MECH 450-010: Robot Motion Planning and Control

Fall 2020

Course Information and Policies

Instructor: Subhrajit Bhattacharya (sub216)

Catalog Description for MECH 450 (Robot Motion Planning and Control)

This course will start with an introduction to the configuration spaces and kinematics of different robotic systems, including holonomic & non-holonomic mobile robots, spatial robots, and robotic manipulators. Following that basic motion planning algorithms, including potential & navigation function-based motion planning and graph search based motion planning, will be introduced. Sensor-based motion planning and motion planning under uncertainties using probabilistic representations will be introduced. Students will learn about estimation and filtering (Kalman filter, Markov filter, particle filters) and probabilistic robot action models (Markov chains, Markov decision processes, POMDP). Students will get hands-on experience in implementing the algorithms on MATLAB/C++. Application to multi-robot coordination problems, multi-robot coverage problems, pursuit-evasion problems, task allocation problems and exploration problems will be discussed. If time permits, students will be briefly introduced to topological motion planning, motion planning on manifolds and motion planning on flow fields. The evaluation will be based on two term projects and a final presentation.

Overall Course Format:

- ***Lecture videos*** will be posted through course-site in an asynchronous manner allowing students to watch/re-watch them at their convenience. Students should watch the lecture videos before the following Zoom meeting.
- ***Zoom meetings*** will have the format of office hours and will allow students to ask specific questions, discuss problems from the assignments, and/or request the instructor to go over specific parts of the video lectures or specific problems described in the video lecture. The Zoom meetings will NOT be recorded.
- ***All assignments*** will all be conducted electronically (may require you to scan and upload solutions as PDF to course-site) as described below.

Lectures:

Video posted on course-site *before* scheduled lecture hours (MW, 1:35pm-2:50pm).

Meetings / Office Hours:

Regular Zoom meeting / office hour on Mondays, 1:35pm-2:50pm.

Based on the number of students available and willing to have a face-to-face meeting on campus, I may also conduct in-person office hours on Wednesdays 1:35pm-2:50pm. If we do not have an in-person meeting on a Wednesday, I will be available for Zoom office hour on that Wednesdays 1:35pm-2:50pm on an as-required basis or by appointment.

Reference Books:

We will use the following reference texts (any edition should be fine) for this class:

1. "Planning Algorithms" by Steve LaValle.
   Available for free download at http://planning.cs.uiuc.edu/
2. "Principles of Robot Motion: Theory, Algorithms, and Implementation" by Choset, et. al.
   Details available at http://biorobotics.ri.cmu.edu/book/
3. "Probabilistic Robotics" by Sebastian Thrun
   Details available at http://www.probabilistic-robotics.org/
4. "A Mathematical Introduction to Robotic Manipulation" by Richard Murray
   Details available at https://www.cds.caltech.edu/~murray/books/MLS/

You need not own a copy of all or any of these books as long as you can get access to these books at the Library.

Expected Background / Prerequisites:

Software and Programming Languages:

In this course we'll use MATLAB (alternatively, Octave) extensively, and discuss a little bit of C++ (you should however be able to complete all the required assignments using MATLAB/Octave only). MATLAB is available for your use through Lehigh University's LTS: https://software.lehigh.edu/install/ . While GNU's C++ compiler is open-source and free, you can download Microsoft's C++ compiler (Visual Studio) from Lehigh University's LTS as well. While I may give a few simple tutorials on these programming languages, if you have never used MATLAB/Octave before, it is expected that you'll self-teach yourself the basics of that as required.

Mathematical Tools:

In this course we will extensively use multi-variable calculus, coordinate geometry, vector algebra, trigonometry and basic probability theory, the basics of which you'll be expected to know. You are expected to review these topics yourselves if you need to.

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Grading Policy:

- There will be **weekly/bi-weekly assignments** ("mini projects" constituting primarily of MATLAB/Octave programming assignments). You will need to turn them in (upload to course-site **as a single PDF file** less than 20MB in size) by the submission date mentioned with each assignment. While you can discuss an assignment with your classmates before you start working on it, you should solve the assignment entirely by your own self. Your submission should be your own individual and original work completed entirely by your own self, and should NOT be a collaborative effort. These assignments will be worth 45% of the total course credit.
- You will need to select **one term project** to work on. The project will be worth 45% of the total course credit.
  - ▷ You'll need to submit a 1-2 page proposal/report during the middle of the semester

(around end of October) outlining your plan for the term project and any preliminary progress you have made (upload to course-site **as a single PDF file** less than 20MB in size).

- ▷ You'll need to submit a 3-5 page final report on the project by the end of the semester (upload to course-site **as a single PDF file** less than 20MB in size).
- ▷ You will also need to make a single 15-20 min presentation of your work closer to the end of the semester.
- ▷ You will have significant freedom in choosing your own topic(s) for the projects, and you are encouraged to choose a topic that closely aligns with (or is an extension of) your current research area, if any.
- ▷ Your project should be your own individual and original work completed entirely by your own self, and should NOT be a collaborative effort.
- ▷ You are free to consult the internet for working on your projects. But your projects should be your own individual and original work. You are NOT allowed to discuss the specifics of your project or seek help regarding those from anyone (including your classmates, friends or online forums

- The remaining 10% of the total course credit will be on **class participation**.

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Policy on Use of Electronic Devices and the Internet:

- All cell phones, PDAs, tablets, smart watches and the like should be silenced/turned off and stowed off and out of sight during any in-person class meeting.
- For working on the assignments or projects, you are free to consult books, notes, any material shared through course-site, or any other printed/written material. You can also use the internet for reading on the topics that we have covered in the class. But your assignment submissions and projects should be your own individual and original work.
- You are NOT allowed to discuss the specifics of an assignment problem with anyone (including your classmates, friends or online forums), nor are you allowed to seek solutions to your project (or any part thereof) from anyone (including your classmates, friends or online forums),

Academic Integrity:

Students are expected to be familiar with all the academic integrity principles of Lehigh University. Please visit the Academic Integrity Resources page for details: https://citl.lehigh.edu/academic-integrity-resources

Accommodations for Students with Disabilities

Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable

accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities .

The Principles of Our Equitable Community

Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.