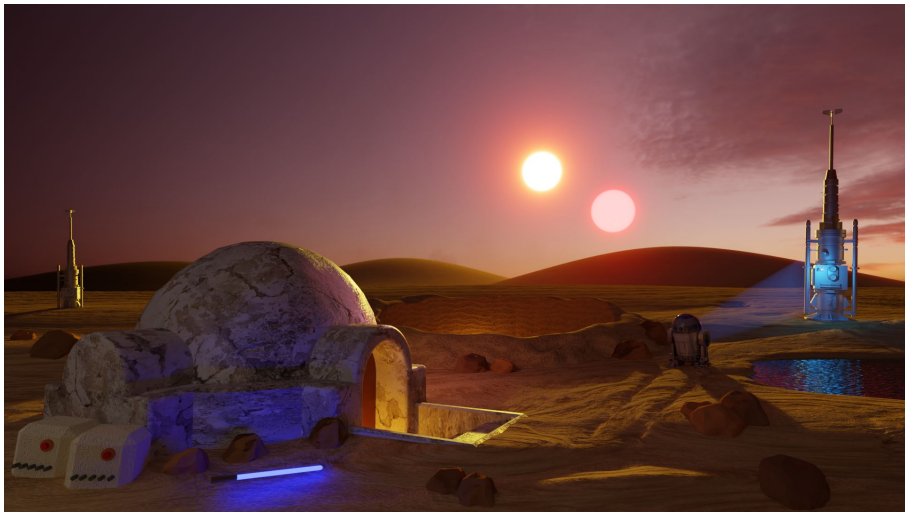

Alberto Mancarella & Max Mayberg, Fall 2023

Sarah Chung and Michael Maffezzoli, Fall 2023

Additional Resources + Exploring!

- The Secrets behind KPop Demon Hunters Visuals
- Using a 3D renderer to generate synthetic data
- NVIDIA Isaac Sim library for synthetic data generation
- Creating music visuals for live performances

- Fundamentals of Computer Graphics, Steve Marschner and Peter Shirley
  - Preview, Book