CPSC 4820/6820: AI AUTONOMOUS VEHICLES

Basic Information

Sections

Sec: 4820-001, CRN: 15172
Sec: 6820-001, CRN: 15233

Class Meeting Times

Tu/Th 6:30 pm - 7:45 pm McAdams Room #114 (and on Zoom)

Class Location

- McAdams, Room #114
- The class will be broadcast on Zoom

  Meeting ID: 955 6853 5593

  Password: 4820

  Link: https://clemson.zoom.us/j/95568535593?pwd=a1U5WnI1MTlhU25TZS9yL3FzakxXUT09

Instructors

Main Instructor: Abolfazl Razi, e-mail: arazi@clemson.edu
Teaching Assistant: Hazim Alzorgan, e-mail: halzorg@exchange.clemson.edu

Office Hours

Instructor Office Hours:

Wednesday 10:00 am – 1:00 pm
@McAdam#203, or online upon request

Extra Office hours:

In-person and Zoom by appointment with 24 hour prior request

TA Office Hours:

TBD

Canvas link: https://www.clemson.edu/canvas

Course Overview

This course reviews different aspects of Autonomous Vehicles (AV) Technology in the intersection of perception, autonomous control, and networking, . Specific potential topics include introduction to unmanned ground and aerial vehicles, principles of autonomy, computer vision for autonomous vehicles, video stabilization, perspective projection, video-based object detection and tracking, Lidars and distance sensors, point clouds, search-based and learning-based path planning, basics of v2v and v2x communications, driving safety, traffic flow, and mobile edge computing.

This course is particularly suitable for senior-level undergraduate and graduate students who are interested in or involved with research in unmanned aerial and ground vehicles (UAV/UGV) or closely

related areas. It is well suited for students who have reasonably solid backgrounds on machine learning, pattern recognition, artificial intelligence, and are familiar with the basics of networking and unmanned vehicles. However, we will review necessary material in the beginning of each topic, to make the course usable by students from different disciplines such as CS, EE, CE, ME.

In addition to class-based lectures and regular assignments, part of the class will be devoted to literature review and presentation, in-class discussions and working with simulators and tools useful for AVs. The assignments will be the combination of conceptual questions, problem-solving, and programming assignments.

Learning Objectives

The main goal of the course is to expose students to the fundamental concepts, algorithms, and tools that are used for unmanned vehicles. The students will gain expertise in developing machine learning, AI, computer vision, and networking protocols that are particularly useful to design, operate, and monitor unmanned aerial and ground vehicles. No prior experience of working with AVs is necessary. Although prior knowledge about AI and machine learning would be advantageous and is highly recommended, we will review basics of each concept before exploring their application to AVs, to make the course usable by a broader range of students.
By the end of the semester, the students are expected to be able to design algorithms and tools that can be useful for different aspects of AVs including perception, control, networking, and analysis. You will become familiar with the current research problems in AVs and related area. The student will get familiar with online tools and datasets, and will gain expertise to conduct research in this area. You will develop skills and knowledge to use virtual simulators to model traffic flow and simulate AV behavior under different situations.

Course Delivery

We will follow the University Policy, Regulations, and Guidelines for the course delivery and student attendance. The situation may change in the beginning of the semester or even during the semester due to the Covid-19 conditions, but here is the current plan. The course will follow a blended model that will involve both synchronous lectures, as well as flipped lectures. In particular, the course will be delivered in the following modes:

- **In-person attendance:** This is the primary and preferred attendance mode. All students are expected to attend the class in person. The only exception will be students who are in the Zucker and ORD campuses and those who have critical medical and personal conditions. Students with critical medical or personal conditions should request for the instructor's approval for online attendance (through Zoom). Attendance is mandatory and will be part of the grading, as you see below. We also will have plenty of in-class quizzes with and without prior notice, and you would need to attend the class to earn quiz points.
- **Real-time (synchronous) mode:** The class will also be offered real-time through Zoom. Students with special conditions who are not able to make the in-person attendance and have the instructor's approval will attend the Zoom meetings.
- **Recorded lectures:** The class lectures will be posted in the same day or one day after the class on Canvas or Ensemble systems, mostly for students who missed the real-time attendance.

- **Flipped classroom:** Occasionally pre-recorded lectures will be posted the same day or the day before the class on Canvas, with additional engagement during the day of the class in terms of brief Q&As, online quizzes, discussion, etc. This choice will be used occasionally, or if the school goes to fully online mode due to the COVID pandemic.
- **Extra Material:** Extra reading material like lectures, tutorials, reading material, solutions to assignments, etc. will be posted by the instructor and TAs on Canvas as PDF documents, URLs, and prerecorded videos.

Prerequisites

Official prerequisites include:
CPSC 1020 or CPSC 1070 or ECE 2220; and MATH 3020 or STAT 3090 or STAT 3300. Students must have earned a grade of C or higher in all prerequisite courses.

The students are also expected to have:

- Familiarity with basic principles of Random Probability, Machine Learning, Artificial Intelligence, Wireless and Vehicular Networking, and Image processing. However, passing a course in these areas are not part of the official prerequisites.
- Some programming experience (Assignments will be in Python, and MATLAB based on the student's preference)

Textbooks

There is no required textbook for the course. Selected articles, course notes, and video lectures will be made available as the course goes on. The following books and resources are likely to be useful:

- Artificial Intelligence: A Modern Approach (3rd edition), S. Russel and P. Norvig
  (Available online: http://aima.cs.berkeley.edu)
- Reinforcement Learning: An Introduction (2nd edition), R.S. Sutton and A.G Barto
  (Available online: http://www.incompleteideas.net/book/the-book-2nd.html)
  -Probabilistic Robotics?
- Probabilistic Robotics, Sebastian Thrun, Wolfram Burgard and Dieter Fox, MIT Press
  (Available online: https://docs.ufpr.br/~danielsantos/ProbabilisticRobotics.pdf)
- Pattern Recognition and Machine Learning, Christopher Bishop, Springer, 2007
  (Available online: https://www.microsoft.com/en-us/research/people/cmbishop/prml-book/)
- Computer Vision: A Modern Approach, David A. Forsyth and Jean Ponce, 2nd Edition
  (Available online: https://eclass.teicrete.gr/modules/document/file.php/TM152/Books/Computer%20Vision%20-%20A%20Modern%20Approach%20-%20D.%20Forsyth,%20J.%20Ponce.pdf)
- Dive into Deep Learning, Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, Release 0.16.0
  (Available online: https://d2l.ai/d2l-en.pdf)

Tentative Schedule/Topic List (Subject to Minor Changes)

1. Introduction to Unmanned Vehicles
   - Autonomous Vehicles (AVs)
   - Unmanned Aerial Vehicles (UAVs): Fundamentals, Challenges, and Future Outlook

2. Computer Vision for AVs
   - Basics of Image formation
   - Image Warping
   - Filtering Methods
   - Camera Modeling and Calibration
   - Perspective Translation and Geo-mapping
   - Deep Learning Methods for AV Perception
   - Object Detection (Cars, Pedestrian, etc.)
   - Review of Classification Methods (Vehicle Classification)
   - Segmentation Methods (semantic, instance), Lane Detection

3. Sensors for AVs
   - Distance Sensors (Visual, RADAR, LiDAR, Ultrasound)
   - Speedometer Doppler Effects
   - Sensor-based Localization
   - Point Clouds
   - Basics of Sensing, Coding, Scheduling
   - Data Fusion

4. Object Tracking
   - Mobility Models
   - Motion Trajectories
   - Video-based Object Tracking (Optical Flow)
   - Sensor-based Object Tracking
   - Hidden Markov Models (HMM)
   - Kalman Filtering

5. Motion/Path Planning for AVs
   - Review of Graph Search Methods
   - Informed Search: A*, Heuristics
   - AV Kinematics
   - MDP and Reinforcement Learning Methods
   - Deep Q Learning for Path Planning
   - Imitation Learning for AVs
   - Inverse Reinforcement Learning for AVs

6. Traffic Safety Analysis
   - Safety Metrics
   - Statistical Analysis of Crash Reports

7. Vehicular Networking
   - Principles of V2V and V2X Networking
   - Vehicle Edge Computing

8. UAV Networks
   - Principles of UAV Networks
   - Aerial Monitoring Systems
   - AI-based Networking

- AI-based Routing
- Mobile Edge Computing

9. Tools and Simulators (We may cover part of the following topics by guest lecturers)
   - Introduction to ROS
   - Introduction to SUMO
   - Introduction to Webots
   - Introduction to Carla
   - Introduction to UAV Flight Simulators
   - Introduction to Traffic Simulators

10. Conclusion
    - The future of Unmanned Vehicles. What's next?

Note1: The syllabus and the offered content are tentative and subject to minor changes based on the student backgrounds, student feedback, and the class progress by professor discretion.

Note2: Some of the above content may not be covered as a regular lecture, rather will be touched as extra reading materials, and journal club presentations.

Grading

Grading will be based on the students' performance on a set of written and programming assignments, in-class and take-home quizzes, journal club, two mid-term exams, and a final exam or project.

- Written/Programming Assignments: 25%
- Quiz and Class Activity: 25% (Includes attendance)
- Two In-class Exams: 25% (15% for highest, and 10% for lowest)
- Final Exam or Term Project: 25%
- Journal Club: Up to 5% Extra Points

A	90% – 100%
B	80% – 90%
C	70% – 80%
D	60% – 70%
F	0% – 60%

The instructor may adjust grades upward based on class participation, extra credit, etc.

Note 1: There will be some lecture content and extra problems in assignments, quizzes, and exams only for graduate students.

Note 2: joining Journal Club is optional but highly recommended, especially for graduate students.

Note 3: Students can choose between the Final Exam and Term Projects.

Assignments
Assignments will be the combination of conceptual questions, problem solving, and programming in Python (or MATLAB). Some programming assignments are centered around an application, and will help you deepen your understanding of the theoretical concepts covered in class. Only online submissions for programming assignments are permitted.

The deadlines are strict, and no quiz/assignment will be accepted after the due date. Under emergency cases with strong personal excuse, the instructor may accept a late submission (for assignment) after receiving the student's **request prior to the deadline**. These decisions will be made on a case-by-case basis, so I encourage you submit your request a head of time. If the student provides a legitimate excuse and the instructor approves a late submission, *a late penalty of 5% per day until a maximum of 5 days will be incurred*. To be on time, I encourage you to submit the work a few hours before the deadline, so you don't run into last-minute problems.

All assignments are individual, unless the instructor explicitly allows the teamwork (work in pair). It is ok to share your thoughts and initiate discussions in canvas, discord, and class sessions, but ultimately y*ou must work by yourself and submit your own answers. Any copy and plagiarism will face severe consequences.*

The assignments will be graded on a 100-point scale. For teamwork, both students will receive the same points. The final programming assignment average will be computed by averaging the student's assignment scores, excluding one assignment with the lowest grade.

Quiz
We will have in-class and take-home quizzes, with and without prior notice. In-class quizzes will be assigned during the class and the submission will be either online or in-person, depending on the quiz type, and students' preference. We will have individual and group quizzes. The individual quiz content will be mainly from topics covered in the last few sessions. However, group quizzes may include questions from the content covered in the same session. The questions will help me gauge the learning progress of students in the class and will help you deepen your grasp of the class lectures by teamwork, and understand the areas on which you need to work more. Take-home quizzes will be assigned during the session and must be submitted by the assigned deadline, which will be in a few days. *No quizzes will be accepted after the deadline*. Each quiz will typically consist of multiple questions and will be graded on a 100-point or 10-point scale.

The final quiz average will be computed by averaging the student's quiz scores excluding the one with the lowest grade.

In-class Exams
We will have two in-class exams to be taken in Late February and Early-April. The exact dates will be announced at least 1 week ahead of time. The exam will cover material from all lectures, quizzes, and programming assignments covered by the exam date. The exams will consist of a mix of short answer, problem solving, and essay-style questions. The exams may have In-class and Take-Home parts. A programming part may be included in a take-home part. The exam will be taken in-person.

Final Exam
The final exam will be cumulative and will cover material from all lectures, quizzes, and programming assignments. The exam will consist of a mix of short answers and essay-style questions. Short answers will require at most a short paragraph, and/or a figure to answer. Essay questions will ask you to extend or combine basic ideas and algorithms from class. The final exam format will be announced later, but will be at the same time for all students.

The tentative date is according to Clemson Calendar (Thursday May 4th @ 7:00pm – 9: 30 pm) unless another date is announced by the instructor.

Note: The students can choose to take Final Exam or Term Projects.

Term Project
Term project is optional and replaces the final exam. Terms project will be similar to the programming assignments with some more aspects to it. Sample topics will be provided by the instructor by the students can also offer a project topic. Projects can be individual, or team based. The best choice would be a team of undergraduate students led by a graduate student to work on a problem related to the role of AI in unmanned vehicles. Each team will offer 3 deliverables, including a 5-page final report, a 15-minute presentation, and the developed source code. Projects may involve using AV simulators, traffic simulators, drone programming, etc. More details and time-plan will be provided in the class.

We will make arrangements that all teams present in regular class time, but we may also need to set up extra make-up sessions for presentations. Attendance beyond regular class times, if happens, will be optional. More details about the expectation, timeline, evaluation will be provided in the class.

Note: The students can choose to take Final Exam or Term Projects.

Journal Club
We will have Journal clubs on a volunteer basis and will reward extra credits (up to 5% of the final grade). The presentations will be in regular class time, but we may also plan to have separate sessions of Journal clubs if most students join the club. Presentation is optional but attending JC sessions is not. All students are expected to attend JC session in regular class time, but attending JC sessions beyond the regular class times is optional.

This activity can be individual or team-based. I encourage all students, especially graduate students to participate in this activity. The process is easy. The instructor will provide a list of topics. Also, students are welcomed to suggest their own topic (related to the applications of AI, deep learning, control theory, sensing, and networking in developing AV systems and networks). After the topics are approved and finalized by the instructor, the teams' job will start. Each team is expected to read a few papers on the selected topic and make a short presentation for the class (10 min for individual presentation and 15 min for team work). You can consult the instructor to find the right papers. In addition to the summary of content from the papers, a good presentation would involve the student's ideas, criticisms, and thoughts on the topic. Demonstrations and programming are not necessary but will reward extra credit. The evaluation will be based on the instructor's observation as well as student feedback based on a rubric to be provided by the instructor.

Grading Differences Between 4000 and 6000

Graduate students at the 6000 level may have been asked to complete more question and problems from advanced material in assignments, quizzes and exams. These questions will reward extra points for undergraduate student who enrolled in the 4000 level session. Note that I expect that all graduate students are enrolled in 6000-level session, and all undergraduate students are enrolled in 4000-level session. If it is not the case for you, please inform me and we may need you to switch the session.

COVID-19 related information

Notification of Absence

For a student who reports testing positive for COVID-19 or is being asked to quarantine/isolate because of exposure to the virus, it will be up to the student to inform the instructor. Students are directed to use the Notification of Absence module in Canvas to initiate this notification. Additional communication via email is encouraged; students should follow up with their instructor to develop a continued plan of study for each course. The instructor and the students will follow the CDC guidelines and the university policy.

Use of Masks for In-Person Classes

Students physically present in class will be encouraged (required if that would be the university policy) to wear a face mask during lectures. Please be familiar with the additional information on the Healthy Clemson website (https://www.clemson.edu/covid-19/), such as the use of disinfectant wipes for in-person classes. If the mask is required, and a student does not have a face covering or refuses to wear an approved face covering without valid documented accommodation, the instructor will ask the student to leave the academic space and may report the student's actions to the Office of Community & Ethical Standards as a violation of the Student Code of Conduct.

Policies

Attendance

Roll will be taken for the first one or two weeks while the class roll fluctuates. Attendance is mandatory and it (along with class discussions and activities) will account for 5% of your final points. We will also have in-class quizzes, so you will lose points if you skip a class. Absence, excused or not, does not change the responsibility for assigned work. The course staff strives for a lively and inclusive course, encouraging active, informed participation in classroom and Canvas discussions, quiz and homework reviews. If you can not attend a class, please submit the absence form at least 24 hours before the class.

Class Cancellation

Students are expected to wait for 15 minutes after the beginning of class before leaving if the instructor is late.

Assignment Late Policy

No late submission will be accepted for assignments, and take-home quizzes. Under emergency conditions, the instructor may or may not approve your late submission, and even in this case, a late penalty of 5% of total points will be applied for each of the first five days that an assignment is submitted late. All extension requests should be submitted before the deadline.

Re-Grade Requests

A student may request a regrade of an assignment within 3 days of the assignment feedback being returned or posted. For a re-grade request, a student should email their course instructor with a detailed justification for the re-grade. Please note your lecture instructor or TA will regrade your entire assignment. Thus, your re-grade could result in a higher or lower grade.

Academic Integrity

As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning". Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form. In instances where academic standards may have been compromised, Clemson University has a responsibility to respond appropriately and expeditiously to charges of violations of academic integrity.

Accessibility Statement

Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to a class should let the professor know, and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848 or by emailing studentaccess@lists.clemson.edu. Students who receive Academic Access Letters are strongly encouraged to request, obtain and present these to their professors as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester. You can access further information here at http://www.clemson.edu/campus-life/campus-services/sds/ .

Non-Discrimination Policy
Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. This policy is located at http://www.clemson.edu/campus-life/campus-services/access/title-ix/ . Ms. Alesia Smith is the Clemson University Title IX Coordinator and the Executive Director of Equity Compliance. Her office is located at 110 Holtzendorff Hall, 864.656.3181 (voice) or 864.565.0899 (TDD).

Inclement Weather Policy
If a class is cancelled due to inclement weather, the instructor will make alternative arrangements for submitting work that was due that day. Please see Canvas for details on assignment and quiz deadline extensions.

Academic Continuity Plan
Clemson has developed an Academic Continuity Plan for academic operations. Should university administration officially determine that the physical classroom facility is not available to conduct classes, class will be conducted in a virtual (online) format. The University issues official disruption notifications through email /www /text notification/Social Media.
When notified, use one of the following links to navigate to Clemson Canvas where you will find important information about how we will conduct class:
Primary access link: www.clemson.edu/canvas
Secondary access link, if needed: https://clemson.instructure.com/
You can also use the Canvas Student App.

Our activities for teaching and learning will occur through our Canvas course. This includes: handout materials, and/or online real-time lectures, and/or video recorded lectures, and/or online quizzes.

Tech Support
If you have trouble with Canvas or another university system, check here first: Clemson System Status (https://status.ccit.clemson.edu/).

CCIT's IT Support Center offers a wide range of support options and hardware repair with several contact methods to help you answer your questions as quickly as possible:

- Phone: (864) 656-3494
- Email: ITHelp@clemson.edu
- Chat: Live Online Chat (http://support.clemson.edu/)
- Web Form: Help Request Form (https://ccit.clemson.edu/support/get-help#help-req-form)
- Troubleshoot: Knowledge Base (https://ccit.clemson.edu/support/kb/kb-login/)
- Everything CCIT Does: Browse Services (https://ccit.clemson.edu/services)

Academic Success Center
The Academic Success Center (https://www.clemson.edu/asc/) offers a variety of free learning and success services for all undergraduate students that include

Mastery of course content

- Tutoring – students can expect a 1:1 meeting with a trained undergraduate peer leader (who made an A or B in the course and was recommended by a faculty member) during which the student can share specific questions they have about course content with the tutor focused on helping the student, through questioning techniques and identification of helpful learning strategies, and master course concepts. Tutors do not help with homework or other class assignments.
- Peer-Assisted Learning (PAL) – students can expect collaborative and active group learning and study sessions focused on mastery of course content and learning strategies that is facilitated by a trained undergraduate peer leader (who made an A or B in the course and was recommended by a faculty member). PAL leaders do not help with homework or other class assignments.

Copyright Notice

Materials used in the course may be copyrighted and are intended for use only by students registered and enrolled in the course for the duration of the course. They may not be retained in another medium or disseminated further.

Syllabus Update Policy

The instructor plans to follow the offered syllabus and make minimal changes to it. However, some minor changes may be required to adapt to the students learning pace and cover new material. Therefore, the instructor reserves the rights to make changes to the syllabus at any times.