Lecture 20:

Course Summary +
Graphics at Stanford Today

Computer Graphics: Rendering, Geometry, and Image Manipulation
Stanford CS248A, Winter 2023
As accomplished CS248A students you’ve now learned the basics of drawing shapes, representing surfaces/light/materials, manipulating images, etc…

(and you have been introduced to core graphics ideas like sampling, anti-aliasing, acceleration data structures, etc.)

What’s next?
Graphics classes (coming quarters) at Stanford

**SPRING**

- **CS348K:** “Visual Computing Systems”, creating efficient systems for photography, 3D graphics, and modern AI (Fatahalian) - **TTh 10:30am**
- **CS348E:** “Character Animation: Modeling, Simulation, and Control of Human Motion” (Liu) - **MW 1:30pm**
- **CS 348N:** “Neural Models for 3D Geometry” (Guibas) - **MW 3:00pm**
- **CS 231N:** “Deep Learning for Computer Vision” (F. Li) - **TTh 12:00pm**

**FALL**

- **CS248B:** “Fundamentals of Computer Graphics: Animation and Simulation “ (Liu, James)
- **CS 448B:** “Data Visualization” (Agrawala)

**WINTER**

- **CS348C:** “Animation and Simulation”, deep dive into animation and simulation techniques (James)
- **EE367/CS448i:** “Computational Imaging and Display”, advanced course on display design (Wetzstein)
- **CS205L:** “Continuous Mathematical Methods with an Emphasis on Machine Learning” (Fedkiw)
Graphics Research at Stanford Today
Maneesh Agrawala
ControlNet: more precise ways to control diffusion-based generative AI
General theme: intuitive controls for content creation

[A. Original body layers]
[B. Original accessory layers]
[C. Deformed body layers]
[D. Deformed accessory layers, no rigging]
[E. Deformed accessory layers, our rigging]
[F. Original accessory layers]
[G. Original accessory layers]
[H. Original accessory layers]
[I. Deformed accessory layers, our rigging]

[Le et al. UIST 21]
Ron Fedkiw
Simulation techniques (often) targeted at film and game production

Now exploring use of machine learning to augment or improve physical simulations
Human motion synthesis and estimation

Scene-aware human behaviors

Human-robot interaction

Human dexterity
Human dance dataset

Train an editable generative model to imitate human motor skills and musicality in dance using Diffusion Models.
Karen Liu

Interests in animation, simulation, and control
Recent Guibas Lab projects

- Computer vision and sensor networks
- Geometric and topological data analysis
- 3D machine learning and 3D representations
- 3D shape/scene analysis and synthesis
- Neural methods for navigation and manipulation
- Affective computing

Algorithmic problems in modeling physical objects and phenomena in vision/graphics/robotics
Leo Guibas
Geometry processing and analysis

PointNet: Deep Learning on Point Clouds

Shape Similarity and Correspondence

PointNet: Deep Learning on Point Clouds

Ground Truth

Wall  Floor  Chair  Desk  Bed  Door  Table
Gordon Wetzstein
Stanford Computational Imaging Lab

Neural Rendering  XR & Wearable Computing  Deep Optics

Single-photon Imaging  Computational Microscopy  Computational Cameras
Efficient 3D GANs – Latent Code Interpolation
Doug James
Cymbal
Kayvon Fatahalian (me)
Example getting-started-in-the-lab project idea

- Take the technology shown on the previous slide and make an interactive “Wimbledon point creator” where folks can visit a web site, click where they want the ball to go, and then download a resulting video.
- I bet it would be a hit if you could get it done and online before Wimbledon 2023
Controlling generative AI by making collages

User creates a collage with standard graphics tools
Collage defines what should be in the image, where it goes, and what it should look like

Generative AI turns the collage into a “plausible” realistic image

Prompt: “a bento box with rice, edamame, ginger, and sushi”
High Interest in AI Agents Across Disciplines

Game-Playing Agents
- Dota 2
- Google Research Football
- OpenAI Hide & Seek

Robotics
- Habitat Rearrangement Challenge
- Autonomous Vehicles (Carla, NV Drive Sim)
- ProcTHOR

Game Development & Debugging
- Unity ML-Agents
- Automated QA & Design (EA SEED)
Generating Simulated Experience is Computationally Demanding: Slow & Expensive Training!

- **OpenAI Five**
  - Rapid: 100k+ CPUs, months of training

- **Habitat 2.0**
  - 25000 FPS on 8 GPUs, Months to Learn Rearrangement

- **Unity ML-Agents**
  - Thoughput Limited by Scaling Strategy
Example: OpenAI Hide & Seek:
What if we redesigned a game engine for running billions of independent training runs? How fast could you go?
Simulating 16,000 worlds at 700,000 fps

Throughput (world updates/sec)

CPU Reference 15K
CPU ECS 140K
GPU ECS 26K
GPU Batch ECS 701K

Hide & Seek
What if up to two instructions can be performed at once?

\[ a = x^2 + y^2 + z^2 \]

**Assume register**

\[ R0 = x, R1 = y, R2 = z \]

```
1 mul R0, R0, R0
2 mul R1, R1, R1
3 mul R2, R2, R2
4 add R0, R0, R1
5 add R3, R0, R2
```

- **R3 now stores value of program variable \( a \)**
Other popular research topics in computer graphics...
Creating physically plausible models

- Via 3D printing, fabrication
- Creatures that locomotes, furniture that stands, etc.

Fabricate models that are balanced to stand

Fabricate robots that can balance and move
Computational photography
Using computation (and increasingly machine learning) to make more aesthetic photographs, simulate behavior of more complex lenses, etc.

Google Pixel 2 Portrait mode

Advanced displays/rendering for VR/AR

Near eye light field display
A fun resource
Ke-sen Huang’s famous site with all the SIGGRAPH papers!
http://kesen.realtimerendering.com/ SIGGRAPH 2022 papers on the web

Page maintained by Ke-sen Huang. If you have additions or changes, send an e-mail.

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Note that when possible I link to the page containing the link to the actual PDF or PS of the preprint. I prefer this as it gives some context to the paper and avoids possible copyright problems with direct linking. Thus you may need to search on the page to find the actual document.


conditionally accepted papers / TOG papers

Ecoclimates: Climate-Response Modeling of Vegetation
 Wojtek Palembici, Milan Makowski, Weronika Gajda (Adam Mickiewicz University), Torsten Hedrich, Dominik L. Michels (KAUST), Soren Pirk (Adobe Research)

DSG-Net: Learning Disentangled Structure and Geometry for 3D Shape Generation
 Jie Yang* (Institute of Computing Technology, Chinese Academy of Sciences) and University of Chinese Academy of Sciences), Kaichun Mo* (Stanford University), Yu-Kun Lai (Cardiff University), Leonidas J. Guibas (Stanford University), Lin Gao (Institute of Computing Technology, Chinese Academy of Sciences) and University of Chinese Academy of Sciences) * Authors contributed equally

A Fast Unsmoothed Aggregation Algebraic Multigrid Framework for the Large-Scale Simulation of Incompressible Flow
 Han Shan*, Libo Huang*, Dominik L. Michels (KAUST) * Authors contributed equally

A Practical Model for Realistic Butterfly Flight Simulation
 Qiang Chen (Jiangxi University of Finance and Economics), Shengguang Lu, Yang Tong, Guoliang Luo (East China Jiaotong University), Xiaowang Jin (Zhejiang University), Zhigang Deng (University of Houston)

Dev2IP: Planar Quadrilateral Strip Remeshing of Developable Surfaces
 Pierre Vrochev (ETH Zurich), Amir Vaxman (Utrecht University), Tim Hoffmann (TU Munich), Olga Sorkine-Hornung (ETH Zurich)

DiffCloth: Differentiable Cloth Simulation with Dry Frictional Contact
 Yiwei Li, Tao Du (MIT CSAIL), Kai Wu (Tsung-Lin Li Research Laboratory), Jie Xu, Wojciech Matusik (MIT CSAIL)

DiffusionNet: Discretization Agnostic Learning on Surfaces
 Nicholas Sharp (Carnegie Mellon University and University of Toronto), Sounhai Attai (LIX, Ecole Polytechnique), Keenan Crane (Carnegie Mellon University), Maks Ovsjanikov (LIX, Ecole Polytechnique)

HRBF-Fusion: Accurate 3D reconstruction from RGB-D data using on-the-fly implicits
 Yabin Xu (Queens University of Aeronautics and Astronautics), Liangliang Nan (Delft University of Technology), Laishui Zhou, Jun Wang (Nanjing University of Aeronautics and Astronautics), Charlie C.J. Wang (The University of Manchester and Delft University of Technology)
Discussion: graphics jobs
Discussion: how to get involved in graphics at Stanford

- Email your graphics professors and ask to talk to them about independent study
  - Although to be honest... the best intro line is ("I took and loved your 300-level graphics class and did well and want to keep going")

- A common way to get started
  - Hack code to contribute to a Ph.D. student’s research project
Why research (or independent study)?

- You will learn **way more** about a topic than in any class.

- You think your undergrad friends are very smart? Come hang out with Stanford Ph.D. students! (you get to work side-by-side with them and with faculty). Imagine what level you might rise to.

- It’s way more fun to be on the cutting edge. Industry might not even know about what you are working on. (imagine how much more valuable you are if you can teach them)

- It widens your mind as to what is possible.
Maybe you might like research and decide you want to go to grad school

Pragmatic comment: Without question, the number one way to get into a top grad school is to receive a strong letter of recommendation from faculty members. You get that letter only from being part of a research team for an extended period of time.

DWIC letter: (“did well in class” letter) What you get when you ask for a letter from a faculty member who you didn’t do research with, but got an ‘A’ in their class. This letter is essentially thrown out by the Ph.D. admissions committee at good schools.
A very good reference

CMU Professor Mor Harchol-Balter’s writeup:
“Applying to Ph.D. Programs in Computer Science”

http://www.cs.cmu.edu/~harchol/gradschooltalk.pdf
Thanks for being a great class!

Good luck finishing projects. Make sure you have fun, that’s the point!