Lecture 1:

Introduction

Computer Graphics 2025

Fuzhou University - Computer Science

Welcome!

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Today's Topics

What is Computer Graphics?

Why Study Computer Graphics?

Course Overview

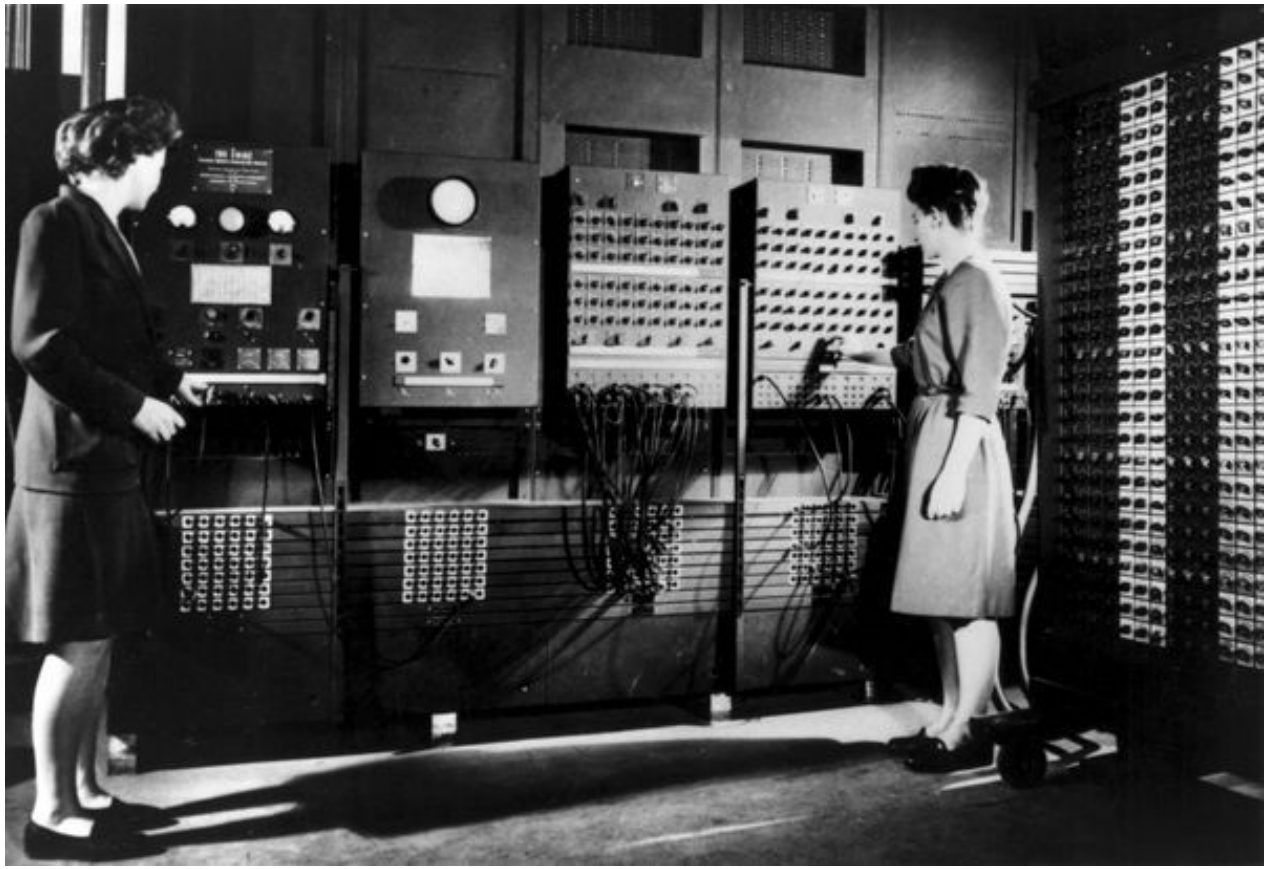
Logistics

What is Computer Graphics?

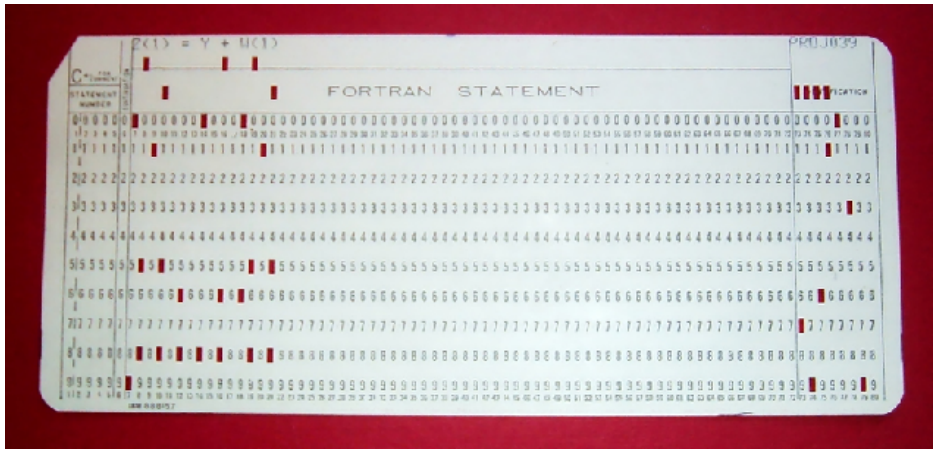

PORTKEY GAMES
HOGWARTS
LEGACY

More fundamentally:
What is Computer Graphics?

Display the computational results

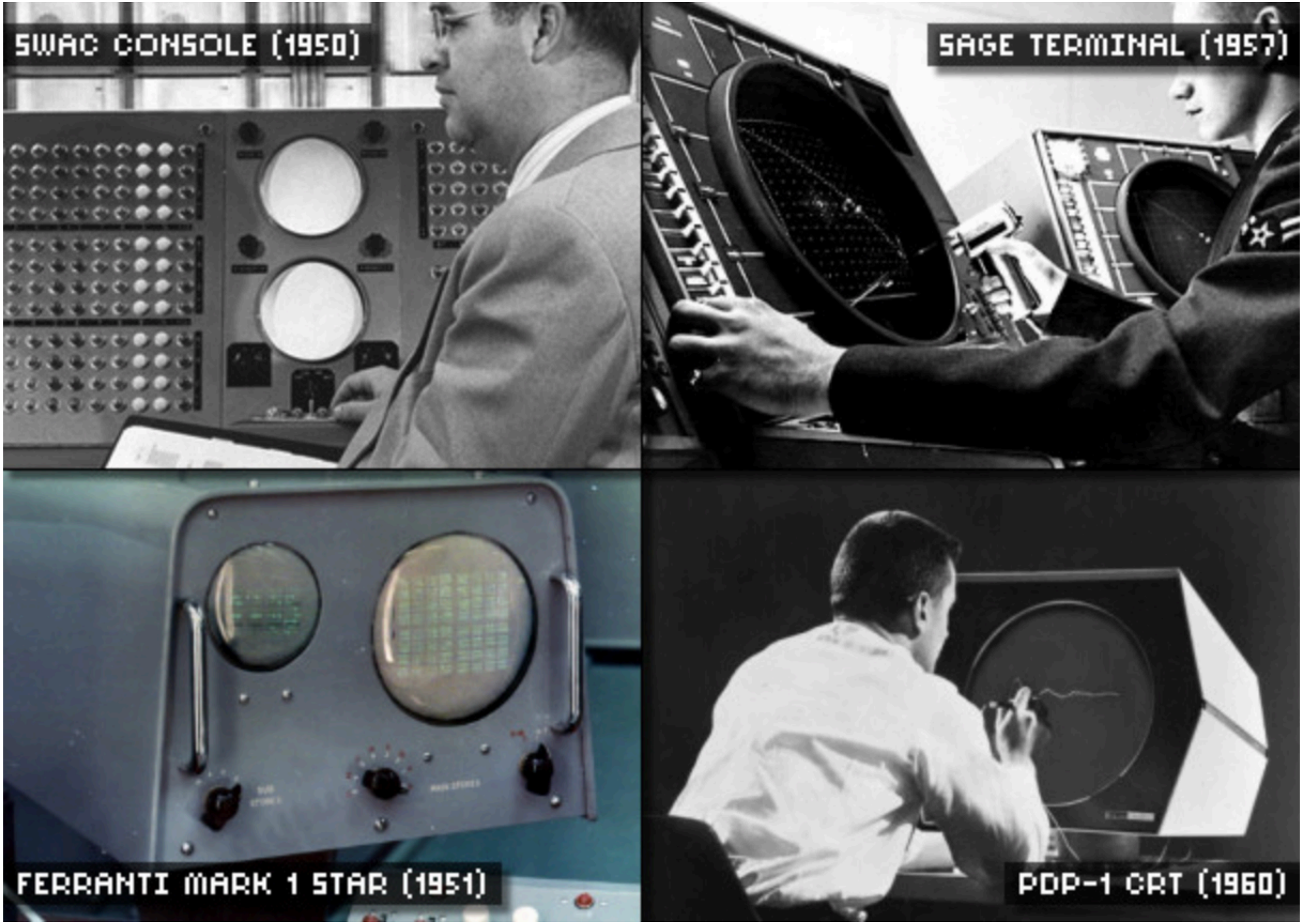


Early computer (ENIAC), 1945



punch card (~120 bytes)

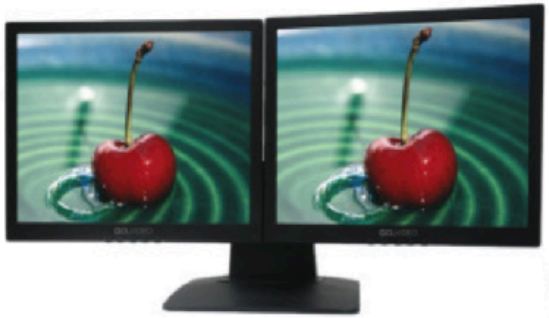
Visual Display

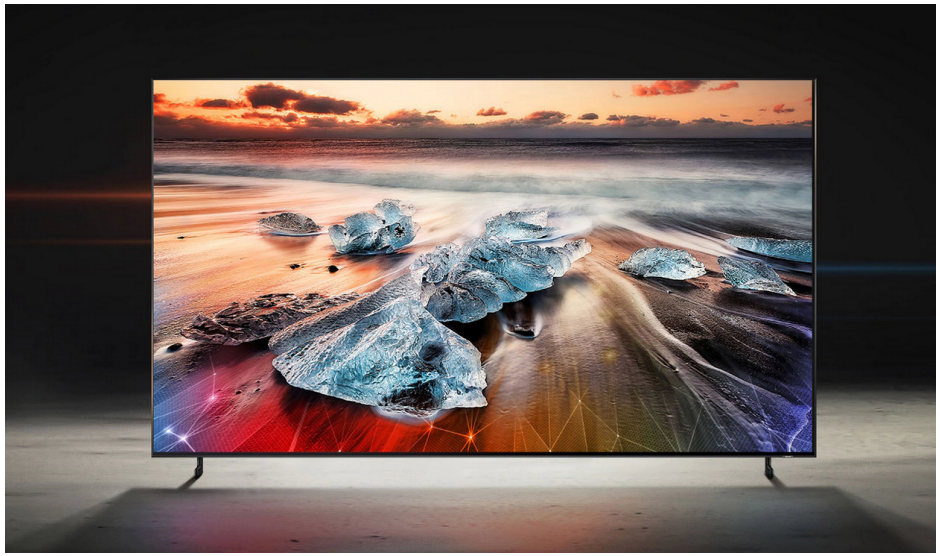


Sketchpad (Ivan Sutherland, 1963)

MACINTOSH (1984)

APPLECOLOR HIGH-RESOLUTION RGB AND MACINTOSH II (1987)

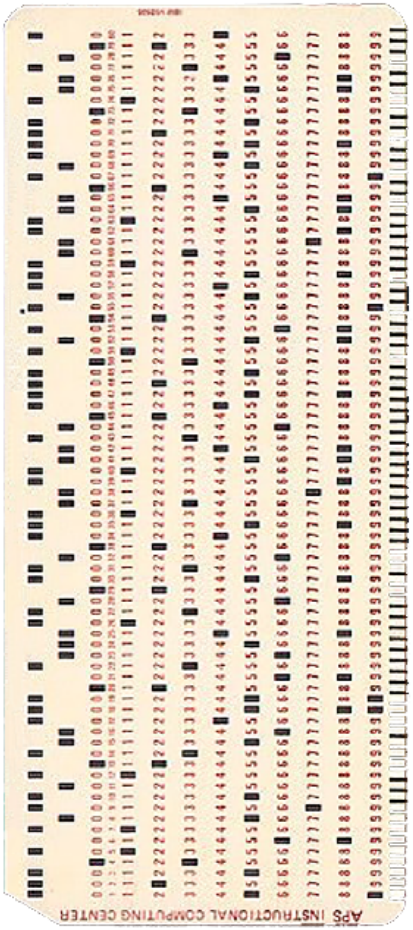




Virtual and Augmented Reality

What is Computer Graphics?

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



digital information

computation

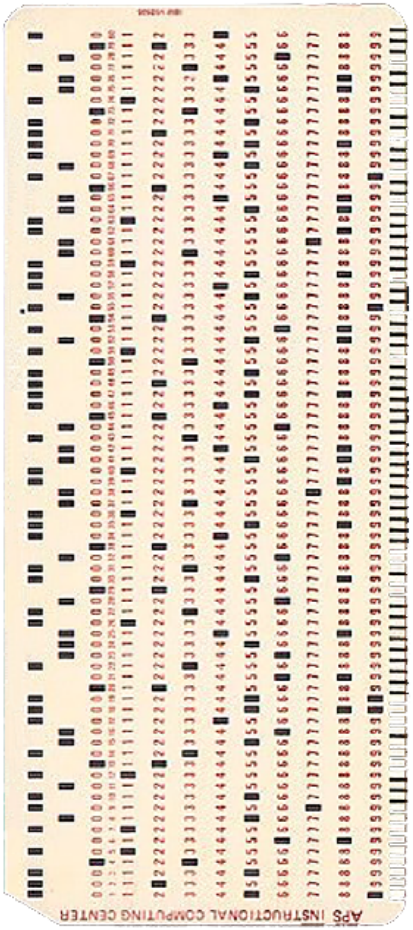
visual information

What is Computer Graphics?

com•put•er graph•ics /kəmˈpy

The use of computers to synthesize visual information.

Why only visual?



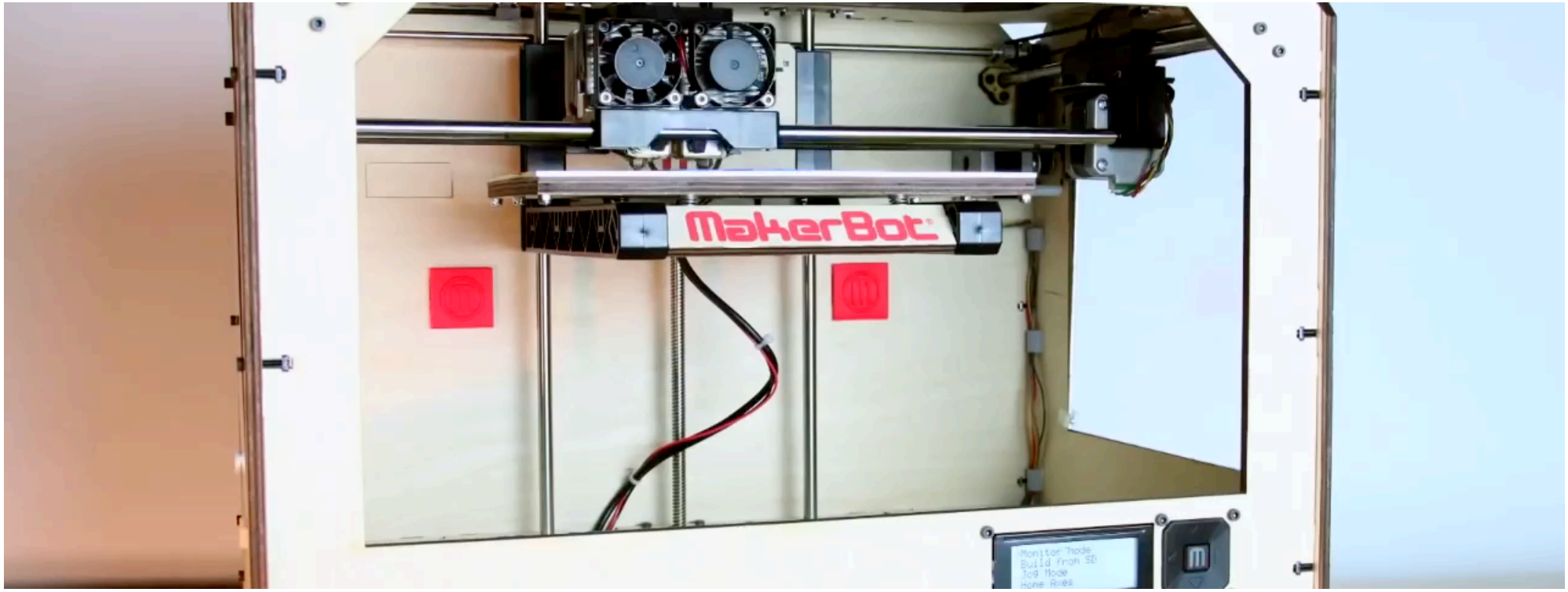
digital information

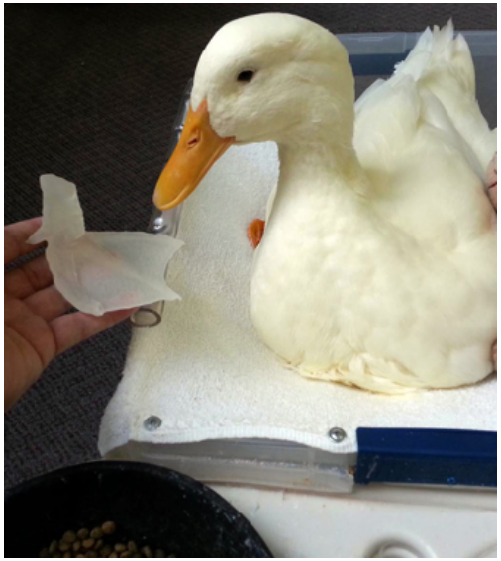
computation

visual information

Graphics has evolved a lot since its early days...
no longer just about turning on pixels!

Turning digital information into physical matter





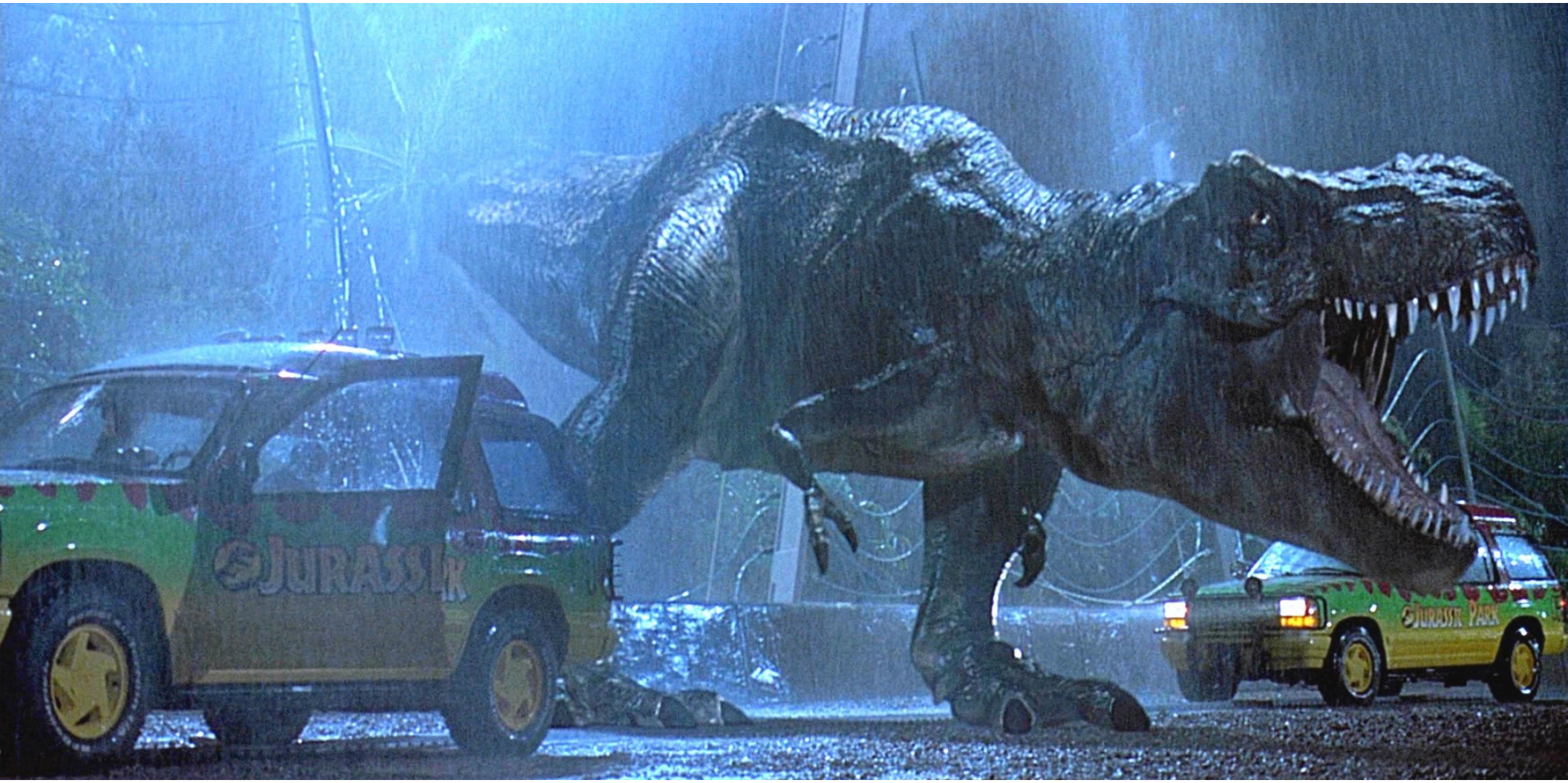
Computer Graphics is everywhere!

What is Computer Graphics?

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

Why Study Computer Graphics?

Movies



Jurassic Park (1993)

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

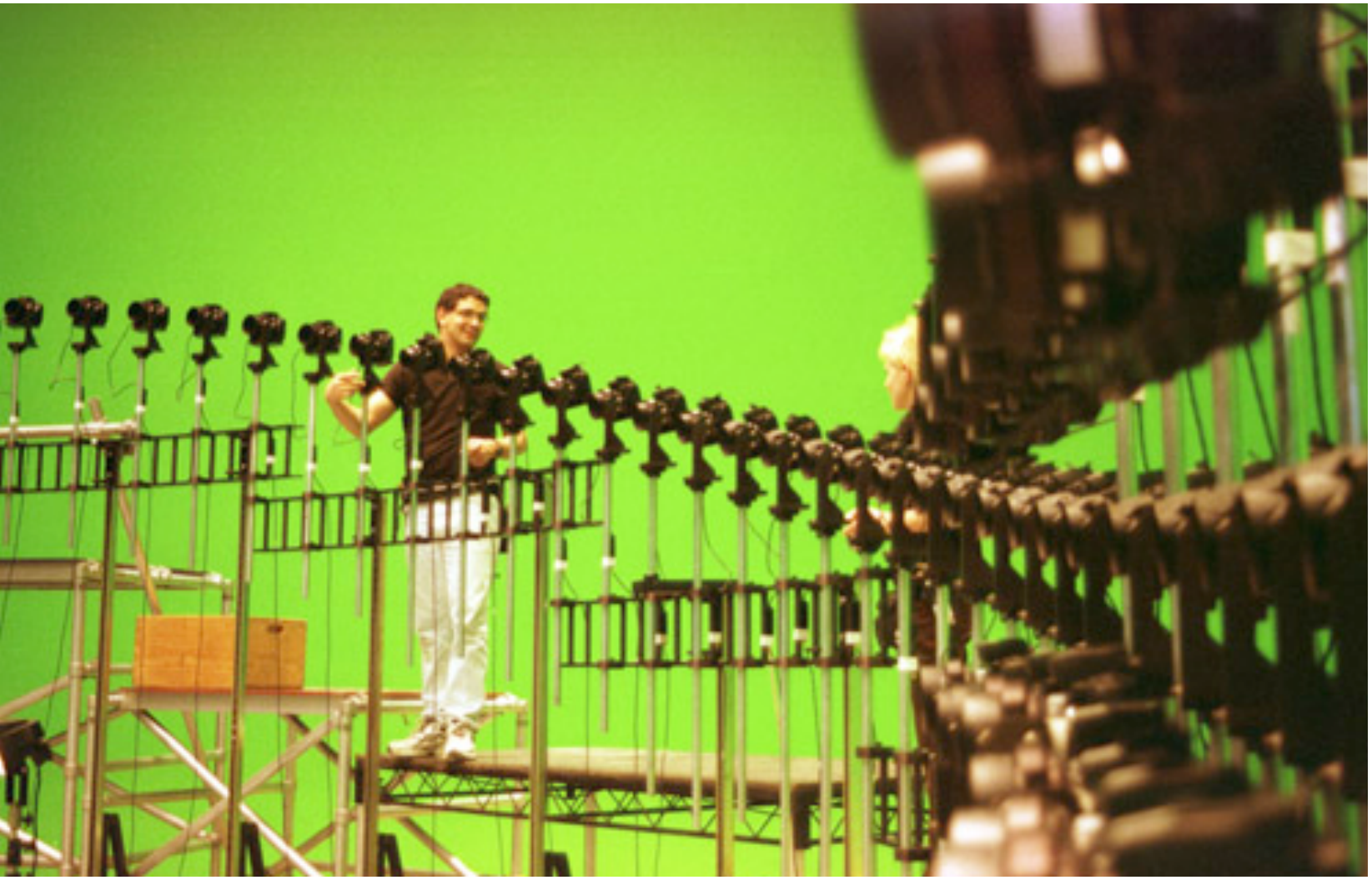
Movies

（特效：子弹头时间）

The Matrix (1999)

Movies

（子弹头时间拍摄方法）



The Matrix (1999)

（动画：人脸运动捕捉）

Avatar (2009)

Movies

（动画：肢体和人脸运动捕捉）

Andy Serkis in The Two Towers

Movies

（动画：毛发细节建模）

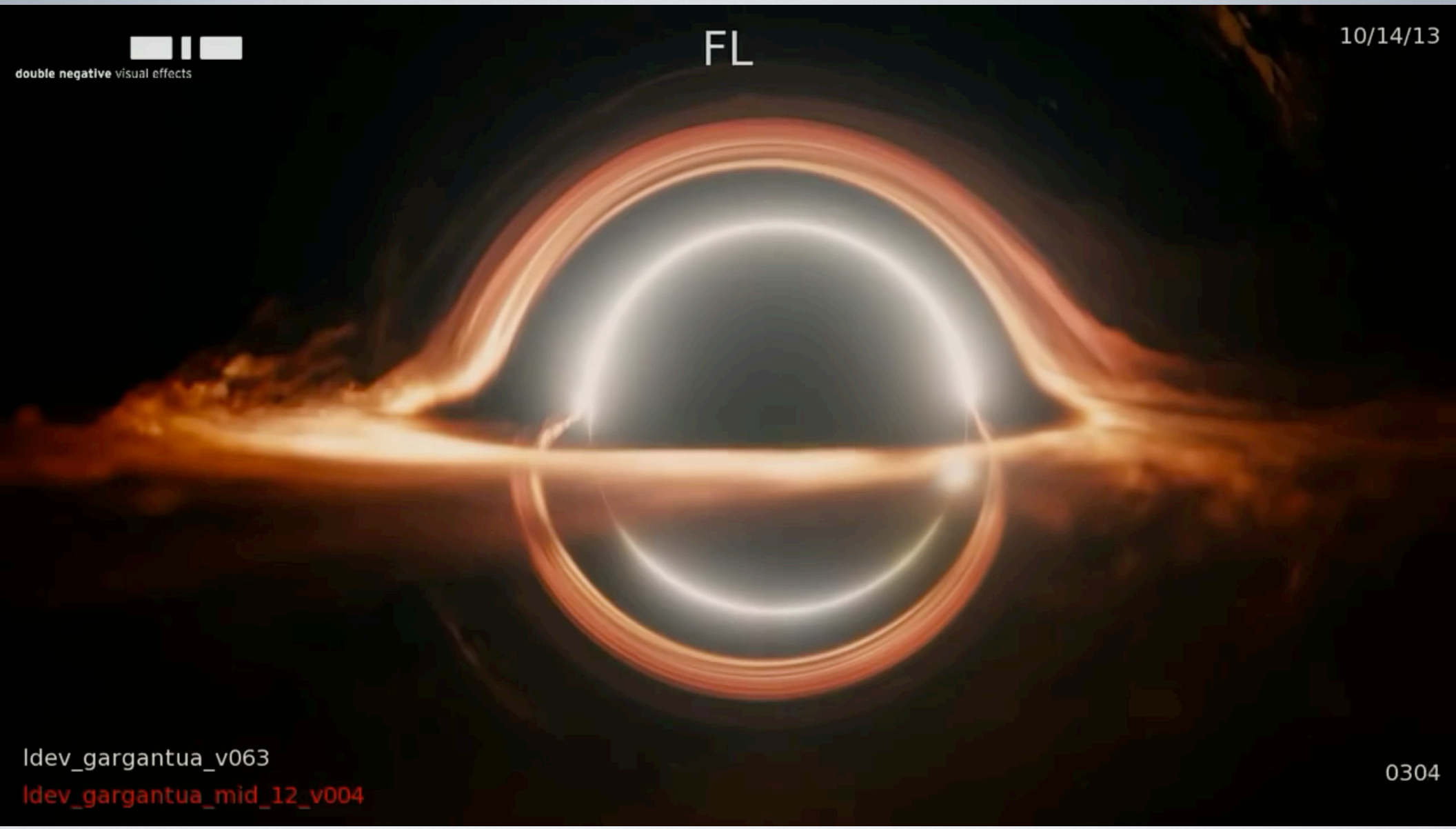
Zootopia (2016)

Movies

（仿真：气流物理模拟）

Frozen 2 (2019)

（可视化：黑洞形状）

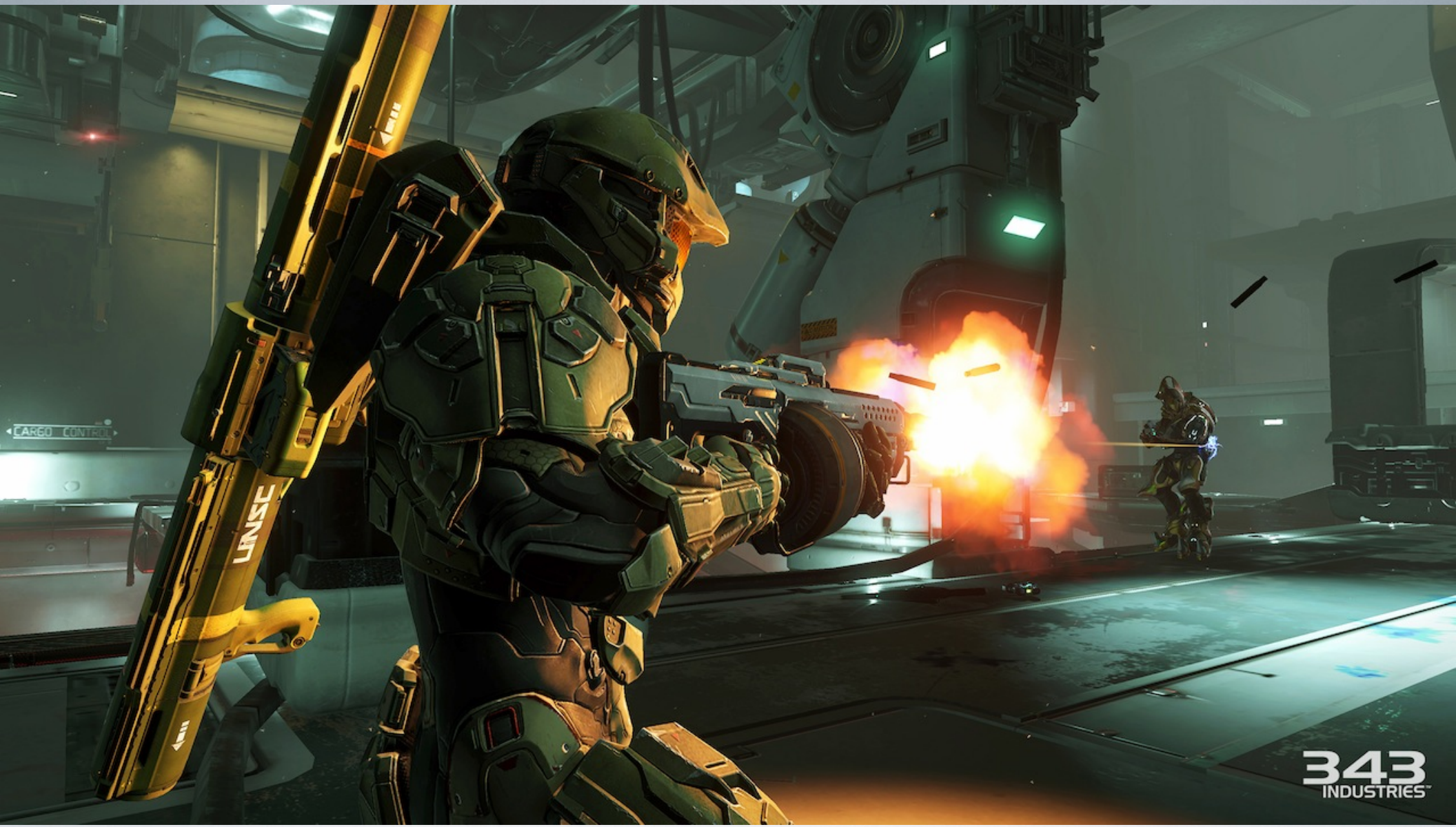


Interstellar (2014)

（可视化：真实黑洞形状）

Event Horizon Telescope collaboration et al.

Games （游戏：建模）



Halo 5 (2015)

Battlefield 5 (2018)

（游戏：大尺度场景）

Red Dead Redemption 2, Rockstar, 2019

Training Simulations

From America's Army

From CAE Inc.

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

Product Design and Visualization

Ikea - 75% of catalog is rendered imagery

Product Design and Visualization

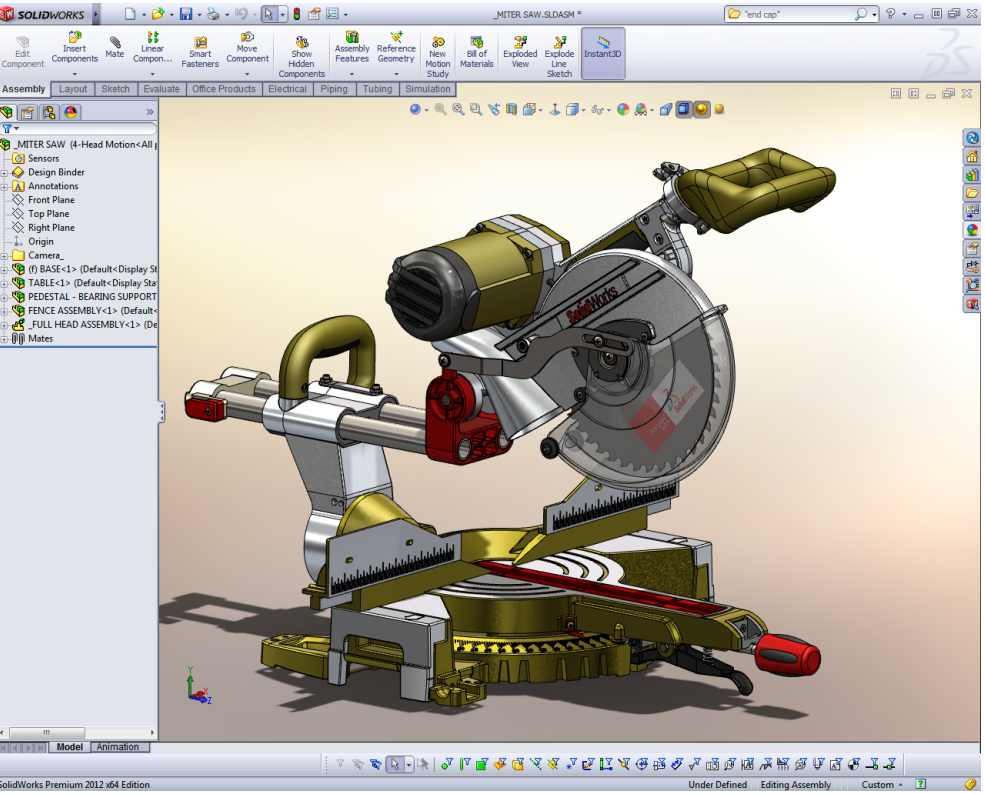
Photograph

Simulation

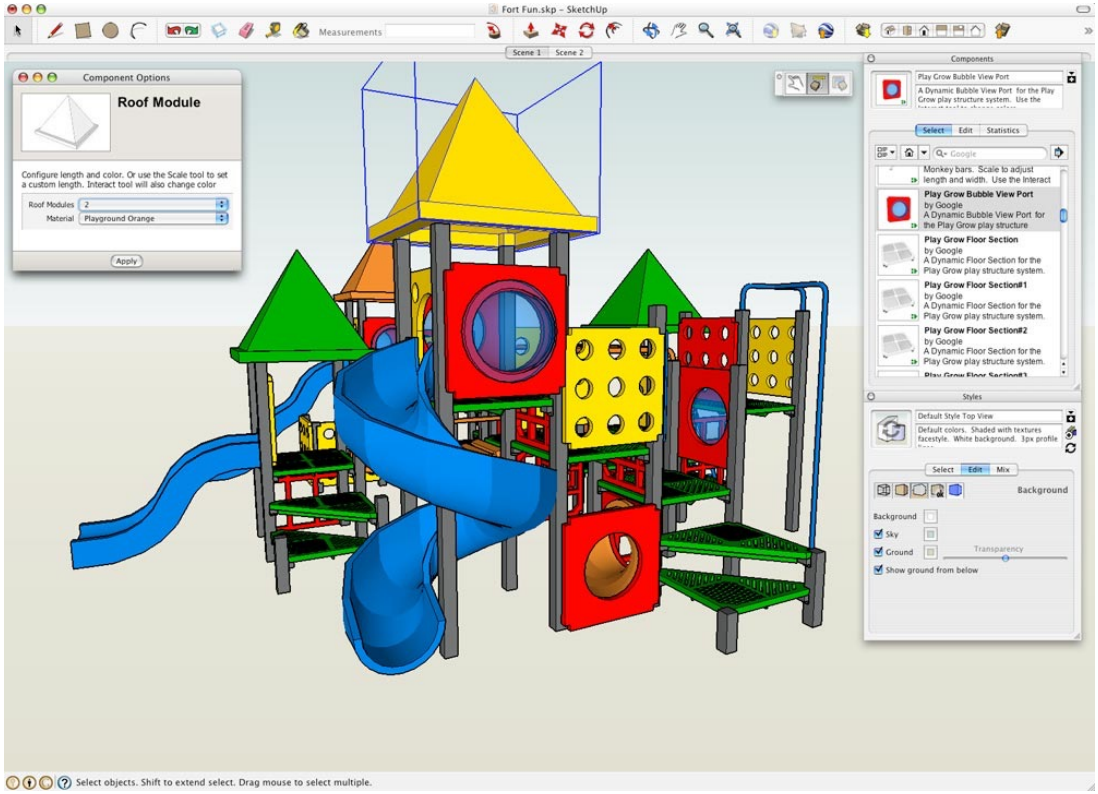
Product Design and Visualization

Tesla Model X concept (2012)

Computer-Aided Design



SolidWorks



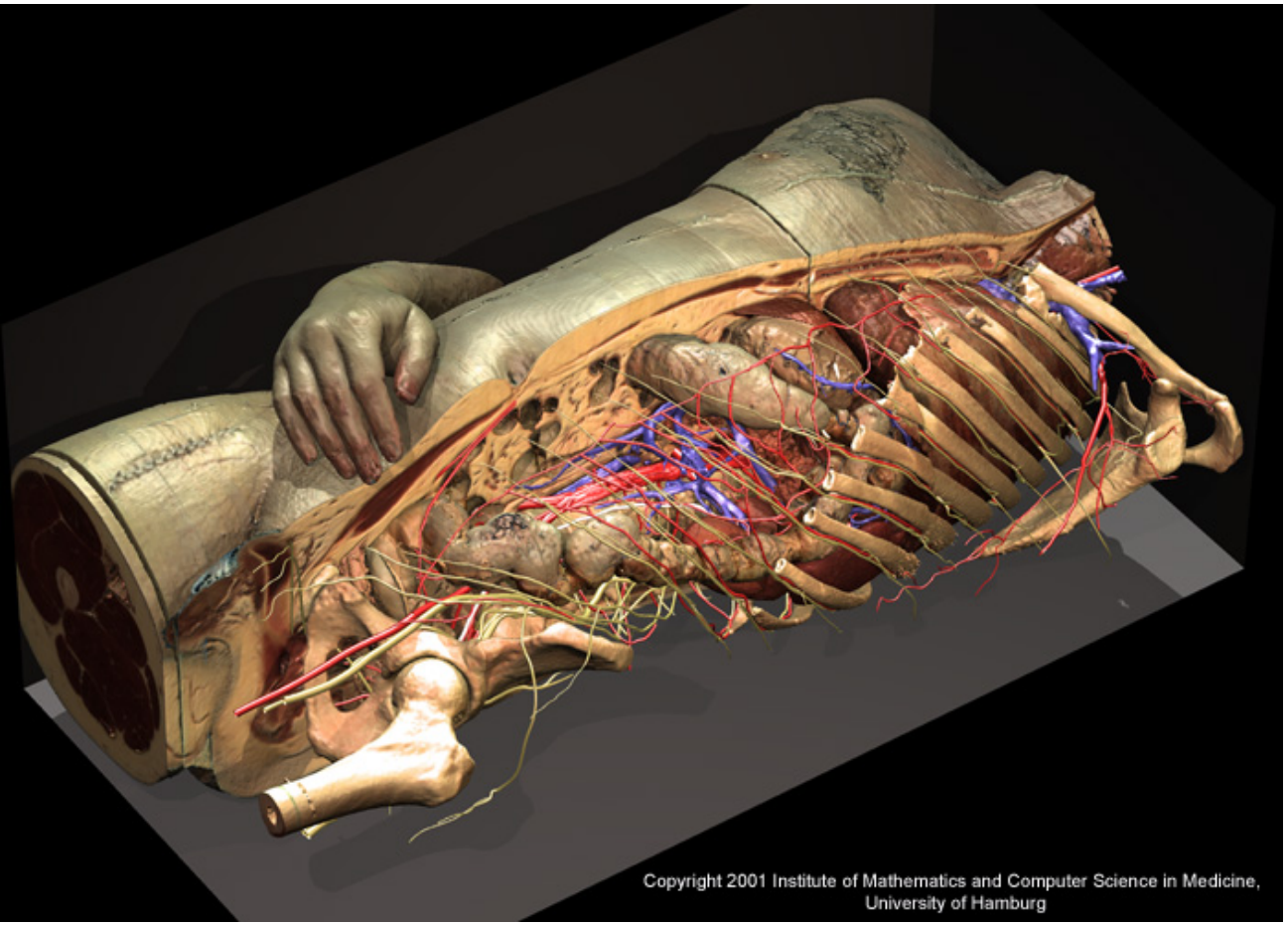
SketchUp

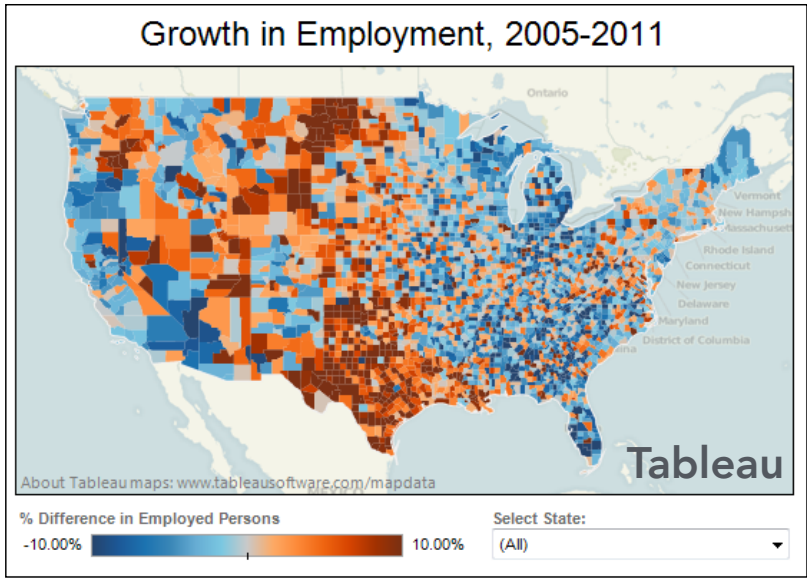
For mechanical, architectural, electronic, optical, …

Architectural Design

Heydar Aliyev Center, Zaha Hadid Architects

Visualization



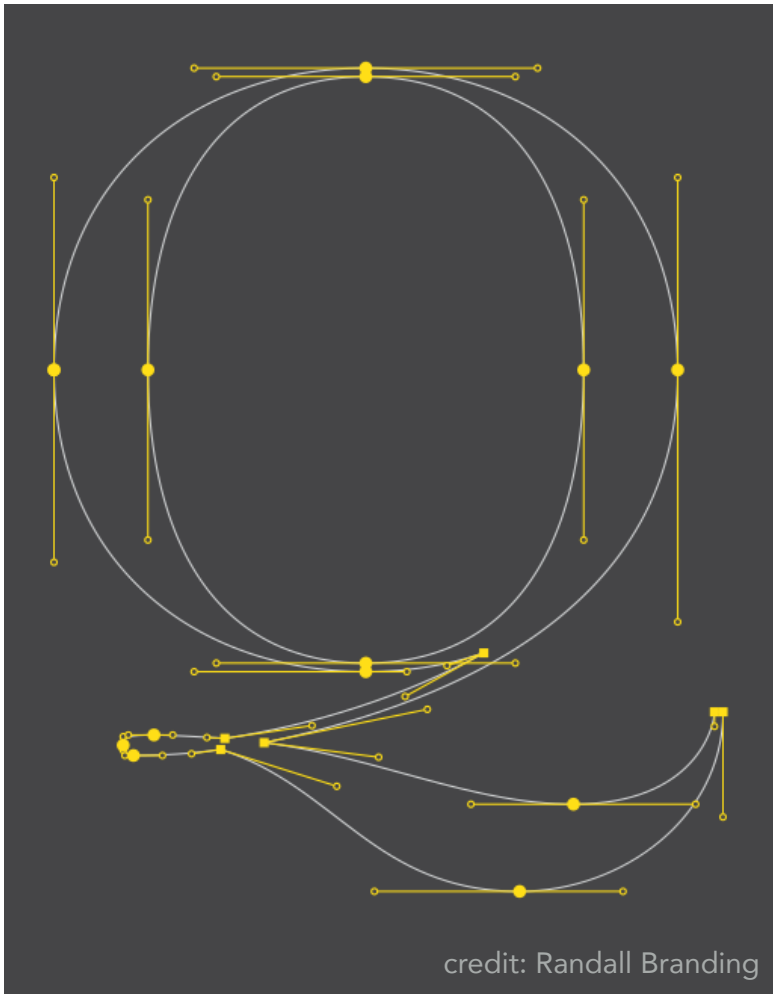


Science, engineering, medicine, journalism, ...

Typography

The Quick Brown Fox Jumps Over The Lazy Dog

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789



Baskerville

Graphical User Interfaces

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

Foundations of Graphics

These applications require sophisticated theory and systems

- Theory
  - basic representations (how do you digitally encode shape, motion?)
  - sampling & aliasing (how do you acquire & reproduce a signal?)
  - numerical methods (how do you manipulate signals numerically?)
  - radiometry & light transport (how does light behave?)
  - perception (how does this all relate to humans?)
- System
  - parallel, heterogeneous processing
  - graphics-specific programming languages

Today's Topics

What is Computer Graphics?

Why Study Computer Graphics?

Course Overview

Logistics

Activity: modeling and drawing a cube

- Goal: generate a realistic drawing of a cube
- Key questions:
  - Modeling: how do we describe the cube?
  - Rendering: how do we then visualize this model?

Activity: modeling the cube

- **Suppose our cube is...**
  - **centered at the origin (0,0,0)**
  - **has dimensions 2x2x2**
  - **edges are aligned with x/y/z axes**
- **QUESTION: What are the coordinates of the cube vertices?**

```
A:(1,1,1)        E:(1,1,-1)
B:(-1,1,1)       F:(-1,1,-1)
C:(1,-1,1)       G:(1,-1,-1)
D:(-1,-1, 1 )    H: (-1,-1,-1 )
```

- **QUESTION: What about the edges?**

```
AB, CD, EF, GH,
AC, BD, EG, FH,
AE, CG, BF, DH
```

Activity: modeling the cube

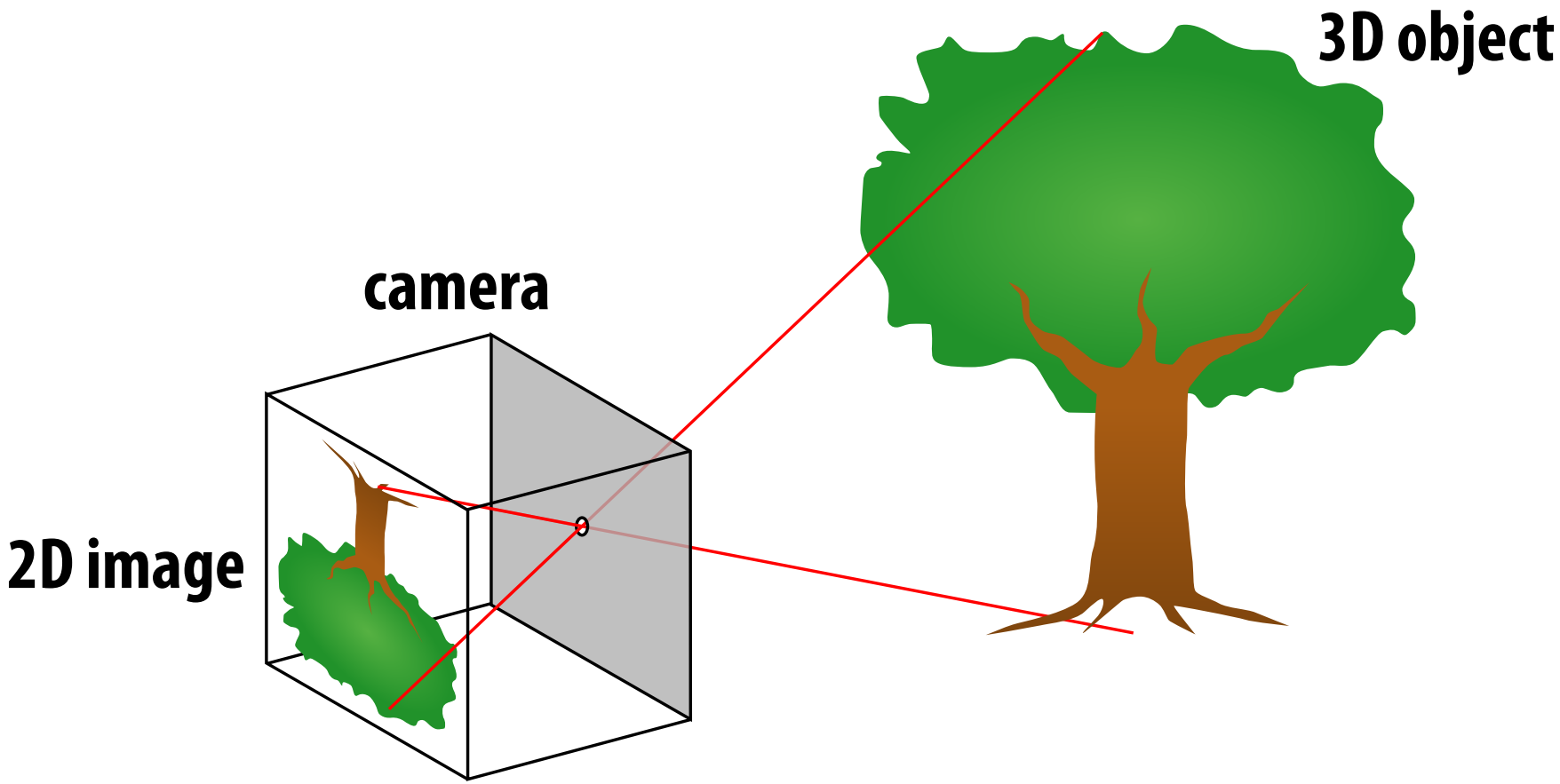
- **Now have a digital description of the cube:**

VERTICES		EDGES
A:(1,1,1)	E:(1,1,-1)	
B:(-1,1,1)	F:(-1,1,-1)	AB,CD,EF,GH,
C:(1,-1,1)	G:(1,-1,-1)	AC,BD,EG,FH,
D:(-1,-1, 1)	H: (-1,-1,-1)	AE,CG,BF,DH

- **How do we draw this 3D cube as a 2D (flat) image?**
- **Basic strategy:**
  1. **map 3D vertices to 2D points in the image**
  2. **connect 2D points with straight lines**

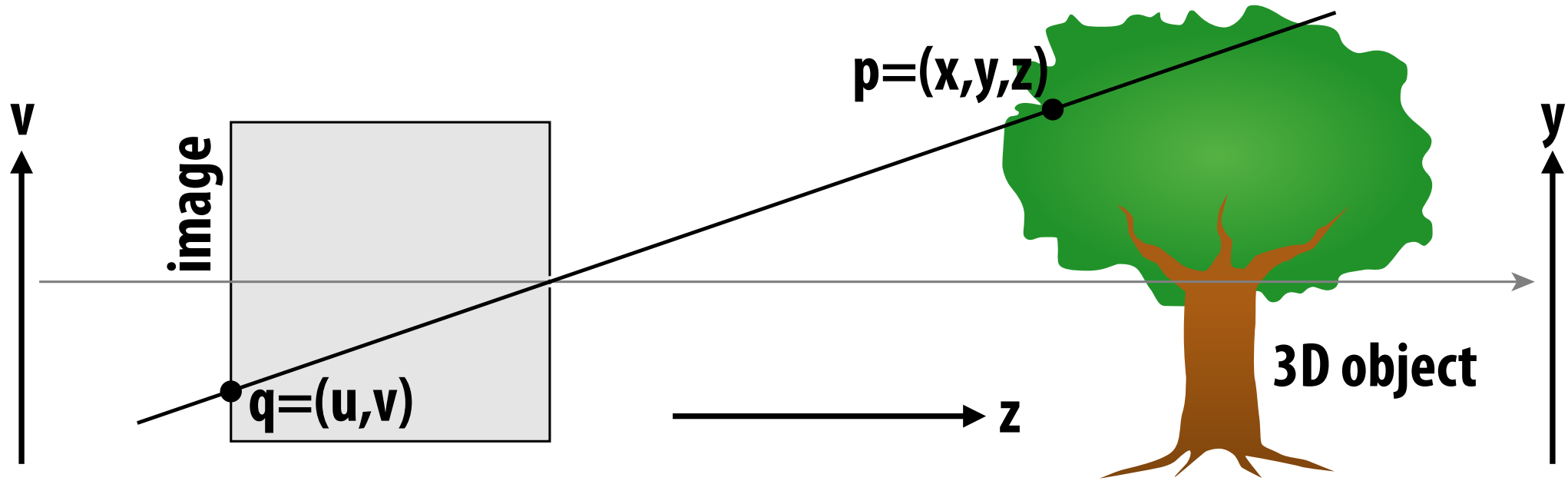
Perspective Projection

- Objects look smaller as they get further away ("perspective")
- Why does this happen?
- Consider simple ("pinhole") model of a camera:



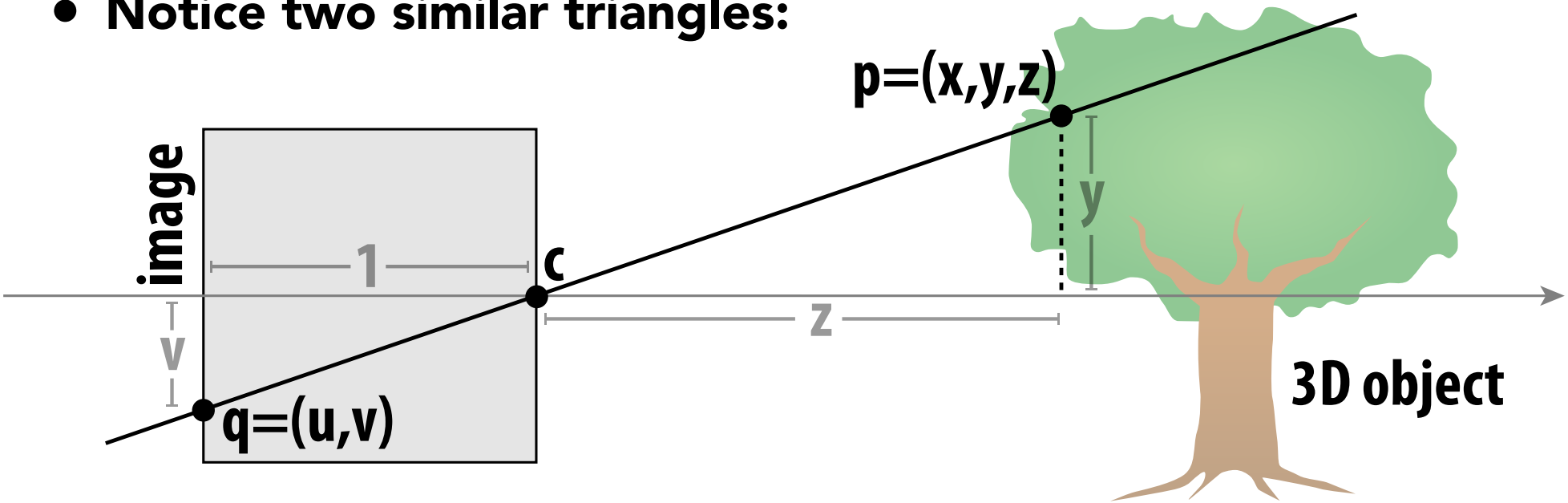
Perspective Projection: side view

- Where exactly does a point p = (x,y,z) end up on the image?
- Let's call the image point q=(u,v)



Perspective Projection: side view

- Where exactly does a point p = (x,y,z) end up on the image?
- Let's call the image point q=(u,v)
- Notice two similar triangles:



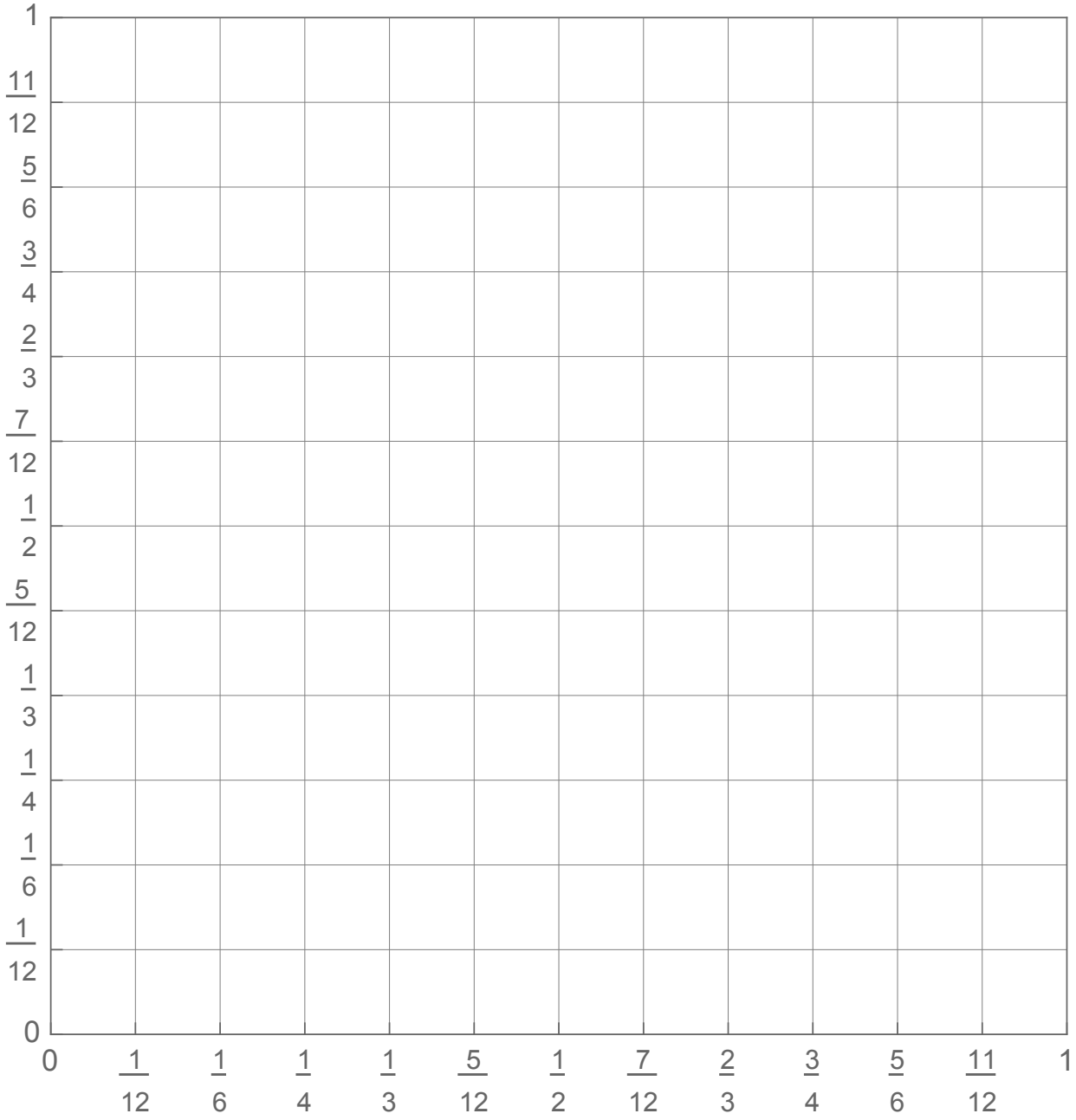
- Assume camera has unit size, origin is at pinhole c
- Then v/1 = y/z, i.e., vertical coordinate is just the slope y/z
- Likewise, horizontal coordinate is u=x/z

Activity: now draw it!

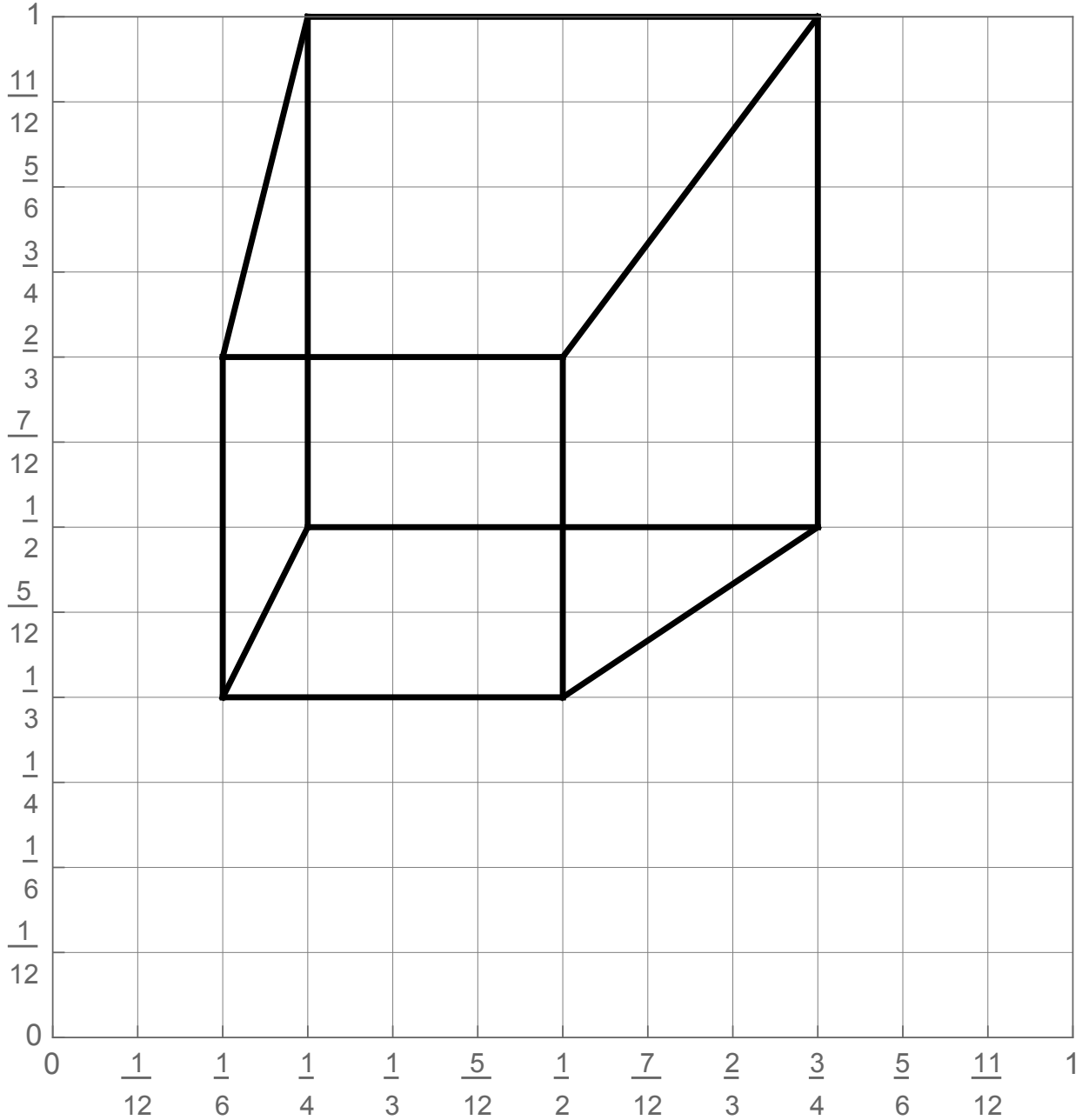
- Need 12 volunteers
  - each person will draw one cube edge
  - assume camera is at c=(2,3,5)
  - convert (X,Y,Z) of both endpoints to (u,v):
    1. subtract camera c from vertex (X,Y,Z) to get (x,y,z)
    2. divide (x,y) by z to get (u,v)—write as a fraction
  - draw line between (u1,v1) and (u2,v2)

VERTICES		EDGES
A:(1,1,1)	E:(1,1,-1)	
B:(-1,1,1)	F:(-1,1,-1)	AB,CD,EF,GH,
C:(1,-1,1)	G:(1,-1,-1)	AC,BD,EG,FH,
D:(-1,-1, 1)	H: (-1,-1,-1)	AE,CG,BF,DH

Activity: output on a graph paper



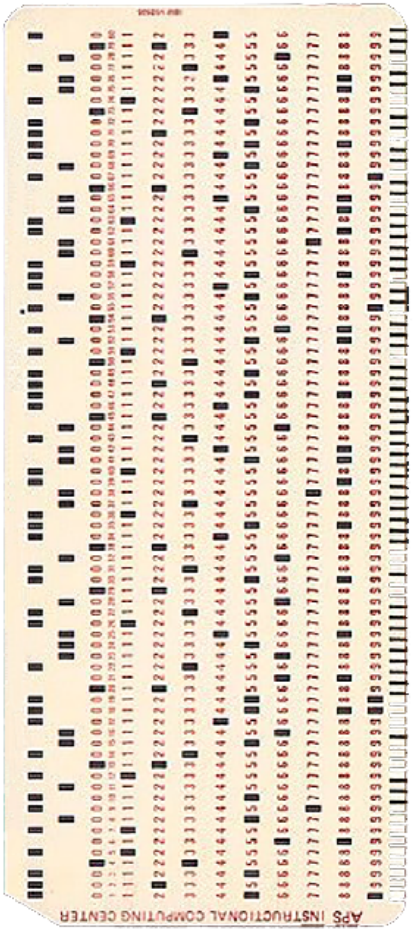
Activity: how did we do?



2D coordinates:

A: 1/4, 1/2
B: 3/4, 1/2
C: 1/4, 1
D: 3/4, 1
E: 1/6, 1/3
F: 1/2, 1/3
G: 1/6, 2/3
H: 1/2, 2/3

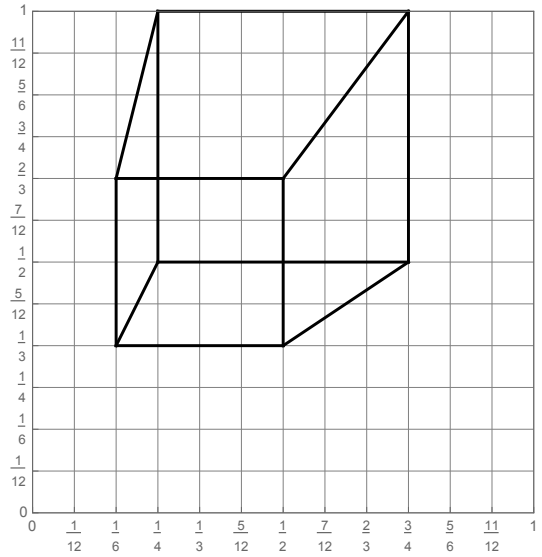
Success! We turned purely digital information into purely visual information, using a completely algorithmic procedure.



digital information

computation

visual information

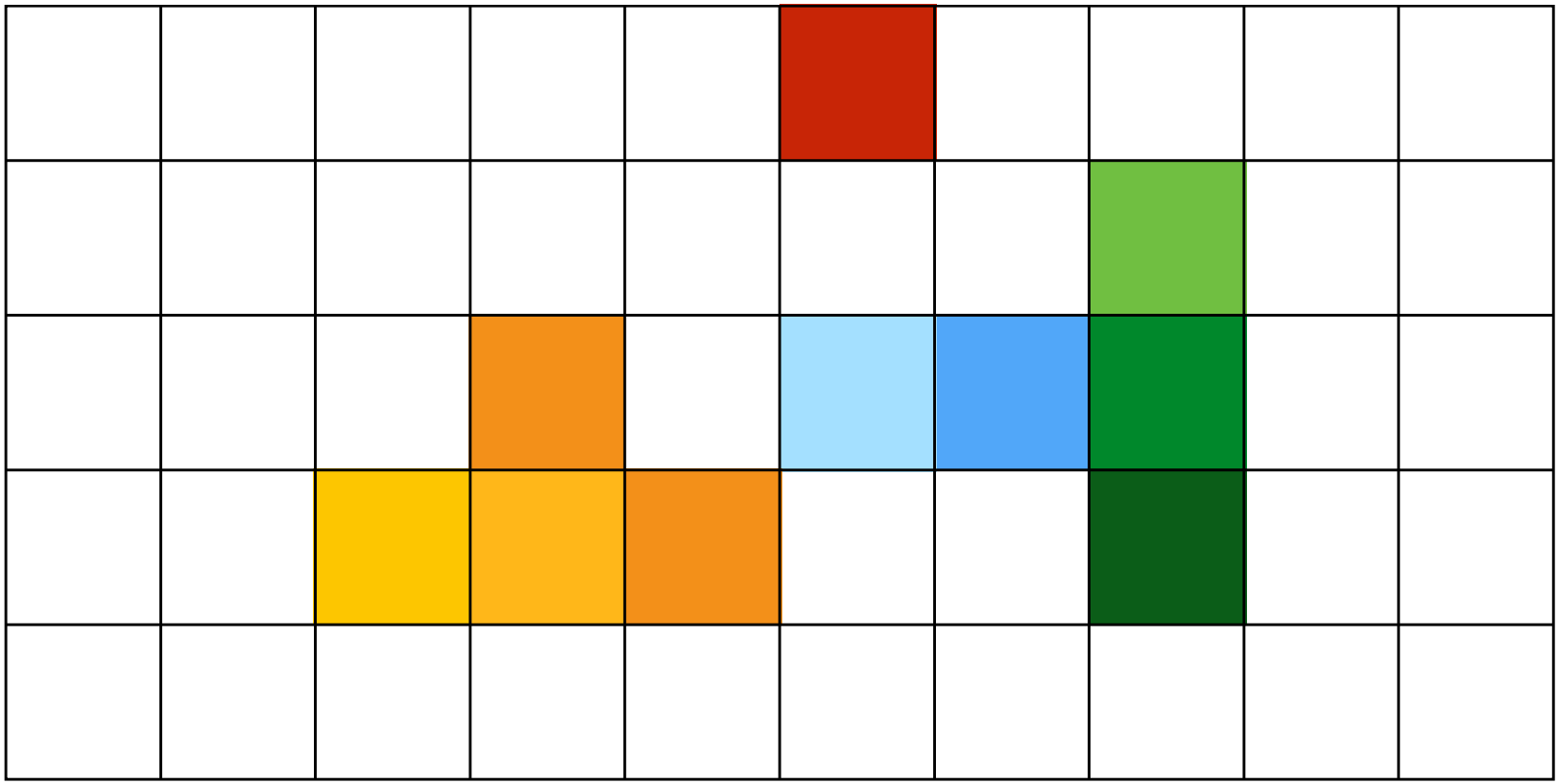


Not finished yet!
how do we draw lines on a computer?

Close up photo of pixels on a modern display

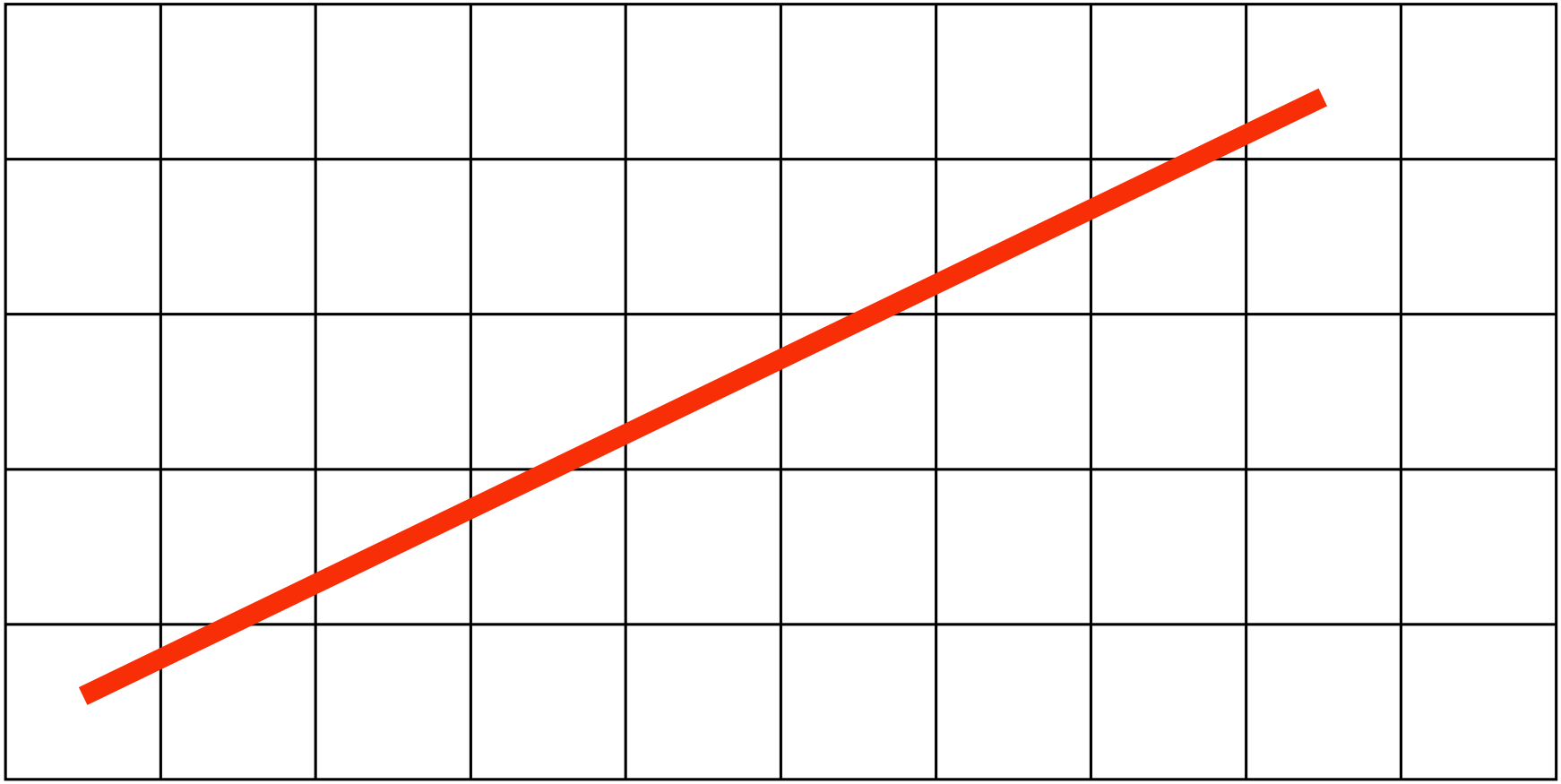
Output for a raster display

- **Common abstraction of a raster display:**
  - **Image represented as a 2D grid of "pixels" (picture elements)**
    Each pixel can take on a unique color value



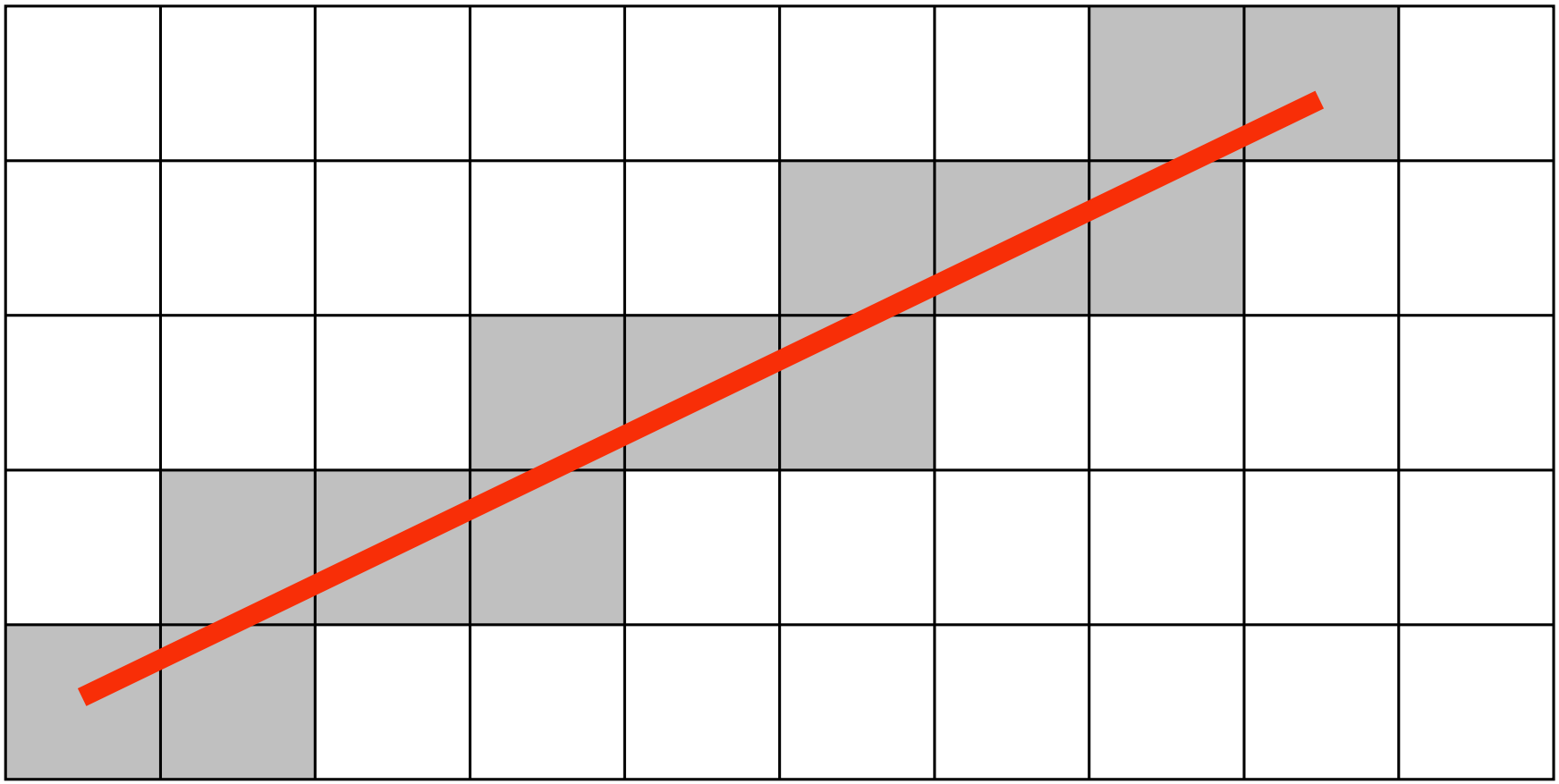
What pixels should we color in to depict a line?

"Rasterization": process of converting a continuous object to a discrete representation on a raster grid (pixel grid)

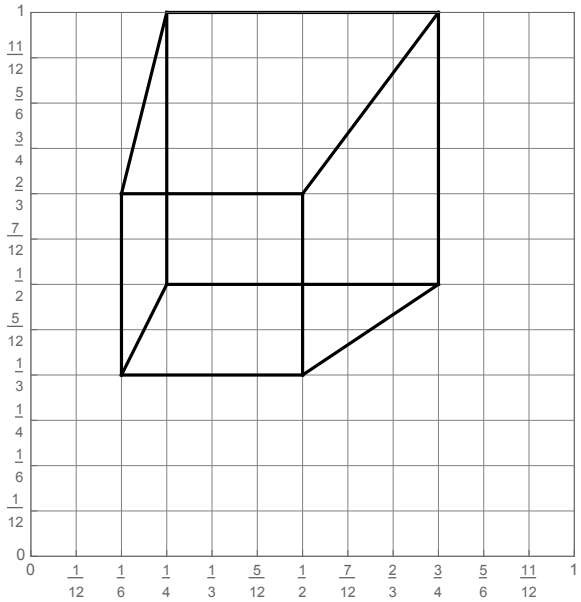


What pixels should we color in to depict a line?

Light up all pixels intersected by the line?



Activity: modeling and drawing a cube



2D coordinates:

A: 1/4, 1/2
B: 3/4, 1/2
C: 1/4, 1
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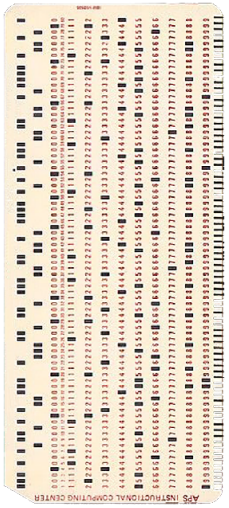


digital information

computation

visual information

We just rendered a simple line drawing of a cube.

But for more realistic pictures, we need a much richer model of the world:

Geometry

Materials

Lights

Cameras

Motions

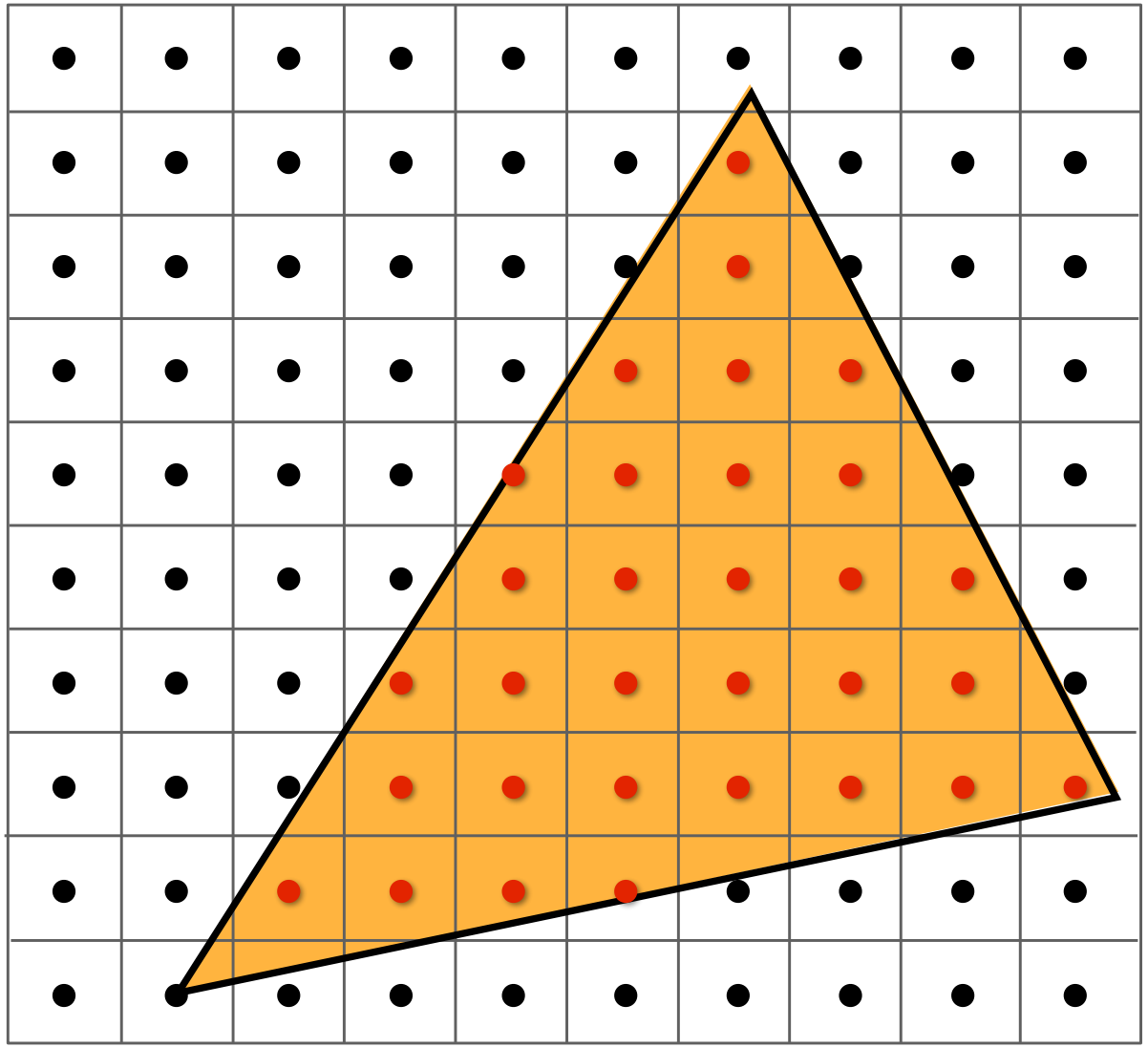
...

Will see all of this as our course progresses.

Course Topics

1. Drawing Digital Images (Rasterization) （图形显示成图像）
2. Filtering and Sampling （图形到图像转变的滤波和采样）
3. Modeling Geometry （三维对象的图形建模）
4. Modeling Material Properties （三维对象的材质属性）
5. Modeling Lighting （光照建模）
6. How Do Cameras Work? （相机模型和成像原理）
7. Animation and Physical Simulation （动画和物理模拟）
8. Virtual Reality （虚拟现实）

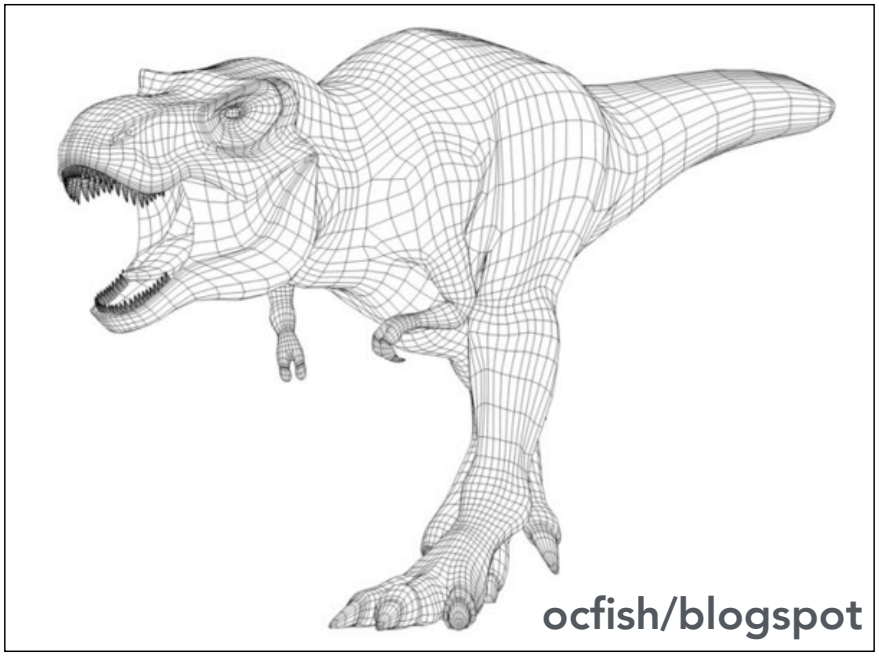
Drawing Digital Images (Rasterization)

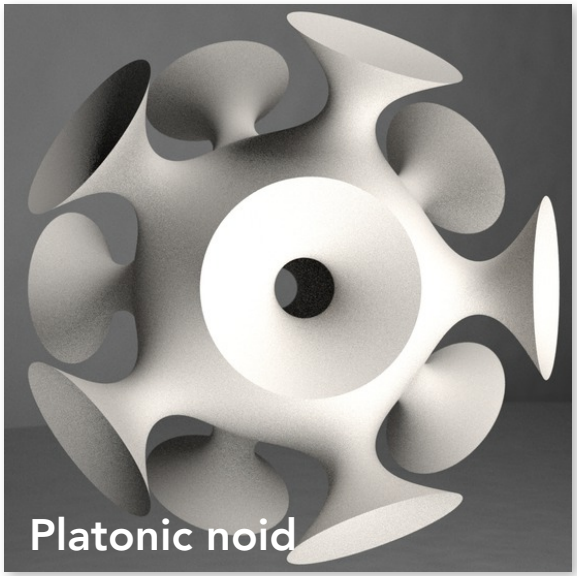


Filtering and Sampling

No Jaggies

Modeling Geometry





Modeling Material Properties

Modeling Lighting

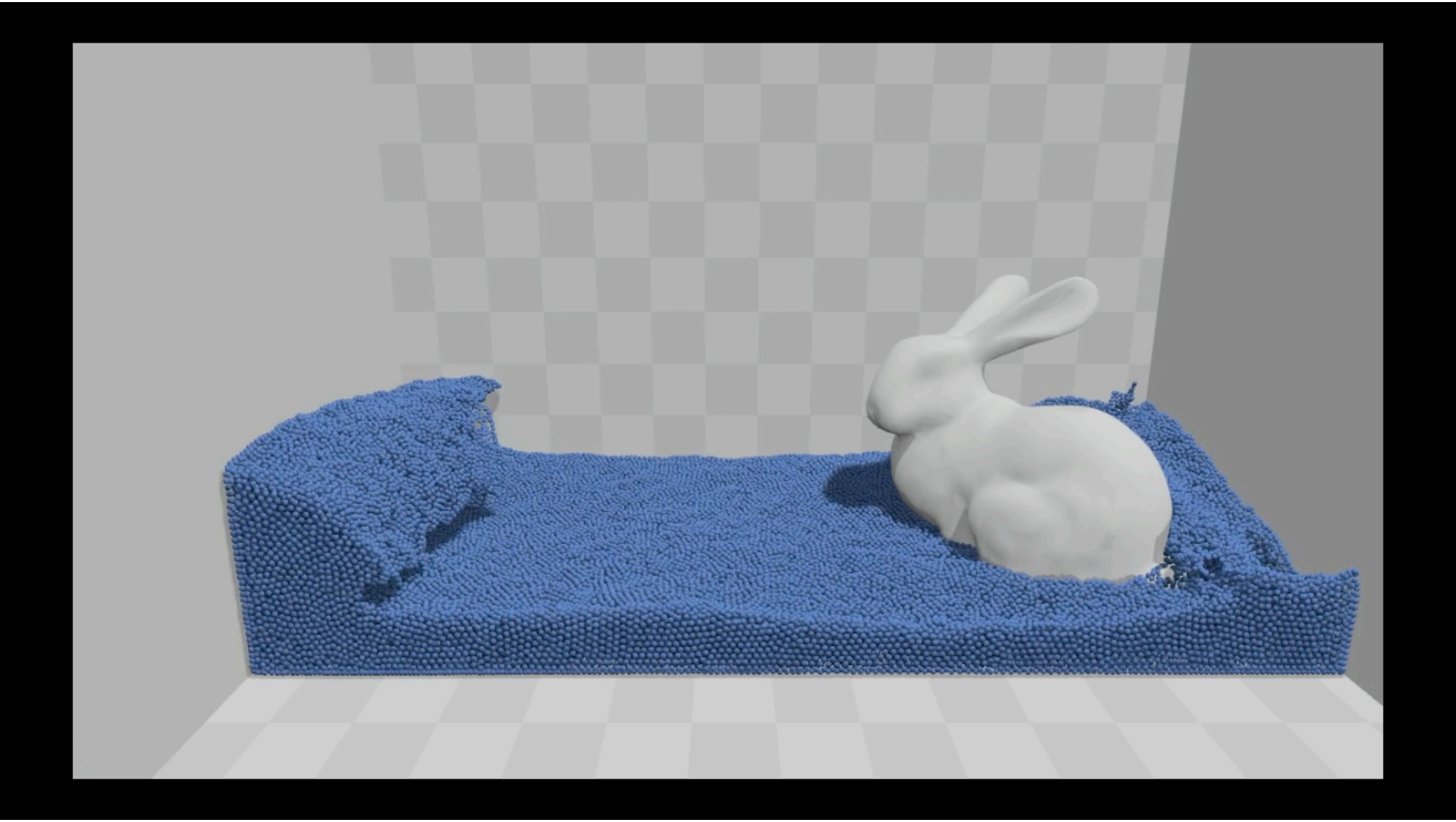
Light Transport and Image Synthesis

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

Course Goals

Overview of core ideas in graphics

- 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, …)

Today's Topics

What is Computer Graphics?

Why Study Computer Graphics?

Course Overview

Logistics

Prerequisites

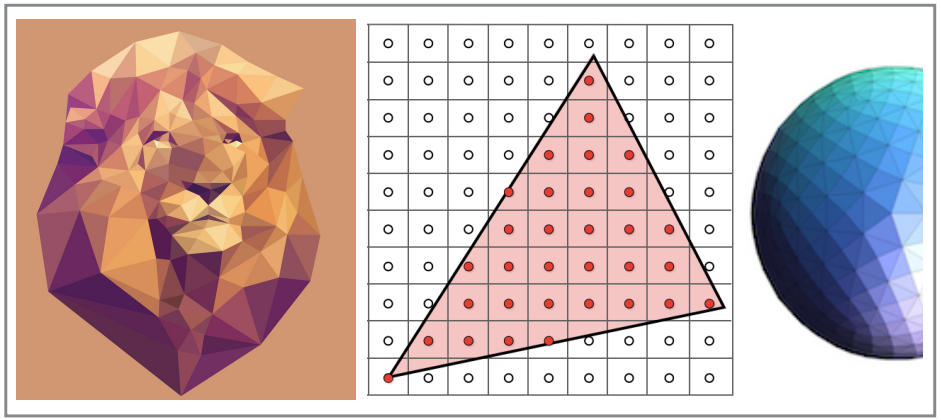
Math

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

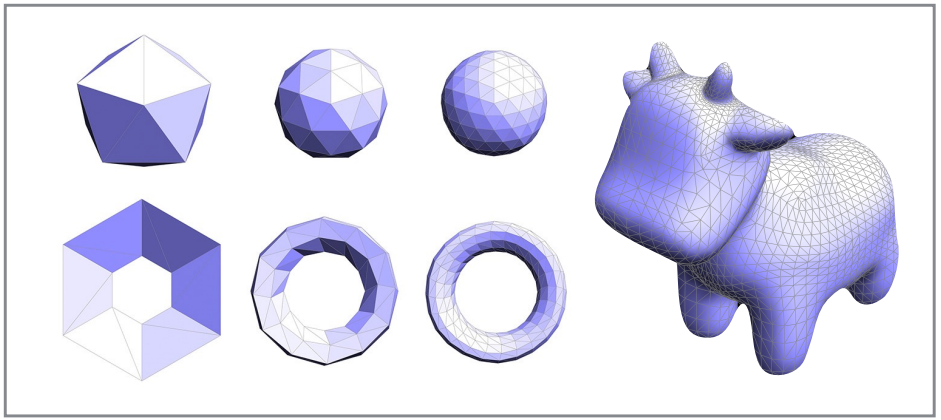
Programming

- Data structures
- Fluent with C and C++
- Fluent with development environment, debugging, etc.

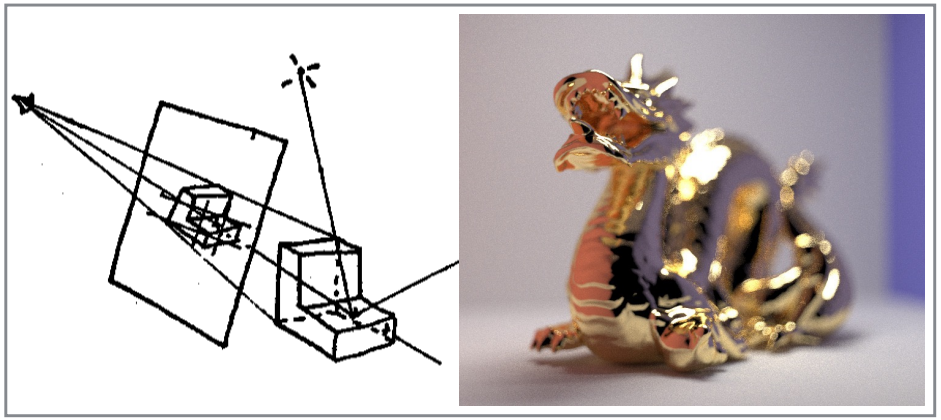
Course Assignments



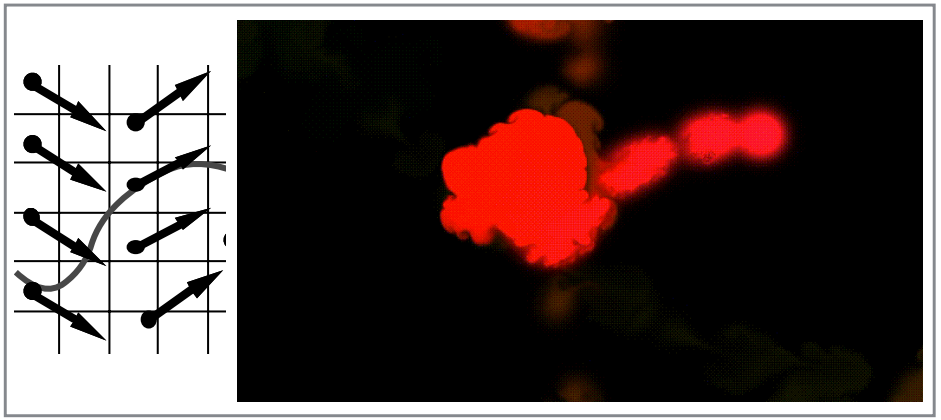
1. Digital Drawing (2 weeks)



2. Geometry (2 weeks)



3. Ray-Tracing (2 weeks)



4. Animation (2 weeks)

Course Deliverables and Assessment

Your course grade is out of 100 total points

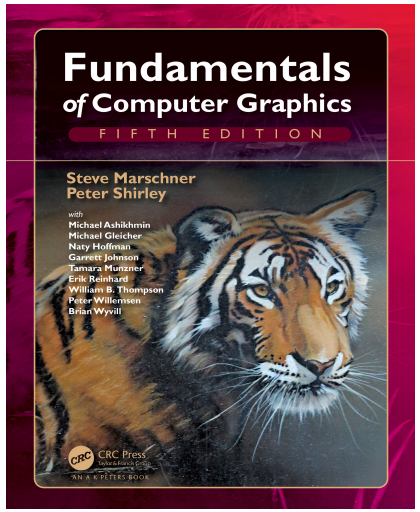
- **Four homework assignments, 10 points each**
- **Final exams, 50 points each**
- **Participation, 10 points**

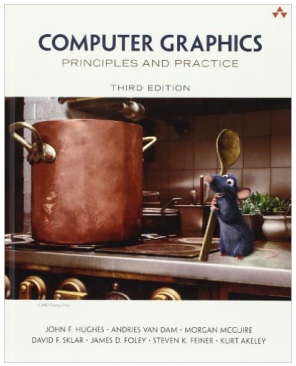
Resources

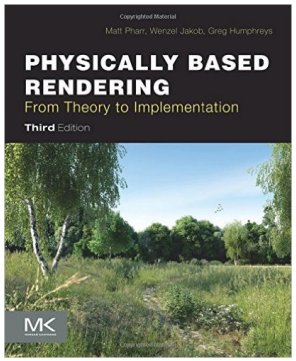
Lectures will be primary source

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







Acknowledgement

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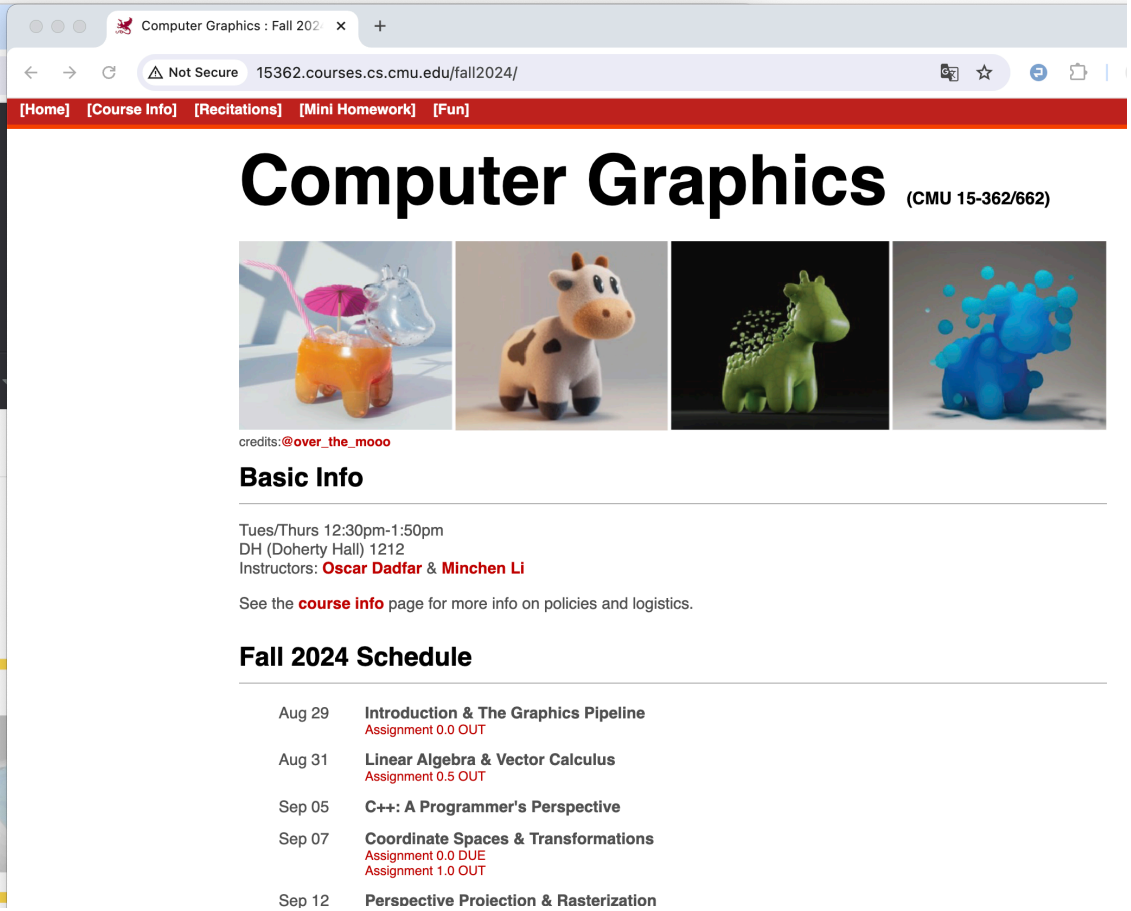

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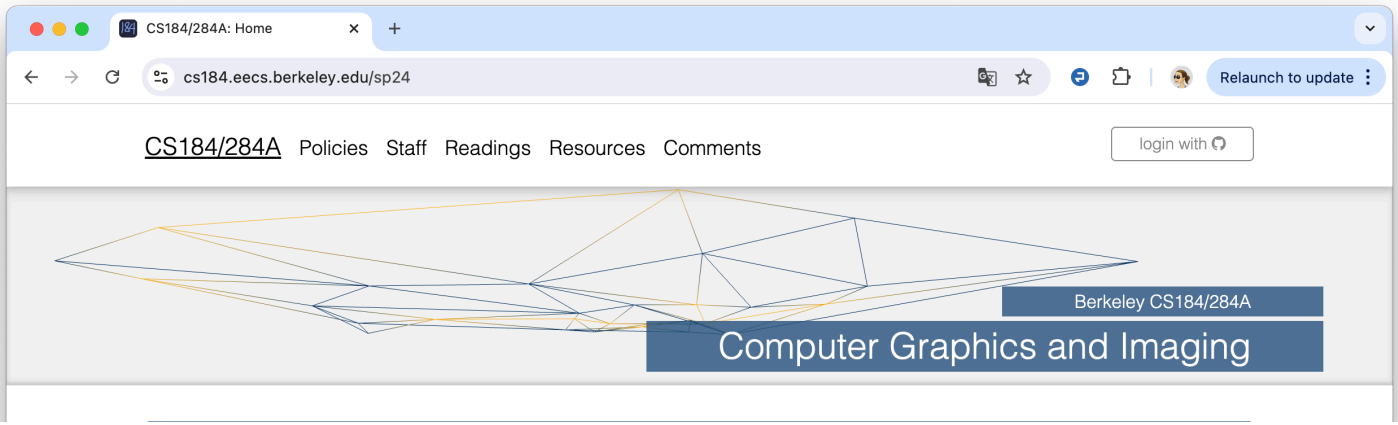
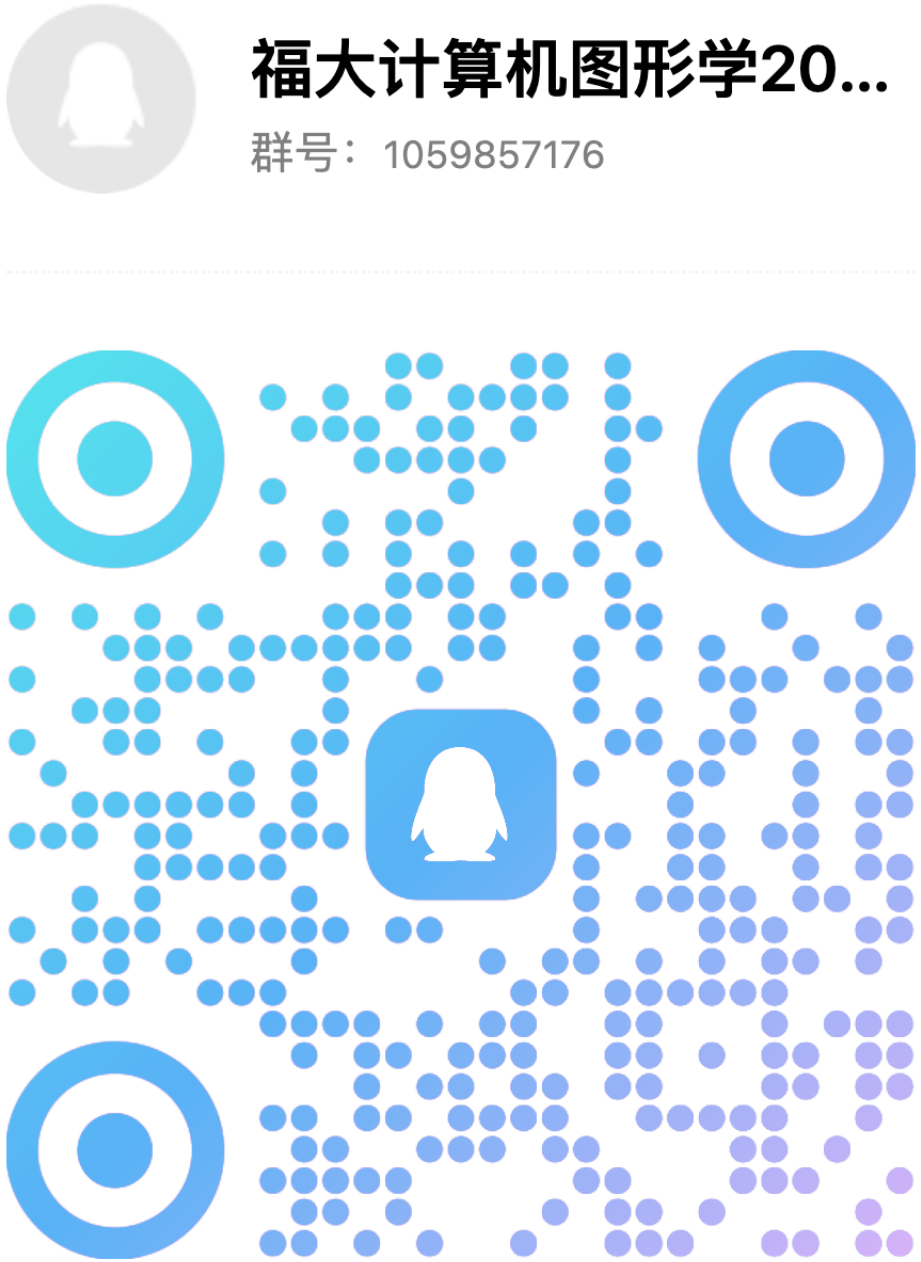


UCB CS184



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