CSC 477/577

Introduction to Computer Vision

GS 701, 1:00 pm to 1:50 pm

Description of the Course

Computer vision is about building systems that see. Such a system would be able to take images as input and output a representation of what is in the world in front of the camera. We are all familiar with this process as it happens whenever we look around. However, putting this capability into a machine has proven to be very difficult and is the topic of much current research. In this course we will study the basic approaches that have been developed to analyze image data in an attempt to solve this problem, and their applications to other related areas such as computer graphics and image databases.

This course should be considered by students interested in computer vision, image processing, image databases, computer graphics, artificial intelligence, and cognitive science.

Topics: Image formation including spectral and geometric camera models and calibration, physics based vision, color, linear filtering, edge detection, texture, segmentation and grouping, local features (e.g. SIFT), recognition using on pose consistency, multiple view geometry and stereo, and recognition using templates and classifiers (i.e., machine learning).

Course Prerequisites or Co-requisites

MATH 215 or equivalent math background (basic calculus and linear algebra). CSC 345, CSC 352 or equivalent preparation in algorithms, data structures, and programming.

Instructor and Contact Information

Instructor:

Kobus Barnard, GS 708, kobus@cs.arizona.edu

Office Hours: MF, 9:15 am to 9:45am and by appointment

Teaching assistant:

Eric Welch, welche@email.arizona.edu

Office hours: Tuesday 12:30 to 1:30 in GS 934

Web information:

Course home page: http://vision.cs.arizona.edu/teaching/cs477/fall17

Instructor home page: http://kobus.ca

We will use D2L and Piazza for this course

Course Format and Teaching Methods

Lecture only.

Course Objectives and Expected Learning Outcomes

The broad objectives of this course are to introduce modern computer vision ideas with an emphasis on fundamental understanding, and mathematical and experimental methods which

are applicable to a number of research problems (not just computer vision). Assignments and exams will develop and evaluate both conceptual understanding and applying the methodology to practical problems.

Concepts related to the course topics listed above that students are expected to learn include:

- computer vision is a fundamentally under constrained problem, and general strategies for dealing with this
- how image formation (both spectral, i.e., color, and geometric, i.e., perspective) can be modeled mathematically and how those models can be applied;
- how shading provides depth information;
- how illumination and surface reflectance is intertwined in image formation, and how they can be decoupled using assumptions about the world (computational color constancy);
- linear filtering theory and how it can be applied to recognize patterns, detect edges, and provide texture representations
- how segmentation can be achieved using clustering
- how grouping can be achieved by fitting models
- how local patterns can be defined for effective matching of features between images;
- how geometric constraints can improve such matching;
- how multiple views can be used to infer depth (stereo);
- why (object) recognition is difficult and how modern machine learning has been leveraged for substantial gains in performance.

Methods and methodologies that students are expected to learn include:

- non-homogenous least squares
- constrained non-homogenous least squares (graduate students only)
- homogeneous least squares
- synthetic and real data computational experiments
- random sample consensus (RANSAC)
- testing on held out data (e.g., cross validation)

Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable: http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences preapproved by the UA Dean of Students (or dean's designee) will be honored. See https://deanofstudents.arizona.edu/absences

Good attendance is expected. Poor attendance in the first few weeks may lead to the student being dropped from the class. Exams must be attended at their appointed time unless you have permission in advance to do otherwise. If you are not able to make an exam time due to extenuating circumstances, the instructor must be contacted in advance to verify that alternative arrangements are justified.

Makeup Policy for Students Who Register Late

In consultation with the instructor, students who register late can makeup for assignments that are past due with optional parts of subsequent assignments or alternative assignments. However, such students are still responsible for the intellectual content of the past due assignments which can be relevant for subsequent assignments as well as exams.

Course Communications

Online communication will be conducted using D2L, Piazza, and, where applicable, official UA e-mail addresses.

Required Texts or Readings

This class largely adopts material from Computer Vision: A Modern Approach, by Forsyth and Ponce. This book is recommended but not required, as all needed material for this course will be provided within lectures (which will be posed on-line via D2L) and assignments (also posted via D2L). The recommended text is no-nonsense book that offers significant insight into the topic. However, many students will find it the advanced level of presentation difficult and not so useful for an introductory foray. The IVILAB has a few copies that are available for short term loan, and the UA library has a copy.

Required or Special Materials

Matlab: Most students will use Matlab for most assignments. While there will be some flexibility in the choice of programming languages, unless there is a reason to do otherwise (please consult with the instructor), students are advised to use Matlab. Matlab is available on a number of student accessible computers across campus including the CS machine general purpose instructional computer "lectura". Students wishing to use Matlab on a personal computer can download and install it through the U. Arizona web pages (http://softwarelicense.arizona.edu/mathworks-matlab).

Required Extracurricular Activities

None.

Assignments and Examinations: Schedule/Due Dates

There will be up to 13 assignments, exactly two quizzes, and a final, as detailed in the table below. Assignments will be weighted roughly equally. For maximum flexibility, I will post assignments soon after we have covered needed material. Exams will emphasize recent material, but some review and/or synthesis questions should be expected. Due dates are nominally midnight, with grace until 8am the following morning. Assignments will be graded within 4-6 days of being due as detailed below. (If assignment due dates are adjusted, targets for returning them will shift by the same amount).

	Description	Due	Graded
HW1	Vision programming	08/29	09/03
HW2	Camera spectral calibration	09/05	09/11
HW3	Line fitting, perspective	09/12	09/18
HW4	Geometric camera calibration (part one)	09/19	09/25
HW5	Geometric camera calibration (part two)	09/26	10/02
HW6	Photometric stereo	10/02	10/07
Midterm one	Up to and including Lecture 17: Image formation (spectral and geometric), light interacting with matter, basic shading, and photometric stereo, basic color.	10/09	10/15
HW7	Color constancy	10/17	10/23
HW8	Linear filters, edge point detection	10/24	10/29

	Online administrative withdraw deadline	10/30	
HW9	Image bases, templates, edge point linking	10/31	11/06
HW10	Feature matching, texture	11/07	11/12
Midterm two	Up to and including lecture 32, with emphasis on color constancy onward.	11/13	11/20
HW11	Clustering and texture	11/21	11/27
HW12	RANSAC and homography	11/28	12/04
HW13	Recognition using classification	12/05	12/08
Final	All course material, emphasis on last third.	12/11	12/13

Final Examination or Project

The final exam will occur on December 11, 2017, from 1pm to 3pm.

For the U. Arizona Final Exam Regulations see
https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information.

For the U. Arizona and Final Exam Schedule,
http://www.registrar.arizona.edu/schedules/finals.htm

Grading Scale and Policies

Assignment grading. Assignment deliverables will generally consist of two parts: 1) all code developed in response to the assignments; and 2) a report, in PDF format explaining what has done, what the results were, commenting on the results, and answering any questions posed in the assignment. The instructor will provide a document that details the expectations of the report. Assignments will be graded with respect to four criteria: 1) reproducibility (the ease by which the grader can run the code to get the reported results); 2) completeness (the extent that the work done and sufficient effort was applied); 3) correctness; and 4) the exposition (clarity, insight, and conformance to the guidelines provided). The weight of these four criteria will vary among the assignments, but students are advised that the fourth criteria will generally have substantive weight.

Graduate students will be responsible for extra parts on assignments and graduate specific exam questions. In short, they will be expected to demonstrate a deeper understanding of the material, as well as explore additional aspects of it. In addition, the exposition part of the assignment will be graded more strictly for graduate students.

Honors credit is available by doing at least 1/2 (by value, not number) of the graduate portion of the assignments. Participation in the computational intelligence seminar can also be used to satisfy some of the requirements for honors. The exam portion of the grad for honors student will be computed as for regular undergraduates.

Undergraduates who want to do extra (grad) parts of assignments can receive modest extra credit. Each assignment grade will be capped at 120%, and the overall assignment grade will be capped at 65/60. These caps will also apply to graduate student if bonus marks are available to them.

Grading breakdown (see above table for more detail).

Assignments: 60%

Midterms: 20%

Final Exam: 20%

90% guarantees an A, 80% guarantees a B, 70% a C, and 60% a D.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal, respectively.

Dispute of Grade Policy. Students wishing to dispute a grade on an assignment or exam should contact the instructor within two weeks of the date that the assignment or exam was returned to the students.

Scheduled Topics/Activities

Date	Activities and topics
08/21	Lecture 1: Introduction
08/22	Posting of HW1 (Matlab)
08/23	Lecture 2: Image formation (spectral) part 1 (physics)
08/25	Lecture 3: Image formation (spectral) part 2 (math), gamma correction
08/28	Lecture 4: Non-homogeneous least squares, and spectral camera calibration
08/29	HW1 due, posting of HW2 (spectral camera calibration)
08/30	Lecture 5: Homogenous least squares and line fitting
09/01	Lecture 6: Image formation (geometric, part 1, perspective projection)
09/04	Labor day (no class)
09/05	HW2 Due, posting of HW3 (line fitting, perspective)
09/06	Lecture 7: Image formation (geometric, part 2, coordinate transformations)
09/08	Lecture 8: Image formation (geometric, part 3, geometric camera model)
09/11	Lecture 9: Geometric camera calibration (part 1, problem setup).
09/12	HW3 due, Posting of HW4 (Geometric camera calibration, part one)
09/13	Lecture 10: Geometric camera calibration (part 2, inference)
09/15	Lecture 11: Geometric camera calibration (part 3, intrinsic/extrinsic)
09/18	Lecture 12: Ambiguity in interpreting images, light interacting with the world
09/19	HW4 due, posting of HW5 (Geometric camera calibration, part two)
09/20	Lecture 13: Reflection models
09/22	Lecture 14: Shape from shading
09/25	Lecture 15: Photometric stereo (finding the normals)
09/26	HW5 due, posting of HW6 (photometric stereo)
09/27	Lecture 16: Photometric stereo continued (integrating to get the surface)
09/29	Lecture 17: Color
10/02	Lecture 18: Color constancy
10/03	HW6 due, break from assignments for midterm prep
10/04	Lecture 19: Simple Color constancy algorithms
10/06	Lecture 20: Review, big picture
10/09	Midterm One
10/10	HW7 posted (color constancy)
10/11	Lecture 21: Linear filters
10/13	Lecture 22: Correlation and convolution
10/16	Lecture 23: Filtering for finding edges

10/17	HW7 due, HW8 posted (filtering, edge point detection)
10/18	Lecture 24: Edge detection
10/20	Lecture 25: Image bases
10/23	Lecture 26: SIFT (distinctiveness)
10/24	HW8 due, HW9 posted (edge point linking, image bases, templates matching)
10/25	Lecture 27: SIFT (descriptor)
10/27	Lecture 28: Texture (textons)
10/30	Lecture 29: Texture continued, HOG
10/31	HW9 due, HW10 posted (matching)
11/01	Lecture 30: Grouping
11/03	Lecture 31: Grouping by clustering
11/06	Lecture 32: Grouping by fitting a model, RANSAC
11/07	HW10 due, short break from assignments for midterm prep
11/08	Lecture 33: Multiple view geometry
11/10	Veterans day. No Class
11/13	Midterm Two
11/14	HW11 posted (clustering and texture)
11/15	Lecture 34: Planar homography
11/17	Lecture 35: Stereo
11/20	Lecture 36: Recognition (concepts)
11/21	HW11 due, HW12 posted (homography, RANSAC)
11/22	Lecture 37: Recognition by finding patterns
11/24	Thanksgiving. No Class
11/27	Lecture 38: Classification, SVM
11/28	HW12 due, HW13 posted (recognition using classification)
11/29	Lecture 39: Neural networks (basic concepts)
12/01	Lecture 40: Convolutional neural networks
12/04	Lecture 41: Bayesian modeling for computer vision (part 1)
12/05	HW13 due.
12/06	Lecture 42: Bayesian modeling for computer vision (part 2)
12/11	Final exam. 1-3pm

Department of Computer Science Code of Conduct

The Department of Computer Science is committed to providing and maintaining a supportive educational environment for all. We strive to be welcoming and inclusive, respect privacy and confidentiality, behave respectfully and courteously, and practice intellectual honesty. Disruptive behaviors (such as physical or emotional harassment, dismissive attitudes, and abuse of department resources) will not be tolerated. The complete Code of Conduct is available on our department web site. We expect that you will adhere to this code, as well as the UA Student Code of Conduct, while you are a member of this class.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Some learning styles are best served by using personal electronics, such as laptops and iPads. These devices can be distracting to other learners. Therefore, students who prefer to use electronic devices for note-taking during lecture should sit towards the back of the class, or an area of the classroom agreed upon between the instructor and students.

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit http://drc.arizona.edu.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://www.library.arizona.edu/help/tutorials/plagiarism/index.html.

Sharing solution keys with others (e.g., students who might take the class in a future term, or who are taking the class in a future term) is considered by the instructor to be a serious violation of academic integrity.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Student Assistance and Advocacy information is available at http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

Please refer to:

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.