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 noon to 1:20pm
Graphics is Pervasive

• Computer graphics is all around us!
• No one prefers a *text only* interface when interacting with a computer, cell phone, DVD player, ATM, or car
  – Note that the text is also visualized via graphics based fonts

• Thus, learning at least a little bit about graphics is highly useful for all computer scientists...
What can I do with graphics?

• At the very least:
  – improve your presentation and communication skills (making demos, visualizations, etc. for your other work)

• That is, make better use of everyday tools:
  – e.g. cell phone (user interface, camera, 2D image processing)
Smartphones (& Cameras)

• 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)
What can I do with graphics?

• Scientists/Engineers need graphics too
• Visualization of various phenomena, computer aided design, virtual prototyping, simulation, etc.
Scientific Visualization

The Virtual Human
Karl-Heinz Hoehne

Outside-In
The Geometry Center
Computer-Aided Design

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 off a box on the bucket list:
  - learn more about the video games that lured many to computers/CS in the first place

AR/VR too...
Video Games

Spore

Crysis

Braid
Graphics Hardware

NVIDIA Fermi

NVIDIA OptiX
Virtual (and Augmented) Reality

Ivan Sutherland: Head-mounted displays, with mechanical tracker

Oculus Rift
What can I do with graphics?

• Of course, Hollywood Visual Effects...

• One 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 too...
- Instead of adding computer generated elements to real world film footage, create a whole new digital world
  - often with its own set of rules

PLAY: Maelstrom Video
Animated Films

Toy Story 3

Monsters, Inc.
Graphics at Stanford
Overview of the Graphics Track

Creative Expression (CE) WAYS course

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 will write code but will not submit any code. Instead, *you will give live demos of working code*
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, 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
CS148 (more details...)
Final Project

Scanline Render: Portal, Valve Corporation

Raytraced Render: San Miguel Scene, PBRT

Math and Optics
<table>
<thead>
<tr>
<th>TUESDAY</th>
<th>THURSDAY</th>
<th>HOMEWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Light and Color</td>
<td>HW 1: set up environment</td>
</tr>
<tr>
<td>Scanline Rendering 1</td>
<td>Scanline Rendering 2</td>
<td>HW 2: openGL</td>
</tr>
<tr>
<td>Geometric Modeling 1</td>
<td>Geometric Modeling 2</td>
<td>HW 3: geometric modeling</td>
</tr>
<tr>
<td>Optics</td>
<td>Shading</td>
<td>HW 4: lighting &amp; shading</td>
</tr>
<tr>
<td>Texture Mapping 1</td>
<td>Texture Mapping 2</td>
<td>HW5: texturing</td>
</tr>
<tr>
<td>Ray Tracing</td>
<td>Sampling</td>
<td>HW 6: sampling</td>
</tr>
<tr>
<td>Reflection and Transmission</td>
<td>Acceleration Structures</td>
<td>HW 7: acceleration structures</td>
</tr>
<tr>
<td>Global Illumination</td>
<td>Photon Mapping</td>
<td>HW 8: photon mapping</td>
</tr>
<tr>
<td>Advanced Rendering</td>
<td><strong>Image Brainstorming</strong></td>
<td></td>
</tr>
<tr>
<td><em>Thanksgiving Recess</em></td>
<td><em>Thanksgiving Recess</em></td>
<td></td>
</tr>
<tr>
<td>Final Project Discussion</td>
<td>Final Project Discussion</td>
<td></td>
</tr>
<tr>
<td><strong>Final Exam: TBA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Final Project Due</strong></td>
</tr>
</tbody>
</table>
Assignments & Grading
50% final project, 32% homework, 18% “engagement”

- The weekly graded homeworks are designed as building blocks towards the final project, which is a single ray traced image
  - We will first learn to do some things using openGL in real time for more efficient scene design
  - Then we will move on to the ray tracer and work towards the final scene
- You may have a partner for both the homeworks and the images
  - You may change partners as often as you wish throughout the quarter
- Homework is assigned Tuesday and due the following Monday from 3-7pm
- Grading is done via live demos with the CAs
  - The CAs will/may ask you various questions
  - 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 0-4 point grading scale
  - If your homework grades are not going well, do not be surprised if your final image grade is lower than you expect
  - Working with *feedback* is very important in computer graphics!
Class Engagement 18%

- Admittedly, it is entirely possible to learn any highly technical subject matter at home, without attending class or even going to college for that matter. However, as a general education WAYS class, CS148 aims to increase those additional things learned (even often about the technology itself) through social interactions. In fact, one should be interacting quite a bit with others when trying to create compelling imagery as there is an artistic component - this will be salient for the class final project/image.

- As such, we aim to increase one’s “engagement” in this course by allowing the use of a partner, having in-person grading sessions, and by promoting class attendance and discussion. In particular, there will be a number of in class exercises that are meant to encourage following along in lecture, thinking about the material as it’s presented, and discussions with others both inside and outside of class. To encourage these interactions, these “engagement” exercises will amount to 18% of the final grade.

- Optionally, if you have to miss some classes for whatever reason, we will aim to address your WAYS liberal arts “engagement” experience with an alternative writing assignment meant to promote both brainstorming and thinking about and/or summarizing the course material. We refer to these as LONG FORM alternatives to the SHORT FORM engagement exercises carried out in class. Generally speaking, a LONG FORM writing assignment should be about 500-1000 words in length (which is 1-2 reasonably typed pages).

- SCPD students will do the SHORT FORM assignments, or a similarly constructed alternative.
Class Engagement 18%

- Nothing today (Lecture 1)

- 1 point each (1%) for the 15 lectures from Lecture 2 to Lecture 16 inclusive

- 1-3 points (1-3%) for submitting an image for Lecture 18
  - Start looking for good images now...

- Lectures 17, 19, and 20 are optional

Some ideas for lecture 18 motivational images...
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 or math course, except that programming and math are necessary enabling technologies
• 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 and rewards creativity above all else; albeit, technical skills are taught and required
  • very few other classes in CS encourage and reward creativity; this is one of your only options
  • academic and 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...
NEW THIS YEAR
(on a trial basis...)

43/26
“Stress-Relief” Points

(“Chill” Points)

8 free points (as in 8% of the grade) applied as follows:

Homework
- Any HW score less than the 4 point maximum is assigned (at most) 1 point in order to raise it
- That is, a 0 raises to a 1, a 1 raises to a 2, a 2 raises to a 3, and a 3 raises to a 4
- No extra points are allowed, so a 4 is NOT raised to a 5
- Essentially, if you can get 3 out of 4 points on every HW, you get a perfect HW score
- We stress, each HW score is raised by 1 point only, and extra points from perfect 4 point HWs cannot be rolled over into other lower scoring HW assignments
- Rationale: Every HW assignment is useful for your final project in some way, so we want you to try on all of them. But, we would like more of a focus on the final projects.

Engagement
- Every time you score a 4 on a HW assignment, the bonus point is rolled into engagement instead, with the rationale that working diligently on programming assignments (hopefully with your partner and the CAs) should also count as a form of immersion
- This means that one could earn from 1 to 8 points towards engagement by completing that number of HWs with a perfect score of 4 out of 4
- Each such point allows you to skip SHORT/LONG form for one of the 15 required lectures
  - or alternatively, points may be applied to the 3 point motivational image
- Your engagement score will be clamped at 18 points (so, there is no rollover into projects)
Some Images from Prior Years...
A 348B image...