CS 445 Computational Photography

Course Description

Computational photography is an emerging field created by the convergence of computer graphics, computer vision, and photography. Its role is to overcome the limitations of the traditional camera by using computational techniques to capture, enhance, and combine imagery for a more vivid and lifelike visual experience.

Course Goals and Objectives

Upon successful completion of this course, you will be able to:

- Write programs to create optical illusions
- Add or remove objects from a photograph
- Insert 3D objects into pictures
- Automatically stitch together photos into panoramas
- Learn core principles of computer vision and graphics that will be of great use in robotics, psychology, media design, art, photography, information retrieval, entertainment technology, and other growing areas
- Develop an appreciation of our own visual ability and write programs that can be used with your own photo collections

Prerequisites

You should enter the course with basic programming skills and a working knowledge of **linear algebra** and calculus. Previous experience with Python, image processing, computer vision, or computer graphics will be very helpful but is not required. Students are recommended to own or purchase a **digital camera**, ideally with manual controls (smart phone should be fine). For the image-based lighting project, you will need a mirrored ball that can be purchased on Amazon.

Textbook and Readings

Lectures are not based on any particular textbook. The most closely related textbook is Computer Vision: Algorithms and Applications by Rick Szeliski, which is available for free online and for purchase at Amazon. You may also want to purchase either Computer Vision by Linda Shapiro and George Stockman or Computer Vision: A Modern Approach (2nd edition) by David Forsyth and Jean Ponce.

Other Useful Books:

- Linear Algebra and its Applications, Gilbert Strang (excellent book on linear algebra)
- Multiple View Geometry in Computer Vision, Hartley & Zisserman (bible on recovering 3D geometry)
- Photography (8th edition), London and Upton (a great general guide to taking pictures)

- Vision Science: Photons to Phenomenology, Stephen Palmer (great book on human perception)
- Digital Image Processing, 2nd edition, Gonzalez and Woods (a good general image processing text)
- The Art and Science of Digital Compositing, Ron Brinkmann (everything about compositing)
- 3D Computer Graphics (3rd edition), Watt (a good general graphics text)
- Fundamentals of Computer Graphics, Peter Shirley (another good general graphics text)

Course Outline

This 4-credit hour course is 16 weeks long. You should expect to invest about 12 hours every week in this course.

Week	Main Topic	Lecture Topics
1	Basics of Working with Images	Orientation; Introduction; Pixels and Image Filters
2	Basics of Working with Images	Thinking in Frequency; Templates and Image Pyramids
3	Basics of Working with Images	Light and Color; Histograms and Color Adjustment
4	The Digital Canvas: Coloring, Blending, Cutting, Synthesizing, and Warping Images	Growing: Texture Synthesis and Hole Filling; Cutting: Intelligent Scissors and Graph Cuts
5	The Digital Canvas: Coloring, Blending, Cutting, Synthesizing, and Warping Images	Pasting: Compositing and Blending; Image Warping (Translation, Rotation, Scale, Etc.)
6	The Digital Canvas: Coloring, Blending, Cutting, Synthesizing, and Warping Images & Modeling the Physical World	Image Morphing; The Pinhole Camera
7	Modeling the Physical World	Single-View Metrology + Camera Model Continued; Single-View 3D Reconstruction
8	Modeling the Physical World; **Midterm**	Review and Midterm; **see Deadlines page for specific exam availability time**

Week	Main Topic	Lecture Topics
9	Spring Break	
10	Modeling the Physical World	Image-Based Lighting; Ray Tracking; Environmental Maps; Light Probes; HDR Light Probes; Relighting
11	Modeling the Physical World & Correspondence and Recognition	The Image as a Virtual Stage; Matching and Alignment with Interest Points
12	Correspondence and Recognition	Automatic photo stitching and RANSAC; Object Recognition, Retrieval, and Augmented Reality
13	Correspondence and Recognition; More Topics of Interest	Opportunities of Scale: Texture, Synthesis, Multi-View Reconstruction, im2gps, Tiny Images, Etc.; Generating and Detecting Fakes
14	More Topics of Interest	How Kinect Works; Computational Approaches to Camera
15	More Topics of Interest	Understanding Faces; Video Magnification
16	More Topics of Interest; **Final Exam**	Cutting Edge and Wrap Up; Final Exam; **see Deadlines page for specific exam availability time**

Assignment Deadlines

For all assignment deadlines, please refer to the **Course Assignment Deadlines, Late Policy, and Academic Calendar** page.

Elements of This Course

The course is comprised of the following elements:

- **Orientation Quiz:** The purpose of the orientation quiz is to ensure that you have gone through the orientation module and acquired the necessary information about the course before you start it. The orientation quiz is a required activity, but it's not part of the course grading. You have unlimited

attempts on the orientation quiz. You need to answer all questions correctly in order to pass the orientation quiz.

- **Lecture Videos:** In each week, the concepts you need to know will be presented through a collection of short video lectures. You may stream these videos for playback within the browser by clicking on their titles or download the videos. You may also download the slides that go along with the videos. **The videos usually total 1.5 to 3 hours each week.** You generally should spend at least the same amount of time digesting content in the video. The actual amount of time needed to digest the content will vary based on your background.
- **Assigned Projects:** There are 5 total project assignments in this course. You may invest 10-30 hours on the project assignments. You have 1 attempt on each assignment. Each project has 100 core points and 30-150 points worth of bells and whistles, which are optional components. Students enrolled in the undergraduate section (3 credits) must complete 425 project points, while those enrolled in the graduate sections (4 credits / online MCS) must complete 500 project points to earn a perfect project grade. You can earn these points through any combination of core points and bells and whistles, minus any late penalties. Any additional points will not impact your final grade.
- **Final Project:** You will complete a final project of your choice. You could implement a paper that you find interesting, something discussed in class, a big extension of one of the existing projects, or something entirely of your own design. The deliverable is a 2-4 page abstract describing your project and the results. The scope of the project should be similar to those of the assigned projects (excluding the “hybrid image” project). You should work with a group of two or up to four, and you are responsible for forming and managing the group. More specific details can be found in the respective week the assignment is due. The proposal is worth 1%, and the final submission is worth 14%.
- **Midterm Exam:** The midterm will cover materials up to and including the single view geometry lectures. Sample problems and answers will be provided.
- **Final Exam:** The final exam will cover the entire semester. Most students do better on the midterm, but if your final exam score is higher than the midterm score, it will replace the midterm score.

Grading Distribution and Scale

Grading Distribution

Assignment	Occurrence	Percent of the Final Grade
Project Assignments	5	55%
Midterm Exam	1	15%
Final Exam	1	15%
Final Project	1	15%

Grading Scale

Letter Grade	Percent Needed
A+	97%
A	94%
A-	90%
B+	87%
B	84%
B-	80%
C+	77%
C	74%
C-	70%

Letter Grade	Percent Needed
D+	67%
D	64%
D-	60%
F	Below 60%

Student Code and Policies

A student at the University of Illinois at the Urbana-Champaign campus is a member of a University community of which all members have at least the rights and responsibilities common to all citizens, free from institutional censorship; affiliation with the University as a student does not diminish the rights or responsibilities held by a student or any other community member as a citizen of larger communities of the state, the nation, and the world. See the University of Illinois Student Code for more information.

Academic Integrity

All students are expected to abide by the campus regulations on academic integrity found in the Student Code of Conduct. These standards will be enforced and infractions of these rules will not be tolerated in this course. Sharing, copying, or providing any part of a homework solution or code is an infraction of the University's rules on academic integrity. We will be actively looking for violations of this policy in homework and project submissions.

You are welcome to discuss projects with your classmates, but do not show or share any code. Also, you may not use any code from the internet or any other outside sources, unless it is specifically approved by the instructor. Be sure to acknowledge any help that you do get from other students or outside works, even if it's just a small suggestion. *Violations will go on record at the university, and the minimum penalty will be a zero for the entire assignment*.

Again, a good rule of thumb: *Keep every typed word and piece of code your own*. If you think you are operating in a gray area, you probably are. If you would like clarification on specifics, please contact the course staff.

Chat GPT and Coding Assistants

You may use ChatGPT and code assistants to complete your projects, acknowledging them as you would StackOverflow and other sources. **You may not use AI assistants or services in exams.**

Disability Accommodations

Students with learning, physical, or other disabilities requiring assistance should contact the instructor as soon as possible. If you're unsure if this applies to you or think it may, please contact the instructor and Disability Resources and Educational Services (DRES) as soon as possible. You can contact DRES at 1207 S. Oak Street, Champaign, via phone at (217) 333-1970, or via email at disability@illinois.edu.

Mental Health

Diminished mental health, including significant stress, mood changes, excessive worry, substance/alcohol abuse, or problems with eating and/or sleeping can interfere with optimal academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings at no additional cost. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do -- for yourself and for those who care about you.

Counseling Center: 217-333-3704, 610 East John Street Champaign, IL 61820

McKinley Health Center:217-333-2700, 1109 South Lincoln Avenue, Urbana, Illinois 61801

CS CARES and CS Values and Code of Conduct

All members of the Illinois Computer Science department - faculty, staff, and students - are expected to adhere to the CS Values and Code of Conduct. The CS CARES Committee is available to serve as a resource to help people who are concerned about or experience a potential violation of the Code. If you experience such issues, please contact the CS CARES Committee. The Instructors of this course are also available for issues related to this class.

Anti-racism and inclusivity