MAE 4180/5180, CS 4758/5758, ECE 4180/5772

Autonomous Mobile Robots

Spring 2022

Creating robots capable of performing complex tasks autonomously requires one to address a variety of different challenges such as sensing, perception, control, planning and interaction with humans. Many advances have been made in recent years towards creating such systems, both in the research community (different robot challenges and competitions) and in industry (industrial, military and domestic robots).

This course will give an overview of the challenges faced and techniques used for creating autonomous mobile robots. Topics include: sensing, localization, mapping, path planning, motion planning, obstacle and collision avoidance and multi-robot control. The course includes a lab portion in which students program the iRobot Create.

Note: This course is very hands-on, requiring students to implement algorithms, debug code and experiment with physical robots. As such, students should have a good working knowledge of Matlab, and should start assignments early.

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Time and Location:

Lectures:	Tue. and Thur.	9:40AM - 10:55AM	online (first 2 weeks), 110 Hollister Hall
Lab sections:	Tuesday	2:40PM - 5:10PM	101a Thurston Hall
	Wednesday	2:40PM - 5:10PM	101a Thurston Hall
	Thursday	2:40PM - 5:10PM	101a Thurston Hall
	Friday	2:40PM - 5:10PM	101a Thurston Hall

Lecture zoom link: https://cornell.zoom.us/j/93212680872?pwd=VWZEa0w4TnBuQjhMS1NoT1Bxa3RtZz09

There will be four labs throughout the semester. Students enrolled in MAE 4180, ECE 4772, or CS 4758 participate only in labs 1,2 and 4, as described below.

Prof. Kress-Gazit's office Hours: Friday 8:30-9:30am.
TA office Hours: Tue 2:30-4pm, Wed 10-11:30am, Thu 3:30-5pm, Fri 1-2:30 pm, Fri 5-6:30 pm

Course website: Announcements, assignment posting, submission and grading will be done through the course Canvas site.

References:
Course Textbooks:

- S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*, MIT Press, 2005. (TBF)
- H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, Boston, 2005. (Choset)

Additional sources:

- R. Siegwart and I. R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, MIT Press, 2004.
- S. M. LaValle, *Planning Algorithms*, Cambridge University Press, 2006.
  Available online at http://planning.cs.uiuc.edu/

- M. J. Matarić, The Robotics Primer, MIT Press, 2007.
  Workbook online at http://roboticsprimer.sourceforge.net/ workbook/Main_Page

Prerequisites: Senior or Graduate standing or permission of instructor. Good knowledge of programming (MATLAB) is essential for the homework and labs.

Laboratory component

This course includes a laboratory component so that students can gain first-hand experience with the algorithms discussed in the lectures. The labs are centered around the iRobot Create platform and involve collecting data, programming the robot and discussing its behavior. All labs include a pre-lab assignment that will be part of the homework sets, a lab manual describing the experiment and a post-lab writeup. Reports are expected to be concise and to the point, and follow the guidelines available on Canvas.

COVID-19 adjustments: We expect to hold all labs in person. If you are sick or in quarantine, let us know as soon as possible and we will find a solution.

Simulator: A MATLAB-based simulator for the iRobot Create will be used in this class in order to facilitate code development for the labs and the final competition.
The simulator can be found at *https://github.com/autonomousmobilerobots/iRobotCreateSimulatorToolbox*

Laboratory Schedule:
Week 02 (02/1): Coding recitation
Week 03 (02/8): Lab 1: Introduction to the iRobot Create and sensors
Week 08 (03/15): Lab 2: Localization
Week 09 (03/22): Lab 3: Mapping **(MAE 5180, CS 5758, ECE 5772 only)**
Week 12 (04/19): Lab 4: Motion Planning

Simulation Competition (4180/4758): Thursday, 05/5
Physical Competition (5180/5758/5772): Tuesday, 05/10 (Last Day of Class)

Coding: To truly understand the concepts and algorithms discussed in the lecture, students will implement most of the algorithms and experiment with simulated and physical robots. Good coding practices will facilitate the implementation and debugging phase and will allow for intelligent code reuse. Students are highly encouraged to be mindful of their code structure and consult the professor and the TAs about ways to improve reusability.
The lab will have Matlab 2021a installed with the following toolboxes:

- Control System Toolbox
- Instrument Control Toolbox
- Statistics and Machine Learning Toolbox
- Symbolic Math Toolbox

It is the responsibility of the students to ensure they are working with the correct versions of Matlab.

MAE 4180, ECE 4180 and CS 4758: Students enrolled in MAE 4180, ECE 4180, or CS 4758 have less of a workload; they are required to do three out of the four labs, they are not required to do one assignment and their competition is in simulation. All students are expected to attend all of the lectures.

Policies

Expectations and accommodations:

- Engineering solves world problems by using technology creatively. We invite and expect every student to contribute creatively as part of their learning process.
- Success in engineering depends critically on teamwork. We invite and expect every student to engage in constructive discourse, to bring their perspective, and to be accepting of others opinions.
- Degrading, abusing, harassing, silencing, or dismissing others in the process is not acceptable behavior. It is also bad engineering.
- We are committed to providing an enriching learning environment for every student. The professor is available to discuss academic accommodations for students with disabilities or with special needs or concerns. Requests for academic accommodations should be made as soon as possible, so that arrangements can be made in a timely fashion. Students are also encouraged to register with Cornell's Student Disability Services as needed.

Lecture notes and recordings: Lectures will be presented using a tablet PC. A skeleton file for the lecture notes will be posted at least an hour before each lecture (typically the night before) and it will mainly include figures and some text. It is recommended that students attend class with the lecture notes skeleton and use it to fill in the material covered in class. The lecture notes will be posted after the class but they will NOT contain all the information and discussion that takes place in class.

All online lectures (first 2 weeks of class, later as directed by the university) will be recorded and posted to the class Canvas site within a few hours, including an auto-generated transcript.

Course announcements: All course related announcements will be posted on Canvas. Students are expected to check the announcements at least once a day during the week. We highly encourage students to enable email notifications from Canvas.

Labs:

- The labs are an integral part of the course and as such, in order to receive a grade, students must complete **all** of the labs required for their course number.
- Students are expected to notify the TAs if they are unable to attend a lab **24 hours in advance**. If a student anticipates they will miss more than one lab throughout the semester, they must get approval from Prof. Kress-Gazit. Missing three or more labs will, in most cases, result in failing the class.
- Makeup labs for students who miss a lab will be scheduled on the week of **May 10th**.
- Lab groups will consist of 2-3 students. Groups will be assigned by the TAs and will change every lab.
- Pre-lab assignments (code needed for the lab, part of the homework sets) will be done **individually** and the post-lab report will be written as a group (one report submitted per group).
- To make the most out of the time in the lab, and to focus on working with the robots and not on debugging code, **all students must attend the lab with working code**. The lab manual for each lab will specify the plots that need to be handed in as proof of working code. Students will not be allowed to do the lab if they do not have working code needed for the lab. If a student wishes to attend a different lab section, they must coordinate with the TAs and it is subject to space constraints (we do not allow more than 18 students per lab section).
- During labs, all group members must remain in the lab until data is collected by all group members, unless approved by the TA.
- Post-lab reports will include a sentence describing the contribution of each team member to the analysis and report.

Video: A few minutes before the lecture starts, Prof. Kress-Gazit will play a video related to robotics. Students are encouraged to submit (in Canvas) links to robot videos.
Grading: The grade will be determined based on the following: in-class assignments (via PollEverywhere), homework sets, labs and a final project.

- **In-class assignments:** To facilitate the learning process and maximize the effectiveness of the lectures, Prof. Kress-Gazit will be using PollEverywhere for in-class assignment. Students who cannot attend class for an extended period of time must discuss the situation with the Prof. **(5% of the final grade, lowest 3 are dropped).**
- **Homework:** Expected homework due dates are stated in the tentative schedule for the class. Homework will include the relevant pre-lab assignments for the upcoming lab and additional questions. Students should begin working on the homework **as early as possible** as they will involve algorithm implementation and testing. Homework will be submitted online through Canvas and gradescope. Written portions of the homework should be typed. **(45% of the final grade)**
- **Post-lab reports:** Each lab includes a set of post-lab questions discussing the concepts highlighted in the lab. Reports will be submitted, one per lab group, **one week** after the lab was completed, through Canvas. Written portions should be typed. **(20% of the final grade)**
- **Final project:** The course will end with a final project either in simulation (4180, 4758 students) or with a physical robot (5180, 5772, 5758 students). **(30% of the final grade)**

Regrades: Regrade requests will be handled through gradescope. All regrade requests must be submitted within 10 days of receiving the grade.

Homework and report submission: Written reports and code are to be submitted through gradescope and Canvas, respectively:

- **Written report:** One file containing all of the figures and text, in .pdf format, submitted on gradescope.
- **Code:** A zip file named according to what is specified in the homework description. All the code and files needed for the assignment, including code for visualization/graphs, must be included. It is expected that by downloading the zip file, the TAs will be able to run the code smoothly.
- **Autograded Matlab assignments:** These will be separate Canvas assignments and each assignment will correspond to a Matlab function that needs to be written. Students may submit as many times as they want before the deadline.

Late policy:

- **In-class assignments:** Late in-class assignments will not be accepted. For the final grade, the worst 3 in-class assignment will be ignored.
- **Homework and post-lab reports:** Each student is allowed one "free late day" which means *one* homework assignment *or* lab report may be uploaded to Canvas up to one day late without penalty (do not email assignment to TAs or Professor). Other than this day, work submitted one day late will be deducted half of the possible points for the assignment. Work submitted more than 24 hours late will not be accepted. Exceptional circumstances with appropriate documentation will be considered by Prof. Kress-Gazit.

Collaboration policy: In-class assignments, homework and part of the final project report are to be done and submitted individually. To enhance the learning process, students are encouraged to discuss the problems with, provide guidance to and ask for help from other students, the TAs and Prof. Kress-Gazit. However, to make sure each student understands the concepts, solutions and code must be written independently. Copying code or solutions, having someone else type or dictate any part of the code, privinding someone else with your solution, or using publicly available code from the Internet (unless explicitly permitted) is not allowed. Posting of code to publicly accessible repositories, such as GitHub, is not permitted.

Post-lab reports and part of the final project report will be done in groups of 2-3 students.

Email communication: To facilitate email communication between students and Prof. Kress-Gazit and the TAs, professional email etiquette is necessary to elicit useful replies. The following guidelines improve student's chances of receiving a helpful response:

- The subject of the email should contain the course number and a short description of the content of the email. Writing MAE4180 (or any other of the course numbers) in the subject ensures the email goes through the right filter and will receive the proper attention.
- The email should be formally addressed, with the proper title (e.g. Prof. Kress-Gazit), to the person the email is intended to and it should be signed with the sender's full name. This way your email is less likely to be mistaken for a mass-email or for spam.
- The body of the email should be grammatically correct, use full sentences and be succinct. Emails are often misunderstood, so taking the time to clarify your intent will increase the chances of getting a helpful reply.
- If you have a general question about the course, the procedure should be:

  1. Check the course documents.
  2. If the information is not there, post on the course discussion board.

Students should expect replies within one business day during Cornell business hours.

Ed discussion: Students are highly encouraged to post questions and answers on the course Ed discussion site, linked in Canvas.

- The site will be monitored on business days by the course staff. Students can expect an answer within one business day.
- Students are expected to communicate in a professional manner.
- Students may NOT write code snippets on the discussion board.

Academic integrity: Students are expected to follow Cornell's Code of Academic Integrity which can be found at http://theuniversityfaculty.cornell.edu/academic-integrity/code-of-academic-integrity/. The purpose of this code is to provide for an honest and fair academic environment. As such, it should be clear to students what is expected of them in the course (see the collaboration policy) and in case of doubt, students should ask Prof. Kress-Gazit. Copying work (code and/or text) and/or allowing others to copy work are considered violations of Cornell's code.

Course staff will use software tools (such as MOSS) to detect code plagiarism.

Life happens policy: In case of a legitimate situation or emergency that arises during the semester that is going to hinder your ability to complete work on time, contact the professor as soon as possible. We can figure things out.