EECS 504 Foundations of Computer Vision

Electrical Engineering and Computer Science

University of Michigan

Syllabus for Fall 2016

Last updated: 16 September 2016

Instructor: Jason Corso (jjcorso)

GSI: Parker Koch (pakoch)

Course Webpage: http://web.eecs.umich.edu/~jjcorso/t/504F16.

Canvas LMS Website: https://umich.instructure.com/courses/106778.

Syllabus: http://web.eecs.umich.edu/~jjcorso/t/504F16/files/504F16_syllabus.pdf.

Meeting Times / Location:

- Main Course: MW 1200–1330 in 1500 EECS
- Optional Discussion Section: W 1900–2000 in Cooley G906

Prof. Office Hours: Tuesday 1350–1450 and Thursday 1100-1200 or by appt.

GSI Office Hours: Tuesday and Thursday 1430–1600

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, discussions and possibly for submitting work (details provided later).

The Canvas link is https://umich.instructure.com/courses/9801.

The instructor's course website is primarily the public portal to the site for broad reach in what the course covers, it will not be updated regularly throughout the term.

Nearly all questions you have about the course, both logistical and technical should be posted to canvas. Only in the event of a concern of privacy, should you directly email the instructor.

Students are expected to help each other through postings and discussions on the Canvas site. To encourage this, an extra 2.5 raw grade points will be added to the overall course scores of the top ten course participants, at the end of the term. Course participation analytics are provided through Canvas and these will be used directly.

We used Piazza in prior years (when we used CTools), but the discussion features in Canvas satisfy our needs.

Main Course Material

Course Description: Computer Vision seeks to extract useful information from images of various types. This course covers the foundations of computer vision. It emphasizes computer vision as a search for visual invariants and computer vision as mathematical modeling. 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. 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. Graduate standing, a working knowledge of calculus, linear algebra, and probability theory. Students are expected to be (or become on their own time) proficient in MATLAB.

Aside from a necessary introduction in the first few classes, we will cover the following mathematical tools on-demand during the term. This is not a math course; there is a fine balance between the level of depth we need to and we can cover each of these. However, these are the tools in the mathematical foundation of computer vision and, at the very least, exposure to them in this course is critical to students' future success 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.

Readings from the following books will be assigned periodically.

- 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.

Assignments (35%) Assignments will be given roughly biweekly throughout the semester. 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 Matlab. 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 MATLAB 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.

Project Challenge (15%) The assignments will develop a progressively capable computer vision system throughout the term. In the last third of the term, the students will be presented with a common challenge problem that will require an integrated use of the various topics and tools they learned in the first two-thirds of the term. The students will work in teams of two to develop a solution to the problem; during class at the end of the term, we will have a "bake-off" in which each team gets to demonstrate their approach on a novel test-data-set. Teams will briefly describe approaches and we will collectively analyze why certain approaches may have performed better than others.

Quizzes (20%) Quizzes will be given in class roughly bi-weekly. The de facto quiz is 10 minutes and presents a combination of rote memory and topic comprehension; if a larger quiz will be given (e.g., in place of a full-out exam, students will be notified within two weeks).

Exam (20%) There will be one exam in mid-November.

Wikipedia Entry(10%) Near the end of the term, each student will select a unique entry in Wikipedia related to computer vision; selections should be based on student interest. The student will revise and contribute to this Wikipedia entry (off-line). The revision and final entry will be due in beginning of December. Upon instructor approval, the student will then make the revisions to the entry in the on-line site.

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 442: This course and EECS 442 have a goal in common: introduce students to computer vision. However, this course significantly differs from 442 in that it strives to present a coherent mathematical framework for computer vision suitable to stand as a foundation for future research at the graduate level. This goal hence necessitates a rather different topical presentation. At its core are elements of foundational computer vision, such as invariance, optimization, and a common problem abstraction, that are discussed only in limited amounts, if at all, in 442.

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.