CS 180/280A

Introduction to Computer Vision and Computational Photography

Syllabus

Instructors:	Alexei Efros	Fall 2023
	Angjoo Kanazawa	M W 5:00 - 6:29 PM
GSIs:	Ruilong Li	Location: Li Ka Shing 245
	Jake Austin	Course Website
Tutors:	Morgan	Ed
	Preston	bCourses
	Max	Gradescope
		Google Calendar

The aim of this advanced undergraduate course is to introduce students to computing with visual data (images and video). We will cover acquisition, representation, and manipulation of visual information from digital photographs (image processing), image analysis and visual understanding (computer vision), and image synthesis (computational photography). Key algorithms will be presented, ranging from classical (e.g. Gaussian and Laplacian Pyramids) to contemporary (e.g. ConvNets), with an emphasis on using these techniques to build practical systems. This hands-on emphasis will be reflected in the programming assignments, in which students will have the opportunity to acquire their own images and develop, largely from scratch, the image analysis and synthesis tools for solving applications.

The course objective is to get a foundation in image processing and computer vision as well as build a more intuitive understanding of mathematical and computational concepts. Topics discussed include:

1. Camera basics, image formation
2. Convolutions, filtering
3. Image and Video Processing (filtering, anti-aliasing, pyramids)
4. Image Manipulation (warping, morphing, mosaicing, matting, compositing)
5. Projection, 3D vision, stereo, multi-view geometry
6. Image-based Rendering: Plenoptic Function, Lightfields
7. Basics of recognition: ConvNets, GANs
8. Gradients, change of basis, interpolation, extrapolation, PCA, FFT

Disclaimer

Assignments in this course will require Python coding without starter code. This course will not teach you how to code, and you are expected to already know how to program in Python.

Prerequisites

This is a **heavily** project-oriented class, therefore good programming proficiency (at least **CS61B**) is absolutely essential and required. Moreover, familiarity with linear algebra (**MATH 54** or **EE16A/B** or Gilbert Strang's online class) and calculus are vital. Experience with neural networks (**CS 182** or

equivalent) is strongly recommended. Due to the open-endedness of this course, **creativity** is a class requirement.

Materials / Textbooks

We will be using the new 2nd edition of Rick Szeliski's Computer Vision textbook.

The following books may also be useful as a reference:
Hartley and Zisserman: Multiple View Geometry in Computer Vision (classic 3D vision textbook)
Forsyth and Ponce: Computer Vision: A Modern Approach
Stephen Palmer: Vision Science: Photons to Phenomenology
Gonzalez and Woods: Digital Image Processing, 2nd edition
Gilbert Strang : Linear Algebra and its Applications

Grading

60% Programming and Written Assignments
20% Final Project
20% Final Exam (**Date TBD**) and some Pop Quizzes

Students will be allotted a total of **5 (five)** late days per semester with each additional late day incurring a 10% penalty.

Students taking CS280A will also be required to submit a conference-style paper describing their final project.

Projects

There are 5-6 projects plus a final project. **All projects are to be done solo** (with the possible exception of the final project). We expect you to derive the math, implement algorithms from scratch, apply your code to your own photos, and create a portfolio website.

What is the difference between CS280A and CS280?

The CS280A course is the mezzanine (e.g., taken by many Master's students, and possibly by PhD students who want a broad overview and fundamentals in image processing), and the CS280 course is the PhD/research-focused course (e.g., reading research papers in the field, primarily targeted at PhD students). In particular, CS280 gets more into details into image recognition topics such as object detection, as well as multi-view geometry, and covers more advanced topics such as transformers, and multimodal models in vision.

Lecture & Office Hours

This is an **in-person** course, so, unless the campus policy changes, lectures will be live and physical attendance is required. We plan to record lectures but will only make them available for emergency circumstances (e.g. covid).

Office hours will be divided into recitation sections and conceptual/programming sections. Consult the CS 180 Calendar for office hour times and locations.

Computational Resources

Students will be encouraged to use Python (with either scikit-image or opencv) as their primary computing platform (although MATLAB with the Image Processing Toolkit is also good). Although it is not required, students are highly encouraged to obtain a digital camera for use in the course.

Ed Etiquette

1. Search for the answer on Ed to see if it has already been answered before making a post.
2. Please post project questions only in the designated project posts.
3. Link/screenshot any external resources you are referencing.
4. Do not post answers/code in public Ed threads.

ChatGPT Policy

We are here to learn — if you use chatGPT to do all of your projects you will not do well in the exam. The point of the implementation is so you understand it!

We need you to type your own code.
No auto-pilot auto-complete because they will be flagged as plagiarism,
Same if you copy directly from chatGPT, we will likely find it.

We don't prohibit using chatGPT, but you are only allowed to use it for debugging purposes, and you need to submit the entire transcript of your conversation with chatGPT/other chatbots.

Academic Integrity

You are a member of an academic community at one of the world's leading research universities. Universities like Berkeley create knowledge that has a lasting impact in the world of ideas and on the lives of others; such knowledge can come from an undergraduate paper as well as the lab of an internationally known professor. One of the most important values of an academic community is the balance between the free flow of ideas and the respect for the intellectual property of others. Researchers don't use one another's research without permission; scholars and students always use proper citations in papers; professors may not circulate or publish student papers without the writer's permission; and students may not circulate or post materials (handouts, exams, syllabi--any class materials) from their classes without the written permission of the instructor.
Any test, paper or report submitted by you and that bears your name is presumed to be your own original work that has not previously been submitted for credit in another course unless you obtain prior written approval to do so from your instructor. In all of your assignments, including your homework or drafts of papers, you may use words or ideas written by other individuals in publications, web sites, or other sources, but only with proper attribution. If you are not clear about the expectations for completing an assignment or taking a test or examination, be sure to seek clarification from your

instructor or GSI beforehand. Finally, you should keep in mind that as a member of the campus community, you are expected to demonstrate integrity in all of your academic endeavors and will be evaluated on your own merits. The consequences of cheating and academic dishonesty—including a formal discipline file, possible loss of future internship, scholarship, or employment opportunities, and denial of admission to graduate school—are simply not worth it.

You can discuss projects, but are not permitted to share code. You may not look up code or copy code from any other source. If you have any questions regarding what is permitted, ask on Piazza.

Inclusion

We are committed to creating a learning environment welcoming of all students. If you anticipate or experience any barriers to learning in this course, please feel welcome to discuss your concerns with me. We intend to support a diversity of perspectives and experiences and respect each other as an individual regardless of their identities and backgrounds. To help accomplish this:

- If you feel like your performance in the class is being impacted by a lack of inclusion, please contact the instructors, your ESS advisor, or the departmental Faculty Equity Advisor (list and information at: https://diversity.berkeley.edu/faculty-equity-advisors. An anonymous feedback form is also available at https://engineering.berkeley.edu/about/equity-and-inclusion/feedback/.
- If you have a name and/or set of pronouns that differ from your legal name, designate a preferred name for use in the classroom at: https://registrar.berkeley.edu/academic-records/your-name-records-rosters.
- If you feel like your performance in the class is being impacted by your experiences outside of class (e.g., family matters, current events), please don't hesitate to come and talk with the instructor(s). We want to be resources for you.
- We are all in the process of learning how to respect and include diverse perspectives and identities. Please take care of yourself and those around you as we work through the challenging but important learning process.
- As a participant in this class, recognize that you can be proactive about making other students feel included and respected.

If you have a disability, or think you may have a disability, you can work with the Disabled Students' Program (DSP) to request an official accommodation. The Disabled Students' Program (DSP) is the campus office responsible for authorizing disability-related academic accommodations, in cooperation with the students themselves and their instructors. You can find more information about DSP, including contact information and the application process here: dsp.berkeley.edu. If you have already been approved for accommodations through DSP, please meet with me so we can develop an implementation plan together.

Students who need academic accommodations or have questions about their accommodations should contact DSP, located at 260 César Chávez Student Center. Students may call 510-642-0518 (voice), 510-642-6376 (TTY), or email dsp@berkelely.edu.

Other Student Resources

Center for Access to Engineering Excellence (CAEE)

The Center for Access to Engineering Excellence (227 Bechtel Engineering Center; https://engineering.berkeley.edu/student-services/academic-support is an inclusive center that offers study spaces, nutritious snacks, and tutoring in >50 courses for Berkeley engineers and other majors across campus. The Center also offers a wide range of professional development, leadership, and wellness programs, and loans iclickers, laptops, and professional attire for interviews.

Counseling and Psychological Services

University Health Services Counseling and Psychological Services staff are available to you at the Tang Center (http://uhs.berkeley.edu; 2222 Bancroft Way; 510-642-9494) and in the College of Engineering (https://engineering.berkeley.edu/students/advising-counseling/counseling/; 241 Bechtel Engineering Center), and provide confidential assistance to students managing problems that can emerge from illness such as financial, academic, legal, family concerns, and more. Long wait times at the Tang Center in the past led to a significant expansion to include a 24/7 counseling line at (855) 817-5667. This line will connect you with help in a very short time-frame. Short-term help is also available from the Alameda County Crisis hotline: 800-309-2131. If you or someone you know is experiencing an emergency that puts their health at risk, please call 911.

The Care Line (PATH to Care Center)

The Care Line (510-643-2005; https://care.berkeley.edu/care-line/) is a 24/7, confidential, free, campus-based resource for urgent support around sexual assault, sexual harassment, interpersonal violence, stalking, and invasion of sexual privacy. The Care Line will connect you with a confidential advocate for trauma-informed crisis support including time-sensitive information, securing urgent safety resources, and accompaniment to medical care or reporting.

Ombudsperson for Students

The Ombudsperson for Students (102 Sproul Hall; 642-5754; http://students.berkeley.edu/Ombuds) provides a confidential service for students involved in a University-related problem (academic or administrative), acting as a neutral complaint resolver and not as an advocate for any of the parties involved in a dispute. The Ombudsman can provide information on policies and procedures affecting students, facilitate students' contact with services able to assist in resolving the problem, and assist students in complaints concerning improper application of University policies or procedures. All matters referred to this office are held in strict confidence. The only exceptions, at the sole discretion of the Ombudsman, are cases where there appears to be imminent threat of serious harm.

Student Advocate's Office [Confidential]:

Provides free, confidential, student-to-student assistance for undergraduate and graduate students navigating issues with academics, financial aid, accusations of misconduct, instances of harassment and discrimination, and other grievances within the scope of the university.

Phone: (510) 642-6912 | Website: https://advocate.berkeley.edu/ | Email: help@berkeleysao.org

UC Berkeley Food Pantry

The UC Berkeley Food Pantry (#68 Martin Luther King Student Union; https://pantry.berkeley.edu) aims to reduce food insecurity among students and staff at UC Berkeley, especially the lack of nutritious food. Students and staff can visit the pantry as many times as they need and take as much as they need while being mindful that it is a shared resource. The pantry operates on a self-assessed need basis; there are no eligibility requirements. The pantry is not for students and staff who need supplemental snacking food, but rather, core food support.

Syllabus is a Contract and Subject to Change:

This syllabus is a contract that you, as an enrolled student in this course, agree to abide by throughout the semester. You agree to complete the assignments in a timely manner in accordance with the schedule printed in the syllabus and to participate in the class using proper student conduct and netiquette. As part of this agreement, your responsibilities are printed clearly within this syllabus with deadlines so that you will know well in advance when readings and assignments are due. The syllabus is also subject to change if deemed necessary by the instructor. You will be afforded ample warning before any new responsibility or assignment is due. Most often, a change to the syllabus will constitute a minor change in reading materials or the cancellation of a day of class. If such a change occurs, a revised syllabus will be made available to students and replace any old copies of the syllabus.

Schedule

Subject to change

Week	Date	Topics	Readings
1	8/23	Introduction	How Photography Became an Art Form by Aaron Hertzmann
2	8/28	Capturing Light… in man and machine	Assignment 1 released
	8/30	Point Processing and Filtering	Szelski Ch. 2
3	9/4	Labor Day Holiday	
	9/6	Convolution and Image Derivatives	Start Szelski Ch. 3 Assignment 1 due
4	9/11	The Frequency Domain	Szelski Ch. 3 & 4 Assignment 2 released
	9/13	**Last day to drop class**	
	9/13	Pyramid Blending, Templates, NL Filters	Szelski 3.5, 3.3 Burt and Adelson, A multiresolution spline with application to image mosaics, ACM ToG, 1983
5	9/18	Image Transformations	Szelski 2.1 Assignment 2 due
	9/20	Image Warping and Morphing	Szelski 3.6 Assignment 3 Released
6	9/25	Data-driven Methods: Faces	Galton, "Composite portraits made by combining those of many different persons into a single figure.", Nature, 1878 Rowland and Ferrett, "Manipulating Facial Appearance through Shape and Color", CG&A, 1995 Blanz and Vetter, "A Morphable Model for the Synthesis of 3D Faces", SIGGRAPH 1999 Cootes, Edwards, and Taylor, "Active Appearance Models", ECCV 1998
	9/27	The Camera	Szelski 2.3
7	10/2	The Camera Cont.	Assignment 3 Due

	10/4	Homographies and Mosaics	Szelski Ch 8 Assignment 4 Released
8	10/9	More Mosaic Madness	
	10/11	Automatic Image Alignment	10/11 Assignment 4 Part 1 Due
9	10/16	Cont. above + Optical Flow	
	10/18	Visual Texture (in human and machine)	
10	10/23	Feature Learning with Neural Networks	Szelski Chapter 5 Assignment 4 Part 2 Due
	10/25	Convolutional Neural Networks	
11	10/30	Convolutional Neural Networks II	Assignment 5 Released
	11/1	ConvNets as a Versatile Tool	
12	11/6	3D Vision: Calibration, Stereo	
	11/8	3D Vision: Epipolar Geometry	
13	11/13	Structure from Motion and Multi-view Stereo	Assignment 5 Due
	11/15	Modeling the Plenoptic Function	Adelson and Bergen, The Plenoptic Function and the Elements of Early Vision, 1991
14	11/20	Image based lighting	Debevec, "Rendering Synthetic Objects in Real Scenes", 1998 Debevec, "Virtual Cinematography: Relighting Through Computation", IEEE Computer, 2006
	11/22	No class - Thanksgiving	
15	11/27	Video and Texture Synthesis	Schodl et al., Video Textures SIGGRAPH' 00 Efros and Leung, Texture Synthesis by Non-parametric Sampling ICCV'99 Efros and Freeman, Image Quilting for Texture Synthesis and Transfer, SIGGRAPH'01 Hertzmann et al. Image Analogies, SIGGRAPH 2001

	11/29 (Last Lecture)	What makes a great picture?	
RRR	12/4	Precann projects due	
	12/6	Final Project Presentation for CS294-26	
Finals week	12/15	Final Project Writeup Due	
	12/11-12/15	Final Exam (TBD)	