EECE 7120-202: Fundamentals of Robotics

Fall 2019
Wednesdays 6:30-9:20
Ball Hall 208

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Office Hours: TBD

Course Description

The purpose of this course is to introduce you to the basics of robotics. The material in this course is a combination of essential topics, techniques, algorithms, and tools that will be used in future robotics courses. Fundamental topics relevant to robots (linear algebra, numerical methods, programming) will be reinforced throughout the course using introductions to other robotics topics that are each worthy of a full semester of study (dynamics, kinematics, controls, planning, sensing).

A majority of the content in this course will be presented in the form of lectures and demonstrations. Students will complete homework, mini-projects and a semester-long project to reinforce their learning. There is no assigned textbook for this course, but lecture notes will be provided online.

Course objectives

Upon completion of this course, students will be able to:

- Describe and explain the methods a robot can use to accomplish tasks
- Develop ROS packages
- Understand and explain complex robotic systems
- Describe and explain the mathematics underlying robotic algorithms
- Understand and apply basics of linear algebra in robotics problems
- Understand and apply coordinate transformation in 2D and 3D
- Understand and describe basics of probability theory and apply it to robotics problems
- Understand and apply optimization algorithms to robotic problems
- Understand and apply best coding practice

Targeted Students

This course is designed to be accessible to graduate students of all levels. We strongly encourage first-year graduate students to take this course as early as possible. Sufficiently experienced undergraduates may also take this course with instructor approval.

Prerequisites

No pre-requisites are needed for this course. We recommend that students have some programming experience (MATLAB is okay, but Python/C/C++ is preferred) and are familiar with linear algebra.

Required and reference texts

No required text. Course notes will be provided by instructor

Reference (optional) texts:

[1] The Matrix Cookbook, Petersen and Pedersen, 2012

[2] Coding the Matrix: Linear Algebra through Applications to Computer Science, Klein, 2013

[3] Numerical methods in engineering with Python, Kiusalaas , 2013

[4] Probabilistic Robotics, S. Thrun, W. Burgard and D. Fox, MIT Press, 2006.

[5] Introduction to Autonomous Mobile Robots, R. Siegwart, I. Nourbakhsh, MIT Press, 2011.

[6] Robotics, Vision, and Control, Peter Corke, Springer, 2011.

Required Equipment

Ideally, all students will have their own laptop capable of running ROS in Linux. This could take many forms, including a laptop that dual-boots into Linux as well as Windows or MacOS, a laptop running a Linux Virtual Machine or a laptop using Docker or similar containers for ROS. If this is not possible, please contact the instructor as soon as possible.

Duckiebots will be provided to each student around the second week of classes. Duckiebots will be used to demonstrate understanding of material in each mini-project. Students are also encouraged but not required to use duckiebots for their final projects. Each student will be responsible for their Duckiebot and must return it to the instructor at the end of the course. Failure to return the Duckiebot in a functional condition will result in an incomplete grade for the course.

Schedule

The purpose of this class is to ensure that all beginning graduate students have a baseline level of understanding of the fundamentals of robotics, so the schedule is subject to change throughout the semester depending on the progress of the class.

Date	Topic(s)	Assignment	Due
Sep 4	Introduction to Robotics Introduction to git and Docker ROS Demonstration and Installation Introduction to ROS	HW1 (ROS1)	
Sep 11	Networking and Robots Duckiebot Demonstration and Assembly Programming in ROS	Mini-Proj 1 HW2 (ROS2)	HW1
Sep 18	Introduction to Autonomy Robot Software Development Testing (and Debugging) Robots		
Sep 25	Vector and Matrix Operations Coordinate Transforms Robot Arms	HW3 (Matrix)	HW2
Oct 2	Numerical Integration and Differentiation Demonstrate Mini-Project 1 Odometry	Mini-Proj 2 HW4 (NM)	Mini-Proj 1 HW3
Oct 9	Linear Algebra Dynamics and Kinematics Basic Closed-Loop Controls	HW5 (Controls)	HW4
Oct 16	Graphs Graph Search Basic Planning Algorithms	HW6 (Planning)	HW5
Oct 23	Probability State Estimation Probabilistic Planning	HW7 (Probability)	HW6
Oct 30	Guest Lecture(s) Demonstrate Mini-Project 2 Perception	Mini-Proj 3	Mini-Proj 2 HW7
Nov 6	Guest Lecture(s) Computer Vision Computer Vision on Duckiebots		
Nov 13	Guest Lecture(s) Feature Extraction Line Detection	HW8 (Vision)	
Nov 20	Robot Systems (putting it all together) Final Project Discussion Optimization	Final Project	HW8
Nov 27	NO CLASS THANKSGIVING		
Dec 4	Human-Robot Interaction Demonstrate Mini-Project 3 Robots and Society		Mini-Proj 3
Dec 11	Machine Learning and Robotics Final Project Check-Up Current Trends in Robotics		
Final	Project Presentations		Final Projects

Evaluation and Grading

Homeworks (30% of grade) will be assigned frequently in the first 2/3 of the class to reinforce understanding of the basic mathematical and algorithmic concepts covered in those lectures. Homework may take the form of problem sets or programming assignments. Homework is due at the beginning of class on the due date. *Late submissions will not be accepted.*

Mini-projects while homework is intended to test a particular concept, mini-projects ensure that the concept fits into the bigger picture. Each mini-project will cover several lectures worth of content. Some steps of each mini-project will overlap with some homework assignments, but the final grade in the mini-project will be based on an in-class demonstration using a duckiebot, code submission, and a brief report.

- *Mini-Project 1* (15% of grade) covers basic robot understanding and programming. Through several check-offs, students will demonstrate that they understand ROS and can program their robot.
- *Mini-Project 2* (15% of grade) covers robot motion. Students will demonstrate that they can program their robot to move along a desired path.
- *Mini-Project 3* (15% of grade) adds sensing to the above project. Students will demonstrate that their robot can react to objects in the environment and move accordingly.

Final Project (25% of grade) Students will form small groups (2-3 people) to complete a project of their choosing. Project topics must be approved by instructor. Groups will be graded on a demonstration, their report, and a presentation of their work.

Final grades will be rounded to the nearest percentage point and distributed as follows:

A: 90-100%
B: 80-89%
C: 70-79%
D: 60-69%
F: <60%

Classroom Conduct

Students are expected to exhibit professional and respectful behavior that is conducive to a mutually beneficial learning environment in the classroom. Examples of inappropriate behavior include: text messaging, listening to music, cell phone use (other than the campus alert system), late arrivals, early departures, use of laptops for other than class purposes, disrespectful comments or behavior, intentional disruptions, failure to follow faculty directives, etc. Students in violation of these standards may be asked to leave class and/or be referred to the Dean of Students for disciplinary action.

Academic Integrity

For homework and mini-projects, you are expected to do your own work. You are encouraged to discuss in groups but the submission you turn in must represent only your work. Turning in code or other homework that is substantially the same as another student's work in plagiarism. Doing the work yourself is an important part of learning the material and is the only way you will be able to master it in order to move on to later classes or career positions in robotics.

Examples and solutions from the internet and other sources may be useful to you in learning this material but you cannot turn in something downloaded from the internet and claim it as your own. That would be plagiarism. If you use something from another source as a reference in one of your submissions, cite it clearly.

Cheating and plagiarism will not be tolerated. A first offense will result in a failing grade for the assignment/exam in question and a formal filing with the Office of Provost according to the Academic Integrity Policy. A second offense could lead to a failing grade in the course, suspension or expulsion, as detailed in the policy, defined here: https://www.uml.edu/Catalog/Undergraduate/Policies/Academic-Policies/Academic-Integrity.aspx

Technology Resources

For a listing of available computing and software resources available to students, visit: https://www.uml.edu/IT/Services/DLC/

Accommodations

In accordance with University policy and the ADA, accommodations are provided for students with documented disabilities. If you have a disability, please contact the Office of Disability Services as soon as possible. Their office is in UC 220 (978-934-4574, Disability@uml.edu). Documentation of disability is confidential. Requests for accommodation for religious reasons should be directed to Equal Opportunity and Outreach at 978-934-3565, Wannalancit Mills, Suite 301.

Counseling Services

As part of the Wellness Center, Counseling Services at UMass Lowell provide mental health counseling, consultation and referrals to help students achieve personal and academic success. They also assist students in better understanding and coping with their feelings, relationships, and choices surrounding their academic success. Visit https://www.uml.edu/student-services/Counseling/

Veterans' Services

UMass Lowell is committed to helping our military students take full advantage of all the educational benefits available through the federal and state governments. For complete information on the services and resources available please visit our website at: https://www.uml.edu/student-services/Veterans/.

University Cancellation Information

If campus is closed (most likely for weather), visit the website for announcements relevant to the class.