Lecture 1:

Introduction

Computer Graphics and Imaging
UC Berkeley CS184/284A

Welcome to CS184 / 284A!

Prof. Ren Ng

- Ph.D. 2006 on Digital Light Field Photography (evolving camera design using graphics technology)
- Founder of Lytro, a light field camera company
- Research interests: color, computational imaging systems, computer graphics, computer vision, human vision
- Fun fact: born Malaysian, became Australian, naturalized American. Had all three speaking accents!

Welcome to CS184 / 284A!

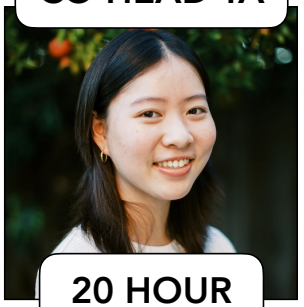

GSI

Alfredo de Goyeneche

Anjali Thakrar

Connor Dang

Daniel Lyu


CO-HEAD TA

20 HOUR

Irene Geng


GSI

20 HOUR

Jessica Lee

Meiqi Sun

Mingyang Wang


GSI

20 HOUR

Neerja Thakkar

Tianyun Yuan

Winston Liu

Your Names: An Important Request

- We want to get to know you
- It starts with your names
- We want to remember, but there are many of us
- Please help us with this rule:
  - Every time you participate in class, section, office hours, please remind us your name.
  - Example: “Hi, this is Xu Yi. My question is about…”
- Thank you very much!

CS184/284A: Computer Graphics & Imaging

Why Study Computer Graphics?

Course Overview

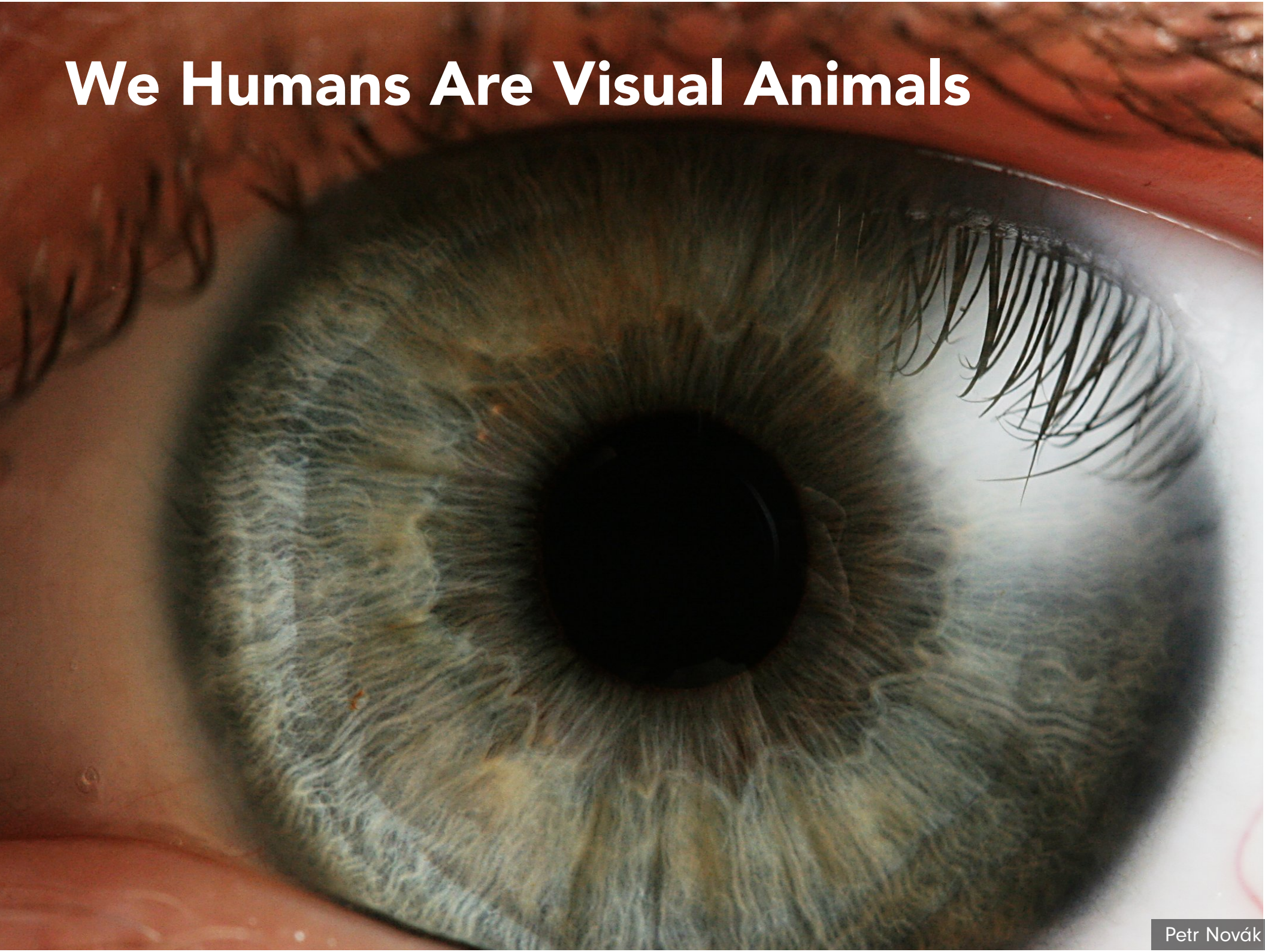
Logistics

What is Computer Graphics?

com•put•er graph•ics /kəmˈpyo͞odər ˈgrafiks/ n.
The use of computers to synthesize and manipulate visual information.

Why Visual Information?

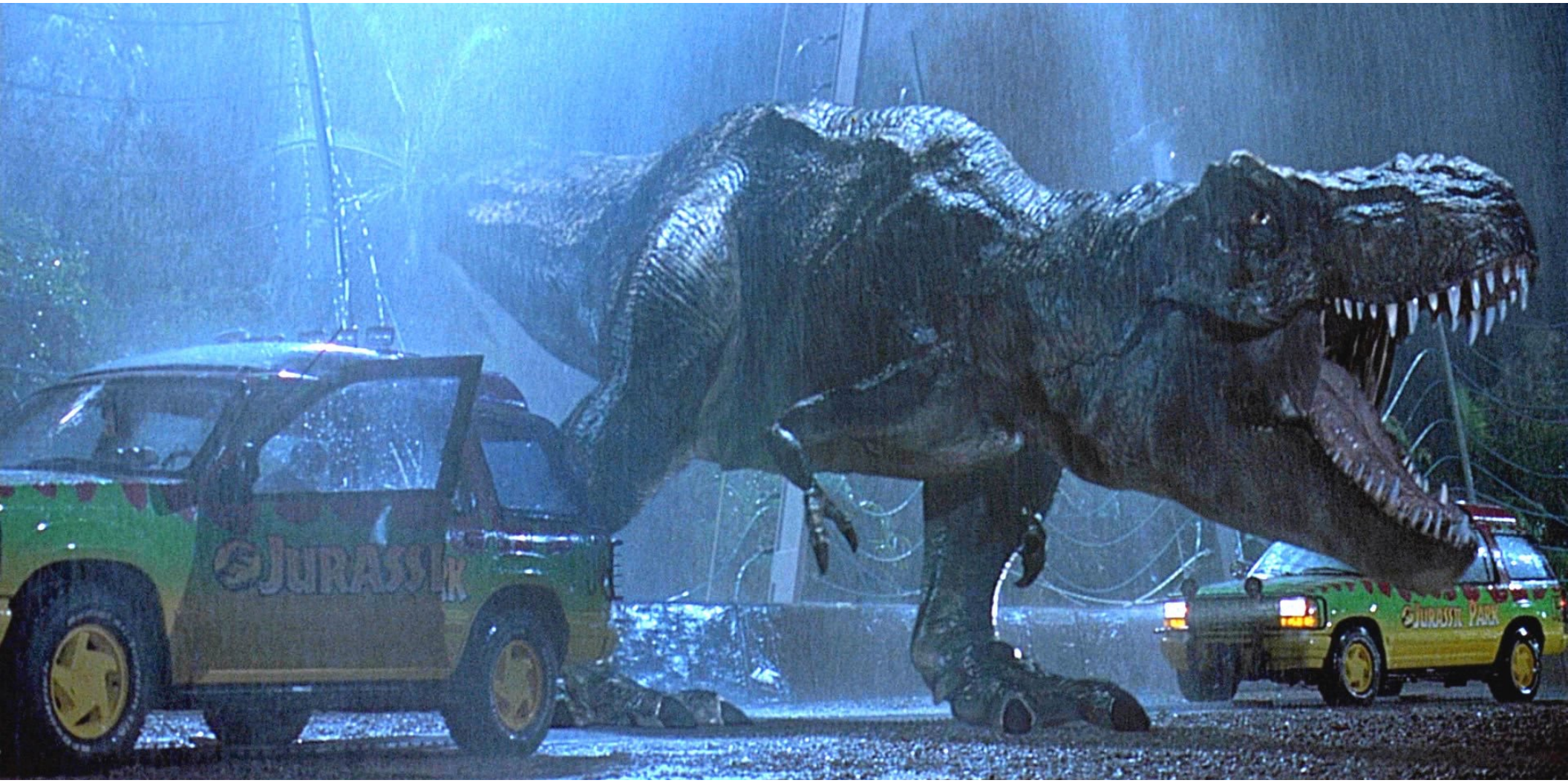
We Humans Are Visual Animals



Petr Novák

Why Study Computer Graphics and Imaging?

Movies



Jurassic Park (1993)

Moments That Changed The Movies: Jurassic Park
https://www.youtube.com/watch?v=KWsbcBvYqN8

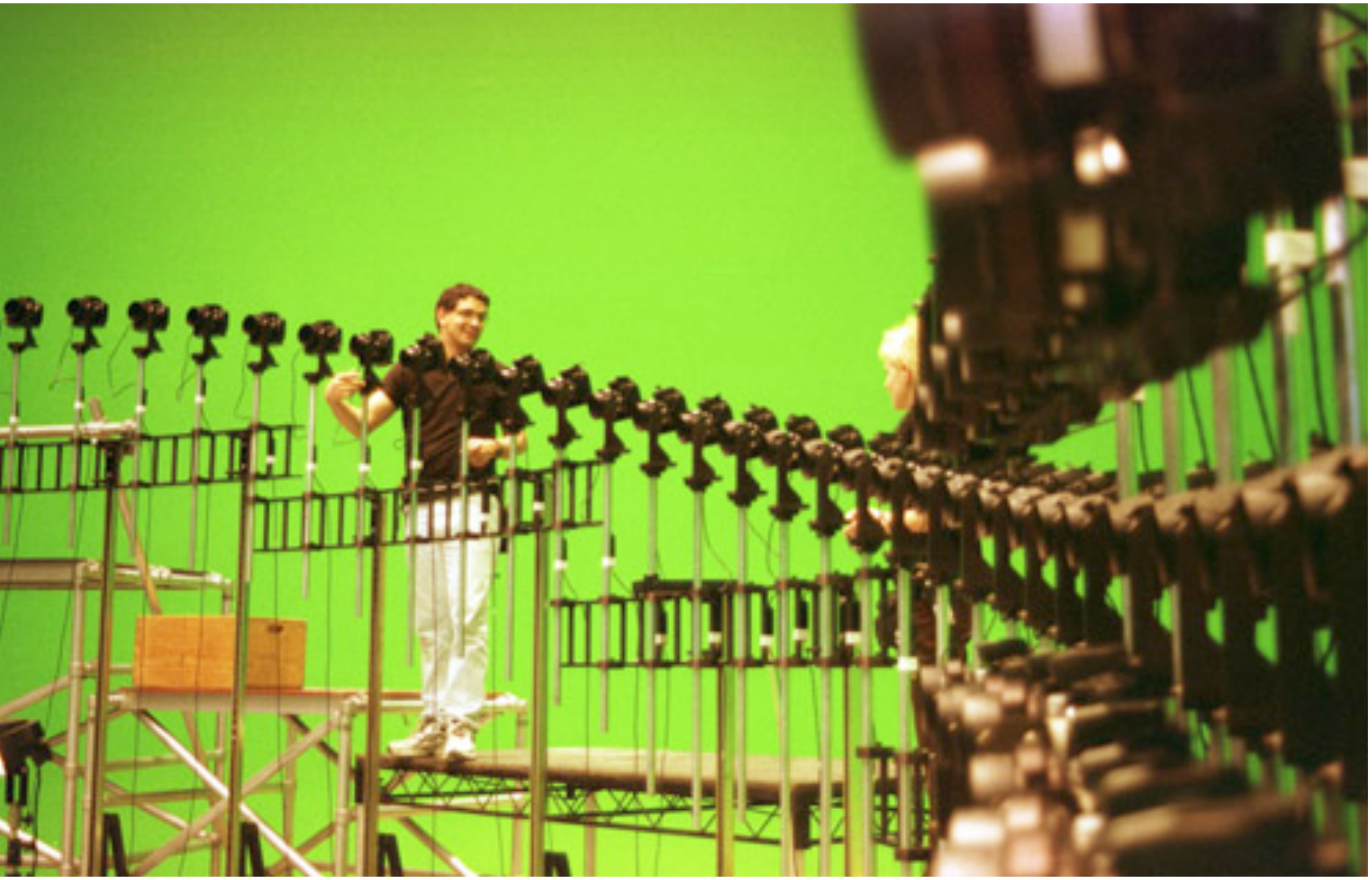
Movies - 3D Geometry, Materials, Lighting

Toy Story (1995)

Movies - Image-Based Computer Graphics

The Matrix (1999)

Movies - Image-Based Computer Graphics



The Matrix (1999)

The Campanile

Debevec, Taylor and Malik SIGGRAPH 1996

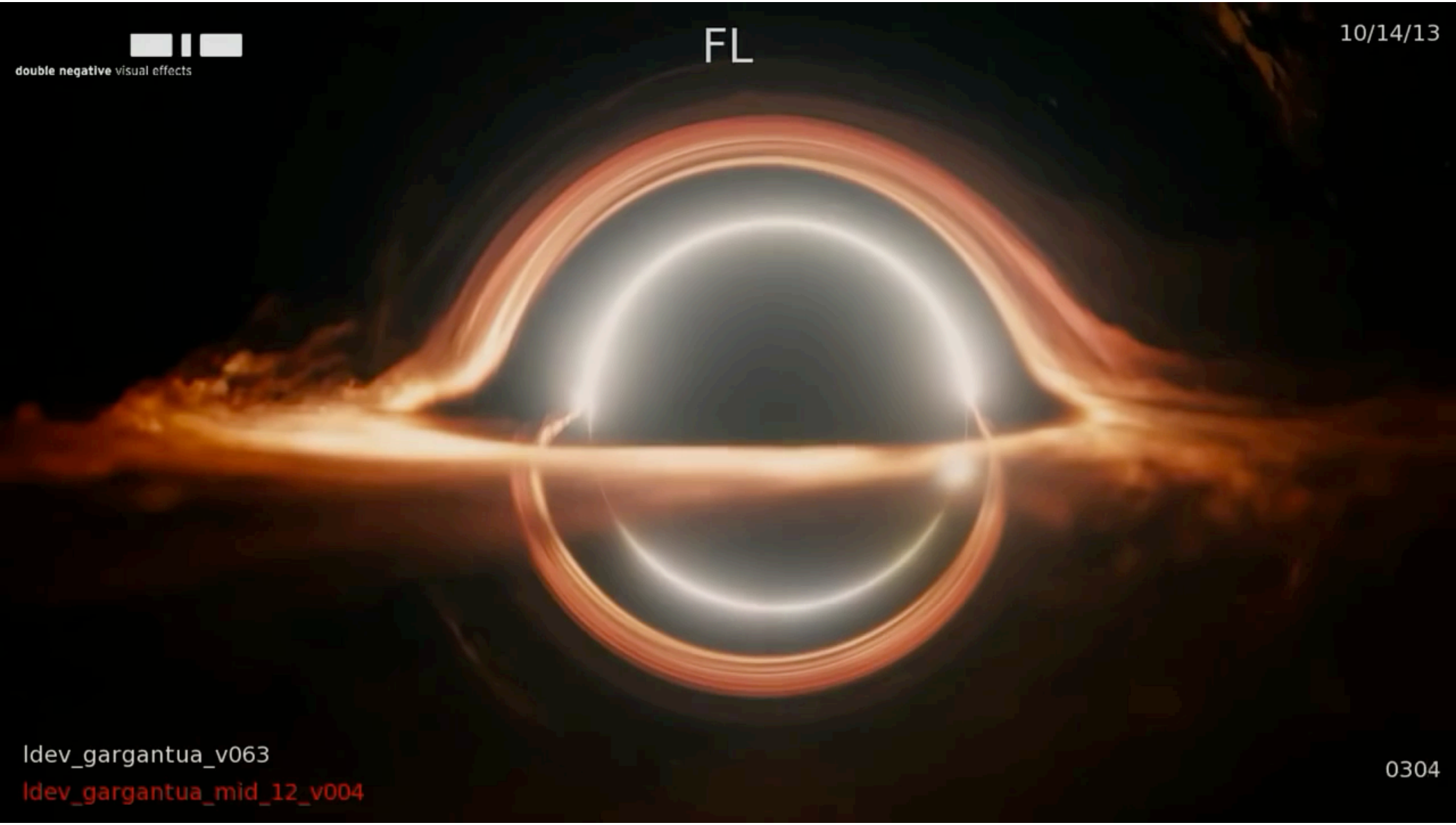
https://www.pauldebevec.com/Campanile/

Motion Capture

Andy Serkis in The Two Towers

Avatar (2009)

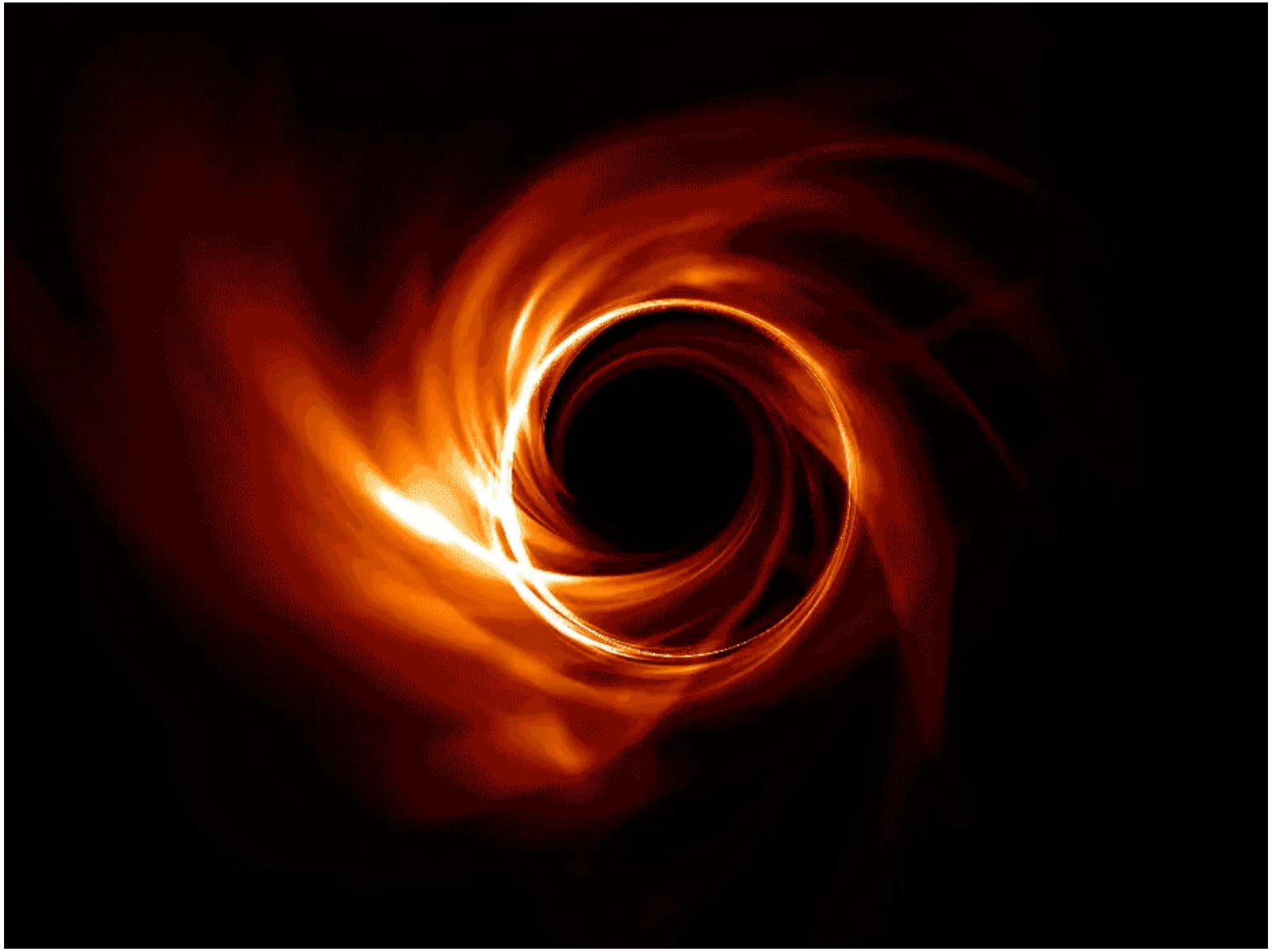
Interstellar (2014)



Computational Imaging - Event-Horizon Telescope

Event Horizon Telescope collaboration et al.

Computational Imaging - Event-Horizon Telescope



Event Horizon Telescope collaboration et al.

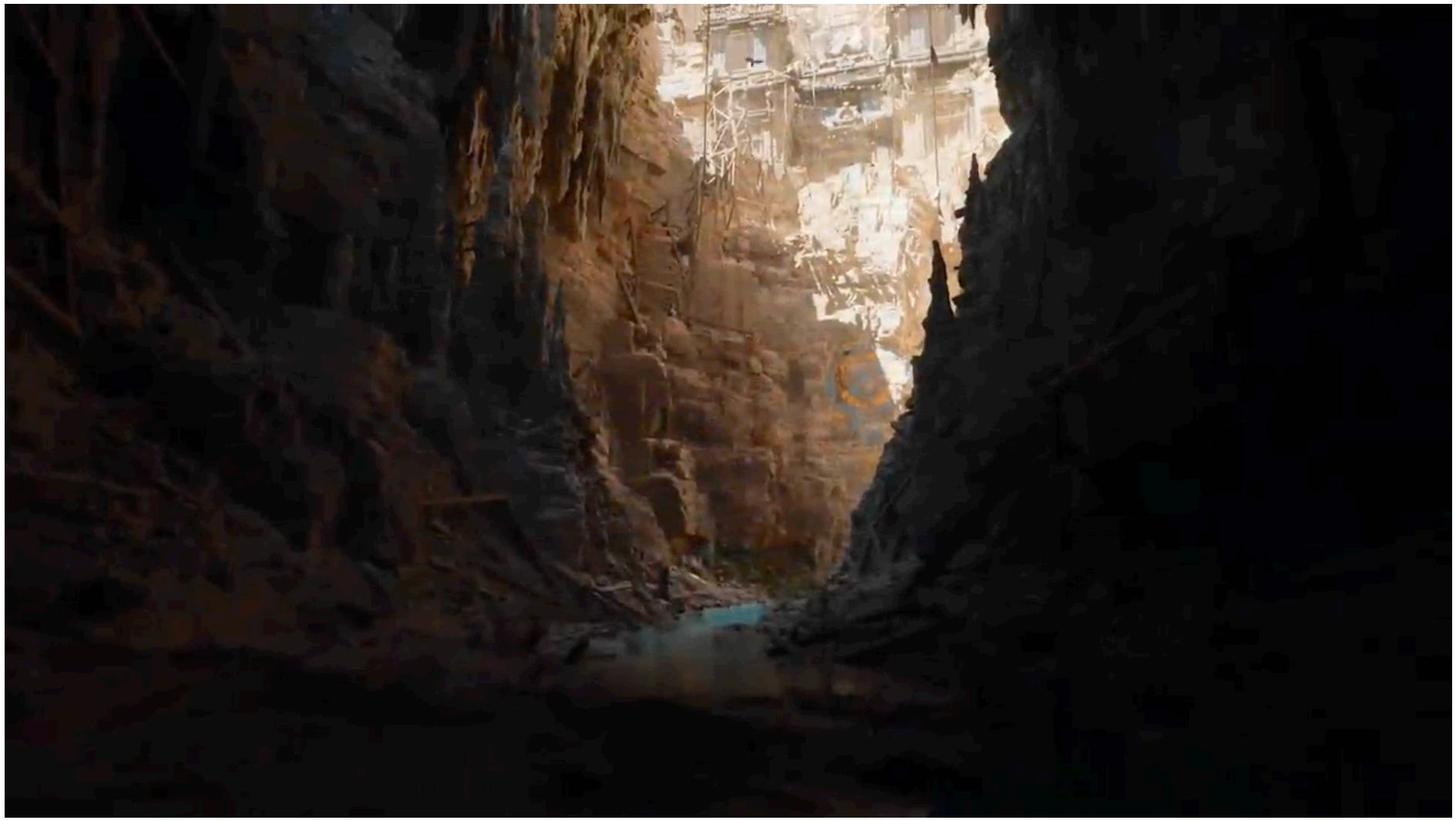
Games

Super Mario World

Child of Light (2014)

Child of Light (2014)

Games



Unreal Engine 5 Demo Realtime in PS5 (2020)

Visual Simulation

Visual Simulation

Driving simulator
Toyota Higashifuji Technical Center

da Vinci surgical robot
Intuitive Surgical

Flight simulator, driving simulator, surgical simulator, …

Virtual Reality

HTC Vive headset and controllers

Augmented Reality

Microsoft Hololens augmented reality headset concept

Augmented Reality

Mixed Reality

CS184/284A

Apple Vision Pro

Ren Ng

Product Design and Visualization

Ikea - 75% of catalog is rendered imagery

Product Design and Visualization

Photograph

Simulation

Product Design and Visualization

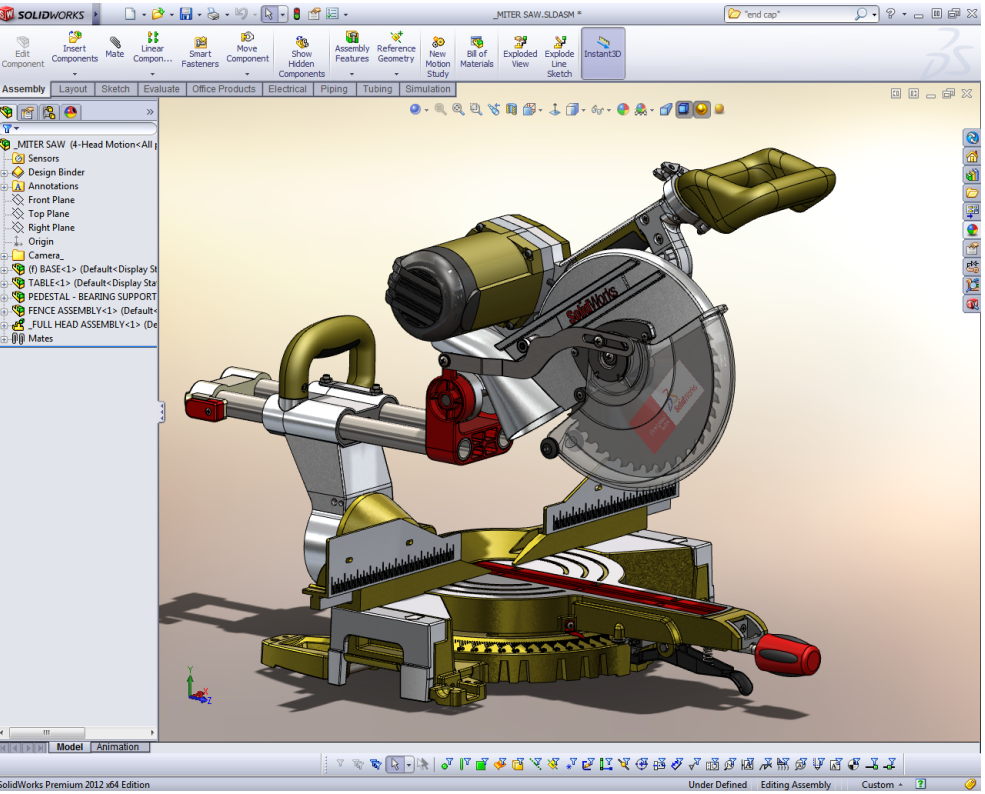
Tesla Model X concept (2012)

Product Design and Visualization

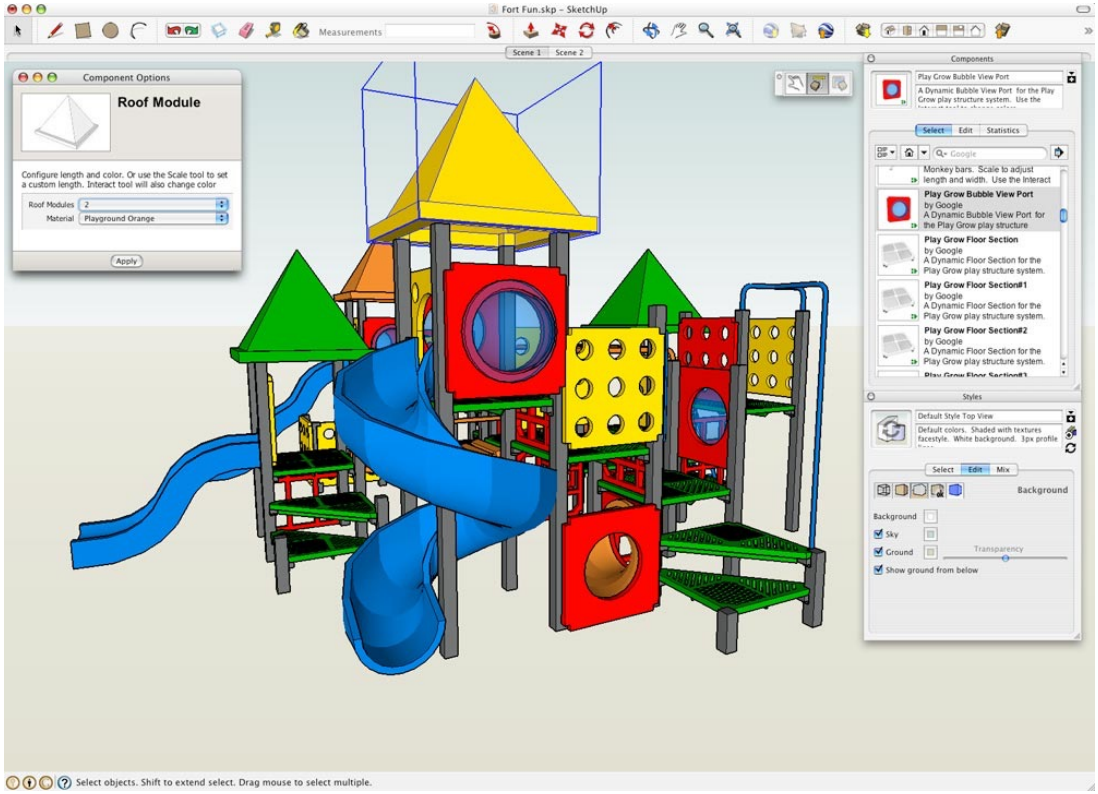
Credit: EV obsession.com, James Ayre

Tesla Model X production

Computer-Aided Design



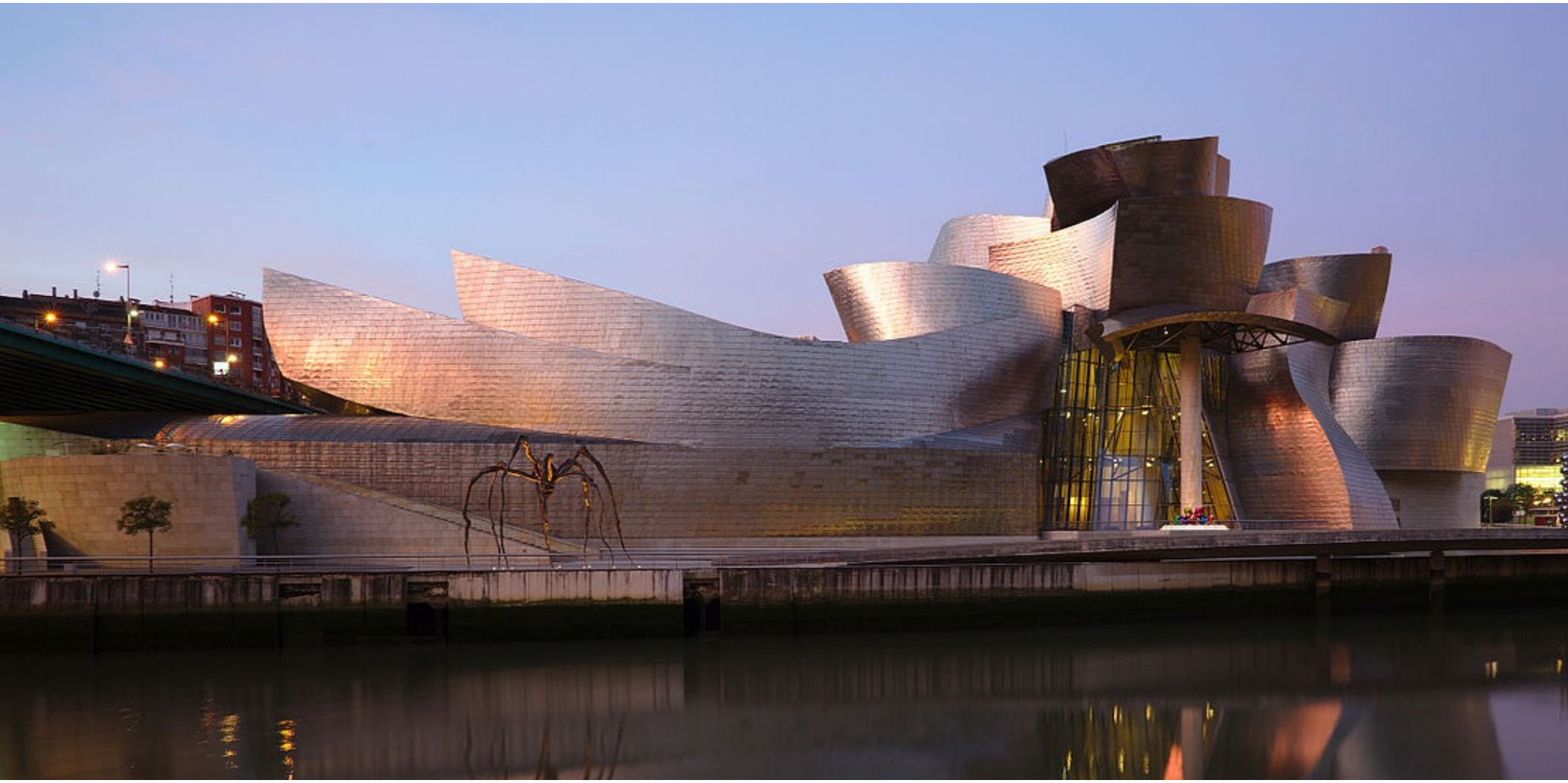
SolidWorks



SketchUp

For mechanical, architectural, electronic, optical, …

Architectural Design

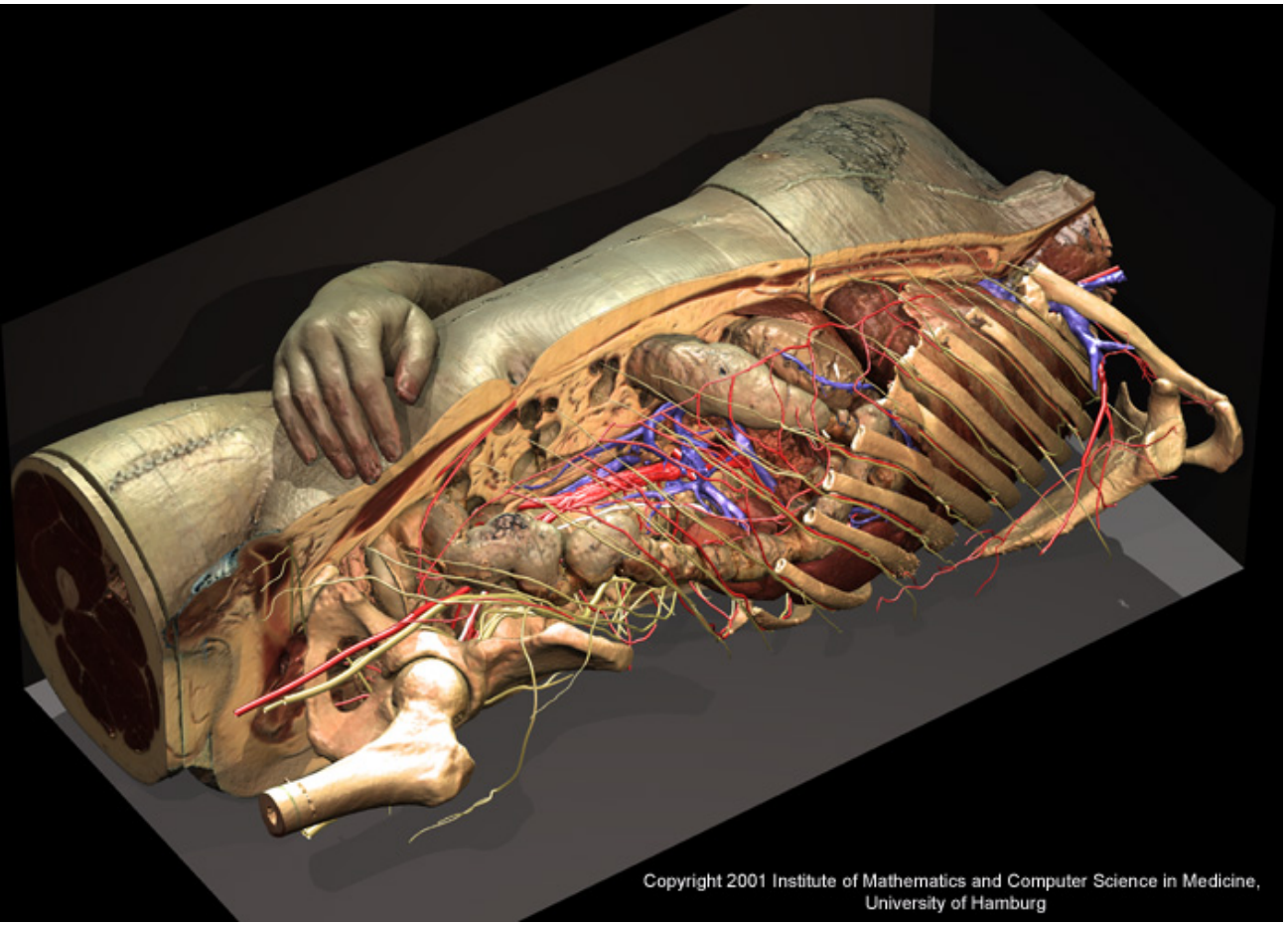


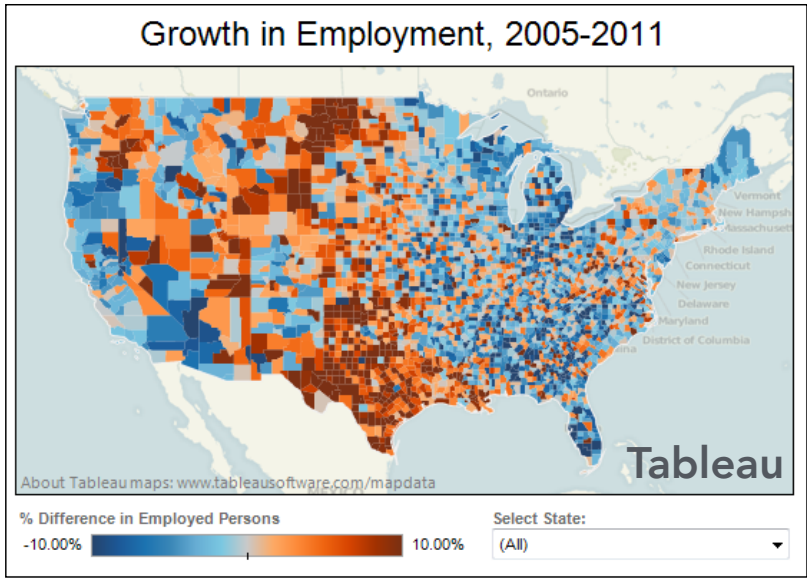
Bilbao Guggenheim, Frank Gehry

Architectural Design

Heydar Aliyev Center, Zaha Hadid Architects

Visualization



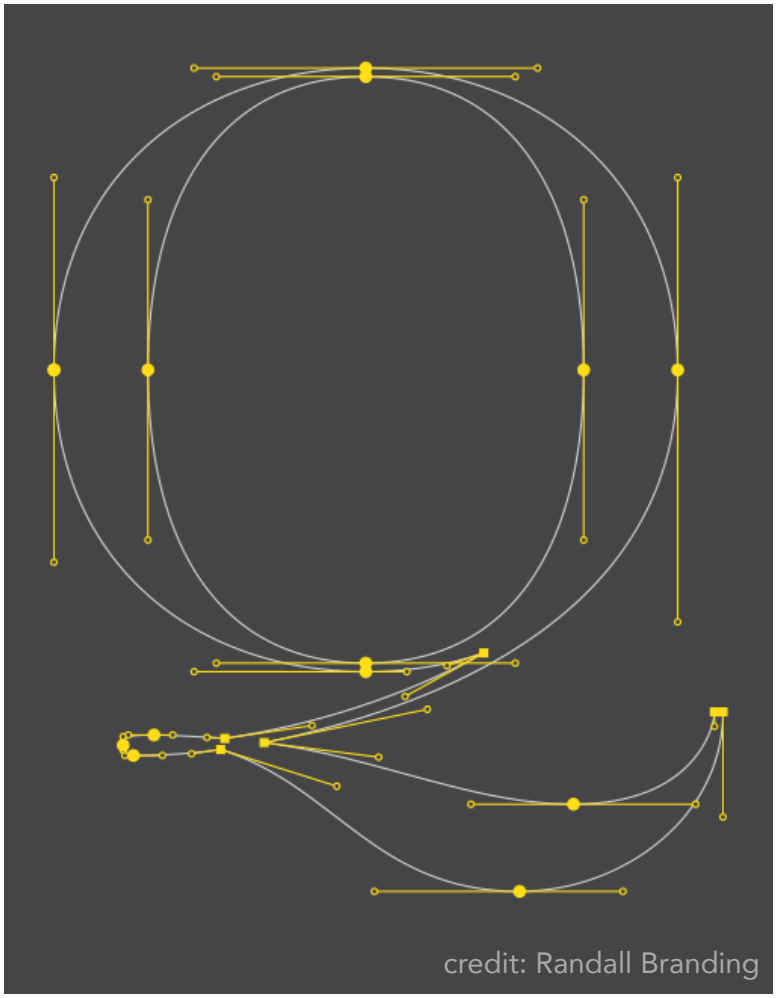


Science, engineering, medicine, journalism, ...

Typography

The Quick Brown Fox Jumps Over The Lazy Dog

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789

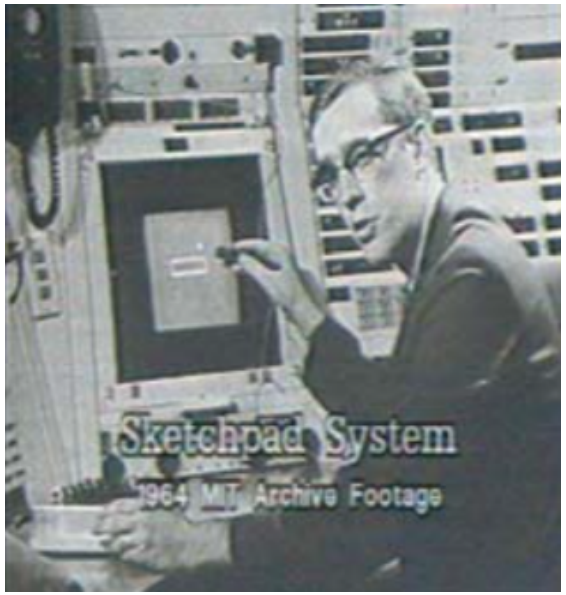


Baskerville

Graphical User Interfaces

Desktop metaphor

- Input: Keyboard, mouse
- Ouput: Cathode-ray tube



Ivan Sutherland, Sketchpad
Light pen, vector display

Doug Engelbart
Mouse

Graphical User Interfaces

2D drawing and animation are ubiquitous in computing.
Typography, icons, images, transitions, transparency, ...

Graphical User Interfaces

2D drawing and animation are ubiquitous in computing.

Typography, icons, images, transitions, transparency, …

Graphical User Interfaces

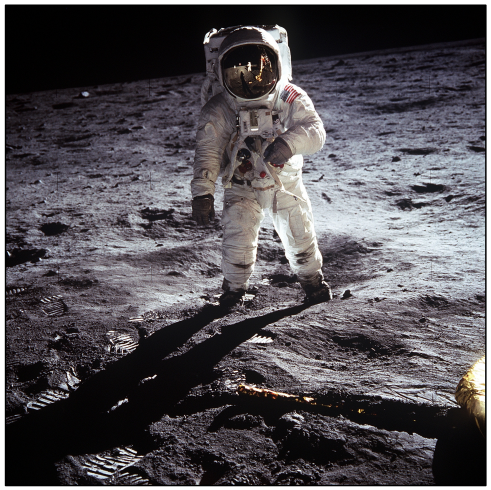
https://www.youtube.com/watch?v=YndL315tQq8

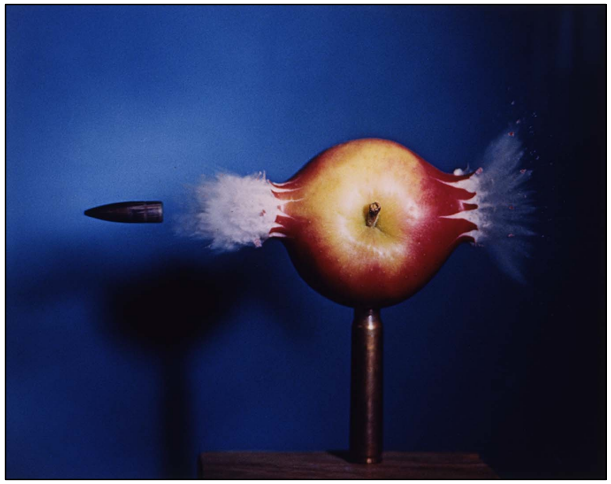
Digital Illustration

Meike Hakkart

http://maquenda.deviantart.com/art/Lion-done-in-illustrator-327715059

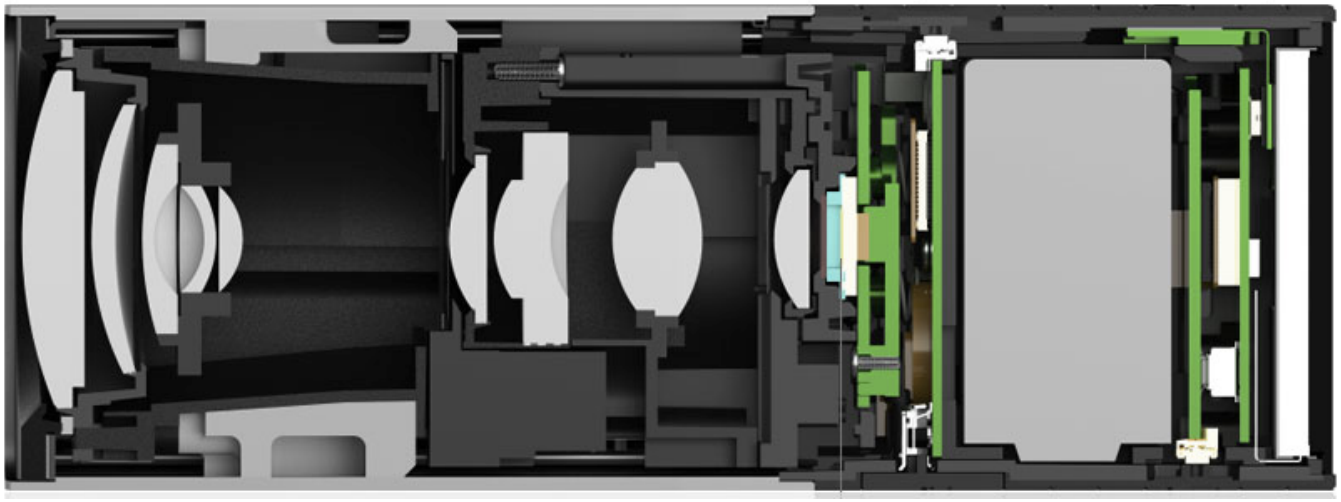
Photography





NASA | Walter Iooss | Steve McCurry
Harold Edgerton | NASA | National Geographic

Digital and Computational Cameras

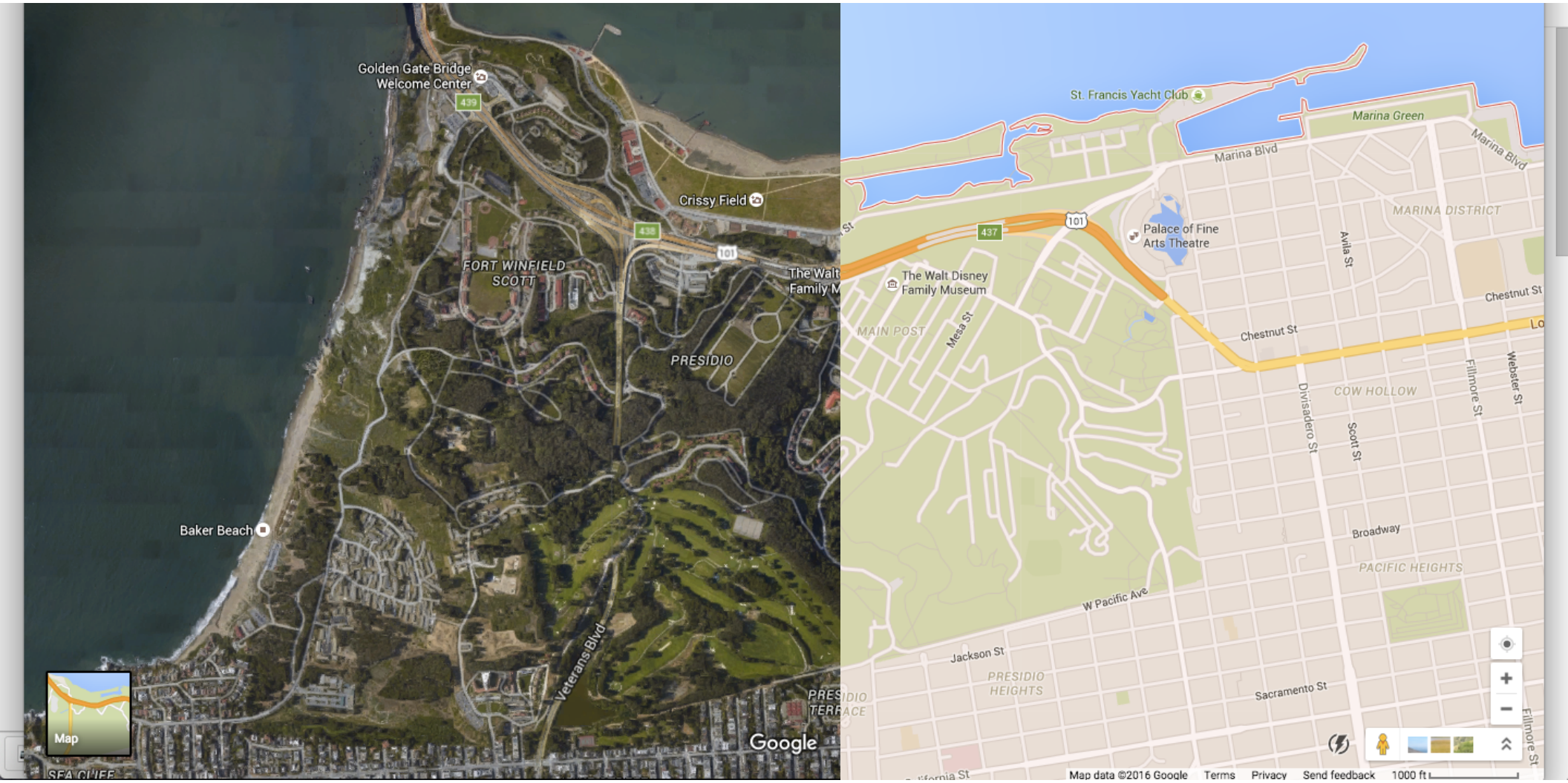


Panaromic stitching, HDR photos, light field cameras, …

Ubiquitous Imaging

Cameras everywhere

Imaging in Mapping



Maps, satellite imagery, street-level imaging,...

Imaging in Mapping

Maps, satellite imagery, street-level imaging,…

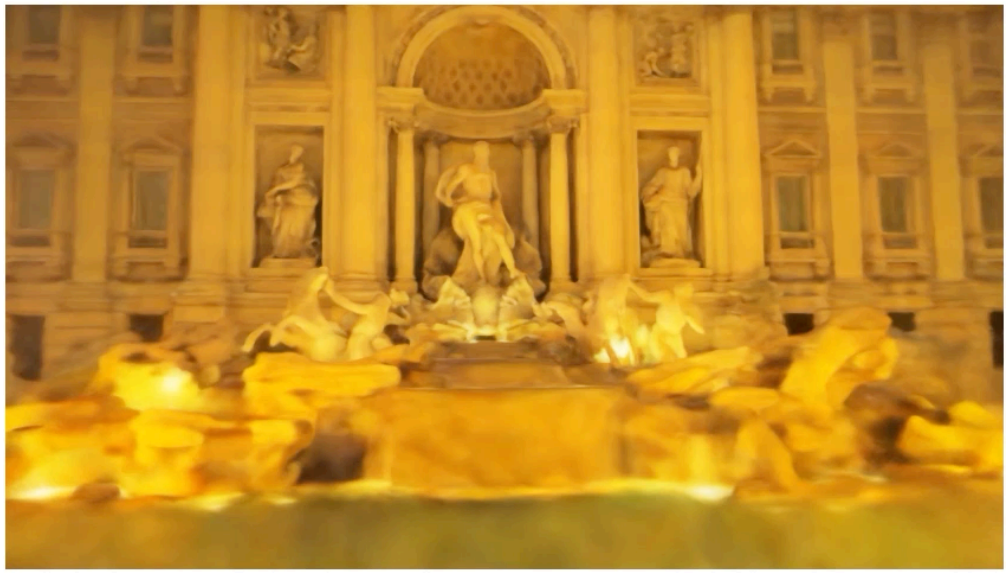
Imaging for Computer Vision

ImageNet: 15M images, 22K categories
http://image-net.org

Imaging for Robotics

Google's "Arm Farm"

Neural Radiance Fields



Generative Visual AI

Photoshop GenFill

Generative Visual AI

CS184/284A

Photoshop GenFill

Ren Ng

Foundations of Graphics and Imaging

These applications require sophisticated theory and systems

Science and Mathematics

- Physics of light, color, optics, …
- Math of curves, surfaces, geometry, perspective, …

Technology and Systems

- Input devices, GPUs, displays, …
- Cameras, lenses, sensors, …

Art and Psychology

- Perception: color, stereo, motion, image quality, …
- Art and design: composition, form, lighting, ...

Course Goals

Overview of core ideas in graphics and imaging

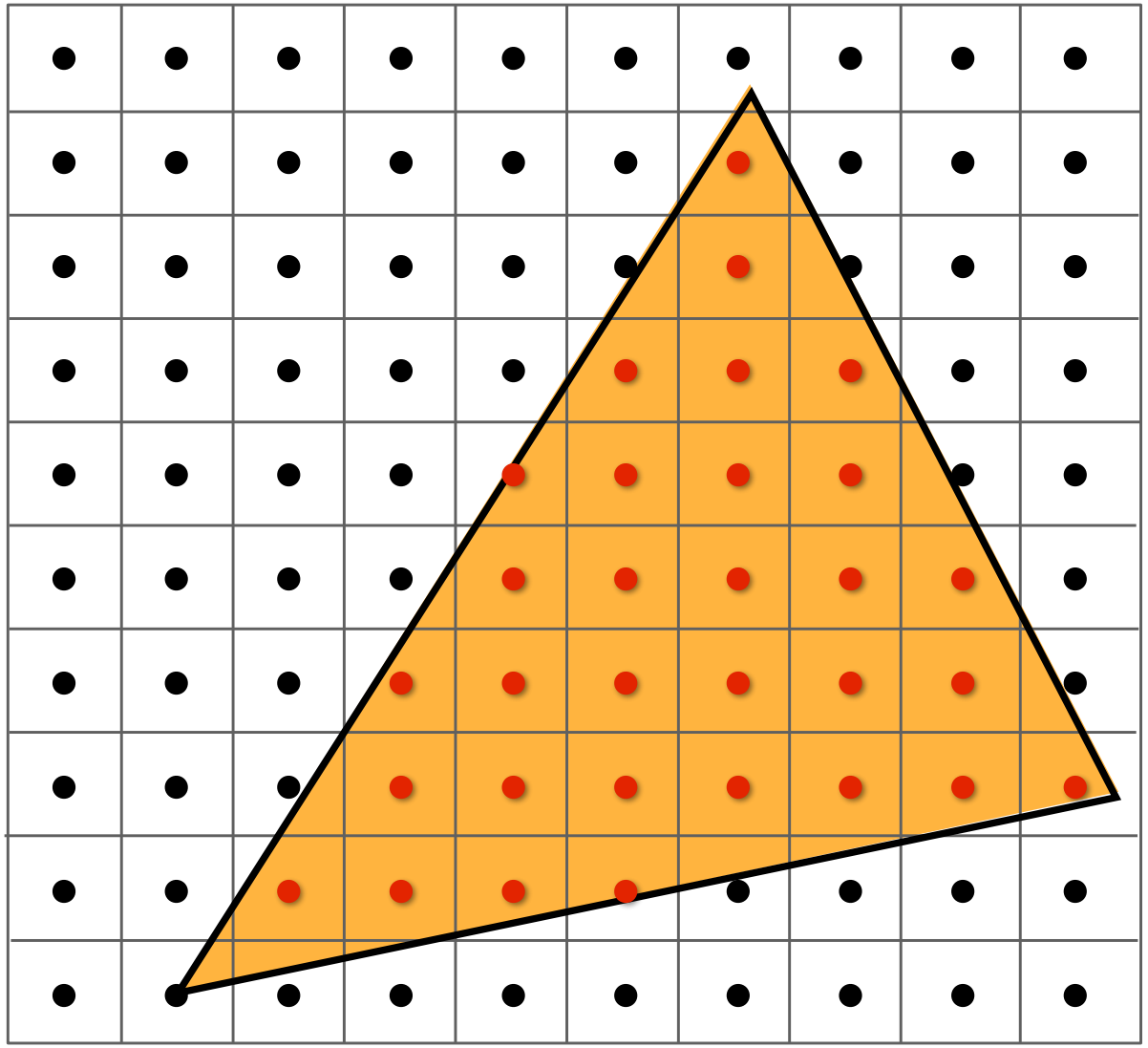
- Modeling the world, image synthesis
- 3D graphics: geometry, rendering, animation
- Image capture, manipulation and display

Acquire core concepts and skills

- Representations (geometry, images, transforms, …)
- Algorithms (sampling, subdivision, ray-tracing, …)
- Technology (GPUs, displays, cameras, …)

Course Topics

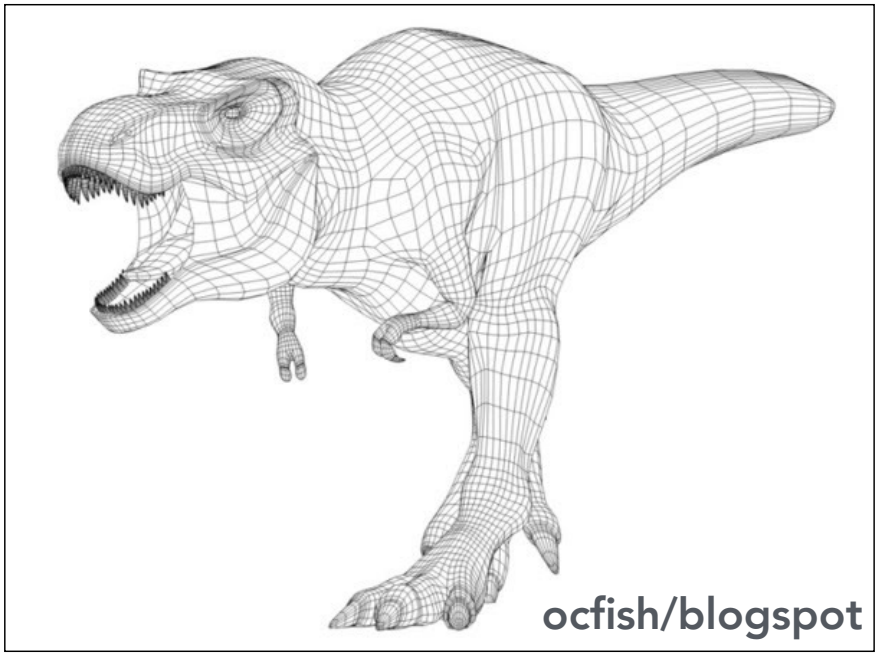
Drawing Digital Images (Rasterization)

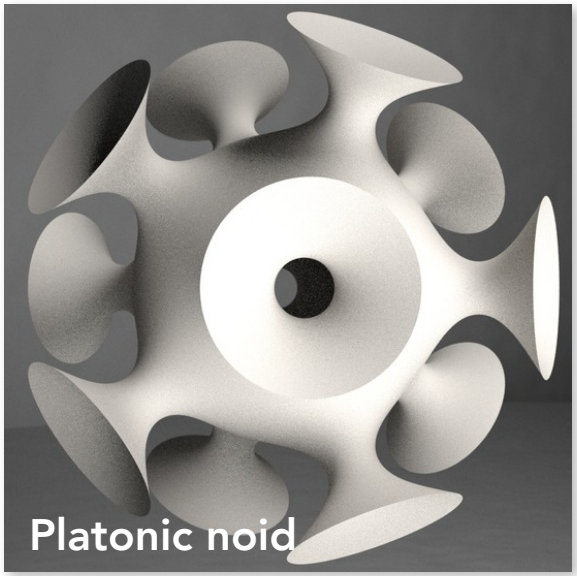


Filtering and Sampling

No Jaggies

Modeling Geometry





Modeling Material Properties

Modeling Lighting

Monster's Inc., 2001

Modeling Lighting

Monster's U., 2013

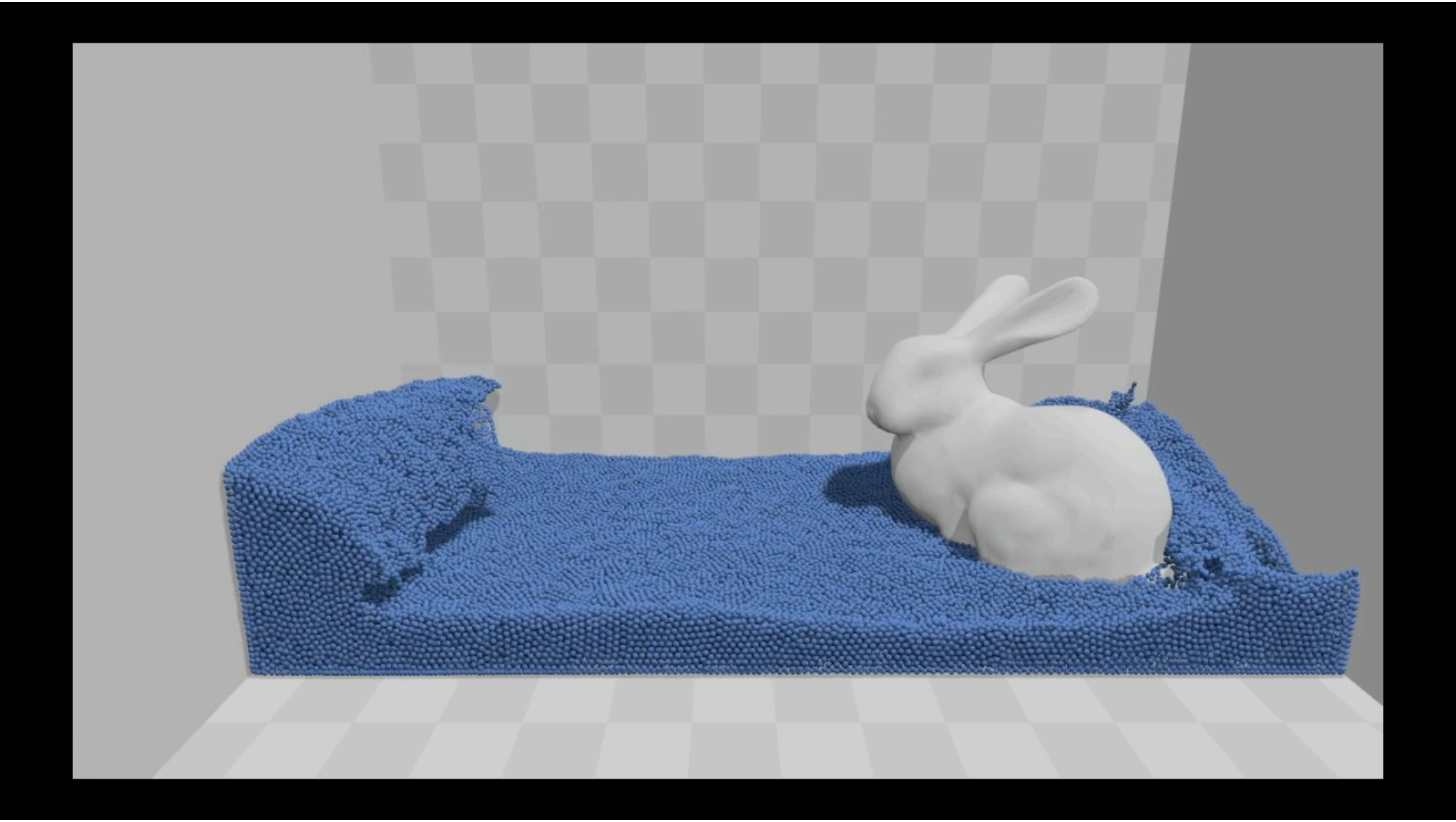
Light Transport and Image Synthesis

Photograph (CCD) vs. computer rendering

How Do Cameras Work?

Glenn Derene, Popular Mechanics

Animation and Physical Simulation

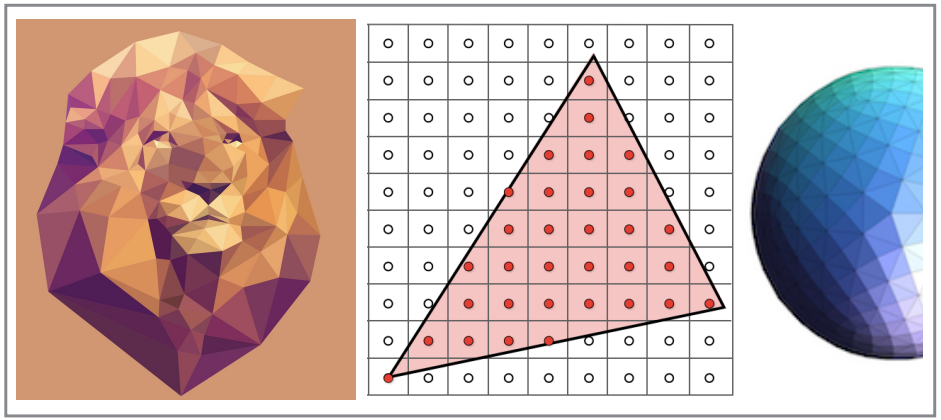


Position Based Fluids, Macklin and Müller

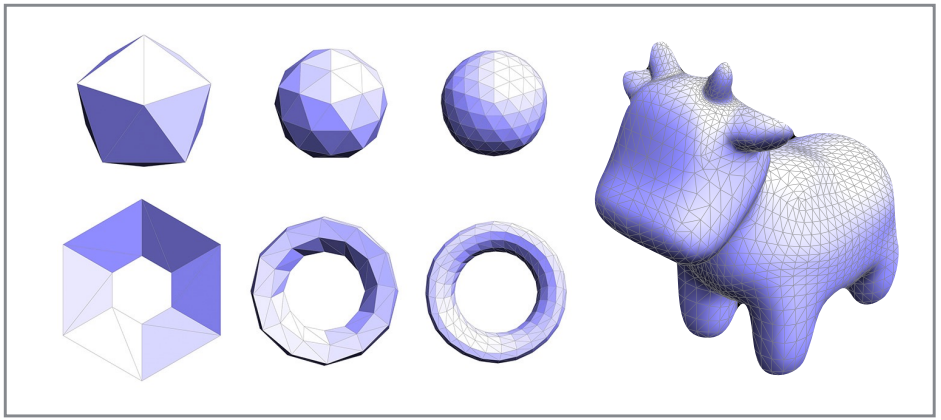
Virtual Reality

Hands-On Learning

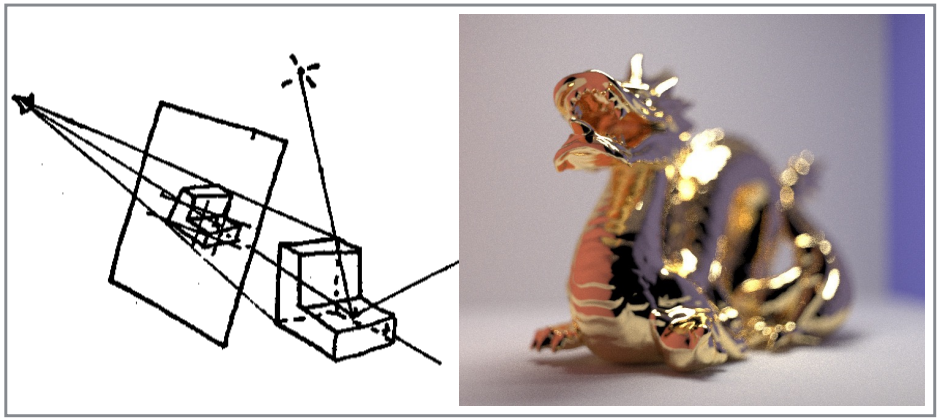
Course Assignments



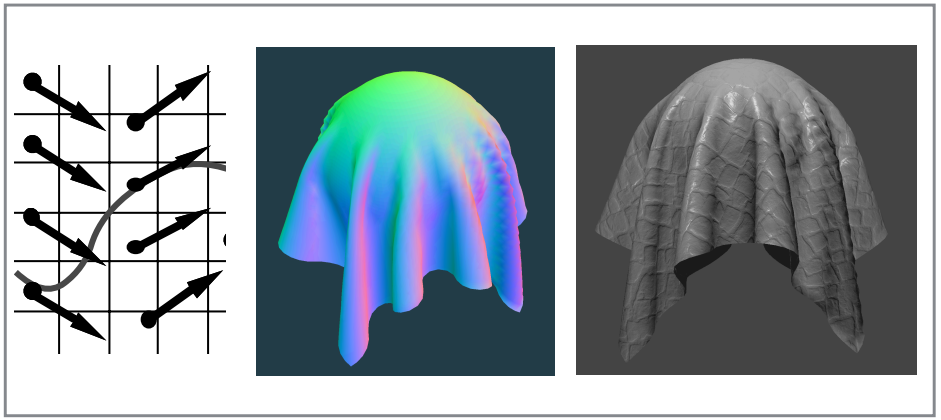
1. Digital Drawing (2 weeks)



2. Geometry (2 weeks)



3. Ray-Tracing (2 weeks)



4. Animation (2 weeks)

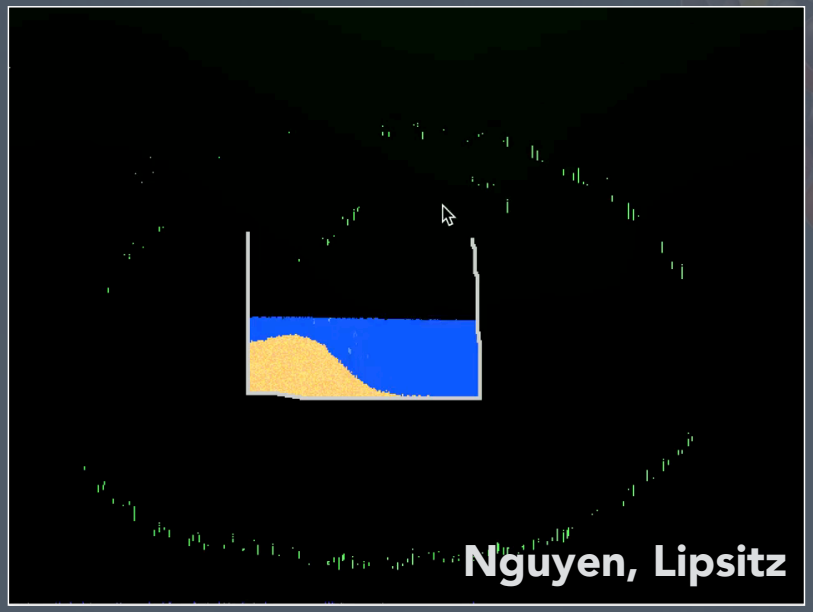
Final Project

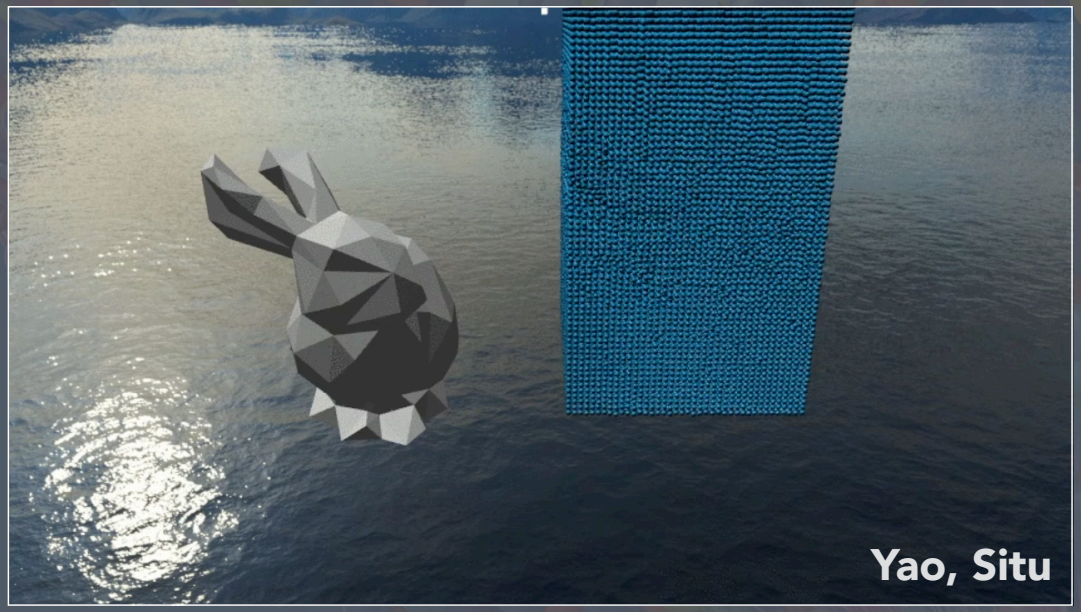
Project Competition

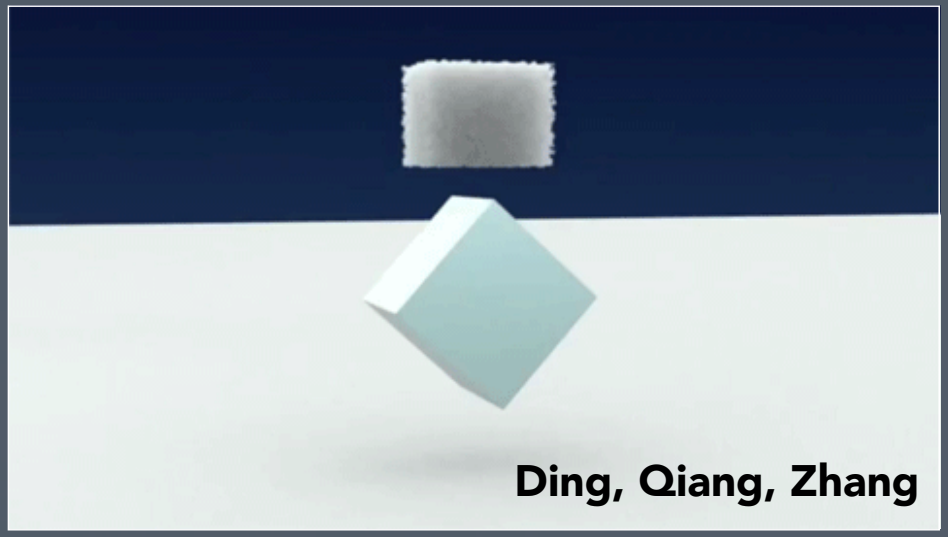
- 4 weeks, let your creativity take flight!
  (we will have suggested projects)
- Proposal; checkpoint; presentation, video, report

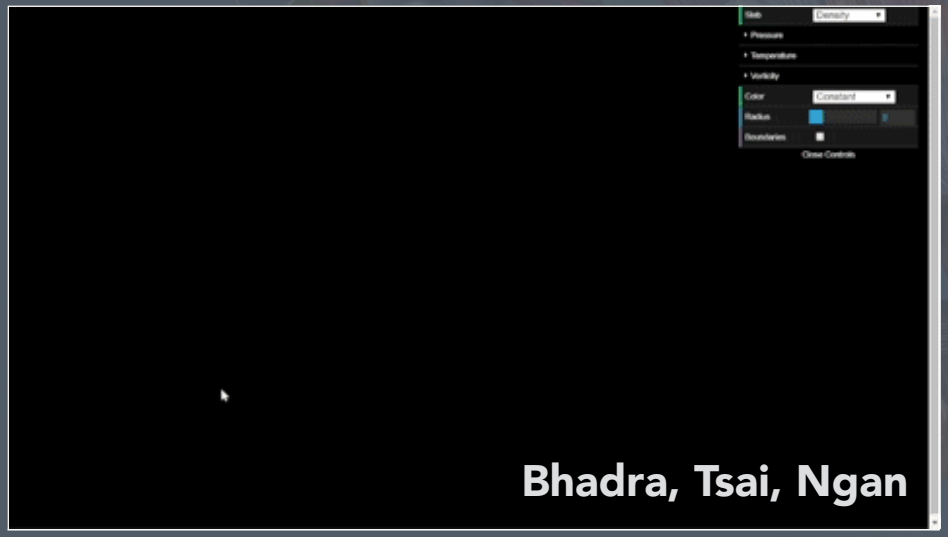
Credit: Pixar, Up

Final Project - Examples



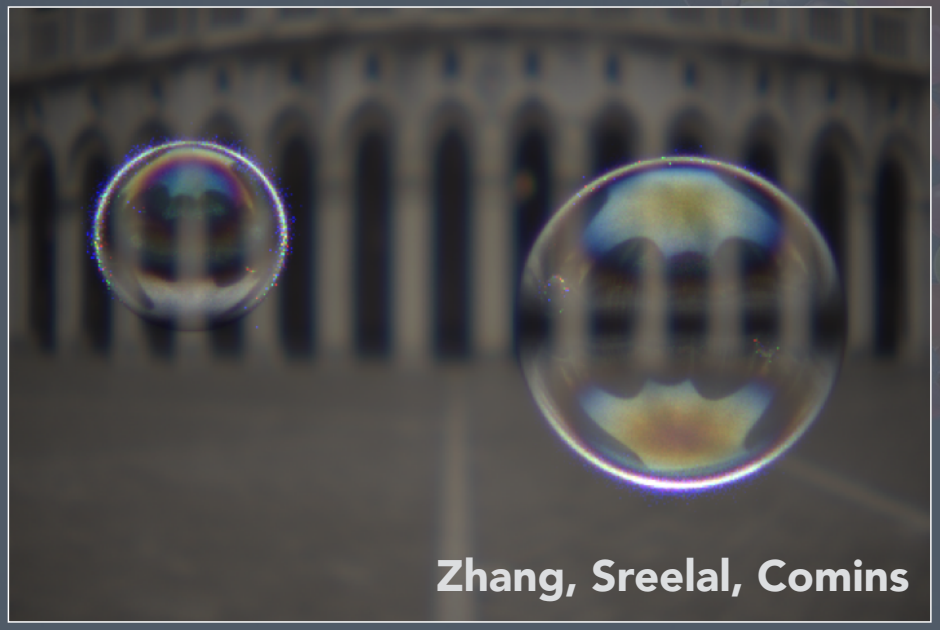


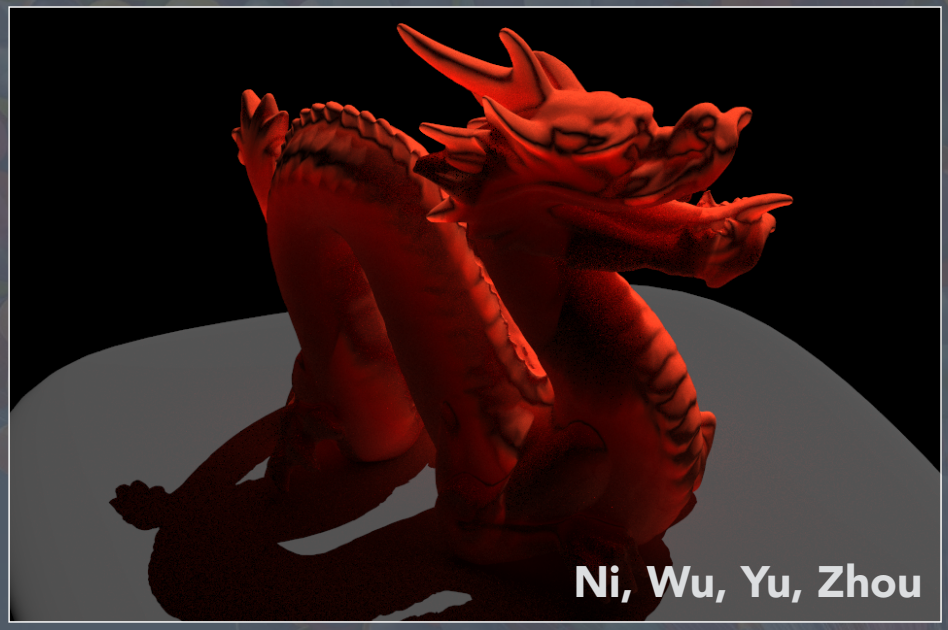


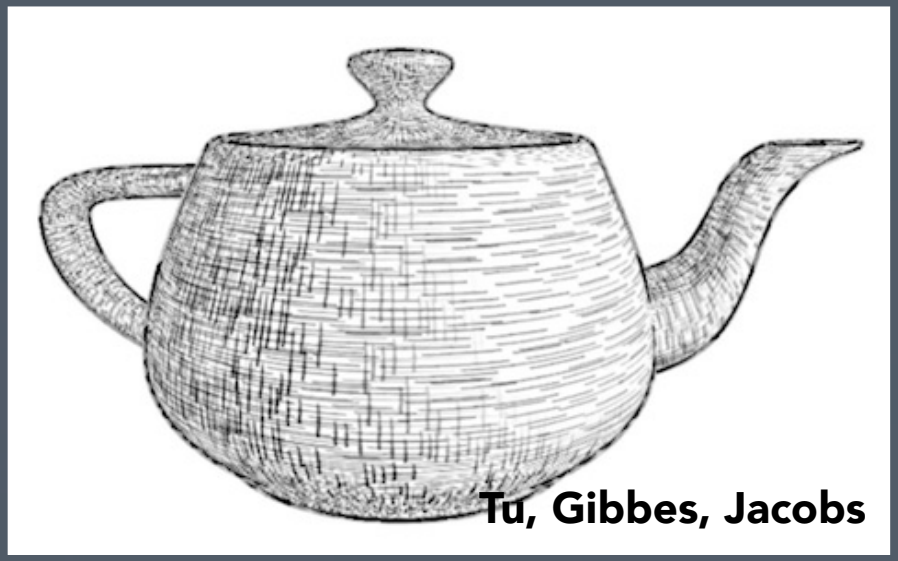


Credit: Pixar, Up

Final Project - Examples

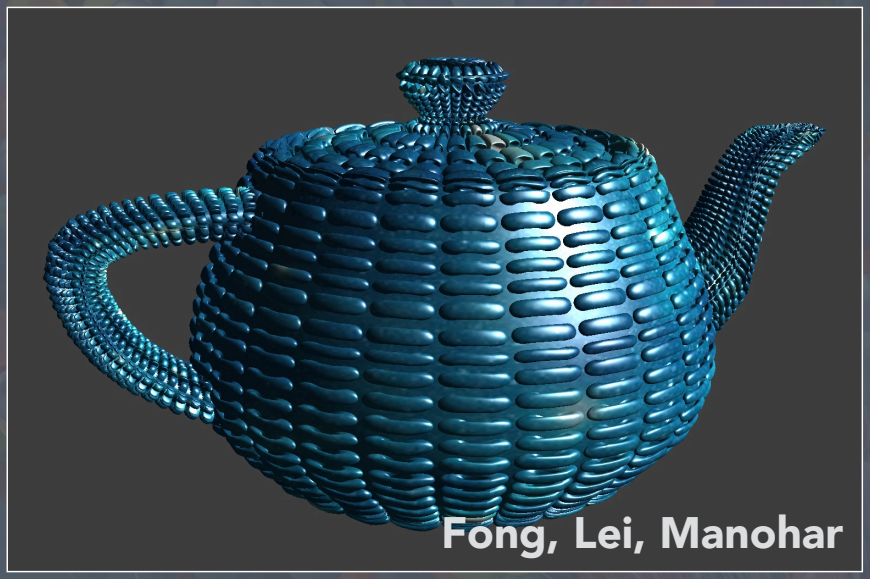


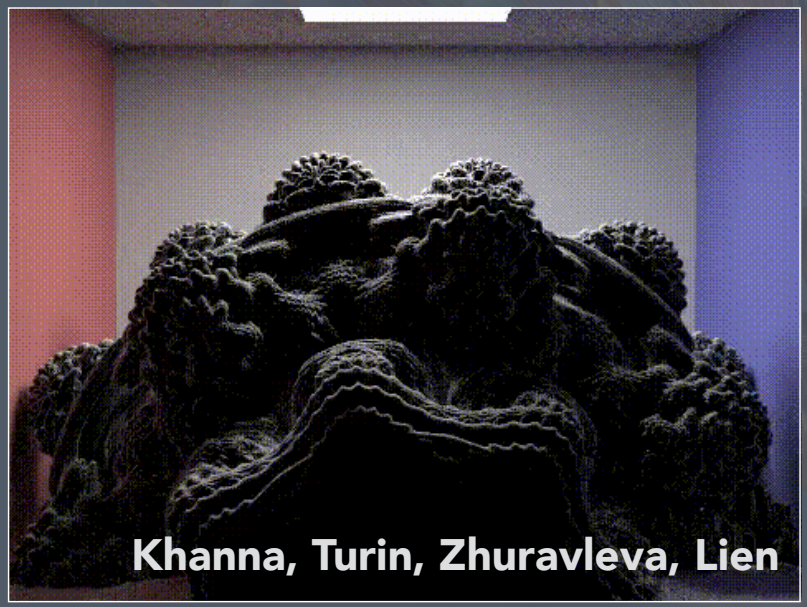




Credit: Pixar, Up

Final Project - Examples





Credit: Pixar, Up

Course Logistics

Prerequisites

Math

- Vectors, matrices, basic linear algebra
- Helpful: exposure to statistics, signal processing, Fourier transform

Programming

- Data structures (CS61B)
- Fluency with development environment, debugging, etc.
- Fluency with C and C++

Enrollment

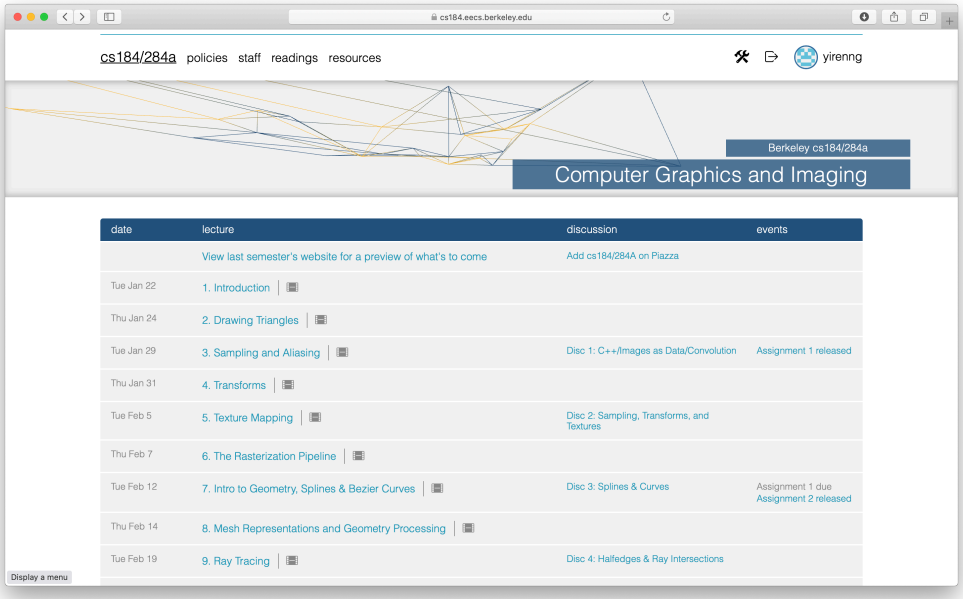
- Past years, high turnover from wait list
- Questions about enrollment:
  - Undergraduate students (CS184): ask scheduler (Cindy Conners) cs-scheduling@berkeley.edu
  - Graduate students (CS284A): contact instructors on Ed
  - Concurrent enrollment: in process; consult your CE coordinator, and check course Ed for updates

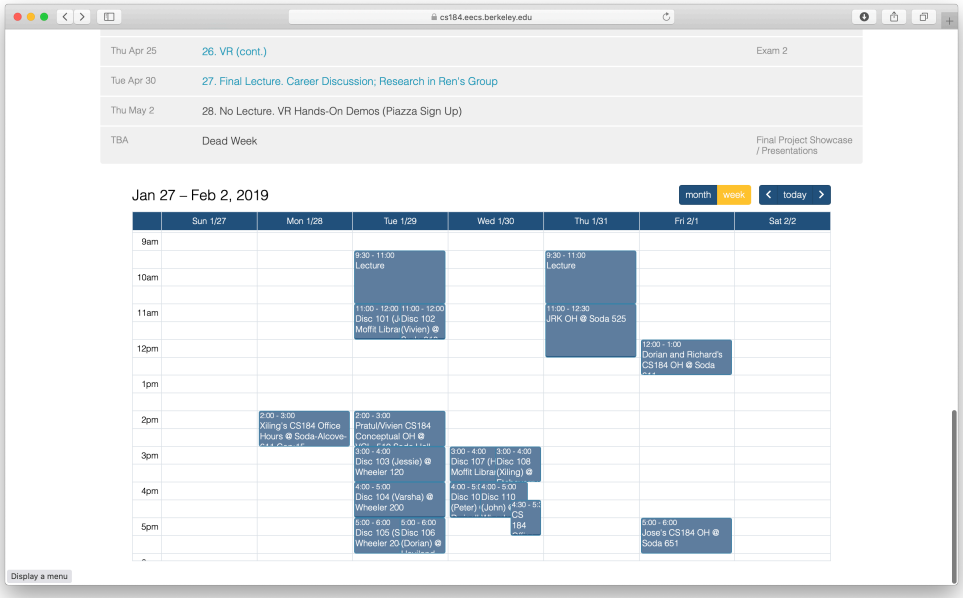
Course Schedule

cs184.eecs.berkeley.edu

Full schedule for class will be on website soon

Note class calendar at bottom for office hours, homework, parties, etc.





Course Schedule - Important Dates

See course website for dates and more info.

Exams

- Monday March 18th 7:00 - 9:00 pm
- Monday April 22nd 7:00 - 9:00pm

Final Project Presentations

- Tentatively scheduled for Thu May 2 / Fri May 3

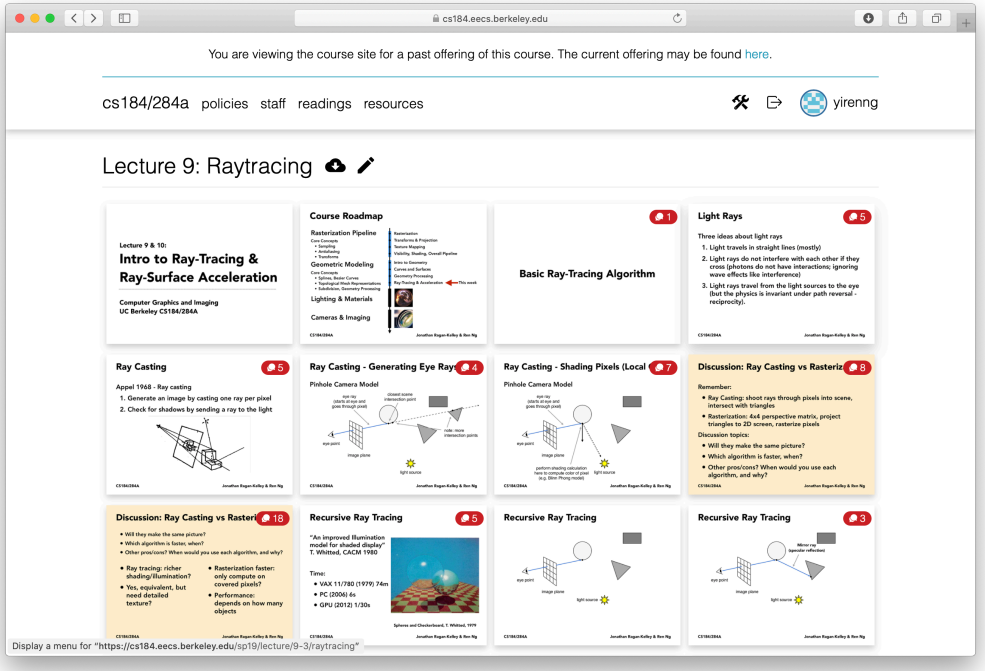
Please check calendars and save these dates now!

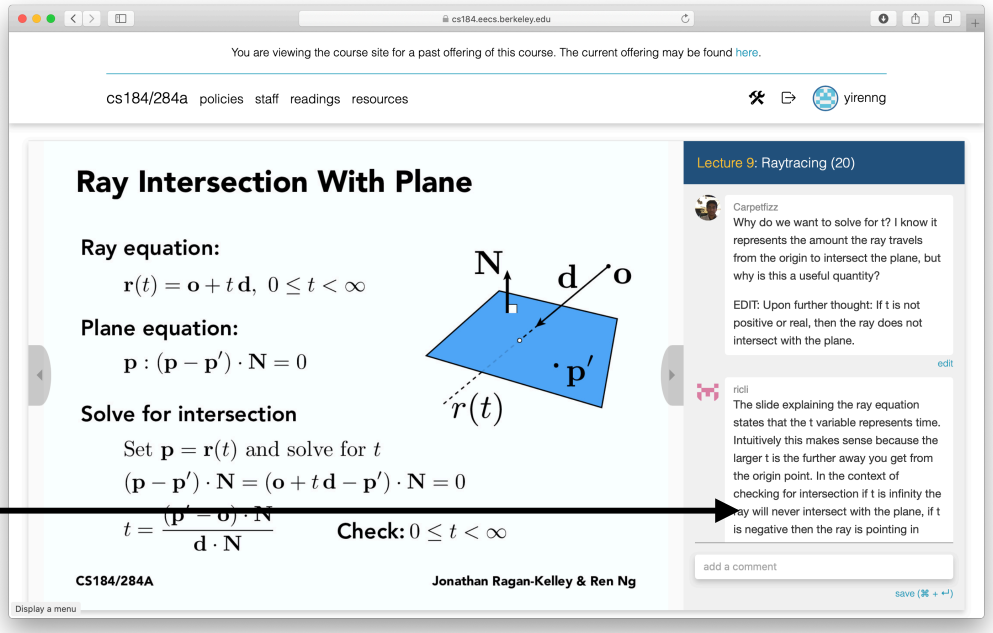
- Send a private Ed message to staff if you have an exceptional circumstance

Lecture Slides

cs184.eecs.berkeley.edu

Lecture slides and instructor/TA/ student discussions on the web are the primary course reference materials





Slide comments and discussion

Ed

edstem.org

You should be added already (if not, please sign up)!

For logistics and general communication / discussion

- Please use Ed instead of email
- But intellectual discussions about content should primarily go on website as slide comments

Webcasting

Lecture will be recorded this semester

- Screen capture and audio only
- Videos will be linked from the course website

Section

Sections start next week, and TAs will give a primer on C++ and building class projects

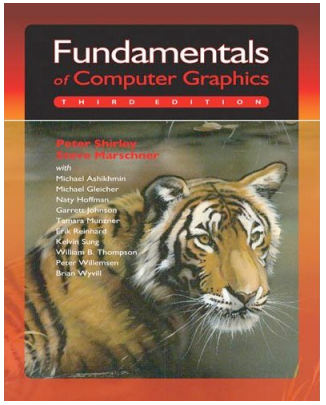
Resources

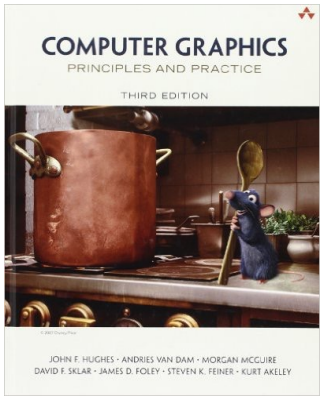
Lectures will be primary source

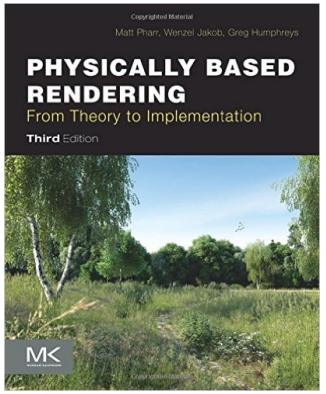
Textbook reference material (optional):

- Fundamentals of Computer Graphics
  by P. Shirley, S. Marschner, et al.
- Computer Graphics: Principles and Practice (3rd Edition)
  by Hughes, van Dam, et al.
- Physically Based Rendering, Third Edition: From Theory to Implementation
  by Pharr, Jakob and Humphreys

Other optional reading resources on class website







Learning, Grading, Collaboration & Culture

Goals:

- Enable you to increase focus on learning rather than assessment
- Encourage your learning through collaboration
- Entrust you with maintaining academic integrity

Main Ideas (details on course website — please review):

- The class is not graded on a curve.
- Collaboration in pairs encouraged on homework assignments.
- Final project in teams of four.
- Two in-person exams.

Details

- Please read the Policies page on the course website; ask questions on Ed.

Course Deliverables and Assessment

CS184: your course grade is out of 100 total points

- Four homework assignments, 12.5 points each
  - Pair projects encouraged. Programming and written reports.
- Two in-person, closed-book exams, 10 points each
  - Check dates on website schedule. No exam during Finals Week.
- Final project, 25 points
  - In teams of four, with final presentation, video, report.
- Participation, 5 points
  - Attend lectures/discussion

CS284A students: Project is 40% of grade, remainder normalized.

Late Days Policy

You have 8 late days for the semester

- Extend a homework assignment deadline (not the final project) by 24 hours using one late day.
- No more than 4 late days on last homework (#4)
- If you do not have remaining late days, 1 point penalty per day.
- Late days are meant to be used for personal schedule conflicts, illness, submission issues and other unforeseen circumstances.
- For exceptional circumstances, contact staff or see website for extension request form.

Participation Policy

Every week, starting week 2, you are eligible for up to 2 participation credits.

- 1 credit for attending lecture
- 0.75 credits for attending discussion, and
- 0.5 credit for making one well thought-out comment on lecture slides on the website

Note that you must earn participation credits week-to-week and cannot "make up" participation at the end of the semester

Policy on Use of Generative-AI Tools

You are welcome to use AI tools for coding and writing reports. But a few rules / comments:

- Must describe use and what you learned
- Exams are in-person, closed-book. Likely will have coding questions
- Current AI tools are not perfect, so supervise your tools closely if you use them
- Low or minimal-effort use of AI tools may result in low or no partial credit
- We encourage you to explore AI tools in a way that augments rather than reduces your learning in class

What We Are Looking For In Slide Comments

Try to explain the slide (as if teaching your classmate to study for an exam)

- "Ren said this, but if you think about it this way it is much clearer"

Explain what is confusing you

- "What I was totally confused about here was…"

Challenge classmates with a question

- For example, make up a question you think might be on an exam

Provide a link to an alternative explanation

- "This site has a really good animation of pre-filtering to avoid aliasing"

Mention real-world examples

- For example, describe what default interpolation functions are used in iOS.

Constructively respond to another student's question

- "@nojaggies, are you sure that is correct? I thought that Ren said…"

It is OK, and even encouraged, to address the same topic (or repeat someone else's summary, explanation or idea) in your own words

- "@cornellbox's point is that subdivision is also used to…"

Class Philosophy

We want to build an active, engaged class community.

Come to class, participate in lecture, discussion, office hour parties, homework parties.

Practice cooperative, supportive learning.

Contribute on the website.

Uphold academic honor individually and collectively.

Inclusive Classroom

We are committed to creating a learning environment welcoming and supportive of all students. Towards this goal, we call on our class community to:

- Respect, welcome and learn from each other as individuals with unique backgrounds, perspectives and identities.
- Collaboration and team learning are encouraged, and will be supported through class staff and resources.
- Homework assignments and final project are a great way to meet new people and make friends; work on building trust and leveraging each other's unique strengths.
- If you feel that your learning is negatively affected by your experiences outside of class (e.g. family matters, current events), please don't hesitate to come and talk with the instructor and/or staff. We want to support you.

Course Roadmap

Rasterization Pipeline

Core Concepts

- Sampling
- Antialiasing
- Transforms

Geometric Modeling

Core Concepts

- Splines, Bezier Curves
- Topological Mesh Representations
- Subdivision, Geometry Processing

Lighting & Materials

Core Concepts

- Measuring Light
- Unbiased Integral Estimation
- Light Transport & Materials

Cameras & Imaging

- Rasterization
- Transforms & Projection
- Texture Mapping
- Visibility, Shading, Overall Pipeline
- Intro to Geometry
- Curves and Surfaces
- Geometry Processing
- Ray-Tracing & Acceleration
- Radiometry & Photometry
- Monte Carlo Integration
- Global Illumination & Path Tracing
- Material Modeling

Questions?

Acknowledgments

Thanks to Angjoo Kanazawa, Pat Hanrahan, Kayvon Fatahalian, Keenan Crane, Mark Pauly and James O'Brien for presentation resources.