Computational Photography

CS445

Instructor: Yuxiong Wang

Some Slides adopted from Derek Hoiem
Yuxiong Wang

- Ph.D. & Postdoctoral Fellow
  - CMU, Robotics Institute
  - Thesis: Learning to learn for small sample visual recognition

- Assistant Professor, 2020-
  - UIUC, CS

- Research Interests
  - Meta-Learning, Computer Vision, Robotics

Hiring! Ph.D., MS., Undergraduates
Kai Yan

• Intro
  – 3rd year PhD student
  – Co-advised by Prof. Yu-Xiong Wang and Prof. Alexander Schwing
  – 1st time as a TA for CS445

• Research Topic – Reinforcement / Imitation Learning
  – Learn to make decisions by historical data and trial-and-error

• What’s fun about CS445?
  – Understand and DIY your PhotoShop/FaceApp!
Hang Yu

- Intro
  - 2nd year MSCS student
  - 1st time as CS445 TA
  - Love freediving

- Research Topic - Long-Tailed Recognition
  - solve the hideous data imbalance issue

- What’s fun about CS445?
  - Understanding what’s happening in Photoshop and Premiere Pro
  - Know your camera better!
Shuhong Zheng

• Intro
  – 2nd year MS student
  – Advised by Prof. Yu-Xiong Wang
  – 2nd time as a TA for CS445

• Research Topic – Bridging Discriminative and Generative Learning
  – Generative models like NeRF and diffusion models to perform visual perception tasks

• What’s fun About CS445?
  – The experiences of handling with your own images! (e.g., Generate fakes and get rid of something on the images that you dislike!)
Today’s Class

• A little about my research

• Intro to Computational Photography

• Course outline and logistics
About My Research

Pottopod

Image credit: S. Savarese, P. Perona
Find the Pottopod

Image credit: P. Bruegel, P. Perona
Machine Recognition

Data labeling factory

supervised learning

Image → Model → Label

"Pottopod"
Why Not Simply Collect More Data?

• The real world is long-tailed
  - Unscalable: Recollect huge data
  - Expensive
  - Difficult
Our Problem: Few-Shot Learning

Few-Shot Loris Classification

Novel (Rare) Class

One-shot (single image)

$f_{Loris}$ Model

Key Insight: Meta-Learning

Learning how to learn on Base (Common) Classes

Few-Shot Cat Classification
Few-Shot Dog Classification
Few-Shot Fish Classification

Learning from Experience

Few-Shot Loris Classification
Novel (Rare) Class

One-shot (single image)

Model
Address Rich Space of Few-Shot Tasks

Q: How many kids are there?
A: Three!

Beyond: NLP, RL...

Task Complexity
My Work:
A Principled Meta-Learning Framework

- Address *rich* space of few-shot tasks
- Explore *various* experience & knowledge

### Learning to Generate Data
- [CVPR18]
- [CVPR19]
- [MM19]
- [ICLR21]

### Learning to Transform Model
- [ECCV16]
- [NeurIPS17]
- [ECCV18]
- [ICCV19]

### Unsupervised Learning
- [CVPR15]
- [AAAI16]
- [NeurIPS16]
- [ICCV17]

### Compositional Learning
- [ICCV19]

### Developmental Learning
- [CVPR17]

### Predictive Learning
- [ECCV18]
- [ECCV18]
- [IROS18]
Some background to computational photography and ...

The Pursuit of Realism
Depicting Our World: The Beginning

Prehistoric Painting, Lascaux Cave, France
~ 15,000 B.C.
The Empress Theodora with her court.
Ravenna, St. Vitale 6th c.
Nuns in Procession. French ms. ca. 1300.
Depicting Our World: Renaissance

North Doors (1424)

East Doors (1452)

Lorenzo Ghiberti (1378-1455)
Depicting Our World: Renaissance

*Paolo Uccello,*  
*Miracle of the Profaned Host* (c.1467-9)
Depicting Our World: Toward Perfection

Jan van Eyck, *The Arnolfini Portrait* (1426-1434)
Depicting Our World: Toward Perfection

Lens Based Camera Obscura, 1568
Depicting Our World: Perfection!

*Still Life*, Louis Jaques Mande Daguerre, 1837
Is reality what we want?
Enter Computer Graphics...
Traditional Computer Graphics

- 3D geometry
- physics
- Simulation

GRAPHICS

projection
Computer graphics

What's wrong?
The richness of our everyday world
Which parts are hard to model?
People

From “Final Fantasy”

Alyosha Efros - On the Tube, London
Faces / Hair

From “Final Fantasy”
Urban Scenes

Virtual LA (SGI)

Photo of LA
Nature

River Cherwell, Oxford
The Realism Spectrum

Computer Graphics
+ easy to create new worlds
+ easy to manipulate objects/viewpoint
- very hard to look realistic

Computational Photography
Realism
Manipulation
Ease of capture

Photography
+ instantly realistic
+ easy to acquire
- very hard to manipulate objects/viewpoint
Computational Photography

How can I use computational techniques to capture light in new ways?

How can I use computational techniques to breathe new life into the photograph?

How can I use computational techniques to synthesize and organize photo collections?
Virtual Real World

Campanile Movie (1997)

http://www.debevec.org/Campanile/
Going beyond reality...

Benjamin Button (2008)

http://www.digitaldomain.com/work/the-curious-case-of-benjamin-button/
https://vimeo.com/72240367
Another example of blending reality with fantasy

Samsung Galaxy S6 regular and “beauty” selfie
Course objectives

1. You will have new abilities for visual creation.
Course objectives

2. You will get a foundation in computer vision.
Got job?

• Google, Facebook, Microsoft, Sony, iRobot, Amazon, Snapchat, Ebay, tons of startups, etc.

Course objectives

3. You’ll better appreciate your own visual ability.
Course objectives

4. You’ll have fun doing cool stuff!
Projects
Project 1: Hybrid Images
Project 2: Image Quilting for Texture Synthesis and Transfer
Project 3: Gradient-Domain Fusion (Poisson Editing)

Photos from James Hays
Project 3: Gradient-Domain Fusion (Poisson Editing)

Photos from Evan Wallace
Project 4: Image-Based Lighting
Project 5: Video alignment, stitching, and editing
Final Project

Something cool!
Course outline

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TAs
• Kai Yan, kaiyan3@illinois.edu
• Hang Yu, hangy6@illinois.edu
• Shuhong Zheng, szheng36@illinois.edu
Learning resources

Lectures
• Lecture modules on Coursera
• Recorded lectures: mainly from Prof. Derek Hoiem

Website
• https://yxw.cs.illinois.edu/course/CS445/S24/

Slides
• On Coursera & Website

Office hours
• On Coursera & Website

Campuswire: for announcements & discussion
• https://campuswire.com/p/G5A5FBEF7
• Code: 5425

Readings/textbook: for depth and details not covered in lecture
Grades

• Projects (55%)
  – 5 projects: each with 100 core points with more optional “bells and whistles”
  – 3 credit (ugrad): graded out of 425 points
  – 4 credit (grad/MCS): graded out of 500 points

• Exams (30%)
  • Midterm 15%: covers first half
  • Final 15%: covers entire semester

• Final Project (15%)
  • 1% for proposal, 14% for final submission
  • Work in a group of two or up to four
  • 2-4 page short report

Late policy
• Up to ten free days total – use them wisely!
• 5 point penalty per day after that
• Project must be submitted within two weeks of due date to receive any points
Project details

• Implement stuff from scratch and apply it to your own photos

• Submit PDF, Jupyter notebook, and Python code
Academic Integrity

These are OK
• Discuss projects with classmates (don’t show each other code)
• Use Stack Overflow to learn how to use a Python module
• Get images from online (make sure to attribute the source)

Not OK
• Copying or looking at project-specific code (i.e. so that you claim credit for part of an assignment based on code that you didn’t write)
• Using external resources (code, images) without acknowledging them

Remember
• Ask if you’re not sure if it’s ok
• You are safe as long as you acknowledge all of your sources of inspiration, images, code, etc. in your write-up
Other comments

Prerequisites

- **Linear algebra**, plus some basic calculus and probability
- Experience with graphics, image processing, or Python will help but is not necessary

Equipment

- Your own camera, but a smartphone is probably good enough
- A mirrored sphere for project 4 (12 cm or bigger) e.g. [https://www.amazon.com/Stainless-Mirror-Polished-Sphere-Ornament/dp/B01ING7L4U](https://www.amazon.com/Stainless-Mirror-Polished-Sphere-Ornament/dp/B01ING7L4U)
Feedback is welcome