

# CS 148: Introduction to Computer Graphics and Imaging

**Creative Expression (CE) WAYS course  
(only if taken for a Letter Grade)**

Ron Fedkiw

**cs148.stanford.edu**

Tuesday and Thursday

12:00 noon to 1:20 pm

(recorded via SCPD)

# Graphics is Pervasive

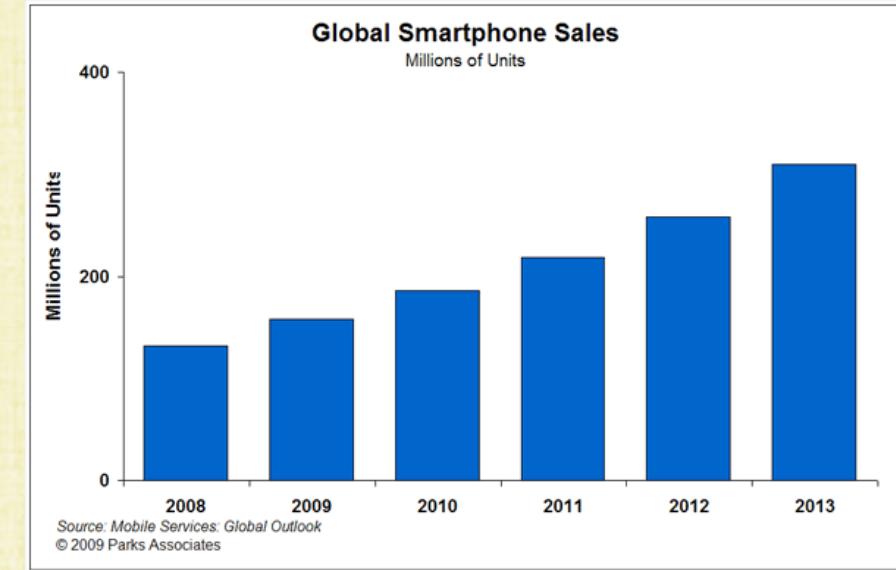
- Computer graphics is all around us!
- No one wants a boring \*text only\* interface when interacting with a computer, cell phone, DVD player, ATM, car, or thermostat
  - And even text is visualized via graphics-based fonts
- (Thus,) Learning at least a little bit about graphics is quite useful for all ~~computer scientists!~~

Everyone!

# What can I do with graphics?

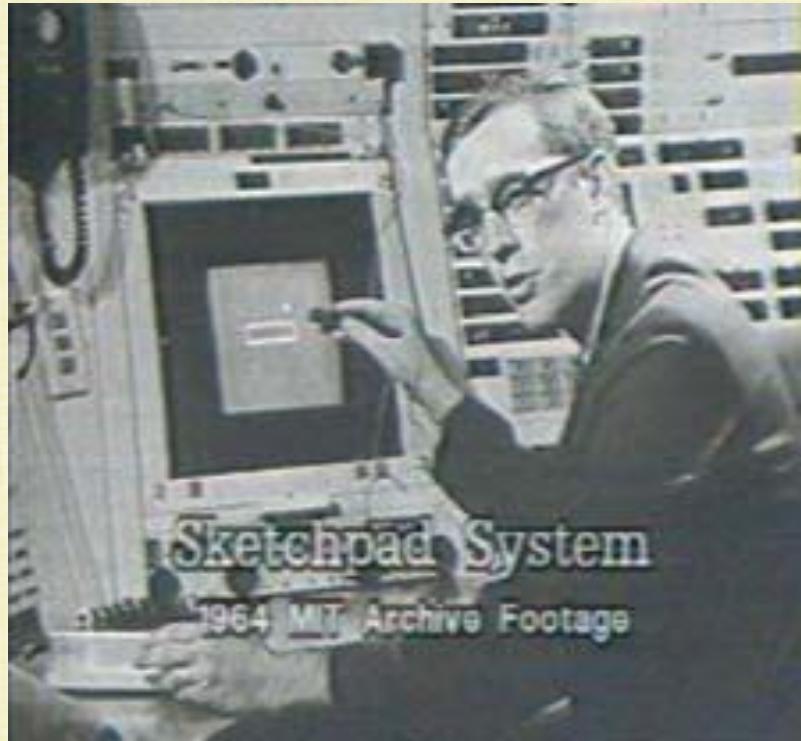
- At the very least, improve your presentation/communication skills
  - make demos, visualizations, etc. for your other work
  - make better use of everyday tools
  - e.g. consider a cell phone:
    - (with its) user interface, camera, 2D image processing, etc.

# Smartphones (& Cameras)... obviously!



- Sales of smartphones outweigh sales of cameras by a factor of 3
- Most smartphones have cameras
- 5 billion mobile phones are in use worldwide
  - 4.4 billion camera phones and 1.2 billion smartphones
- World population is 7 billion

# User Interfaces



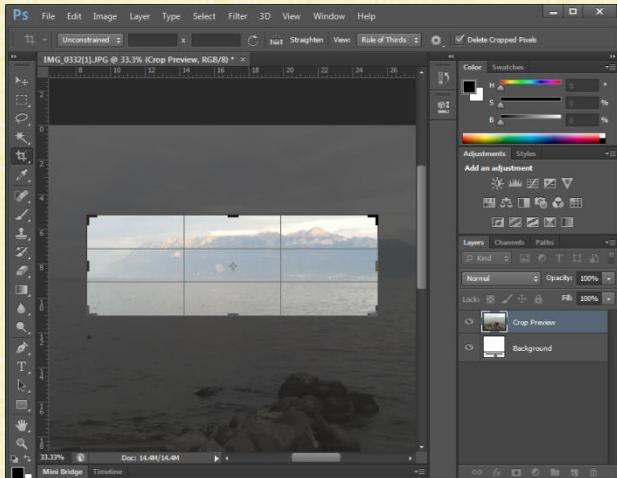
Ivan Sutherland,  
Sketchpad, Light-pen,  
vector display



Apple iPad

Game Console  
Controller

# 2D Image Processing



# Digital Media Technologies

- Digital photography
- Inkjet and laser printers
- Digital video and HDTV
- Electronic books
- Graphics on the web:
  - Photos (flickr)
  - Videos (youtube)



**Sony Video Camera**



**Apple Laserwriter**

# What can I do with graphics?

- Scientists/Engineers need graphics too
- Visualization of various phenomena, computer aided design (CAD), virtual prototyping, simulation, etc.

# Scientific Visualization



**The Virtual Human**  
**Karl-Heinz Hoehne**

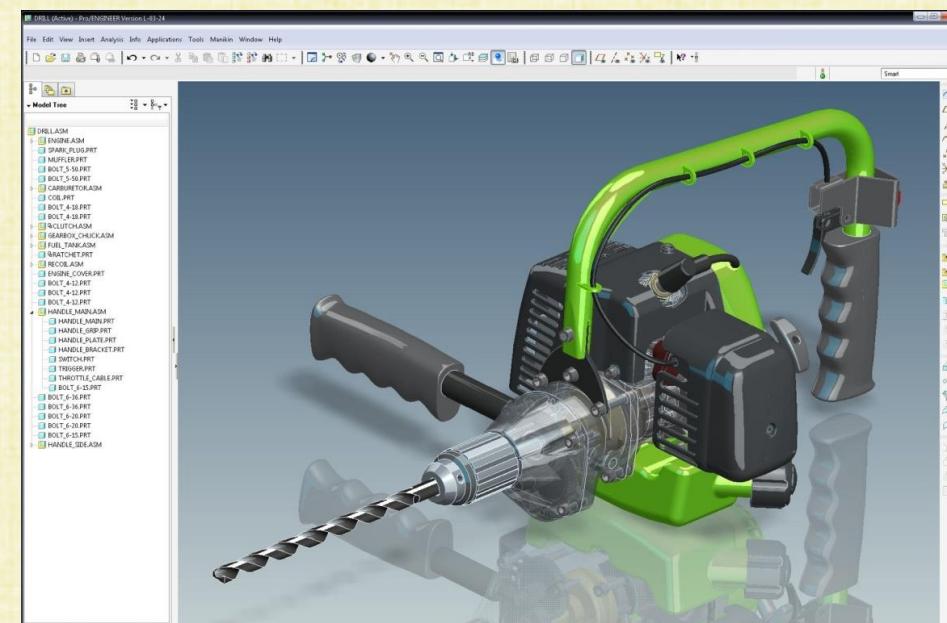


**Outside-In**  
**The Geometry Center**

# Computer-Aided Design (CAD)



**Sketchup**



**ProEngineer**

# Visual Simulation and Training

- Apollo spacecraft
- Flight simulators
- Driving simulators
- Surgical simulation



**Davinci surgical robot**  
**Intuitive Surgical**



**Driving simulator**  
**Toyota Higashifuji Technical Center**

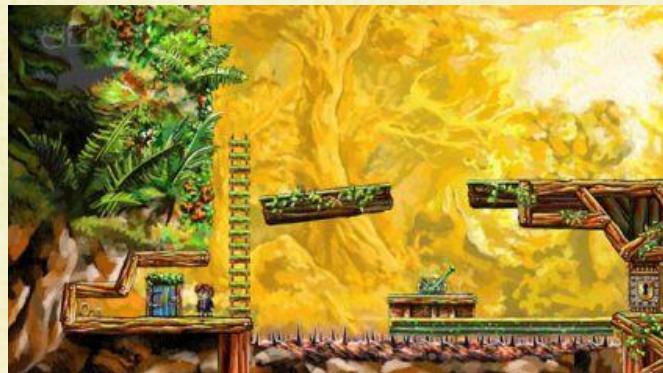
# What can I do with graphics?

- Learn more about the video games that lured many to computers and computer science in the first place:  
**Check a box off your bucket list!**
- AR/VR too...

# Video Games



**Spore**

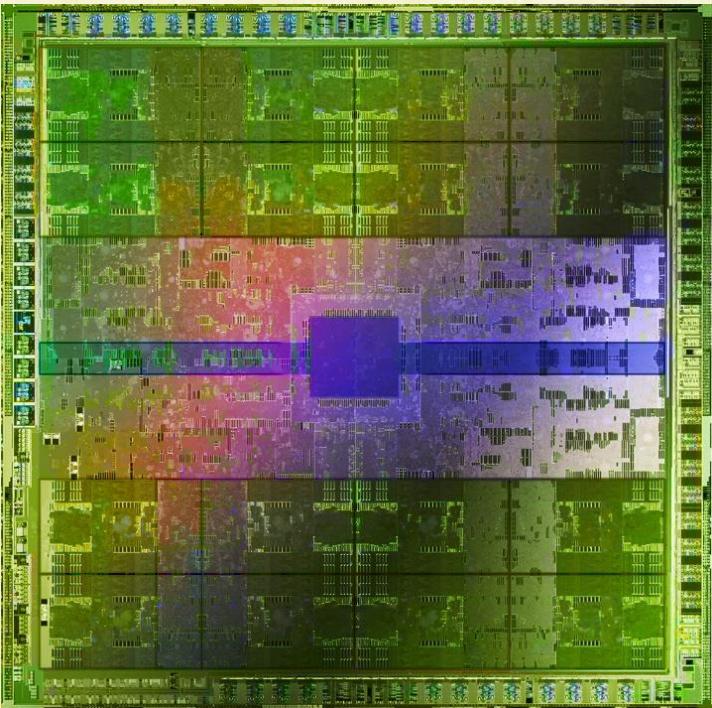


**Braid**

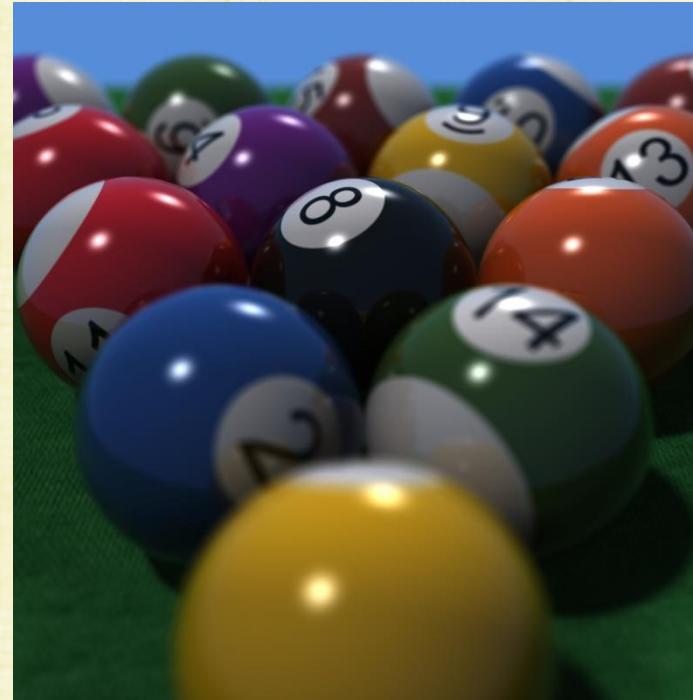


**Crysis**

# Graphics Hardware



NVIDIA Fermi



NVIDIA OptiX

# Virtual (and Augmented) Reality



**Ivan Sutherland: Head-mounted displays, with mechanical tracker**



**Oculus Rift**

# Personalized Avatars



"I'd love to get to the point where you have **realistic avatars of yourself**, where you can make real authentic eye contact with someone and have real expressions that get reflected on **your avatar**." He compared his desired quality with Epic's MetaHuman ... but he wants Facebook to generate these kinds of avatars through **machine learning at a large scale**.

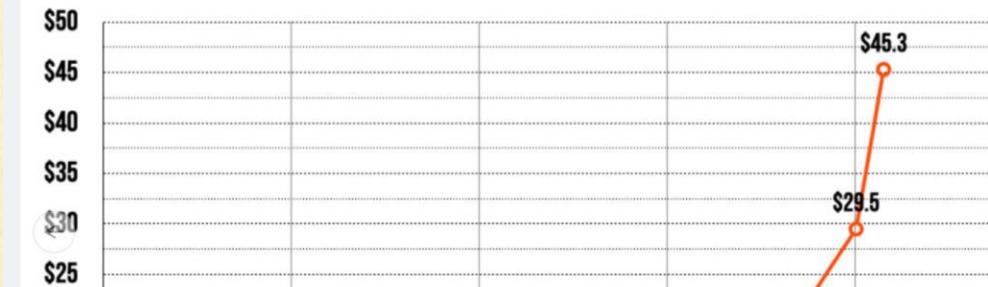
## Putting Roblox's incredible \$45 billion IPO in context

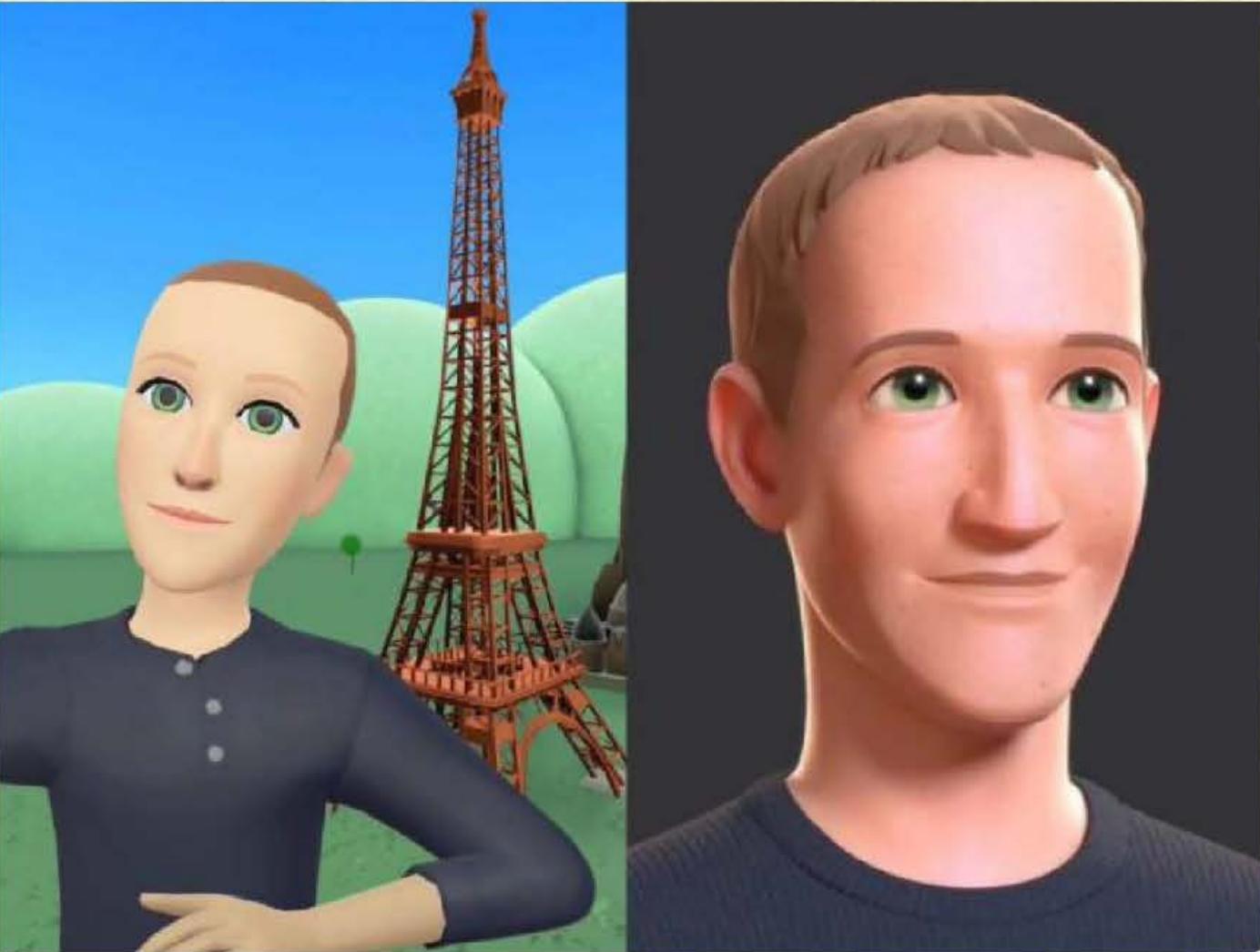
Wednesday's stock offering values the user-created game platform higher than EA.

KYLE ORLAND - 3/11/2021, 12:11 PM

### TOTAL MARKET VALUE OF ROBLOX CORP.

Billions of dollars





I don't usually post on linkedin, but for this I have to. I'm new to Meta and created [Mark Zuckerberg](#) avatar from scratch- sculpted, modeled, lit, textured, and rendered in real time in a little under 4 weeks, with art direction from [REDACTED]

[REDACTED] We went through probably 40 iterations in that time before landing on something we were happy with. Mark liked it enough to post it! Could not be more stoked.

# What can I do with graphics?

- Hollywood Visual Effects!
- Often, cannot film various real-world situations required in order to tell a story
  - The situation may be too dangerous, impractical, expensive, or rare
  - Or the situation doesn't exist in reality, only in an alternative reality

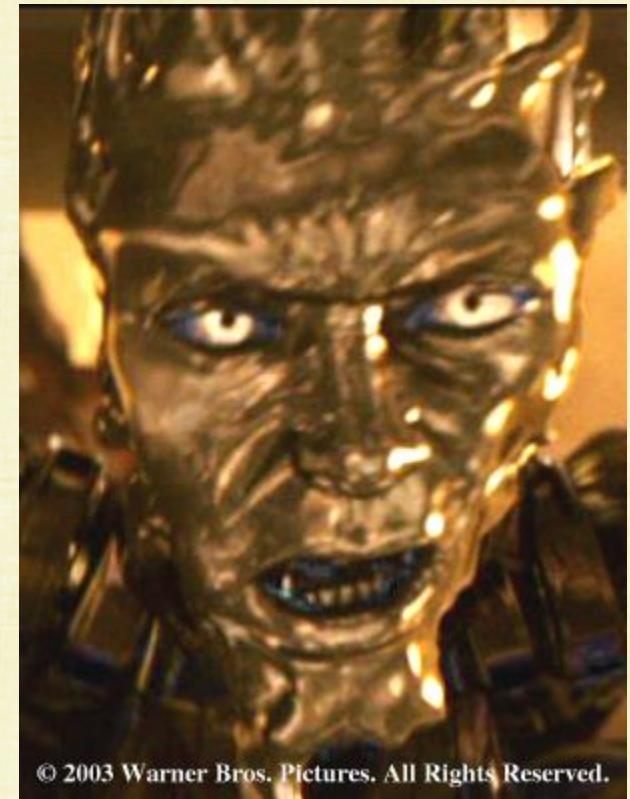
# VFX: Liquids



**Battleship**



**The Day After Tomorrow**



© 2003 Warner Bros. Pictures. All Rights Reserved.

**Terminator 2**

# VFX: Gases



**Harry Potter and the Order of  
the Phoenix**



**Terminator 3**



**Star Wars Episode III**

# VFX: Solids

- Destruction: fracture, explosions, etc.



**Super 8**



**2012**

# VFX: CG Creatures



**Yoda, Star Wars Episode II**



**Sméagol/Gollum, The Lord of  
the Rings**

# VFX: Digital Doubles



**The Curious Case of Benjamin Button**

# Motion Capture Technology



Facial capture in Avatar



**Motion capture of Olympic swimmer  
Dana Vollmer by Manhattan Mocap**  
(technology transition)

# What can I do with graphics?

- Animated Films!
- Instead of adding computer generated elements to real world film footage, create a whole new digital world
  - often with its own set of rules

# Animated Films



**Toy Story 3**



**Monsters, Inc.**

# Graphics at Stanford

# (Brand New): Visual Computing Track

1. **CS 148** (typical intro to graphics)
  - A. Using the computer to draw pictures
  - B. Theoretical background (math/physics) for the technical aspects of drawing pictures
  - C. Coding: You write code but do not submit any code; instead, you *give live demos of working code*

Creative Expression (CE) WAYS course

# (Brand New): Visual Computing Track

A. Choose any 2:

- Core Graphics: 248A (systems/programming themed)
- Machine Learning on Images: 231N (computer vision themed)
- Animation/Simulation: 248B (math/robotics themed)

B. Choose 4 from:

- Rendering: 148, 348B (or more graphics: 348's and 448's)
- Math & Machine Learning: 205L (possibly: 221, 229, 230, 236, 331B)
- Computer Vision: 231A (possibly 131)
- Geometry: 233
- Robotics: 223A
- Virtual Reality: EE267
- Parallel Computing: 149

# Graphics Faculty



**Leo Guibas**  
Geometry/ML



**Pat Hanrahan**  
Rendering/Viz



**Ron Fedkiw**  
Physics/ML



**Maneesh Agrawala**  
HCI/Media



**Doug James**  
Simulation/Interactivity

More recently:



**Kayvon Fatahalian**  
Systems/ Scalability



**Karen Liu**  
Animation/Robotics



**Gordon Wetzstein**  
AR/VR

CS148  
(more details...)

# Ray Tracing!



# Class Re-organization (Fall 2020)

- Moved Ray Tracing closer to the beginning (of the course), allowing key concepts to be covered simultaneously for both Scanline Rendering and Ray Tracing
- Moved Geometric Modeling and Texturing towards the end of the course, so that one can focus on project-oriented goals during the related HWs/lectures
- Blender for HW assignments (supports both Scanline Rendering and Ray Tracing)
  - No longer using (aging) OpenGL and Ray Tracing codes from prior years
  - (CS248 is the graphics-engine implementation-heavy course)



# Blender

- We use Blender in this course, so that you have a real-world working graphics engine at your disposal
  - Open source: so you can see all the code and how it works
  - Scanline Rendering: implemented via OpenGL for previz, enabling real-time scene design
  - Ray Tracer: to render the final images, so they can be quite impressive
- Since this is a CS course, we will be modifying code in Blender in order to illustrate various concepts
  - This requires an understanding of scanline rendering, ray tracing, and the underlying mathematics (which we will cover in the lectures)
  - Please: Watch the lectures in order to acclimate yourself to the material \*before\* attempting the HW and/or speaking with the CAs

# Lectures & HW

TUESDAY	THURSDAY	HOMEWORK
Introduction (9/27)	Working with Light (9/29)	HW 1: set up environment (Mon 10/3)
Virtual World (10/4)	Triangles (10/6)	HW 2: virtual world & triangles (Mon 10/10)
Ray Tracing (10/11)	Recursive Ray Tracing (10/13)	HW 3: ray tracing (Mon 10/17)
Optics (10/18)	Shading (10/20)	HW 4: lighting & shading (Mon 10/24)
Global Illumination (10/25)	Photon Mapping (10/27)	HW5: global illumination (Mon 10/31)
Sampling (11/1)	Advanced Rendering (11/3)	HW 6: advanced rendering (Mon 11/7)
No Class (11/8)	Geometric Modeling (11/10)	
More Geometric Modeling (11/15)	Texture Mapping (11/17)	HW 7: geometric modeling (Fri 11/18)
<i>Thanksgiving Recess (11/22)</i>	<i>Thanksgiving Recess (11/24)</i>	
More Texture Mapping (11/29)	Final Project Discussion 1 (12/1)	HW 8: texturing (Fri 12/2)
Final Project Discussion 2 (12/6)	Final Project Discussion 3 (12/8)	
Final Exam: None		Final Project Due (soft deadline)

# Assignments & Grading

## 50% final project & 50% homework

- The weekly graded homeworks are designed as building blocks towards the final project, which is a single ray traced image
- You may have a partner for both the homeworks and the final project
  - you may change partners as often as you wish throughout the quarter
- Homework is assigned Tuesday and due the following Monday from ~~3-7 pm~~ Assigned time slots!
  - Last 2 assignments are moved to Fridays (since we lose a lecture for the election holiday)
- Grading is done via live demos with the CAs
  - The CAs will/may ask you various questions about the code
  - Make sure you can answer questions about all parts of the code, regardless of which parts you or your partner may have done individually
- Grading is based on a **0-5 point grading scale**
  - If homework is not going well, do not be surprised if your final image grade is lower than you might expect
  - Working with \*feedback\* is very important in computer graphics!
- Quiz Questions: As part of each HW grading session, there will be 1 (or more) random quiz question(s), which you and your partner should prepare for ahead of time (collective answers on the quiz questions are fine/allowed/encouraged)

# How To Approach This Course

- This is (essentially) a project based course
- Your goal is to explore digital image creation via various computer graphics techniques
  - The course is supposed to be fun!
  - It's not supposed to be a programming course or a math course, except that programming and math are necessary enablers for success
- The instructor and CAs are your guides
- Lectures are meant to lead you in the right direction --- just to get you started
  - They are not meant to tell you everything
  - You should utilize the reference reading materials
  - You should utilize the CAs, your classmates, online resources, and your imagination
- WARNING: There are limited options to explore creativity and artistry in CS courses; exploit this one... ☺

Don't do this...



# Reasons to take this class

- Creativity
  - this class counts as a CE, creative expression, WAYS course
  - this class encourages/rewards creativity above all else; albeit, technical skills are taught/required
  - very few other classes in CS encourage/reward creativity; this is one of your only options
  - academic/industry research requires creativity, so it's good to develop
  - by mixing visual artistry and computer science, one hopes to learn how to better use creativity in their everyday technical approaches
- Machine Learning
  - CNNs are built off the human visual system and follow the nonlinear projection space used by one's eyes
  - Computer Vision is one of the main application areas for machine learning, and this class discusses light, geometry, materials, cameras, etc. in a way that adds more insight to computer vision
  - GANs and similar ideas were developed intuitively by thinking about human vision and photographs (material covered in this class)
  - Graphics is full of procedural methods for texture, geometry, etc. which are all good candidates for machine learning (good research topics)
- Computer Graphics
  - Introductory course for the sequence

# Reasons to take this class

- The class can still be done 100% remote, if desired

# Project Proposal (Bonus Points!)

- Find a motivational image (or a couple), and write a short Project Proposal (approximately 1 paragraph) explaining the goals for your project as motivated by the image(s)
- This proposal can be handed in at any point in **THE FIRST 8 WEEKS** of the course, and can be iterated on or modified as the course proceeds (**no late days!**)
- Work with your partner, the CAs, etc. on this proposal, and make sure that you and your partner agree
- The Project Proposal will be graded on a 0-5 scale, similar to the HW assignments, and those points will count as extra credit towards your HW assignment grade (which is clamped at 5 times the total HWs, i.e. 40 point max)
- Some sample motivation images...









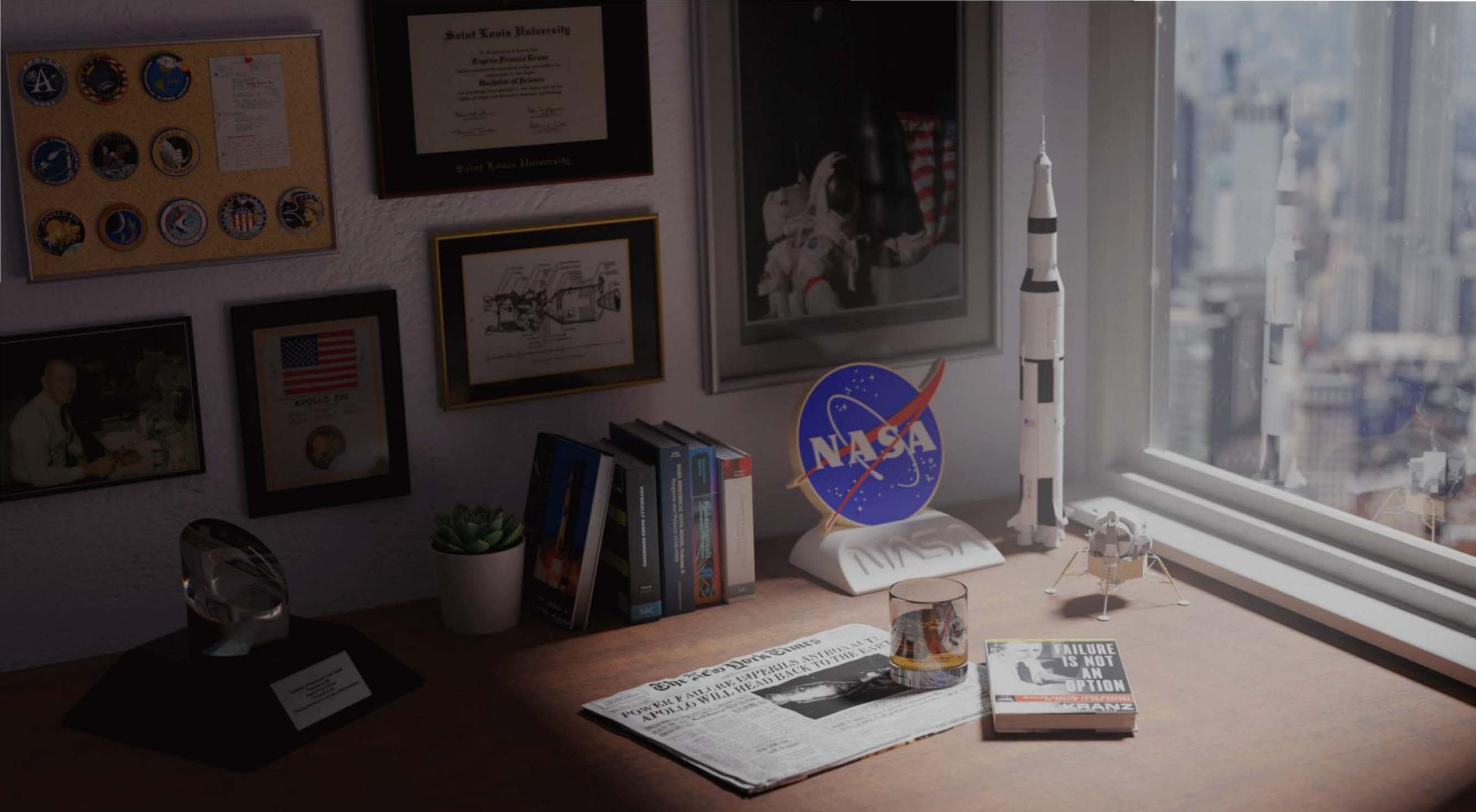


# Projects

- See the handouts!

Here are some projects from prior years...



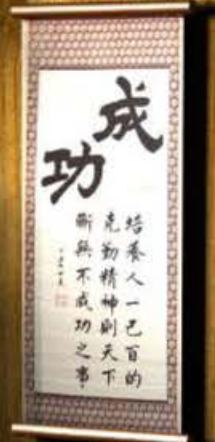














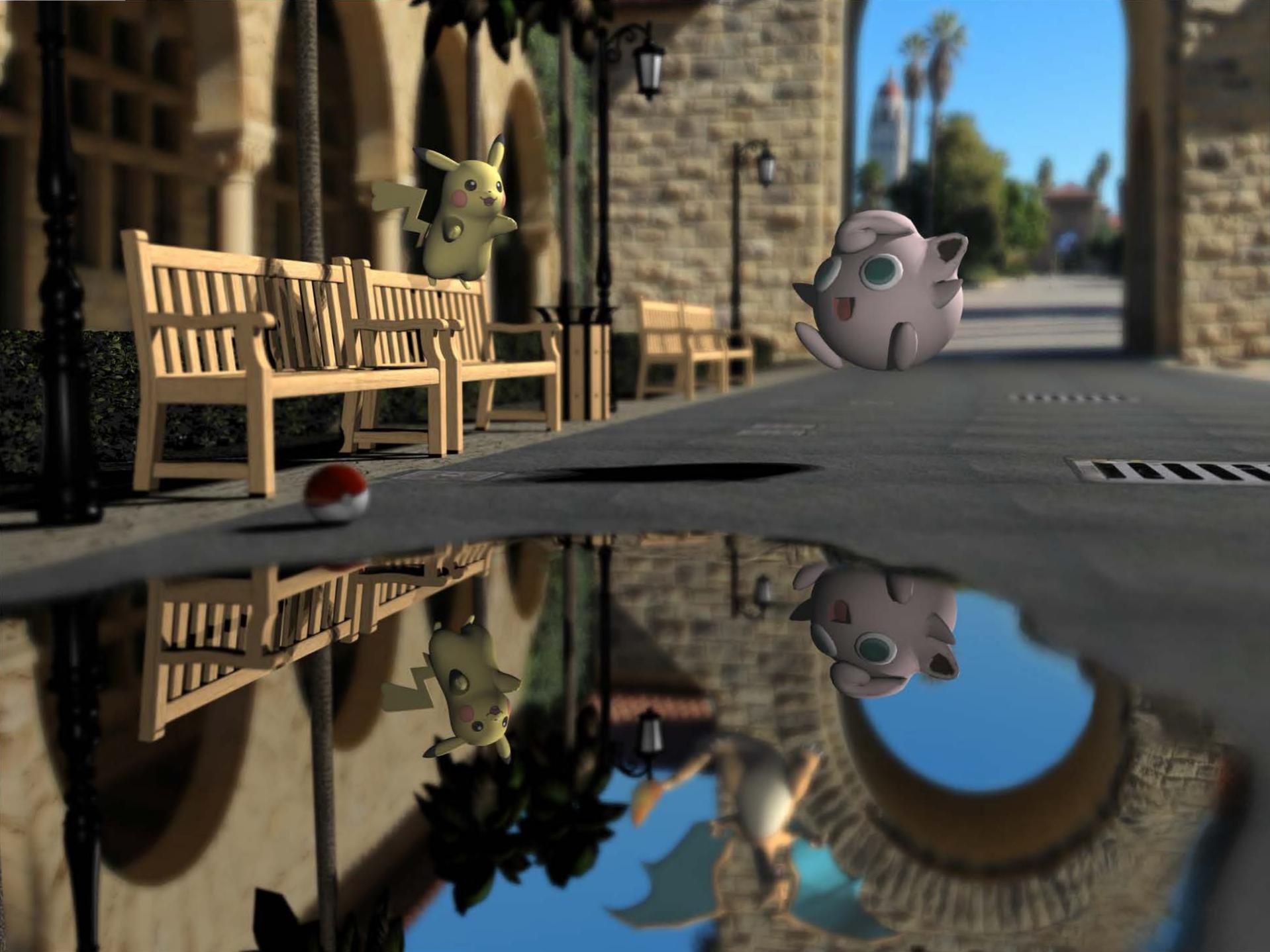


















ultimate  
sophistication.

personal  
computers

apple

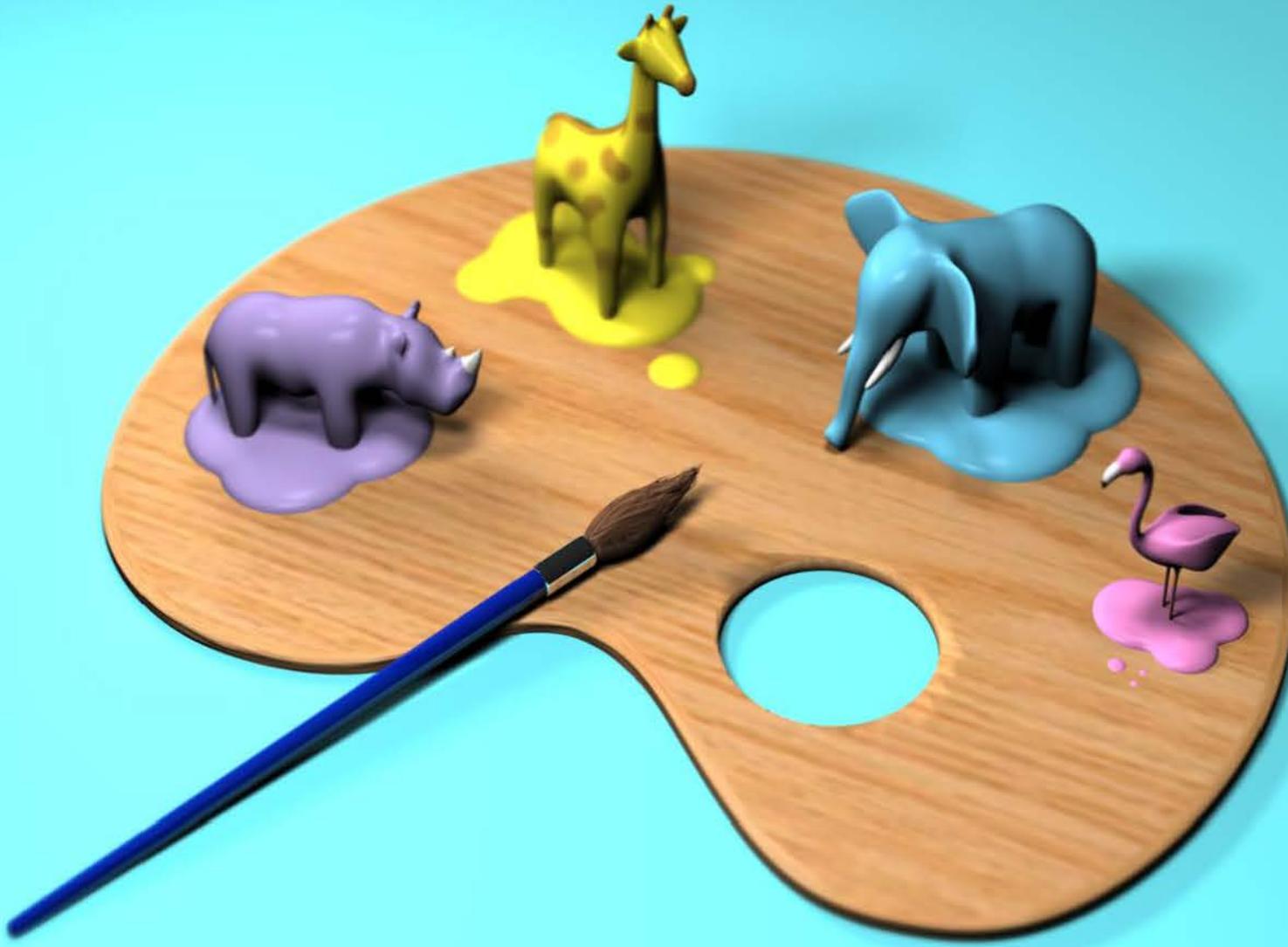
Introducing  
the Apple IIgs

the

com

apple

DATAFILE



A 348B image...

