SE498: Introduction to Autonomous Vehicle Systems

Spring, 2021

Instructor: Prof. William R Norris
wrnorris@illinois.edu
(704) 607-2742

3:30 – 4:50 TR
Undergraduate – 3 hr CRN 68168
Graduate – 4 hr CRN 68169
Office Hours – By Appointment

Teaching Assistants

Konur Yigit yigit2@illinois.edu Office Hours - TBD
Jiaming Zhang jz73@illinois.edu Office Hours - TBD

All course materials will be available on Compass
https://compass2g.illinois.edu/webapps/blackboard/content/listContentEditable.jsp?content_id=_4627576_1&course_id=_52989_1

Lectures are on-line and synchronous using Zoom

Join Zoom Meeting

Phone one-tap: US: +13126266799,,3271510472# or +12678310333,,3271510472#

Meeting URL: https://illinois.zoom.us/j/3271510472?pwd=OHNyeTk3NzVoUjYwREpPL1NCR0JZdz09
Meeting ID: 327 151 0472
Password: 353544

Join by Telephone

For higher quality, dial a number based on your current location.
Dial:

US: +1 312 626 6799 or +1 267 831 0333 or +1 301 715 8592 or +1 470 250 9358 or +1 470 381 2552 or +1 646 518 9805 or +1 651 372 8299 or +1 786 635 1003 or +1 929 205 6099 or +1 213 338 8477 or +1 253 215 8782 or +1 346 248 7799 or +1 602 753 0140 or +1 669 219 2599 or +1 669 900 6833 or +1 720 928 9299 or +1 971 247 1195
Canada: +1 647 558 0588 or +1 778 907 2071 or +1 438 809 7799 or +1 587 328 1099 or +1 647 374 4685
Germany: +49 695 050 2596 or +49 69 7104 9922 or +49 30 5679 5800
Korea, Republic of: +82 2 6022 2322 or +82 2 6105 4111
United Kingdom: +44 131 460 1196 or +44 203 051 2874 or +44 203 481 5237 or +44 203 481 5240
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Skype for Business (Lync)

https://illinois.zoom.us/skype/3271510472

Course Description/ Overview:

This course will involve the introduction of autonomous vehicle technologies that serve as the foundation for development and operation. This will include the identification and development of autonomous system subsystems, simulation methods and incorporate topics on algorithms for localization, dead reckoning, sensor fusion, perception, deep learning, planning/control, and payload development.

Objectives:

- Identify and list the common subsystems and technologies deployed in autonomous vehicles.
- Use the MATLAB/Simulink toolsets to model autonomous systems
- Use MATLAB/Simulink and ROS to do model-based system development and control
- Discuss the various types of sensors used within autonomous systems and describe suitable sensor fusion methods
- Describe the common methods used autonomous systems to perform Guidance, Navigation, Obstacle Detection and Control functions

Primary Text

Introduction to Autonomous Mobile Robots (Intelligent Robotics and Autonomous Agents series) Siegwart, Roland, ISBN-10: 0262015358

Additional References

Creating Autonomous Vehicle Systems (Synthesis Lectures on Computer Science), Shaoshan Liu (Author), Liyun Li (Author), Jie Tang (Author), ISBN-10: 1681730073

Introduction to Autonomous Robots: Kinematics, Perception, Localization and Planning, Correll, Nikolaus, ISBN-10: 0692700870

Tentative Syllabus Schedule

Overall Schedule (Tentative)

Week	Date Range		Lab	Homework	Lecture
1	25-Jan	29-Jan	-	HW0 - Simulink and System Identification	Intro
2	1-Feb	5-Feb	Lab 0 - !Introduction to Simulink and ROS		Systems Archtecture
3	8-Feb	12-Feb	Lab 1 -Turtlebot Simulation	HW1 - Kinematic and Dynamic Modeling,	
4	15-Feb	19-Feb	Lab 2 - IR Wall Following		Vehicle Kinematics and Modeling
5	22-Feb	26-Feb		HW 2 - Modeling in Spatial V2	
6.	1-Mar	5-Mar	Lab 3 - LIDAR on GEM		Sensors
7	8-Mar	12-Mar		HW 3 - Control of Kinematic and Dynamic Models	
8	15-Mar	19-Mar	Lab 4 - Camera Lane Following		Sensor Fusion
9	22-Mar	26-Mar		HW 4 - Control of Gazebo Models via ROS	
10	29-Mar	2-Apr			Localization
11	5-Apr	9-Apr	Lab 5 - Final project	HW 5 - Kalman Filtering	
12	12-Apr	16-Apr			Navigation and Path Planning
13	19-Apr	23-Apr		HW 6, - Classifiers	
14	26-Apr	30-Apr			Obstacle Avoidance
15	3-May	7-May		-	
16.	10-May	14-May	-	-	Final

Lecture Topics (Tentative)

1.	**Introduction to Autonomous Systems (1/2 week)**.	
	An introduction into system autonomy and mission configurations.	
2.	**System Architecture (1/2 week)**.	
	Various autonomous vehicle control architectures will be presented and discussed.	
3.	**Vehicle kinematics and Dynamic Modeling (2 weeks).**	**Chapters 2 and 3**
	Introduction to vehicle design, system dynamics, and vehicle structures.	
4.	**Sensors (2 weeks).**	
	Classes will introduce the classes of sensors typically found on autonomous vehicle systems. Sensors used for mobility platform control and those utilized within payloads will be discussed.	
5.	**Sensor Fusion (2 weeks).**	**Chapter 5**
	Techniques, like Kalman Filters, used to combine sensor inputs to create more robust estimates of environmental conditions and system states will be presented.	
6.	**Localization (2 weeks).**	**Chapter 5**
	Methods used to determine the vehicle's position within a given reference frame and techniques used to map the operational environment will be reviewed.	
7.	**Navigation/ Path Planning (2 weeks).**	**Chapter 6**
	Topics relating to vehicle guidance and path planning, navigation, vehicle control, and mission planning will be presented.	
8.	**Obstacle Detection and Avoidance (2 weeks).**	**Chapter 4 and 6**
	Topics related to the deployment of sensors used to detect a range of objects and their strengths and weaknesses will be presented.	
9.	**Human/Operator Interface (1 week).**	
	Methods and technologies used to communicate the operator's intent to the autonomous vehicle will be presented.	
10.	**Topical Items (1 week).**	
	Will include expert systems and neural networks	

Labs

0. Robot Operating System (ROS) and Simulink introduction lecture (1 wk)
1. ROS intro II with skid steer robot and control implementation on Turtlebot sim (1 wk)
2. Obstacle avoidance and wall following using infrared sensor and collision sensor (2 wk)
3. Collecting and interpreting LIDAR data from GEM autonomous vehicle (2 wk)
4. Lane detection and following using Raspberry Pi 3 camera module (2 wk)
5. Final competition to implement control and localization on Jackal and compete to see who can most closely follow a provided path

The weeks allocated for each part of the lab may be subject to change.

Homework

0. An introduction to model generation in Simulink and system identification (2 wk)
1. Developing kinematic and dynamic models in Simulink for skid steer and Ackerman steer vehicles using their equations of motion (2 wk)
2. Modeling Jackal dynamics using Simulink and Spatial V2 forward dynamics package (2 wk)
3. Designing control systems to control the previously designed models (2 wk)
4. Using Simulink's ROS interface and the controllers developed in the previous week to control a Jackal simulation in Gazebo (2 wk)
5. Designing a Kalman Filter using Matlab/Simulink to filter multiple pieces of localization data together (2 wk)
6. Using neural networks to perform image classification (2 wk) The

weeks allocated for each homework may be subject to change.

Expectations

To succeed in this class, you will need to:

- Read the chapter before coming to class, and formulate questions
- Participate in the class
- Make sure you understand the homework problems and solutions

Seek out help when you have trouble

Obtaining help: The main two ways to obtain help are online at Piazza or in person at office hours. You can also speak with your professor briefly after lecture. Please do not send email directly to TAs or professors for routine help or absences. In cases of emergencies related to exams (e.g., illness) you should email your professor at the earliest possible opportunity.

Online Resources/ Forum

Email

Email communication should be addressed to both the instructor and TA. All relevant email will start with the subject line: SE 498: [SUBJECT]. The TA will respond to emails as soon as possible and will check emails at least once per day.

Compass

We will use Illinois Compass as the central site for course resources. This includes announcements, online homework questions, a discussion board, and grades.
https://compass2g.illinois.edu/

Piazza

This class uses Piazza for all communication between the instructor, TAs, and students. Please visit https://piazza.com/illinois/spring2021/se498/home to register. The Piazza link will take you to the current class page at any time. Official class announcements will be sent via Piazza, so you must register with an email address that you regularly check. If you desire, you can post anonymously on Piazza or make a private post just to the instructors (this should be done rather than emailing the professor directly). TAs are scheduled to be checking Piazza three times per day during the week. Note that Piazza should be used to communicate with your instructors, rather than email.

Media Use in Class

Please turn off your phone-ringer before class.

Activities and Grading

There are two sections for this class. The 4-credit graduate students will be assigned extra problems/extra homework. 3-credit undergraduate students may attempt these problems for EXTRA CREDIT. The grade break-down:

Participation 5 %
Assignments 30 %
Lab Reports – total 30 %
- Labs 1-4 20%
- Final Lab Project 10% Mid-
term Examination 15 % Final
Examination 20 %

Participation
Participation in class and group work is essential to success in any project and in this class. The quality and quantity of contributions to the class activities and discussion will contribute 5% to each student's final grade.

Assignments
Assignments will be given during this course for completion individually. These assignments will apply lecture and reading material and require specific skills and knowledge. There will be 7 assignments that will be posted on the course website. They are on due dates that will be shown in Compass. Homework must be turned physically in class AND electronically to Compass.

IMPORTANT: Students are responsible for ensuring that their work is correctly and successfully submitted electronically and should notify the instructor of any problems in this matter at least 30 minutes before the homework deadline. Students are encouraged to submit their homework assignments at least 40 minutes before the deadline.

Lab Reports
All lab reports are to be turned in at the beginning of the lab period designated by your TA as the due date, using the time between labs to organize and formalize your lab reports. The lab report (except for the data pages completed in the lab) must be typed and printed. You must leave the lab room with your own data in ink and with your TA's initials on the data sheets. Lab reports turned in after the beginning of lab when they are due will be considered late. Lab reports more than one week late are not accepted.
Lab grades:
- Quality of presentation and format 20 %
- Experimental data 40 %
- Analysis simulations and discussion 40 %

The grades of individual students in the same team may be different, based on their attendance and participation in the laboratory.
The TA may modify the above as he or she sees fit.

Examination and Cumulative Final
There is one in-class exam and a cumulative final. If you are unable to sit for the exam for legitimate reasons (e.g. family emergencies, serious illness, attending a conference, etc.), please let the instructor and TA know in advance so that we can accommodate you. Not showing up w/o prior notice will result in 0 (zero) grade for the exam in question.

Final Grade
The final grade will be related to the total number of grade points you have earned during the course. Grades will be posted in Illinois Compass so that you can monitor your progress. Attendance of lectures and active participation are a plus. A total points-to-grade scale will be based on gaps in the total final score of the class students.

Grade ranges:

98 + -- A+	77-78 -- C+
92-97 -- A	72-76 -- C
89-91 -- A-	69-71 -- C-
87-88 -- B+	61-68 -- D
82-86 – B	60 and below -- F
79-81 – B-	

Course Policies

Read and abide by the Code of Policies and Regulations Applying to All Students at http://www.admin.uiuc.edu/policy/code/index.html. Please be aware that this syllabus may change during the semester. Changes to the syllabus will be announced in class and on Compass.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.
Other information about resources and reporting is available here: wecare.illinois.edu.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Disability-Related Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic- records/ferpa/ for more information on FERPA.

Anti-Racism and Inclusivity Statement for Inclusion in Course Syllabi

The intent is to raise student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility in creating an inclusive learning environment.

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Emergency Response Recommendations

Emergency response recommendations can be found at the following website: http://police.illinois.edu/emergency-preparedness/. I encourage you to review this website and the campus building floor plans website within the first 10 days of class. http://police.illinois.edu/emergencypreparedness/building-emergency-action-plans/.

Diversity Statement

UIUC is committed to equal opportunity for all persons, regardless of race, ethnicity, religion, sex, gender identity or expression, creed, age, ancestry, national origin, handicap, sexual orientation, political affiliation, marital status, developmental disability, or arrest or conviction record. We value diversity in all of its definitions, including who we are, how we think, and what we do. We cultivate an accessible, inclusive, and equitable culture where everyone can pursue their passions and reach their potential in an intellectually stimulating and respectful environment. We will continue to create an inclusive campus culture where different perspectives are respected, and individuals feel valued.