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

11:30am to 12:45pm

(recorded via SCPD)

Graphics is Pervasive

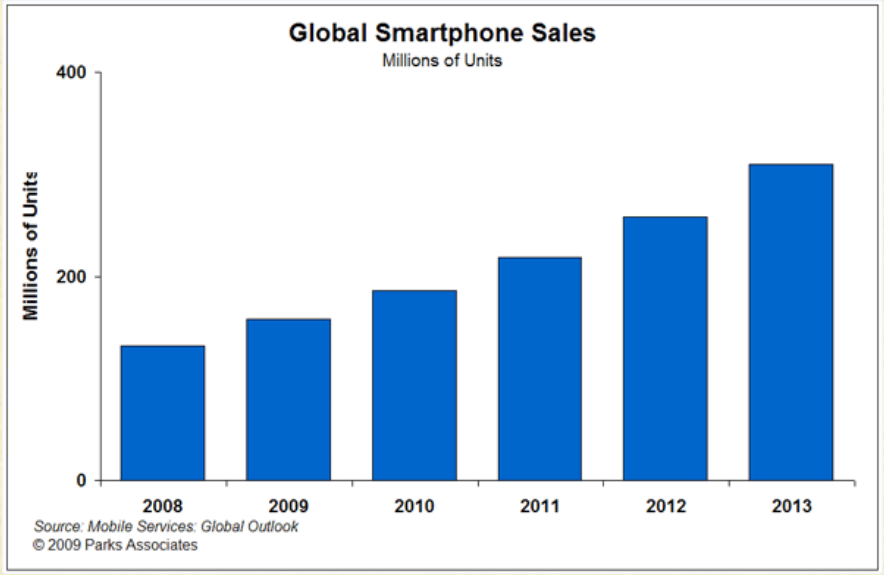
- Computer graphics is all around us!
- No one wants a boring *text only* interface when interacting with a computer, cell phone, DVD player, ATM, car, or thermostat
  - And even text is visualized via graphics based fonts

- (Thus,) Learning at least a little bit about graphics is quite useful for all computer scientists!

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

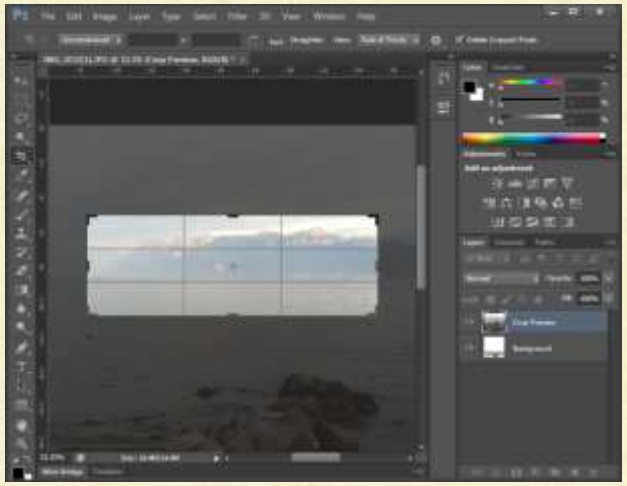
User Interfaces

Ivan Sutherland, Sketchpad, Light-pen, vector display

Apple iPad

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.

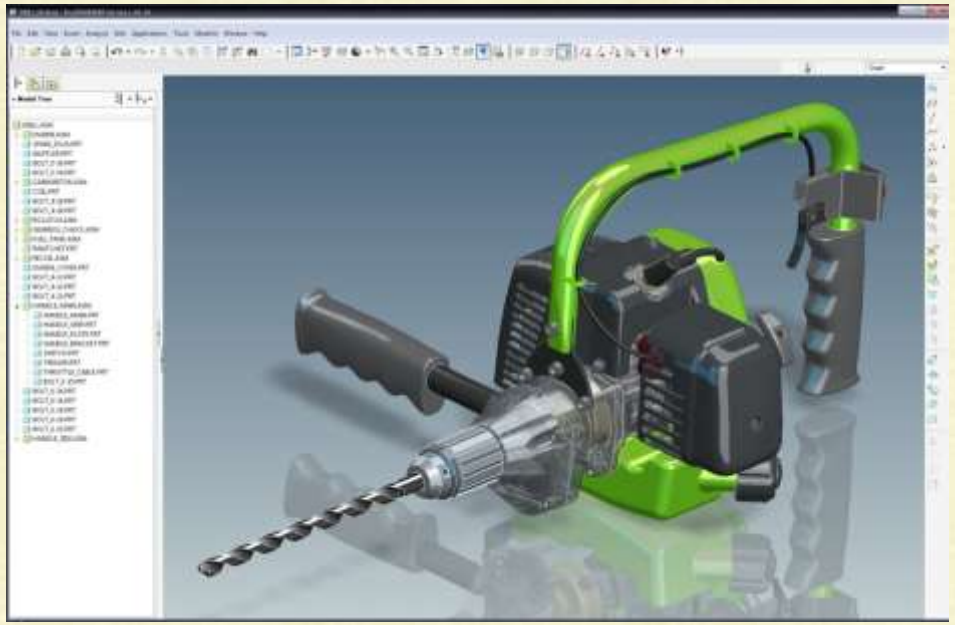
Scientific Visualization

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?

- Check a box off your bucket list!
- Learn more about the video games that lured many to computers and computer science in the first place

- AR/VR too…

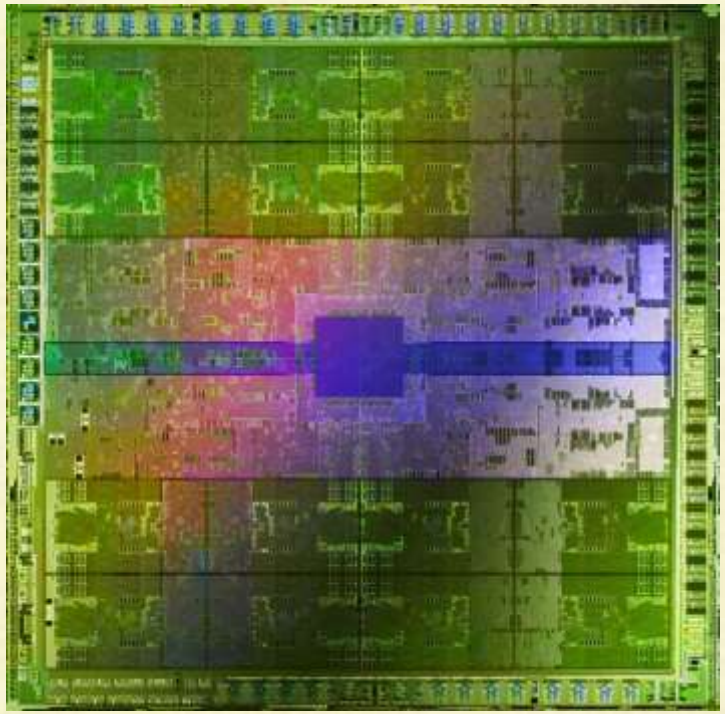
Video Games

Spore

Braid

Crysis

Graphics Hardware



NVIDIA Fermi

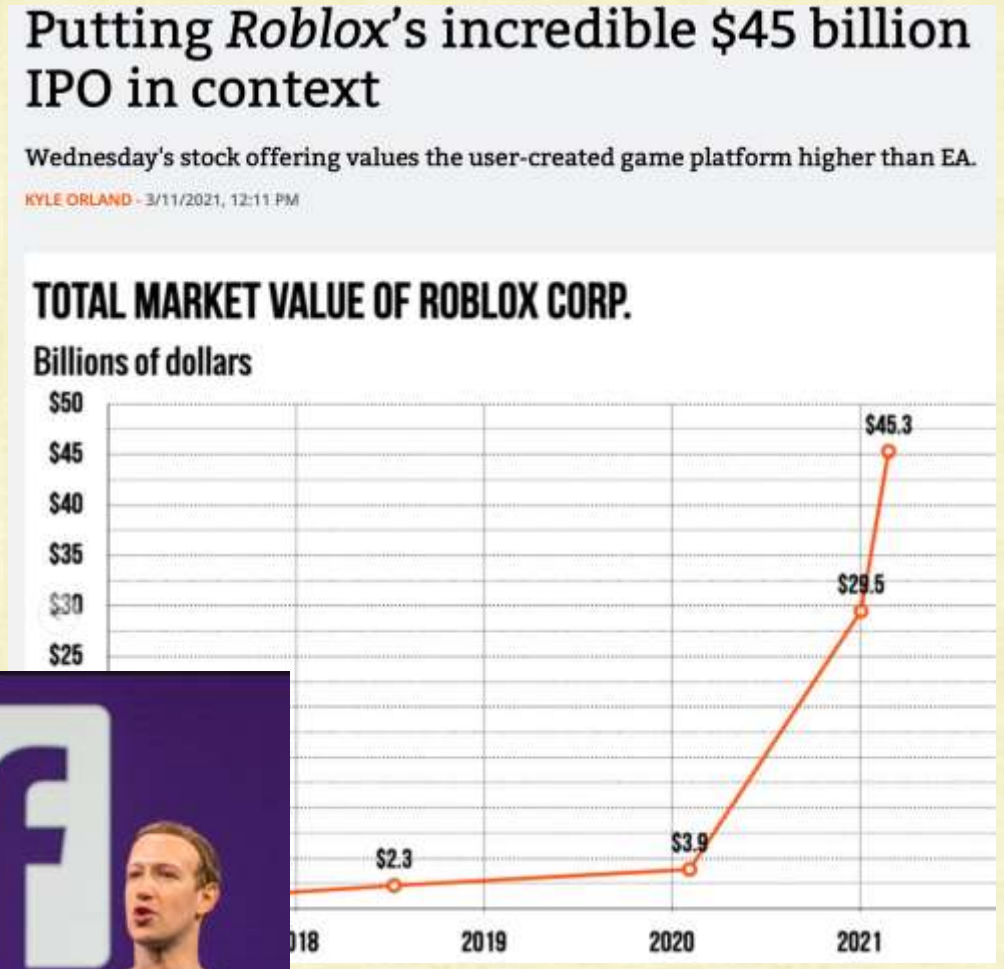
NVIDIA OptiX

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.

What can I do with graphics?

- Of course, 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

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

Overview of the Graphics Track

1. **CS 148** (core class)
   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

Overview of the Graphics Track

A. *Core Courses* CS 148, 248, 348B
B. *Special Topics:* CS 448
C. Math (e.g. CS205L), Geometry (e.g. CS348A)
D. Computer Vision, Image Processing, Robotics, Mobile Devices, Machine Learning, Systems, Etc.

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 graphics engine implementation heavy!

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)
  - 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	Working with Light	HW 1: set up environment (Mon 9/27)
Virtual World	Triangles	HW 2: virtual world & triangles (Mon 10/4)
Ray Tracing	Recursive Ray Tracing	HW 3: ray tracing (Mon 10/11)
Optics	Shading	HW 4: lighting & shading (Mon 10/18)
Global Illumination	Photon Mapping	HW5: global illumination (Mon 10/25)
Sampling	Advanced Rendering	HW 6: advanced rendering (Mon 11/1)
No Class	Geometric Modeling	HW 7: geometric modeling (Fri 11/12)
More Geometric Modeling	Texture Mapping	HW 8: texturing (Fri 11/19)
More Texture Mapping	**Final Project Discussion 1**	
Thanksgiving Recess	*Thanksgiving Recess*	
Final Project Discussion 2	**Final Project Discussion 3**	
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 3-7pm
  - The last 2 assignments are extended to Friday, as we lose a lecture for the new Election Holiday
- Grading is done via live demos (using Nooks this quarter) 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 your homework grades are 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 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
  - 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 their 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

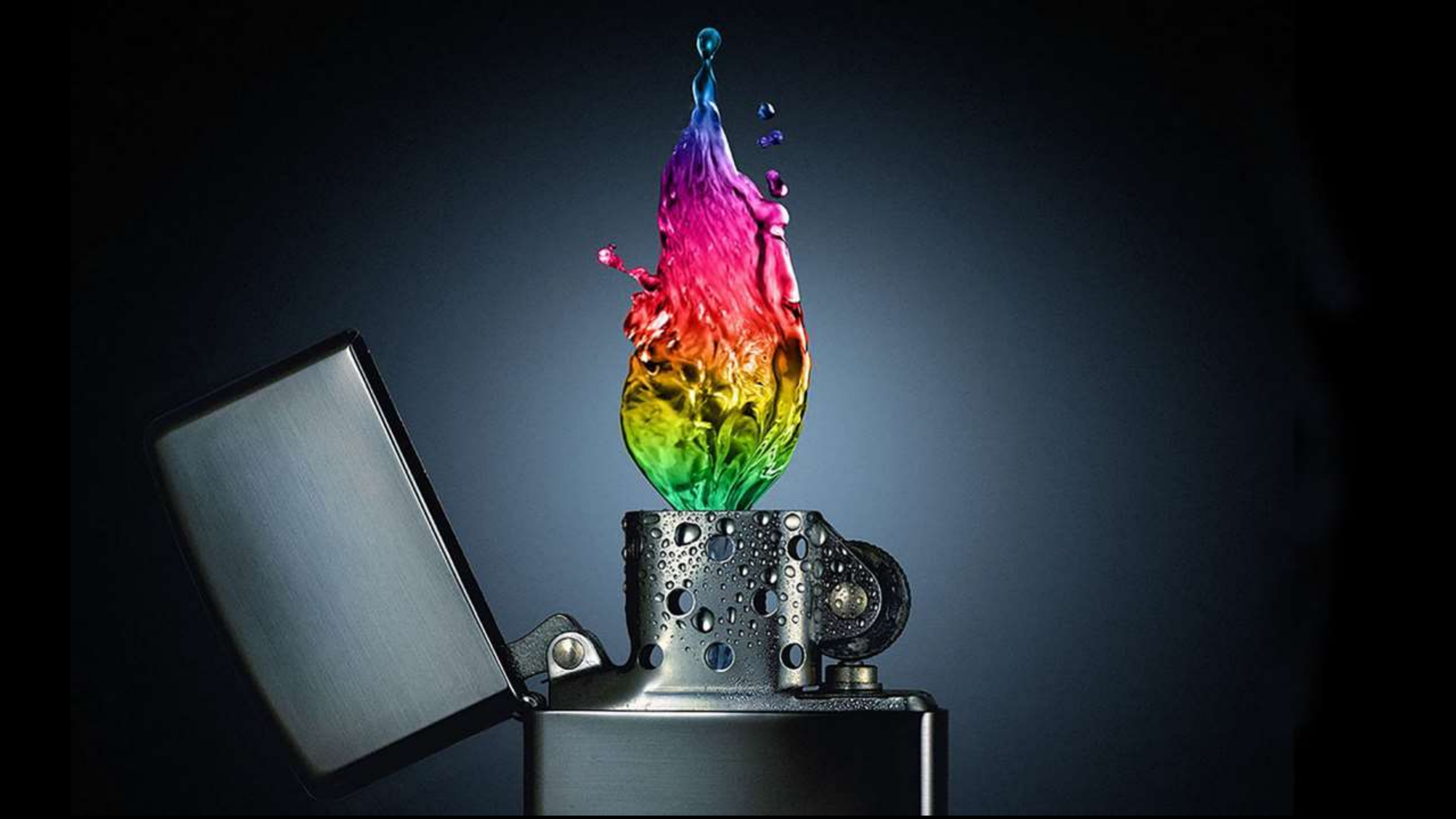
- Covid
  - We are staying 100% online this quarter, so you can minimize contact hours

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…


Carlsberg



Projects

- See the handouts!

Here are some projects from prior years…


Saint Louis University
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

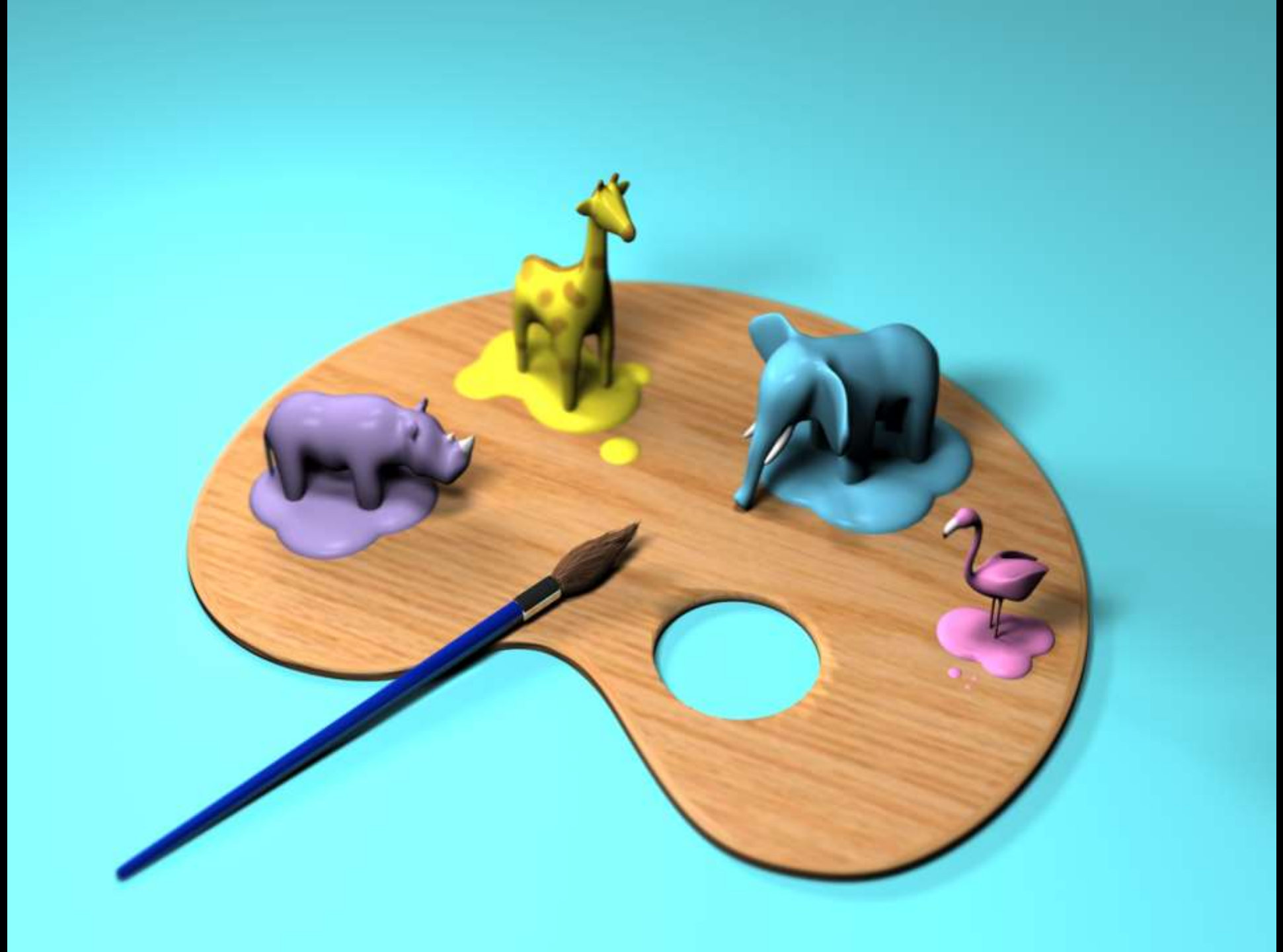

DAWS
OLD CU


成功
培養人一己百的
克勤精神剛天下
斷無不成功之事


OCEAN
INDIAN
OCEAN
Armenia
TURKEY
Anatolia
(Republic, 1923)
SYRIA
Cyprus
French Mandate, 1920
IRAQ
(MESOPOTAMIA)
British Mandate
1920
Plan of Sevastopol
1854-1855
Scale 1: 200 000.
Miles.
1. The city proper
DR. HENRY JONES


A 139


personal
computers
apple
sophistication.
apple II



A 348B image…