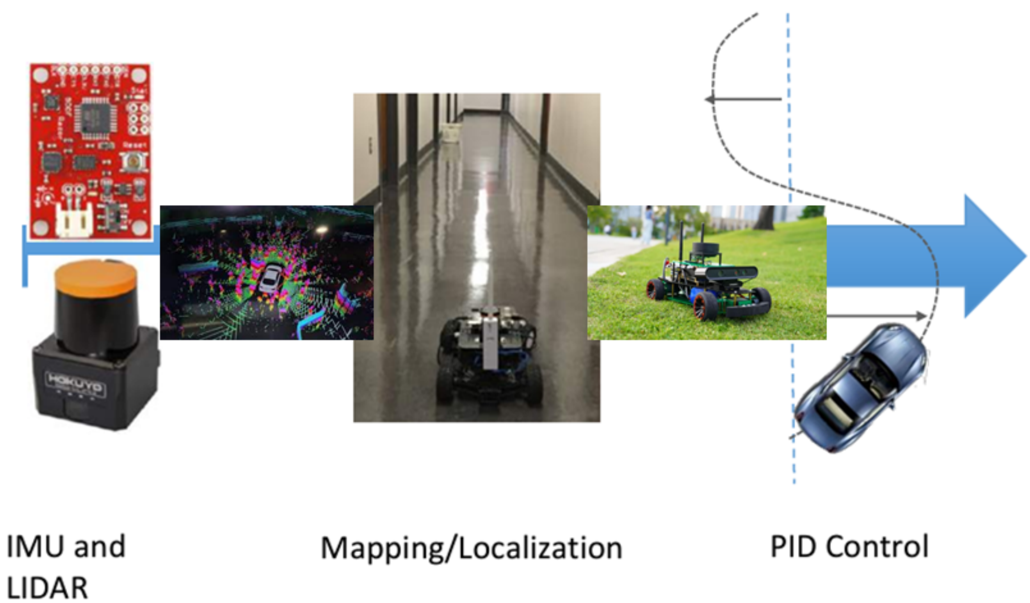
Autonomous Mobile Robots
Spring
(3-0-3-4)



About this Course

Whether you're talking about established car manufacturers such as Tesla or tech giants like Google, a wide array of companies are actively engaged in the advancement of autonomous vehicles. This rapidly evolving domain offers tremendous opportunities, and if you're eager to grasp the fundamentals of autonomous driving, then this course is tailor-made for you.

This isn't just another theoretical lecture series. In this course, we'll dive into practical, hands-on learning. You will learn the fundamentals of autonomous driving in the field of perception, planning and control and how to program them. Right from the start, we'll immerse you in both a simulated environment and real hardware.

What you will learn

Mobile Robots delves into the building blocks of autonomous systems that operate in the wild. We will cover topics related to state estimation (bayes filtering, probabilistic motion and sensor models), control (feedback, PID), planning (roadmaps, heuristic search). Students will be forming teams and implementing algorithms on a mobile car with Ackerman steering structure as part of their assignments. Concepts from all of the assignments will culminate into a final project with a demo on the mobile car. The course will involve programming in a Linux and Python environment along with ROS2 for interfacing to the robot.

Instructor: Dr. Mick West

Office: KLAUS 2316

Time and place:

Email: mick.west@ece.gatech.edu (best way to reach me is by email)

Online resources: Canvas Learning Management System: http://canvas.gatech.edu. Check daily for updates or set notifications to push to email/messenger.

Office phone: TBD

Office hours: TBD, or by appointment.

TAs: TBD

Catalog Description: Comprehensive introduction to the components of autonomous systems and exposes the students to the concept of autonomous systems from the perspective of autonomous mobile robotics. Course may contain team projects and hands-on labs.

Pre-requisites: ECE 3550 or ECE 3084

Textbook (optional):

1. Thrun, Sebastian, Burgard, Wolfram and Fox, Dieter. **Probabilistic Robotics.** Cambridge, Mass.: MIT Press, 2005. ISBN: 9780262201629
2. Siegwart, Nourbaksh and Scaramuzza, **Introduction to Autonomous Mobile Robots**, 2nd Edition. MIT Press, 2011. ISBN: 9780262015356 (required)
3. Nikolaus Correll, **Introduction to Autonomous Robots, Magellan Scientic**. ISBN-13: 978-0692700877. (optional) Free Online version can be obtained: https://open.umn.edu/opentextbooks/textbooks/introductionto-autonomous-robots

Additional Material:

Class Notes, Course Handouts & Problem Sets/Homework. Please keep track of what is being posted on **Canvas.** Canvas is our primary method of communication.

Grading: Homework (60%), Project (30%), Participation (10%)

Course Outcomes: Upon successful completion of this course, students should be able to:

1. Describe mathematical models of mobile robot dynamics.
2. Develop models for sensing for mobile robots.
3. Develop tools from estimation theory applied to mobile robotics.
4. Design Bayes filters to estimate the state of the robot and the environment.
5. Design control laws to track a given path using stability or optimality criteria.
6. Develop planning algorithms to compute feasible, collision-free paths between two locations.
7. Apply localization, control and planning to a mobile robot to navigate an environment in a safe and efficient manner.
8. Conduct experiments demonstrating localization, control and planning of a mobile robot.

Student Outcomes

In the parentheses for each Student Outcome:

"P" for primary indicates the outcome is a major focus of the entire course.
"M" for moderate indicates the outcome is the focus of at least one component of the course, but not majority of course material.
"LN" for "little to none" indicates that the course does not contribute significantly to this outcome.

1. (P) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. (M) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. (M) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
4. (LN) An ability to communicate effectively with a range of audiences
5. (LN) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
6. (LN) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
7. (LN) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
8. (LN) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Communications: Verbal notices may be given in class. It is your responsibility to attend the class and obtain this information in class. Announcements may also be posted on course website or delivered via email. Visit course website and read your email regularly.

General Info.: The midterm exams and the final exam are closed book and closed notes. One formula sheet (both sides of 8.5" x 11" paper) is allowed for the midterm exam, and two for the final exam. The formula sheet(s) should be handwritten originals; not photocopied.

The final exam is comprehensive. It will cover all the material presented in the course.

Questions concerning a grade given for any assignment or exam must be presented to the instructor within 5 days after the grade is received. *No exceptions to this rule will be permitted at any time, for any reason.*

Attendance: Class attendance is **very strongly** encouraged, but will not be verified. It is the student's responsibility at all times to keep abreast of course procedural announcements, obtain handouts, etc. All homework, solutions, handouts, etc., will be posted on the Canvas.

If, for some extremely important, verifiable reason (i.e., written excuse from doctor, etc), you cannot take any of the exams at the scheduled time, the instructor must be notified **prior** to exam time, so proper arrangements can be made to administer the exam. *No excuses after the date of the exam will be considered. No makeup exams will be given unless you notify Dr. West via email prior to the scheduled time and have a legitimate excuse for absence.* There will be no dropping of any exam grades. Failure to complete an exam will result in a score of zero.

Homework: Homework will be collected on the due date announced on Canvas. Homework may be solved in groups provided that all in the group participate fully. Copying is not permitted. Late homework will receive a penalty in grade (−10 pts for every 24 hours). No homework will be accepted after the solutions are posted.

What is Expected of Students:

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Students are encouraged to work together on homework problems, but individual solutions must be submitted.

All students are responsible for materials covered in and/or assigned in class REGARDLESS of whether they attended class.

Student-Faculty Expectations Agreement: At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of us and that we have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, we encourage you to remain committed to the ideals of Georgia Tech while in this class.

General Course Outline:

- Introduction to Robotics
- Preliminaries
  - Linear Algebra
  - Probability Theory
- Modeling and Kinematics
  - Locomotion wheeled, aerial, underwater …
  - Kinematic models
  - Maneuverability
  - Robot workspace
- Sensing for Mobile Robots
  - Wheeled (odometry)
  - Beacon (GPS)
  - Time of flight
  - Camera
- Estimation (Overview Directed towards robotics)
  - MLE
  - MAP
  - MMSE
- Localization
  - Bayes Filter
  - Probabilistic measurement models

  - Particle filter
  - Kalman filter
- Map Representation
  - Occupancy grid
  - Height map
  - Point clouds
  - Surface representations
  - Landmark
  - Topological map
  - Distance map
- SLAM
  - Introduction SLAM
  - FastSLAM
  - Factor Graph representation of SLAM (Dellaert GTSAM)
- Mobile Robotics Control
  - PID
  - Stability/nonlinearity
  - Linear Quadratic Regulator
- Path Planning
  - Introduction Planning
  - Roadmaps
  - Heuristic search (A*, Weighted A*, ..)