Introduction to Robotics Syllabus ME 490/ECE495
Fall 2021
Duke University, Department of Mechanical Engineering and Materials Science

Prerequisites *Math 216* –Linear Algebra & Differential Equations
Corequisites *ME 344L/ECE 382L* –Control of Dynamic Systems
Recommended *EGR 244L* – Dynamics

Instructor
Siobhan Oca, *email*: skr23@duke.edu, *pronouns:* she, her, hers
Teaching Assistants
Luca Di Muro [technical assignments]
Juan Lasso Velasco [coding assignments]

Course Description
Robotics as an application draws from many different fields and allows automation of products as diverse as cars, vacuum cleaners, and factories. This introductory course is a challenging introduction to basic concepts used broadly in robotics; it is valuable for students who wish to work in the area. Topics include simulation, kinematics, control, sensing, and system integration. The mathematical basis of each area is emphasized, and concepts are motivated using common robotics applications and programming exercises. Students will participate in two projects over the course of the semester, in which they will implement algorithms that apply each of the topics discussed in class to real robotics problems.

Learning Objectives: By the end of the course you will be able to:
- Describe kinematics, kinetics, sensing and control of robotic manipulators
- Model manipulators and analyze their performance by running simulations with Robot Operating System (ROS)
- Understand and utilize Robot Operating System (ROS) to perform basic tasks with a robot arm manipulator
- Describe key aspects of robot system development for a given application and understand the limits of this system

Textbooks: There is no set textbook for this class and you need not buy one. A few useful textbooks are listed below; excerpts will be provided as needed for background reading.
- Lentin Joseph, *Robot Operating System (ROS) for Absolute Beginners*, Apress, 2018.
- Brian Gerkey, Morgan L. Quigley, and William D. Smart, *Programming Robots with ROS: A Practical Introduction to the Robot Operating System*, O'Reilly Media, 2015.
- Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017.

Other useful resources:
- Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, Wiley, 2006.
- John J. Craig, *Introduction to Robotics: Mechanics and Control*, Addison-Wesley Publishing, 1989.
- Alonzo Kelly, *Mobile Robotics: Mathematics, Models, and Methods*, Cambridge University Press, 2013.

Grading
10% Quantitative Homework
10% Conceptual Homework

30% Quizzes (3 during the semester)
25% Midterm Project (15% weekly coding check-ins)
25% Final Project (10% weekly coding check-ins)

Topics

- Intro to ROS (robot operating system software) and Gazebo
- Linear Algebra Review
- Rigid Transformations
- Rotations and Rotation Matrices
- Forward Kinematics, Configuration Space
- Inverse Kinematics (IK)
- Numerical IK and Jacobians
- Trajectory and Singularities
- Feedback/PID control
- Invited Lecture: Advanced Control Methods: Model Predictive Control
- Calibration
- Visual Sensing / Perception
- Mobility and Manipulation
- System Integration
- Invited Lecture: Human Robot Interaction/Safety
- Invited Lecture: Medical Robotics

Assessments

Weekly Homework

Weekly homework will be assigned to help you learn the course material. Since the primary purpose is to give you a chance to practice the skills introduced in the lectures, your lowest assignment grade will be ignored when calculating your overall assignment grade.

On odd weeks, there will be a technical/math based homework assigned, like problem sets in other engineering courses, where students are encouraged to work through applying concepts taught in weekly lectures. On even weeks, conceptual homework which will require describing concepts in your own words. You will also describe a research paper in the area of focus.

Additionally, there will be graded weekly coding check-ins for structured progression on the midterm and final project, so all work (and therefore last-minute issues) can happen throughout the semester rather than in the last week of classes.

You are welcome to work with classmates, but 1) credit anyone who helped you with a footnote, and 2) be mindful of whether you are developing each skill. You will turn in your homework assignments through Gradescope. Code, graphs, or other files should be included in the same file as the rest of your homework. For most software, you can create pdf printouts and append them together to create a single file. Assignments submitted over 2 days late or through any other means will not earn the privilege of TA feedback and will count as 0% grades. Assignments submitted within two days of the deadline, but late will receive a maximum 80%. The two lowest assignment grades will be dropped.

Individual Projects

There will be a midterm and final project to show mastery of concepts through application in the industry standard platform (at least for open source)—ROS (robot operating system). The midterm project will be using a robot arm file, provided by the instructor, in simulation to perform move the end effector in your initials. The final project will be a group project proposing a robot system for a task of your teams choosing (approved by the instructor) and showing the physical robot in simulation.

Quizzes
There will be 3 quizzes in the semester to assess topics and applications presented in class.

Conduct Expectations
It is the expectation that students, TAs, and the instructor will regard each other with mutual respect. Students will abide by the Duke Community Standard:

I will not lie, cheat, or steal in my academic endeavors;
I will conduct myself honorably in all my endeavors;
and I will act if the Standard is compromised.

Course Policy: *Absences and Late Work*
Absence due to illness will need to be reported within the same day of missed lecture or assignment deadline by submitting a Short Term Illness Notification Form (STINF); late work will not be accepted and will be assigned a 0, unless proper STINF documentation is supplied. Varsity athletes must comply with all regulations given by Trinity College. In addition to these formalities, students need to communicate with the instructor in person or by email.
Extenuating circumstances (such as family emergencies) that will prevent a student from attending class or lab or reaching assignment deadlines should be discussed with the instructor as soon as possible and will be accommodated on a case-by-case basis.

Disability Statement
Students with disabilities who believe they may need class accommodations should read through the Student Disability Access Office webpage (in particular, the Rights and Responsibilities for Students section) or contact the Office directly at (919) 668-1267. Note that accommodation requests should be submitted very early in the semester.