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 CGOE)

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 everyone. ~~all computer scientists~~ everyone.

- The recent success of LLM's has greatly increased the efficacy of text-based input, but most still prefer visual (instead of text-based) output.

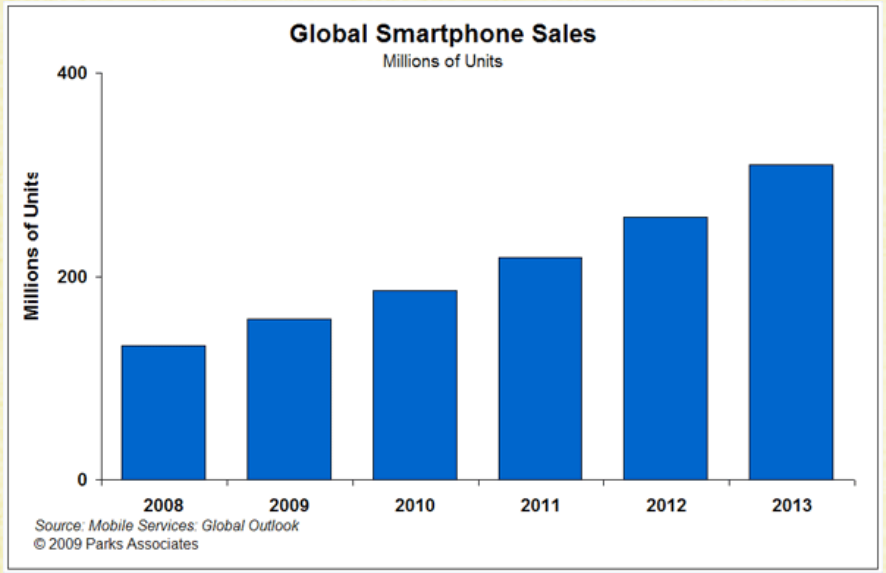
What can you do with graphics?

- 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…

- LLMs and related technologies such as text-to-image, text-to-geometry, etc. are facilitating visual content creation, but these technologies still lack the controllability present in the standard graphic pipeline.
- On the other hand, LLMs and related technologies are helping to enhance the graphics pipeline.

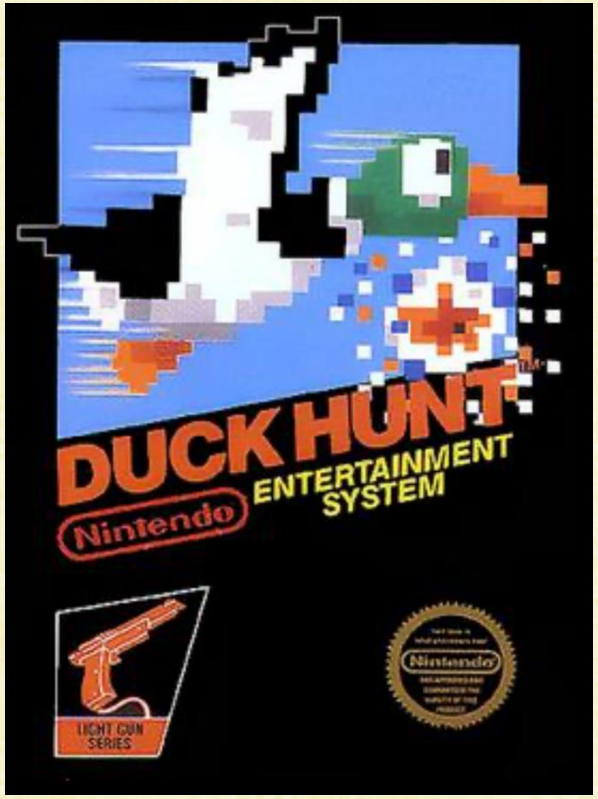
Smartphones (& Cameras)… obviously!



- 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

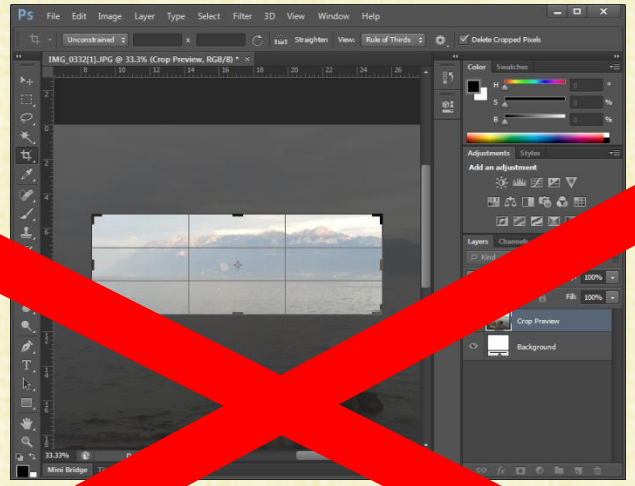
Ivan Sutherland, Sketchpad, Light-pen, vector display



Light Guns

Game Console Controller

2D Image Processing



2D Image Processing

- This is one of the first areas being replaced almost completely by modern AI techniques. There is a flurry of good papers on portrait editing for example.

PHOTOSHOP FEATURES

Tap into the power of AI in Photoshop.

Explore generative AI features in Photoshop powered by Adobe Firefly. Remove distractions in a click, get amazing photorealistic results, and add more picture to your picture.

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

- Understanding hardware (cameras, printers, displays, image formats, etc.) remains important whether one is utilizing modern AI tools or not.

What can you do with graphics?

- Scientists/Engineers need graphics too…

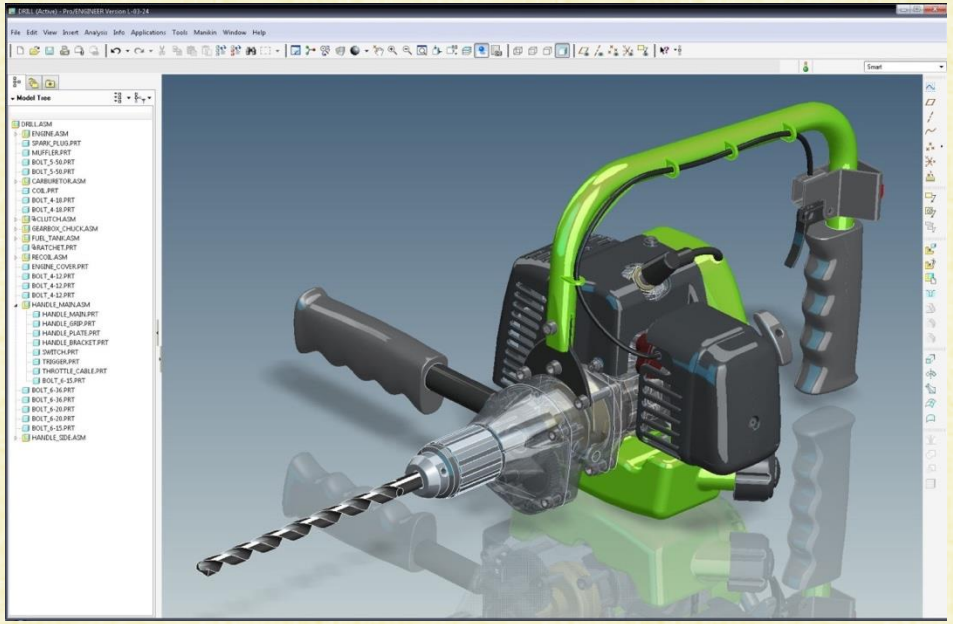
Scientific Visualization

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…

  This is a very big deal these days!

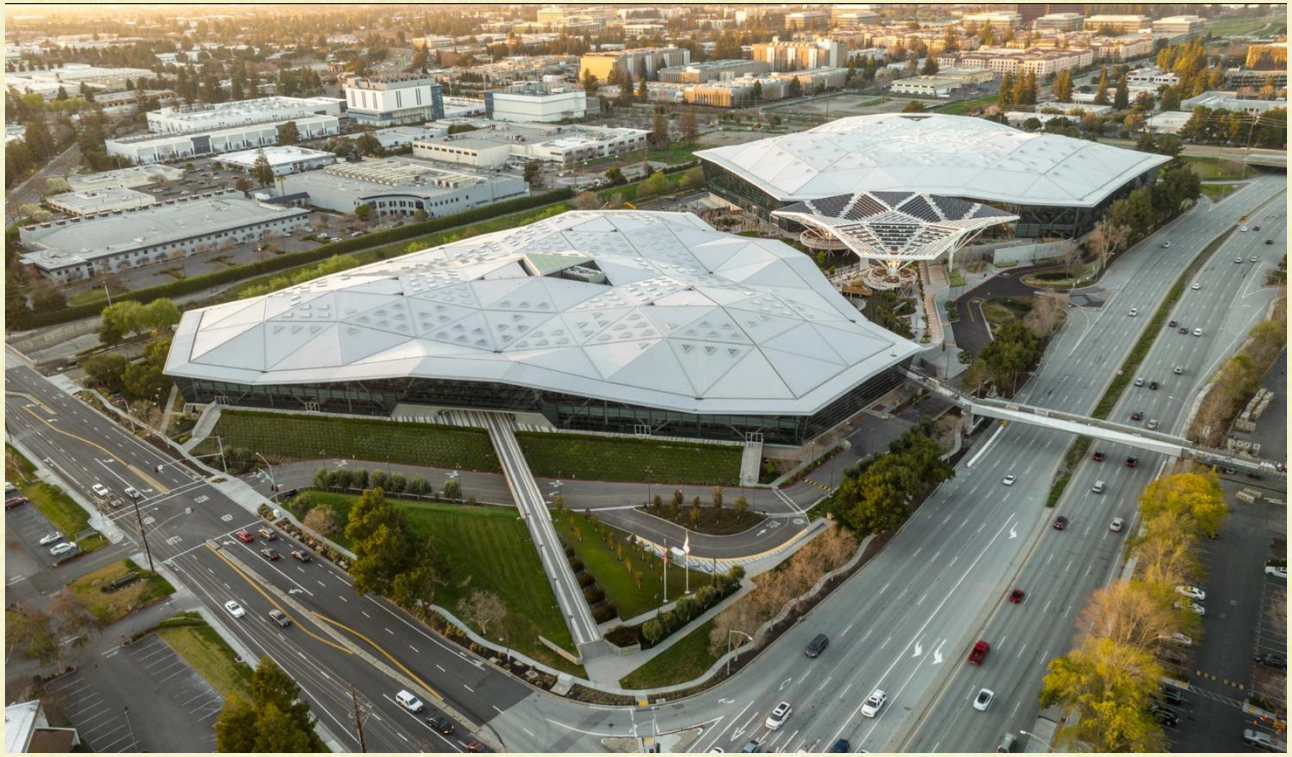
Video Games


PONG
FOR YOUR HOME TV
PONG
FOR YOUR HOME TV
TELE-GAMES
PONG
PONG
BATTERY
ELIMINATOR
ATARI

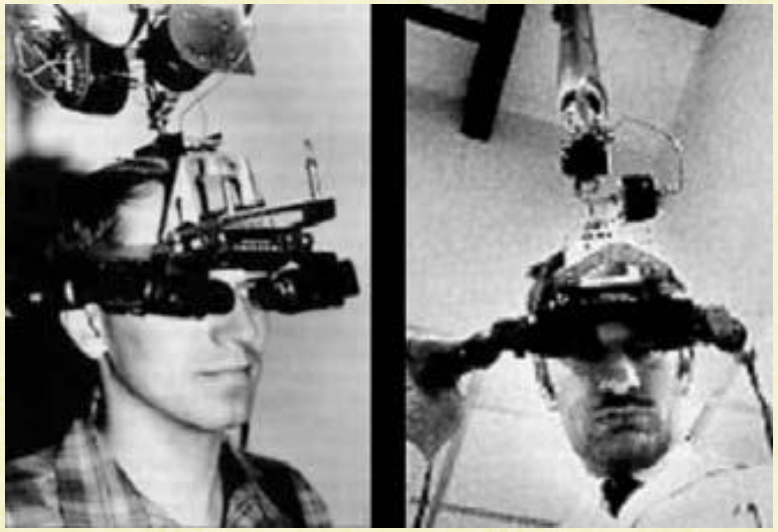

Williams
DEFENDER
DEFENDER
Williams
DEFENDER


ATARI
CENTIPEDE

Graphics Hardware



Virtual (and Augmented) Reality



Ivan Sutherland: Head-mounted displays, with mechanical tracker

Oculus Rift

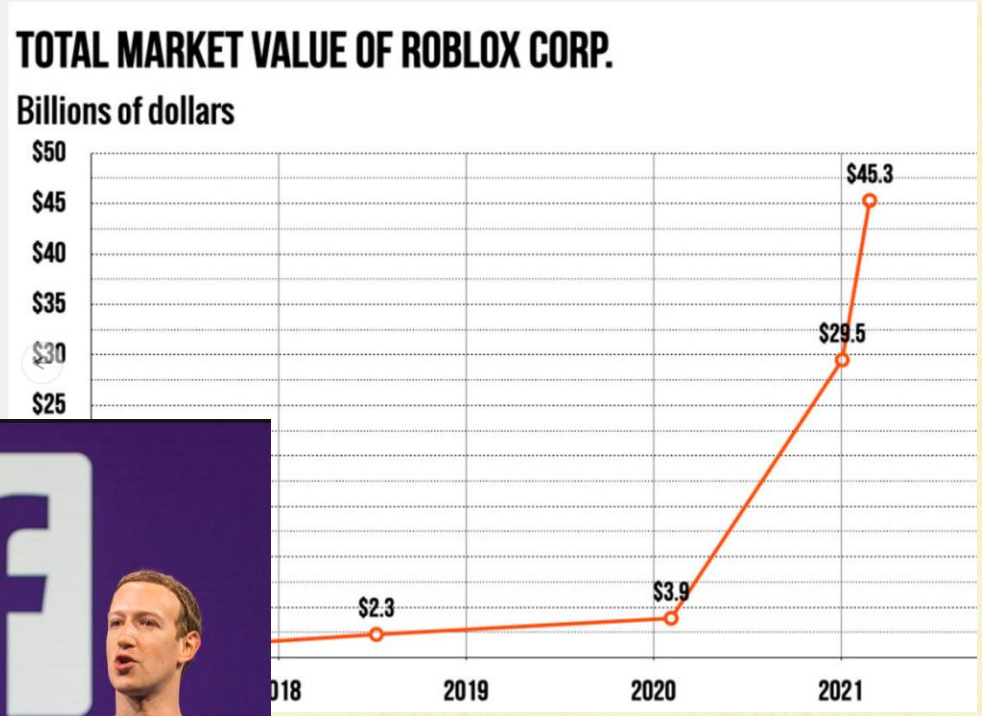
Apple Vision Pro

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



"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

Terminator 2

The Day After Tomorrow

VFX: Gases

Harry Potter and the Order of the Phoenix

Terminator 3

Star Wars Episode III

VFX: Solids

- Destruction: fracture, explosions, etc.

Super 8

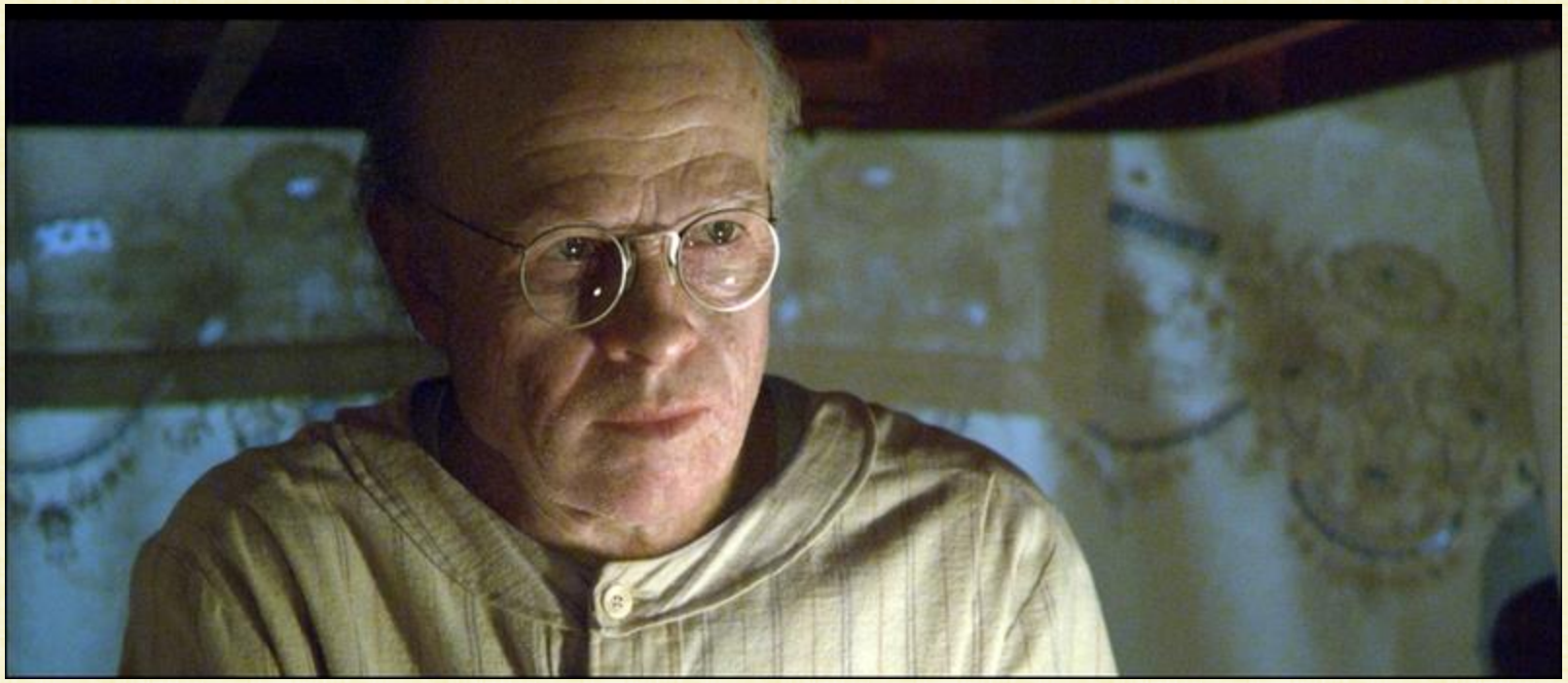
2012

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)

Generative AI

Generative Visual Effects

With Gen-3 Alpha Image to Video, it's now possible to turn still frames from live action footage into Generative Visual Effects (GVFX) shots, which you can then comp back into your main live action plate for seamless effects.

GVFX Runway Academy →

https://runwayml.com/product/use-cases/gvfx

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)

Animated Films

Toy Story 3

Monsters, Inc.

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!

ray tracing on the PS5 was announced Fall 2019

Class Re-organization (Fall 2020)

- Cover key concepts simultaneously for both Scanline Rendering and Ray Tracing
- Geometric Modeling and Texturing are discussed towards the end of the course
  - This allows us to focus on these topics when you need them for your project (and the relevant HWs are project-oriented)
  - This is also a good place to discuss Generative AI for Content Creation
- Blender for HW assignments (supports both Scanline Rendering and Ray Tracing)
  - CS248A is the graphics-engine implementation-heavy course

Blender

- We use Blender, 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 adequately impressive
- Since this is a CS course, we will modify code in Blender in order to illustrate various concepts
  - This requires an understanding of scanline rendering, ray tracing, and the underlying mathematics (which will be covered in the lectures)
  - 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 (9/23)	Working with Light (9/25)	HW 1: Blender Intro (Mon 9/29)
Virtual World (9/30)	Triangles (10/2)	HW 2: Triangles & Transformations (Mon 10/6)
Ray Tracing (10/7)	Recursive Ray Tracing (10/9)	HW 3: Ray Tracing (Mon 10/13)
Optics (10/14)	Shaders (10/16)	HW 4: Lighting & Shading (Mon 10/20)
Global Illumination (10/21)	Photon Mapping (10/23)	HW5: Global Illumination (Mon 10/27)
Sampling (10/28)	Advanced Rendering (10/30)	HW 6: Advanced Rendering (Mon 11/3)
No Class (11/4)	Project Kickoff (11/6)	Project Proposal (11/10)
Geometric Modeling (11/11)	More Geometric Modeling (11/13)	HW 7: Geometric Modeling (Mon 11/17)
Texture Mapping (11/18)	More Texture Mapping (11/20)	HW 8: Texturing (Mon 12/1)
Thanksgiving (11/25)	*Thanksgiving (11/27)*	
Work on Project (12/2)	**Work on Project (12/4)**	
No Final Exam		Final Project Due (12/11 - 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 with 8am-9pm sign-up slots
  - (except Thanksgiving, where you get an extra week)
- Grading is done via live demos with the CAs
  - The CAs will 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)
  - We'd like to hear the answers in YOUR OWN WORDS, and you SHOULD NOT BE READING A SCRIPT

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 in graphics
- 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); the same goes for NERFs and Gaussian Splats
  - 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

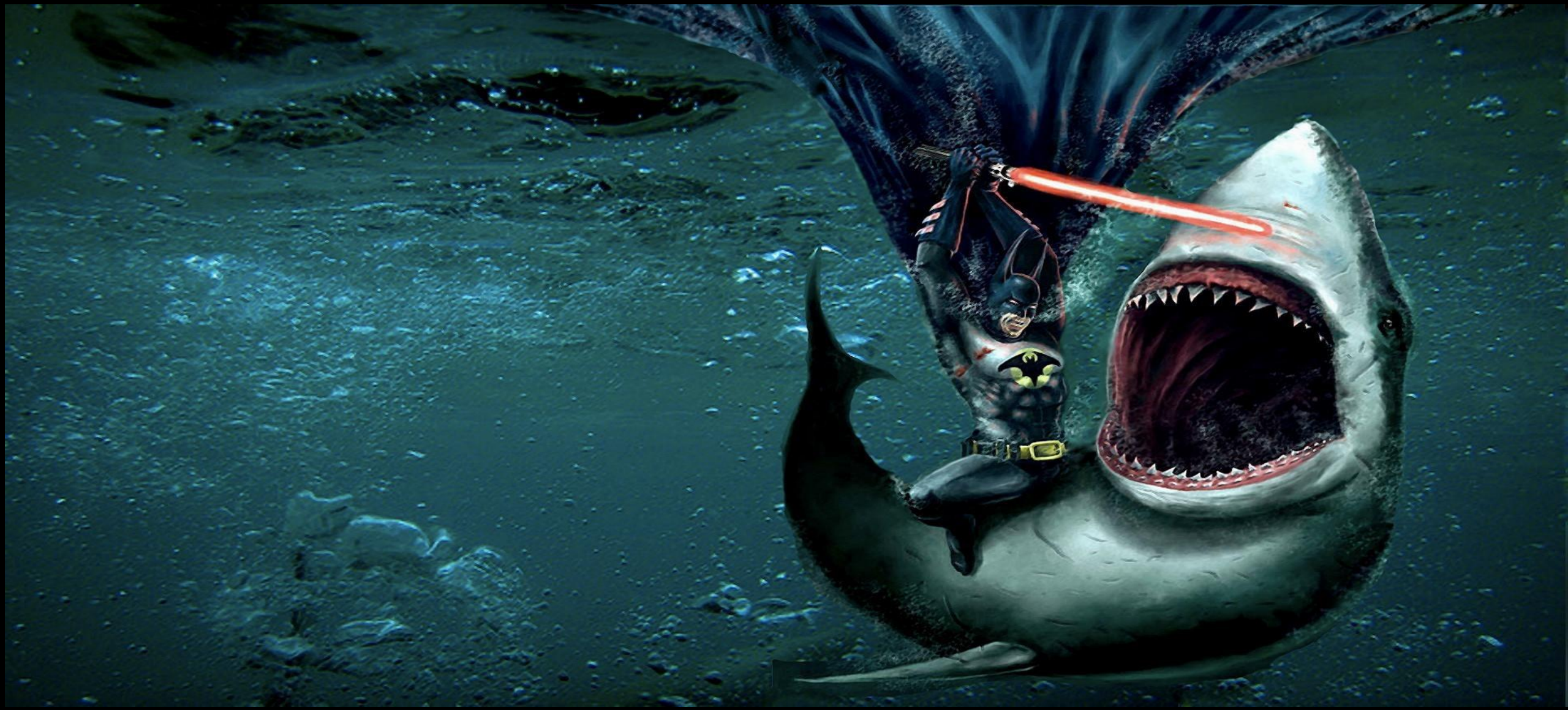
Reasons to take this class

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

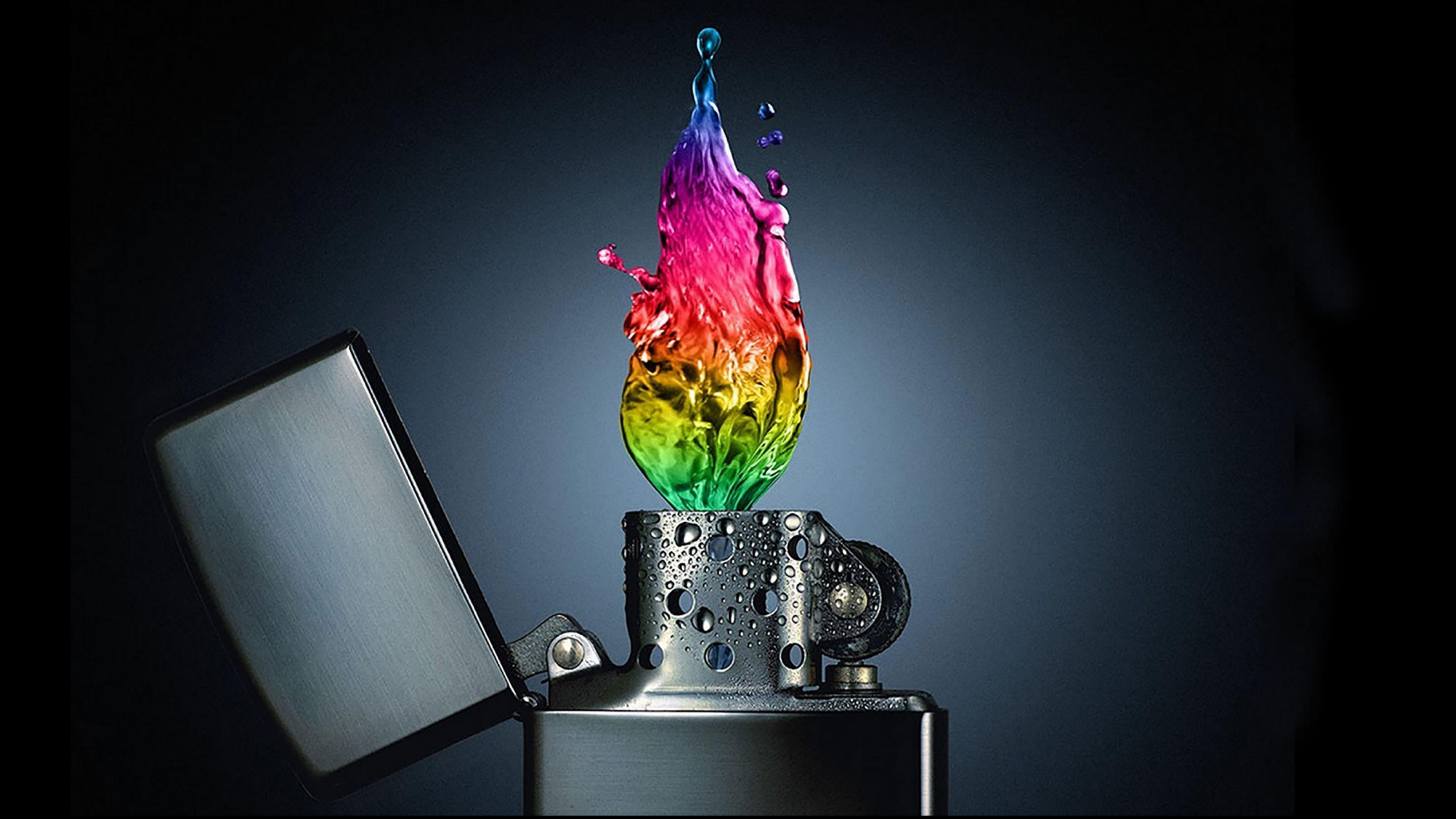
Project Proposal (Bonus Points!)

- 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)
- Due 11/10 this year
- Work with your partner, the CAs, etc.
- Make sure that you and your partner are in agreement
- The Project Proposal is graded on a 0-5 scale, just like the HW. Those points count as extra credit towards your HW grade (which is clamped at 5 times the total HWs, i.e. 40 points max)

- Some sample motivation images…




Carlsberg

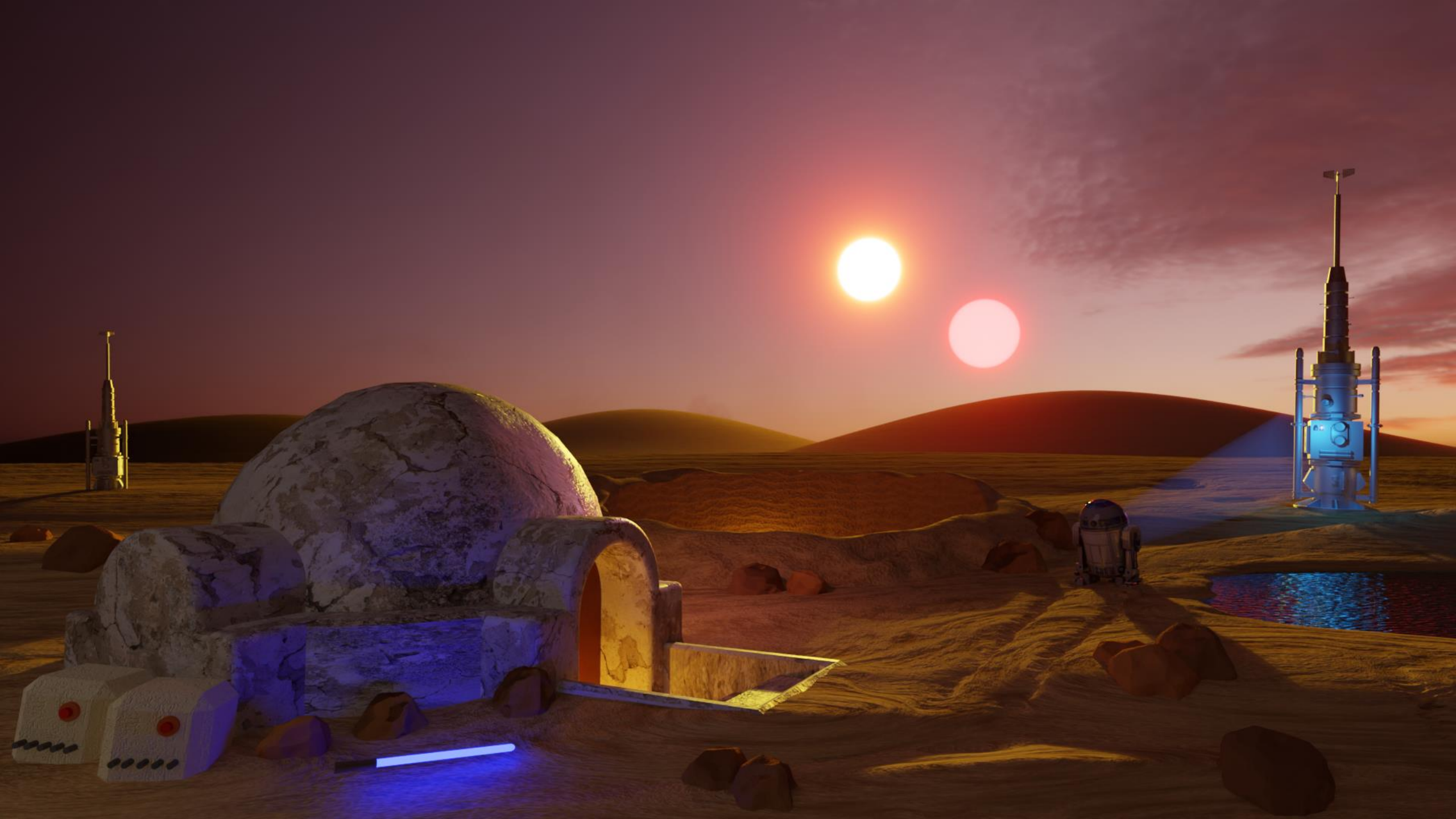


Projects

- See the handouts!

Here are some projects from prior years…


MAIN QUAD
LAKE LAG
COLLECT
$200.00 SALARY
AS YOU PASS
YO




POPEYE
OPEN 24 HRS


CS148 OH


Saint Louis University
Eugene Francis Kranz
Bachelor of Science
Saint Louis University
APOLLO XIII
NASA
The New York Times
POWER FAILURE IMPERILS ANOTHER APOLLO WILL HEAD BACK TO THE EAR
FAILURE IS NOT AN OPTION
KRANZ


PEDIGREE
PETER
DAWSON
BLENDED SCOTCH
OLD CUR


成功
培養人一己百的
克勤精神刷天下
斷無不成功之事
金秋神韵


DR. HENRY JONES
Plan of Sevastopol
1854-1855
Scale 1: 200000.
Miles.
1. The city proper
French Mandate, 1920
IRAQ (MESOPOTAMIA) British Mandate 1920
In 1898 Crete became an autonomous state ruled by a High Commissioner under the protection of Great Britain, Russia, France and Italy. In 1906 the King of Greece was empowered to appoint the High Commissioner