

# 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](https://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
  - Even text is visualized via aesthetically-pleasing graphics-based fonts
- Thus, learning at least a little bit about graphics is quite useful for ~~all computer scientists~~

Everyone!



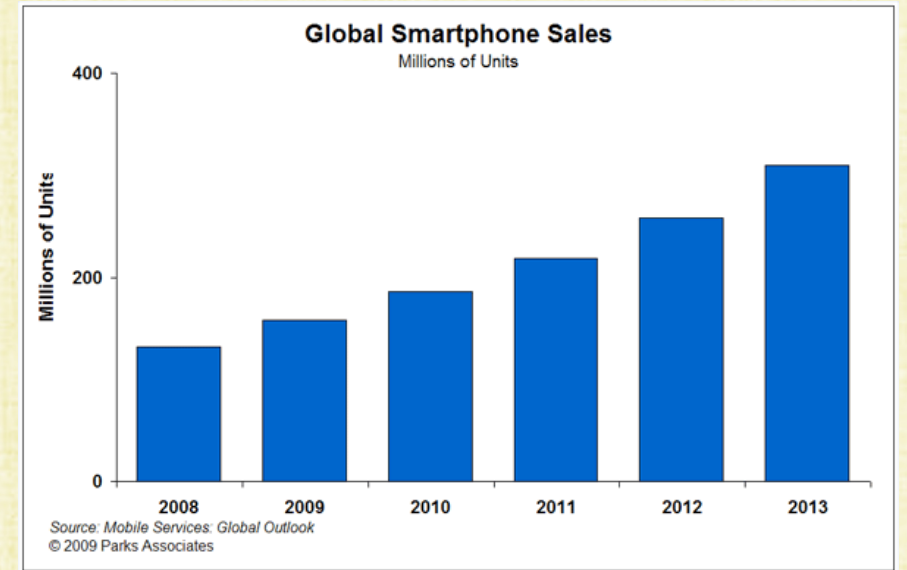
# What can you do with graphics?

- Improve your presentation/communication skills
  - make demos, visualizations, etc. for your other work
  - make better use of everyday tools
    - e.g. cell phone, with its user interface, camera, 2D image processing, etc.

A picture is worth a thousand words...



# Smartphones (& Cameras)... obviously!



- Sales of smartphones outweigh sales of cameras by a factor of 2
- 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**



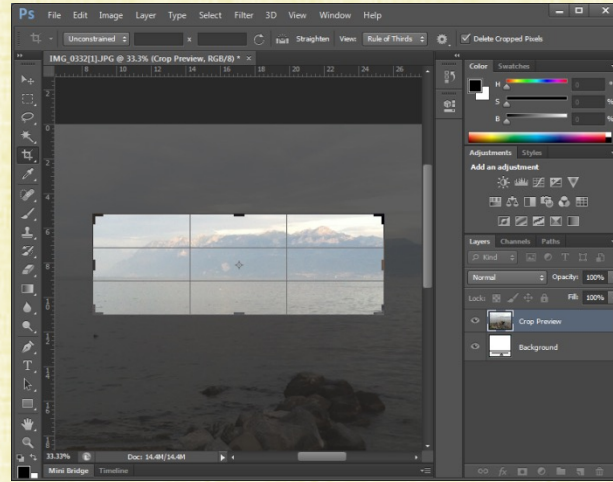
**Apple iPad**



**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 you 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**



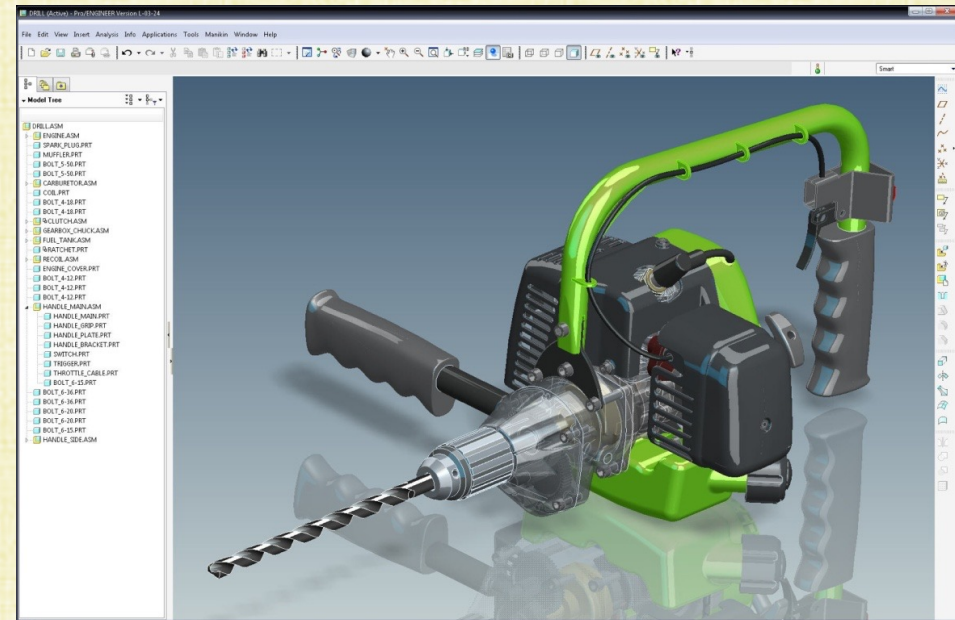
**Outside-In**  
**The Geometry Center**



# 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 you 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**



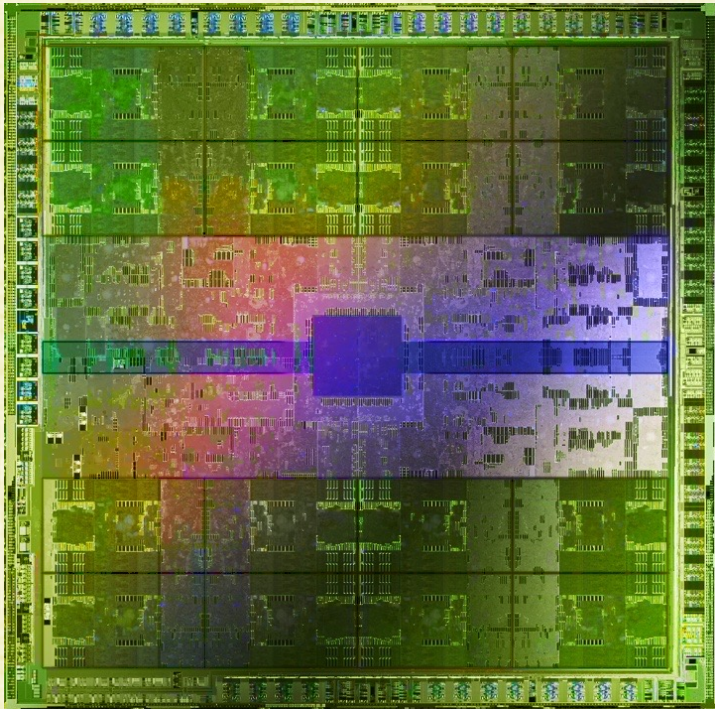
**Braid**



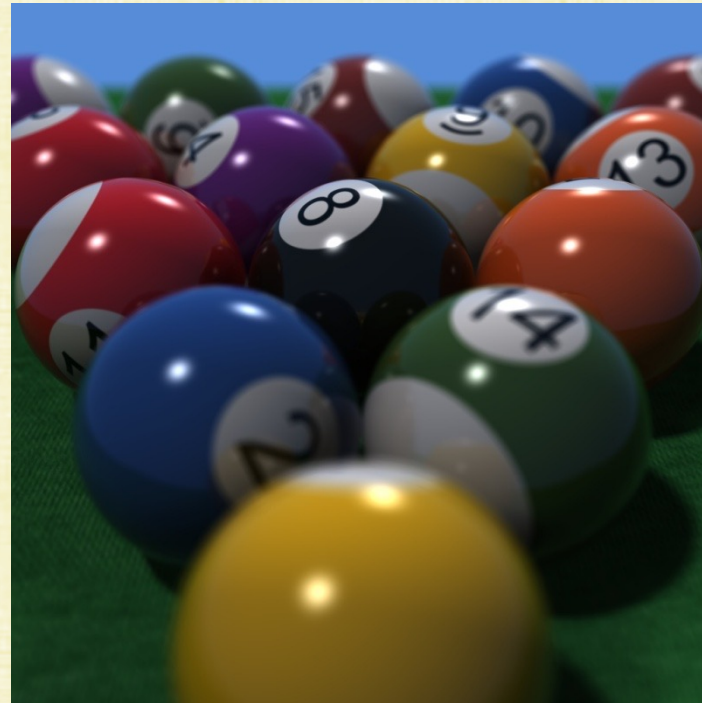
**Crysis**



# Graphics Hardware



**NVIDIA Fermi**



**NVIDIA OptiX**



# Virtual (and Augmented) Reality



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



**Oculus Rift**



# Personalized Avatars



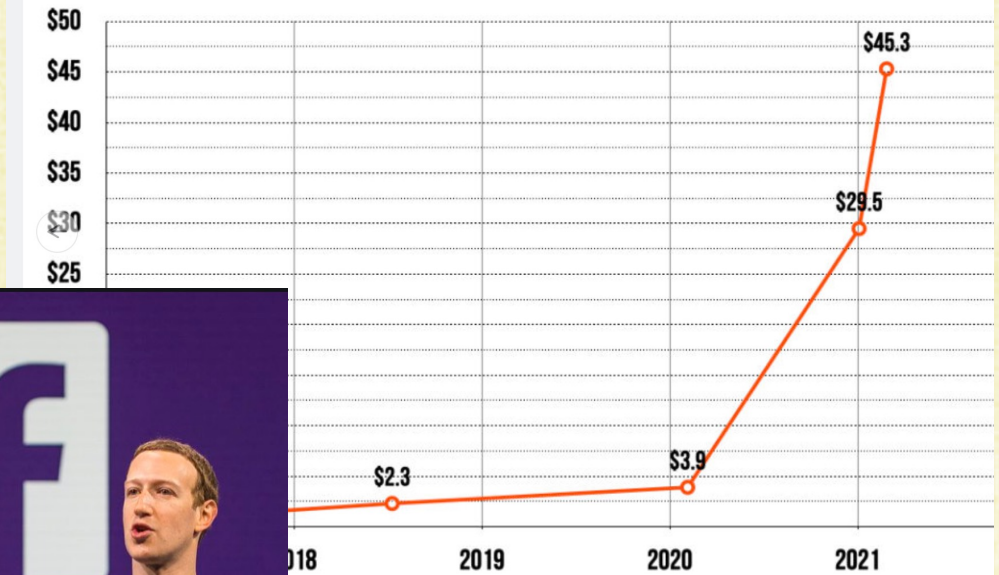
## Putting *Roblox's* incredible \$45 billion IPO in context

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’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**.







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]. 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.

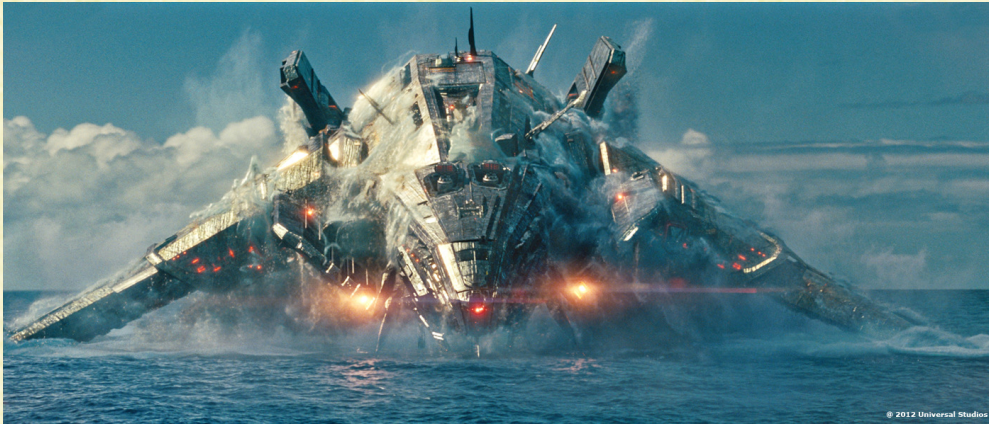


# What can you do with graphics?

- 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 may not exist in reality (only in an alternative reality)



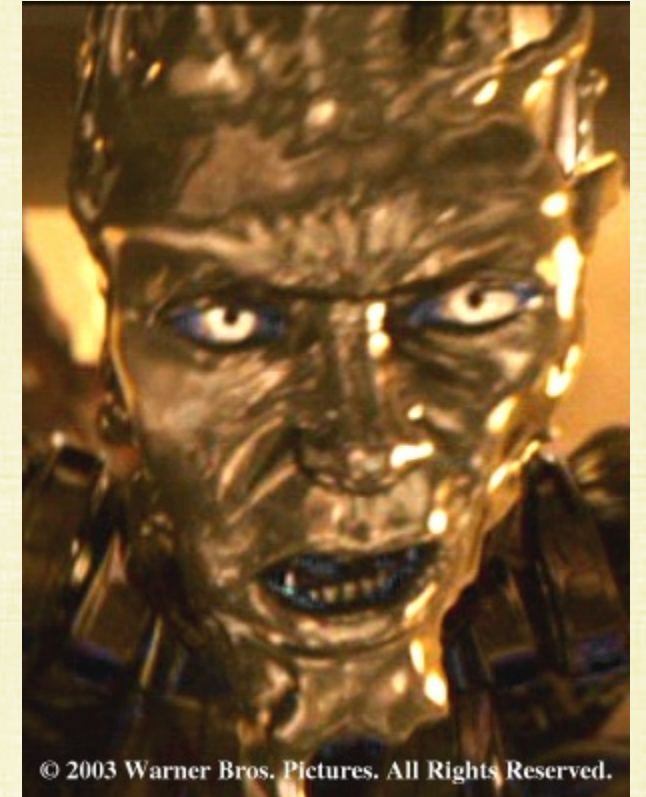
# VFX: Liquids



**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 you 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)







# Graphics at Stanford



# Visual Computing Track (BS & MS)

## 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



# Visual Computing Track

## A. Choose any 2:

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

## B. Choose 4 from:

- Rendering: 148, or advanced graphics (348's and 448's)
- Math & Machine Learning: 205L, 221, 229, 230, 236
- Computer Vision: 131, 231A
- Geometry: 233
- Robotics: 223A, 225A
- 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



**Kayvon Fatahalian**  
Systems/ Scalability



**Karen Liu**  
Animation/Robotics



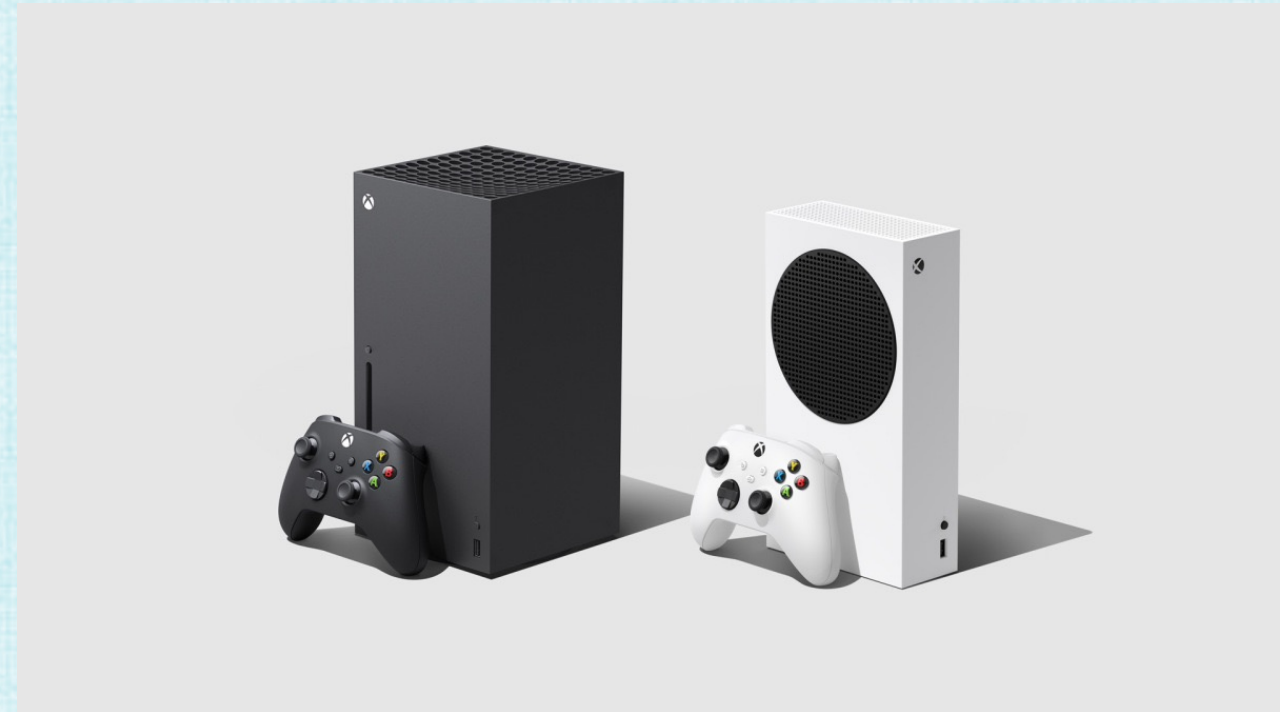
**Gordon Wetzstein**  
AR/VR



CS148  
(more details...)



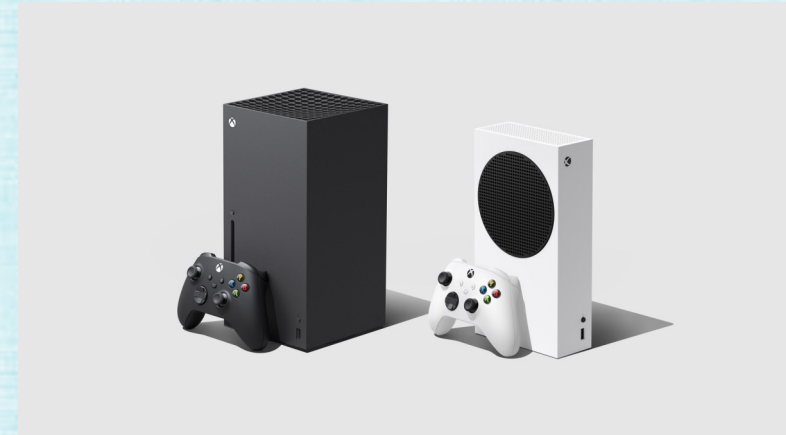
# Ray Tracing!





# 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 to 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 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 (covered in the lectures)
  - Please: Watch the lectures in order to acclimate yourself to the material \*before\* attempting the HW (and before office hours with the CAs)



# Lectures & HW

TUESDAY	THURSDAY	HOMEWORK
Introduction (9/26)	Working with Light (9/28)	HW 1: set up environment (Mon 10/2)
Virtual World (10/3)	Triangles (10/5)	HW 2: virtual world & triangles (Mon 10/9)
Ray Tracing (10/10)	Recursive Ray Tracing (10/12)	HW 3: ray tracing (Mon 10/16)
Optics (10/17)	Shading (10/19)	HW 4: lighting & shading (Mon 10/23)
Global Illumination (10/24)	Photon Mapping (10/26)	HW5: global illumination (Mon 10/30)
Sampling (10/31)	Advanced Rendering (11/2)	HW 6: advanced rendering (Mon 11/6)
No Class (11/7)	Final Project Kickoff (11/9)	
Geometric Modeling (11/14)	More Geometric Modeling (11/16)	HW 7: geometric modeling (Fri 11/27)
<i>Thanksgiving Recess (11/21)</i>	<i>Thanksgiving Recess (11/23)</i>	
Texture Mapping (11/28)	More Texture Mapping (11/30)	HW 8: texturing (Fri 12/4)
Work on Project (12/5)	Work on Project (12/7)	
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 4-7pm**
  - (except for Thanksgiving, where you get an extra week)
- Grading is done via live demos with the CAs
  - The CAs 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 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 your 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
  - counts as a CE, creative expression, WAYS course
  - encourages/rewards creativity above all else; albeit, technical skills are taught/required
  - very few 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 based on the human visual system and follow the nonlinear projection space used by your 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 for 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 research topics
- Computer Graphics
  - Introductory course for the sequence



# Reasons to take this class

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



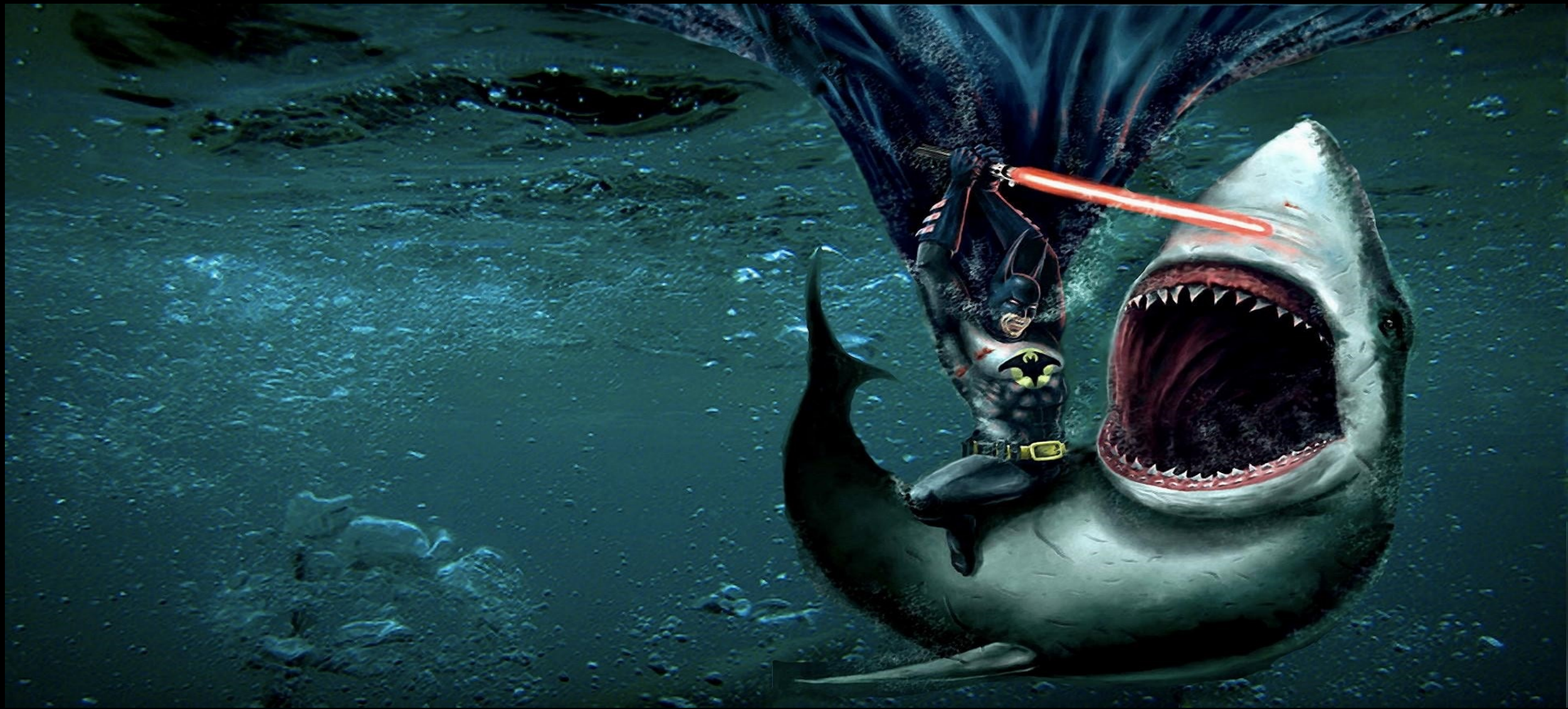
# Project Proposal (**Bonus Points!**)

- Find a motivational image (or a couple of images), 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
- 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 points max)
- Some sample motivation images...























# Projects

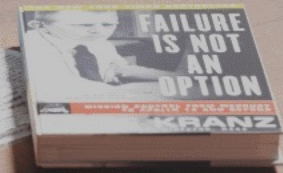
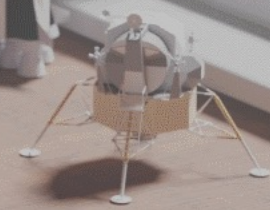
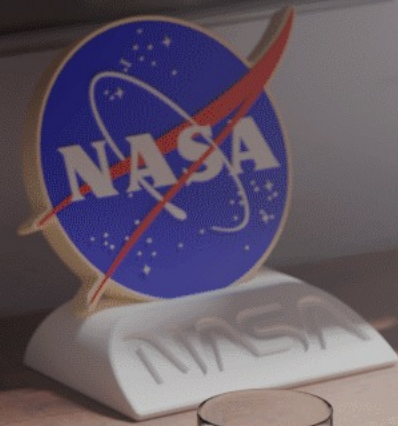
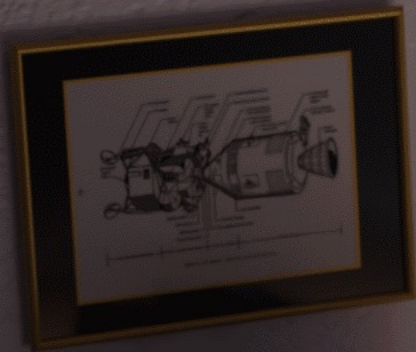
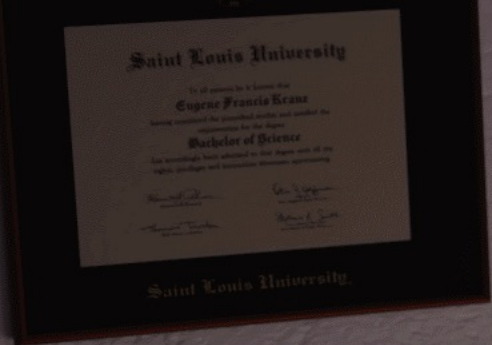
- See the handouts!

Here are some projects from prior years...





























成功  
培养人一己百的  
克勤精神则天下  
断无不成功之事























DR. HENRY JONES



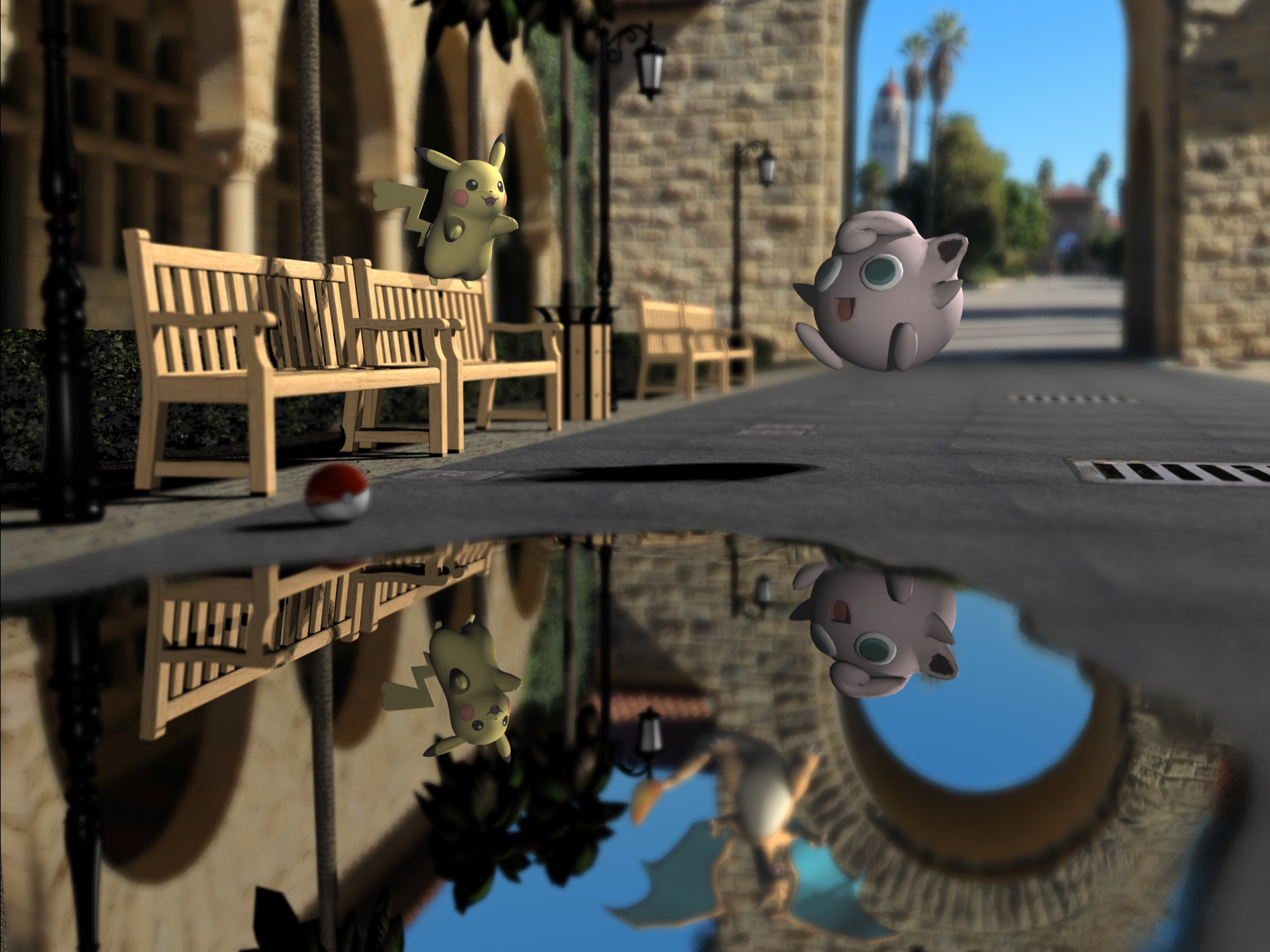
















A 139







