PURDUE UNIVERSITY | College of Engineering

Engineering Faculty Document No.: 75-24
February 7, 2024

TO: The Engineering Faculty

FROM: The Faculty of the Lyles School of Civil Engineering

RE: New graduate course – CE 57400: Introduction to Applied Computer Vision in Civil Engineering

The Faculty of the Lyles School of Civil Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:

CE 59700 Image-based Sensing 3 credits

Fall 2023 (13), Fall 2019 (13), Fall 2016 (18)

No Prerequisites

TO:

CE 57400 Introduction to Applied Computer Vision in Civil Engineering

Fall

Three total credits

No Prerequisites

Course Description: This course is an introduction to fundamental topics within applied computer vision-based sensing for management and condition assessment of civil infrastructure systems. Some of the topics covered in this course include basic concepts in digital image processing, pattern recognition, and computer vision that are applicable for segmentation, clustering, 3D reconstruction of civil infrastructure elements, strain and displacement measurement, defect detection and structural health monitoring. Upon successful completion of this course the student shall be able to understand and utilize fundamental concepts in computer vision, image processing and machine learning to analyze images, stitch images, reconstruct the 3D scene, classify and recognize objects/damage, and quantify and track changes.

RATIONALE:

The rapid advancement of Artificial Intelligence (AI) has paved the way for groundbreaking interdisciplinary approaches in numerous fields, including civil engineering. This course is introduced to address the critical need for professionals who can harness the power of AI,

specifically through image-based sensing and applied computer vision, to enhance the management and condition assessment of civil infrastructure systems. As infrastructure becomes increasingly complex, the integration of AI with traditional civil engineering practices is essential for the innovative analysis, monitoring, and maintenance of these critical systems. Students will learn to apply fundamental concepts in AI-driven image processing, machine learning, and computer vision to tackle real-world challenges such as 3D reconstruction of infrastructure elements, defect detection, and structural health monitoring. The interdisciplinary nature of this course bridges the gap between cutting-edge computational techniques and practical engineering applications, empowering students to lead the way in developing smart, AI-integrated solutions for the sustainable and resilient infrastructure of the future.

Head/Director of the Lyles School of Civil Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:27498/form

Lyles School of Civil Engineering CE 57400 Intro to Applied Computer Vision
August 23 – December 6
W 2:30 – 3:20 pm, HAMP3153 W 3:30 – 5:20 pm, PHYS 117

Instructor

Mohammad Jahanshahi
Office: HAMP 4116
Office hours: T 10:00 am – 11:30 am or by appointment
https://purdue.webex.com/purdue/j.php?MTID=m642bb388d6ced956fa97b8f0eefd8cc4
E-mail: jahansha@purdue.edu

Prerequisites

Willingness to learn and time to pick up MATLAB/Python; Linear algebra

Course Description

This course is an introduction to vision-based sensing for management and condition assessment of civil infrastructure systems. Some of the topics covered in this course include basic concepts in digital image processing, pattern recognition, and computer vision that are applicable for segmentation, clustering, 3D reconstruction of civil infrastructure elements, strain and displacement measurement, defect detection and structural health monitoring.

Upon successful completion of this course the student shall be able to understand and utilize fundamental concepts in computer vision, image processing and machine learning to analyze images, stitch images, reconstruct the 3D scene, classify and recognize objects/damage, and quantify and track changes.

Reference Books

Digital Image Processing, W. K. Pratt, John Wiley & Sons Inc., 2007.
Digital Image Processing, R. C. Gonzalez and R. E. Woods, Pearson, 2007.
Digital Image Processing Using MATLAB, R. C. Gonzalez, R. E. Woods and S. L. Eddins, Gatesmark Publishing, 2009.
Computer Vision: Algorithms and Applications, R. Szeliski, Springer, 2011.
Multiple View Geometry in Computer Vision, R. Hartley and A. Zisserman, Academic Press, 2004.
Deep Learning, I. Goodfellow, Y. Bengio and A. Courville, MIT Press, https://www.deeplearningbook.org/.

Grading

Class Participation	5%	
Assignments	30%	Tentative due dates: 9/20, 10/25 and 11/17
Paper Presentation	10%	
Term Paper	55%	
Project Proposal (5%)		Due on Thursday, September 28 at 11:59 pm
Progress Report (10%)		Due on Thursday, November 16 at 11:59 pm
Final Report and Presentation (40%)		Due on Wednesday, December 6 at 12 pm

Assignments

There will be up to 3 assignments. All require computer programming. The grade will be assigned based on the solution procedure, results, *organization*, and *presentation*. Each solution shall be explained with all the details and figures necessary for another person to review your work thoroughly. Students currently taking this class can work together to conceptualize general approaches to assignments. However, unless otherwise specified for a particular assignment, the work you submit must be done

completely on your own. This includes text, numerical calculations, mathematical derivations, diagrams, graphs, computer programs, and output. Fifty percent will be deducted for an assignment that is 24 hours late. Illegible assignment solutions and solutions submitted later than 24 hours after the deadline will receive a grade of zero.

Paper Presentation

Paper presentations are seen as educational devices to help students master a specific topic on the use of vision-based sensing related to engineering or scientific applications.

Term Project

The term project is a chance to further explore a topic of interest with application to a specific engineering problem. The projects consist of the following components: (1) identify a specific (civil) engineering problem; (2) devise an approach to address the problem using vision-based sensing and analysis techniques; (3) implement the approach and evaluate its performance using an experimental or a real-world case study.

Groups of up to three students are encouraged. Possible scenarios for term project: (1) replicate an interesting paper; (2) compare different methods to a test bed; (3) utilize an existing approach to address the problem; or (4) propose a new approach.

Project proposal should not exceed 2 pages. The project proposal must include the following sections: (1) introduction: introduce the problem you want to solve and its significance; (2) technical approach; (3) project milestones, deliverables and timeline; and (4) references.

Project progress report should not exceed 4 pages. The progress report should include the following sections: (1) introduction: introduce the problem you want to solve and its significance; (2) technical part; (3) achieved project milestones; (4) remaining project milestones and timeline; and (5) references.

Term project report/presentation should include the following sections: (1) introduction: introduce the problem you want to solve and its significance; (2) literature review; (3) contribution; (4) proposed approach; (4) experimental results and discussion; (5) conclusion and future work; and (6) references. Term project report/presentation will be evaluated based on the quality of the writing/slides, the clarity of your technical explanation and, overall, how well you get your message across. Term project source codes of your working program need to be submitted on Brightspace. This file is due on the project submission deadline date. The presentation must not exceed 12 minutes long and it should be split uniformly among the team members.

Classroom Conduct

Attendance is expected in all lectures. Participation grade will constitute 5% of your grade.
Involvements in class are highly encouraged and are considered towards the grade for attendance.
Cell phones must be silenced. Texting is not allowed.
Disruptive classroom behavior will not be tolerated. You may be asked to leave (and, in some cases, never come back). Examples of disruptive behavior includes, but not limited to: talking in class, making inappropriate comments, engaging in activities not related to class, and sleeping.

Academic Integrity

Assignments are to be solved and submitted individually. Obtaining solutions from any external source or another student's assignments or sharing your assignments with another student is absolutely not allowed. Giving and receiving help on concepts is allowed and encouraged. You are also expected to

properly reference the source of any information used in a submission that is not your own. This includes any book, article, web page, PowerPoint presentation or personal correspondence from someone else that you used to create your work. It is also inappropriate to use assignments, problem sets, examinations or projects submitted in other schools as a source, unless otherwise authorized. If you have any questions about how these policies relate to a specific situation, please speak to the instructor for clarification. Remember, when you have doubts, ask the instructor for assistance. Dishonesty will be reported to the Dean of Students, who has the authority to include the report in student records.

Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty" (Section B.2.a of the Student Regulations). Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of ghost-written papers, the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest" (University Senate Document 72-18, December 15, 1972).

Purdue's Honor Pledge: *"As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue."*

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Incidents of academic misconduct in this course will be addressed by the course instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered.

By registering for this course you agree to abide by the course honor code that you shall never take unfair advantage of others in this course. Purdue University academic policies and procedures apply:

> *Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]*

Actions violating the University academic integrity and honesty policies will result in failure in the course. Those who are caught cheating and those who aid and abet cheating directly or indirectly will receive F grade (Failing) as the course grade for academic dishonesty. This policy applies to

transgressions in quizzes, exams as well as in homework. Parties involved in dishonest activity will be reported to the Office of the Dean of Students for additional disciplinary action.

No material from this course shall be shared with anyone outside this class in any form whatsoever (printed, digital, direct mailing, website posting, etc.). These material include handouts, lecture notes, lecture videos and other recordings, quiz problems and solutions, exam problems and solutions, homework problems and solutions, and the notes you take during the class. All of these materials, including your notes are subject to the instructor's copyright. Note that your notes are considered to be 'derivative works' of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials. Commercial note-taking is prohibited. Those who violate the "no sharing" policy will be reported to authorities and pursued to the full extent of the University regulations and the Law.

More info on academic integrity can be found here: https://www.purdue.edu/odos/osrr/academic-integrity-brochure/

Academic Guidance in the Event a Student is Quarantined/Isolated

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you with academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, being available for academic support, and offering suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Purdue Academic Calendar for Fall 2023 can be found here (Academic Calendar).

Attendance Policy during COVID-19

Students should stay home and contact the Protect Purdue Health Center at 765-496-INFO if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, through Brightspace. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747. Our course Brightspace includes a link on Attendance and Grief Absence policies under the University Policies menu.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (765-496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Nondiscrimination Statement

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. More details are available on our course Brightspace table of contents, under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247. More details are available on our course Brightspace under Accessibility Information.

Mental Health Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign-up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you are struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Emergency Preparation
In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email. You are expected to read your @purdue.edu email on a frequent basis.

Special Needs
If you have any disability-related needs that might affect your performance in this course, please contact your instructor within the first two weeks of class.

Course outline (This outline may be revised during the semester)
1. Fundamentals of Image Sensing and MATLAB
2. Camera Models and Calibration
3. Image Enhancement and Filtering
4. Edge and Corner Detection
5. Feature Descriptors
6. Feature Extraction and Matching
7. Image Registration and Mosaic
8. Structure from Motion (3D Scene Reconstruction)
9. Morphological Image Processing
10. Machine Learning Principals
11. Segmentation, Clustering, and Classification
12. Neural Networks
13. Convolutional Neural Networks
14. Object Recognition
15. Crack Detection and Quantification
16. Corrosion Detection
17. Pavement Condition Assessment
18. Sewer Pipeline Condition Assessment