EECS 442 Computer Vision & 504 Foundations of Computer Vision

Electrical Engineering and Computer Science

University of Michigan

Syllabus for Fall 2018

Last updated: 7 September 2018

*Note that this is a combined syllabus for EECS 442 and EECS 504. These courses overlap for 66% of the lecture and a sufficient amount of the material that it makes sense to combine the syllabi. Any 442 or 504-specific elements will be denoted as such in the syllabus by a boldface **442** or **504** preceding the content.*

Instructor: Jason Corso (jjcorso)

Instructor Office Hours: M 1600–1700, F 1100–1200 and by appointment.

GSI:

- **504** Nadha Gafoor (nadha) Hours: T 1430–1530, R 1300–1400, F 1030–1130
- **442** Anuj Gargava (anujgrgv) Hours: T 1230–1430, R 1130–1230
- **442** Jeffrey Dominic (jdomini) Hours: M 1600–1730, F 1230–1400

All GSI Office Hours are in the GSI room in 3312 EECS. Note that students may attend any of the office hours regardless of the enrolled course. This will help ensure that there is a time that fits everyone's schedule.

442 Canvas LMS Website: `https://umich.instructure.com/courses/234318`.

504 Canvas LMS Website: `https://umich.instructure.com/courses/235235`.

Meeting Times / Location:

- Main Lecture: F 1430–1630 in AUD CHRYS
- **504 only** Focus Lecture: M 1300–1400 in G906 COOL.
- **442 only** Focus Lecture: M 1500–1600 in 1013 DOW.
- **442 only; 504 optional if seats available** Discussion Sections: (1) W 1300–1400 in G906 COOL and (2) W 1730–1830 in G906 COOL.

Course Information Flow and A Note On Contacting The Instructor: This courses primarily uses Canvas to manage information flow. It will be used for announcements, lecture notes, assignments, and possibly for submitting work (details provided later).

The Canvas links for each course are above.

Piazza will be used for discussions. Nearly all questions you have about the course, both logistical and technical should be posted to piazza. Note that these discussions are primarily for student-to-student and student-to-GSI engagement; the professor will monitor piazza at most weekly. Only in the event of a concern of privacy, should you directly email the instructor.

Posts on Piazza will be restricted in such a way that the instructor will always know the identity of the poster. However, posts may be anonymous to the classmates.

Piazza will also be used during the class: in a class of 200+ or even the Monday discussions of 80 or 120, it is often a challenge for a student to raise his or her hand during class. So, I will monitor piazza during class and we can answer posts immediately.

iClickers will be used to facilitate in class informal assessments and graded quizzes. Note that this is the first time Professor Corso has used them, so there will be some learning curve on what works best. But, fair warning: they will be used and course attendance is required.

Students are expected to help each other through postings and discussions on the Piazza and other course tools like Canvas. In fact, some of this is factored into your grade.

Main Course Material

Course Description: Computer Vision seeks to extract useful information from images of various types. This course introduces the main topics in computer vision, emphasizing the breadth of problems in computer vision as well as recent application advances. This course will introduce an intellectual framework for computer vision. In the 504 version, the theoretical aspects, including vision as a search for invariants and vision as a set of optimization problems, will be emphasized, whereas in the 442 version, a more topical approach with emphasis on applications and uses will be taken. Foundational representations of images and image content will be discussed. Cross-cutting problems of reduction (e.g., feature extraction, segmentation), estimation (e.g., post estimation, camera calibration), and matching (e.g., image stitching, stereo reconstruction) will be concretely defined and elaborated through many real examples from modern computer vision.

The course is designed for graduate students and will prepare them for future work in computer vision. The students will develop a strong understanding of formulating and solving problems in computer vision. The students will develop a set of capable computer vision systems over the course of the semester through homework assignments.

This course approaches the teaching of computer vision in a rather unique way in comparison to typical introductory courses in computer vision. This course seeks to lay a foundation of the core elements of computer vision by developing these in a common mathematical framework. In the 442 version, the course will attend to examples and pseudocode more than the theory and mathematical framework. However, some attention to the core mathematics is needed. These core elements include how problems in extraction of useful information from images are represented, that computer vision is nicely posed as a set of optimization problems, that computer vision is a search for invariants of different forms, and that there are just a few common problem abstractions that cross-cut modern computer vision: reduction, estimation, and matching problems. In approaching vision from this foundation, we expect the course to prepare students both for future academic studies in computer vision as well as for industrial jobs in computer vision—these foundations are thoroughly expounded upon by detailed examples from modern computer vision, both in class and in assignments.

Rough Topic Outline: *Subject to change; updated and detailed outline will be posted to Canvas.*

1. Representation and Computer Vision as Optimization
2. Visual Invariance (photometric, geometric (shift, rotation, affine, scale), projective, structural, deformation, rate)
3. Reduction Problems (feature extraction, segmentation and grouping, etc.)
4. Estimation Problems (line and curve fitting, pose estimation, camera calibration, bundle adjustment, etc.)
5. Matching Problems (stereo correspondence, image stitching, image registration, etc.)

Course Goals: After taking the course, the student should have a clear understanding of

1. the foundations of computer vision, including representation, invariance, reduction, estimation and matching;
2. examples of modern computer vision methods in each of the above foundations;
3. implementation of computer vision methods on real data; and
4. exposure to elements of graduate-level research, including reading papers, implementing papers and reviewing papers.

These goals are evaluated through the assignments, quizzes and exams.

Prerequisites: No prior course in computer vision is needed. EECS 281 or sufficient prior training in programming and data structures, which is necessary not only to work on real computer vision problems but also to understand how typical methods work.

A working knowledge of calculus, linear algebra, and probability theory. Students are expected to be (or become on their own time) proficient in MATLAB.

The following is a list of some mathematical tools needed for this course. We will cover them as necessary, and when we do, we will cover them in as much detail as necessary to understand how to use them but not why they work. This is not a math course. These are the tools of the math of computer vision and are needed to work in computer vision.

- Eigenvector decomposition
- SVD
- Linear least squares
- Non-linear least squares
- Robust estimation
- Dictionary learning and sparse coding
- Combinatorial Optimization

- Cuts on graphs
- Linear programming
- Dynamic programming

Textbooks: There is no required textbook for this course. Instructor notes will be made available as external reading and readings from the following book will be assigned periodically to deepen the understand of the material. All readings are required.

- Szeliski *Computer Vision: Algorithms and Applications* published by Springer and available for purchase on various website or as a download (free) at http://szeliski.org/Book/.

Another reference for computer vision is below.

- Forsyth and Ponce *Computer Vision, A Principled Approach*. Prentice Hall, 2nd Edition, 2011. (ISBN-13: 978-0136085928 ISBN-10: 013608592X) The textbook has a website: http://luthuli.cs.uiuc.edu/~daf/CV2E-site/cv2eindex.html.

Course Work and Evaluation

Planned and subject to change based on time and class size.

Detailed Planned Schedule:

Friday Date	Key Topic for Friday-Monday Week	Notes	Recommended Readings	Written Assignments
9/7	Introduction and Preliminaries	Coding and Math Preliminaries on Monday		
9/14	Getting Excited About Computer Vision	Coding and Math Preliminaries on Monday		HW0: Basics (Not Graded)
9/21	Images as Functions		Szeliski 2.1.1, 3.0-3.1	HW1: Images as Functions
9/28	Image Operations		Szeliski 3.0-3.2, 3.6	
10/5	Case Study: Local Interest Points		Szeliski 3.5.3, 4.1, 6.1.1	HW2: Interest Points
10/12	Case Study: Deep Learning	**No Monday Class on 10/15**	Szeliski 14, Karpathy Notes	
10/19	Images as Points	**EXAM 1: Monday 10/22 Evening (Review During Class)**	Szeliski 3.4, 3.5.4	HW3: Images as Points
10/26	Case Study: Learning Bases	Friday class may be moved as the auditorium is needed by a student group.	Turk and Pentland	
11/2	Images as Graphs		Szeliski 5.2, 5.4, 5.5	HW4: Images as Graphs
11/9	Case Study: Image Labeling		Szeliski 5.2, 5.4, 5.5	Project Selection
11/16	Estimation Problems: Robust Estimation		Szeliski 4.3, 6.1	
11/23	**No Class: Thanksgiving**			
11/30	Case Study: 3D Vision		Szeliski 2.1, 2.3, 6.3, 7.1, 7.2, (11)	
12/7	Case Study: 3D Vision	**EXAM 2: Monday 12/10 Evening (Review During Class)**	Szeliski 7.3-7.5, 8	
12/14	Project Pow-Wow During Final Exam Time All Students Present and All Group Presenting.	Day/Time/Location TBA (442 and 504 are together for this)		Project Due

Homework Assignments (28%) Four graded assignments will be given. Assignments may have analytical components and a programming components. The programming components will progressively develop a capable computer vision system. All programming will be in Python. All data for programming assignments will be provided by the instructor. Problem sets may be discussed in groups but must be written independently, including programming. Over-the-shoulder Python debugging, for example, is not permitted. No code from other students, on-line or off-line resources other than that explicitly mentioned in the assignment is permitted. There will be one component of the assignments that overlap across 442 and 504 and one component of each assignment that is different.

Project (22%) There will be an end-of-term team project where groups of (4) students will form a mock-computer-vision-startup company. The teams will create a computer-vision-driven idea that has a relevant social application. The end of term project presentation will take the form of a "startup pitch." More details on this will be provided later in the term.

Quizzes/Participation (10%) Quizzes will be given in class regularly. Quizzes will be discussed in class as a learning tool.

Exams (40%) There will be two exams with one in mid-October and one in early December. 442 and 504 exams will be different.

Readings Recommended readings will be provided for most topics. Students are not required to read this material but are expected to take an active role in learning.

No assignments will be dropped. Quizzing through iClicker will be given frequently; we expect to drop roughly the lowest of every 6th or so.

Late Work and Missed Exam Policy: **No** late work will be accepted. Ample time will be given to complete the assignments; use it wisely. Similarly, the date of the exam will be known at least one month in advance. Do not miss the exam. **No** make-up exams will be given other than for those University approved reasons. This is a firm policy. Do not expect special treatment.

Regrading: Any questions about the grading of a piece of work must be raised within one week of the date that the work was returned by the teaching assistant or the instructor. In other words, if you do not pick up your work in a timely fashion, you may forfeit your right to question the grading of your work.

Additional Information

Differences from EECS 542: This course introduces the foundation of modern computer vision. EECS 542 builds on this foundation by driving into a deep study of a particular topic area within modern computer vision. These courses are, hence, both depth courses, but they have complementary goals.

General Notes

If you don't understand something covered in class, ask about it right away. The only silly question is the one which is not asked. If you get a poor mark on an assignment or exam, find out why right away. Don't wait a month before asking. The instructor and GSI(s) (if associated). Don't be afraid to ask questions, or to approach the instructor or TA in class, during office hours, through the discussion board or through e-mail. This course is intended to be hard work, but it is also intended to be interesting and fun. We think computer vision is interesting and exciting, and we want to convince you of this.

Disabilities

If you think you need an accommodation for a disability, please let me know at your earliest convenience. Some aspects of this course, the assignments, the in-class activities, and the way the course is usually taught may be modified to facilitate your participation and progress. As soon as you make me aware of your needs, we can work with the Office of Services for Students with Disabilities (SSD) to help us determine appropriate academic accommodations. SSD (734-763-3000; http://ssd.umich.edu) typically recommends accommodations through a Verified Individualized Services and Accommodations (VISA) form. Any information you provide is private and confidential and will be treated as such.

Counseling Center

Your attention is called to the Counseling and Psychological Services (734-764-8312), 3100 Michigan Union. The Counseling Center staff are trained to help you deal with a wide range of issues, such as how to deal with exam-related stress and other academic and non-academic issues. Services are free and confidential and do not impact student records. Shivaun Nafsu is the CAPS consultant directly within COE: snafsu@umich.edu or 734-763-8211. Their web site is http://caps.umich.edu/.

Standards of Conduct – Behavioral Expectations

The following are classroom "etiquette" expectations:

- Attending classes and paying attention. Do not ask an instructor in class to go over material you missed by skipping a class or not concentrating.
- Not coming to class late or leaving early. If you must enter a class after lecture has clearly begun, do so quietly and do not disrupt the class by walking between the class and the instructor. Do not leave class unless it is an absolute necessity.

- Not talking with other classmates while the instructor or another student is speaking. If you have a question or a comment, please raise your hand, rather than starting a conversation about it with your neighbor.
- Showing respect and concern for others by not monopolizing class discussion. Allow others time to give their input and ask questions. Do not stray from the topic of class discussion.
- Not eating during class time.
- Turning off the bothersome electronics: cell phones, pagers, and beeper watches.
- Avoiding audible and visible signs of restlessness. These are both rude and disruptive to the rest of the class.
- Focusing on class material during class time. Sleeping, talking to others, doing work for another class, reading the newspaper, checking email, and exploring the internet are unacceptable and can be disruptive.
- Not packing bookbags or backpacks to leave until the instructor has dismissed class.

College of Engineering Honor Code

The full Engineering Honor Code is available at `http://www.eecs.umich.edu/acal/honor.html`. All students are expected to read, understand and follow the honor code.

The Honor Code outlines certain standards for ethical conduct for persons associated with the College of Engineering at the University of Michigan. The policies of the Honor Code apply to graduate and undergraduate students, faculty members, and administrators.

In 1915, the students of the College of Engineering petitioned for the establishment of an Honor Code. The Code was promptly adoped with faculty approval and has been basic to life in the College of Engineering.

The Honor Code rests upon the following principles:

- Engineers must possess personal integrity both as students and as professionals. They must be honorable people to ensure safety, health, fairness, and the proper use of available resources in their undertakings.
- Students in the College of Engineering are honorable and trustworthy persons.
- The students, faculty members, and administrators of the College of Engineering trust each other to uphold the principles of the Honor Code. They are jointly responsible for precautions against violations of its policies.
- It is dishonorable for students to receive credit for work which is not the result of their own efforts.

The Engineering Honor Code is based on the principle that students will follow all guidelines for study and prepared work set forth by the instructor, and that students can be trusted to take examinations without cheating.

Students are responsible for reporting infractions of the honor code.