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
“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
- Terminator 2
- The Day After Tomorrow
VFX: Gases

Harry Potter and the Order of the Phoenix

Star Wars Episode III

Terminator 3
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)

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

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<td>HW 1: set up environment (Mon 9/27)</td>
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<td>Virtual World</td>
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<td>HW 2: virtual world &amp; triangles (Mon 10/4)</td>
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<td>Recursive Ray Tracing</td>
<td>HW 3: ray tracing (Mon 10/11)</td>
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<td>HW 4: lighting &amp; shading (Mon 10/18)</td>
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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...
Projects

• See the handouts!
A 348B image...