ME/CS 133(a): Robotics

Lecturer: Prof. Joel Burdick, Gates-Thomas 245, x4139, *jwb@robotics.caltech.edu*
T.A.s: Amanda Bouman, Anushri Dixit, Andrew Singletary
T.A. office hours: See course Web site for updates and contact information
Meeting Time: MWF 3:00-3:55 pm.
Location: Gates-Thomas 135

Intended Scope of ME/CS 133(a,b)

ME/CS 132 is a two-quarter introduction to Robotics. The first quarter will be primarily devoted to the study of robot kinematics. We will review basic principles in theoretical kinematics, which is the study of motion (without regard to the forces that generate the motion). We will then apply these priniciples to the analysis of common robotic mechanisms, such as wheeled mobile robots and robot manipulator arms. This year, we will also study the dynamics of quadroter (and multi-rotoro) vehicles, as they will play a role in the experimental part of the course.

The second quarter (ME/CS 132(b)) will first provide a brief overview of robot navigation. We will first review some classical robot motion planning algorithms, which enable an autonomous mobile robot to determine its movements in a cluttered environment so as to achieve motion goals while avoiding collisions. The ability of a robot to plan its motions without explicit human guidance is a basic prerequisite for robotic autonomy. We will then review sensor based robot motion planning algorithms and robot sensing modalities (such as laser range finders, accelerometers and gyroscopes, and RGB-D vision) which are used in sensor-based navigation. Sensor-based motion planning allows a robot to operate in the presence of an a priori unknown or poorly known geometry of the robot's surroundings. The robot's perception system provides the data needed by a sensor-based planning algorithm to execute its plan. The class will then focus on *robotic mapping*

The educational goals of ME/CS 133(a,b) are to:

- Provide a broad overview of basic robotic devices and robot operation.
- Introduce students to the kinematics of robotic mechanisms
- Introduce students to simple quadrotor dynamic models
- Review classical motion planning theory and some of the most widely used classical motion planning algorithms.
- Introduce the basic concepts behind sensor-based motion planning algorithms.
- Introduce students to some of the currently and commonly used software tools in the practice of robotics, such as ROS (the Robot Operating System) and OOMPL (the Object Oriented Motion Planning Library).

- Enable students (via laboratories) to implement basic motion control and sensor- based planning algorithms on a mobile robot.
- Enable interested students to read and understand the robot kinematics and robot motion planning research literature after completing this course.
- Enable students (possibly in teams) to carry out a significant final project in the area of robotic systems.

Course Mechanics and Grading

The course work will consist of both traditional problem sets as well as laboratory exercises where students program both ground and aerial robots. The labs will largely take place in the new Center for Autonomous Systems Technology (CAST). The course-work in the first quarter will consist of 4-5 homeworks, and 3-4 labs. The first labs will be aimed at getting students familiar with the experimental hardware and the operations of CAST. Thereafter, the labs will allow students to implement the theory learned in class, and to experience modern robot software packages, such as ROS.

There is no mid-term exam in this course, and no final exam. Instead, all students must complete a final project (which can be carried out individually, or in small teams). The final project is intended to allow students to demonstrate their knowledge of the course material in a project-based way.

- Homework: 35
- Labs: 30
- Final Exam or Project: 35

The second quarter will have a greater emphasis on labs and the final project. The second quarter will also have a more substantial final project, accounting for a larger percentage of the final grade. This project, which can be tackled in teams, will allow students to integrate material from both quarters.

Course Prerequisites

There are no formal course prerequisites. However, students are assumed to have a working knowledge of linear algebra at the level of eigenvalues and eigenvectors. Some of the homeworks, and all of the labs, will require programming. There is no preferred programming language for the course homework. Mathematica or MATLAB should suffice. For programming the laboratory robots, some amount of knowledge of the C++ language is required.

Course Web Site:

We will use two web sites. The Caltech *moodle* system will be used for turning in homeworks, labs, and final project reports. We will use the following site

$http://robotics.caltech.edu/wiki/index.php/ME\_CS\_133\_2018\text{-}19$

as a repository for the course text book, other reading material, course handouts, homeworks lab assignments, and lab/homework solutions. This site will also contain a syllabus most class handouts (all the ones that are available in electronic form), and links to information that will be useful for final projects. Important annoucements will also be archived on this page. You should visit this site if you miss class.

Course Reference Texts:

The main text for this course is:

- R.M. Murray, Z. Li, and S.S. Sastry, A Mathematical Introduction to Robotics, CRC Press, 1994.
- Web Site: $http://www.cds.caltech.edu/\ murray/mlswiki/index.php/MainPage$

We will refer to this text by the acronym "MLS" (the initials of he authors' last names). This book is freely available on-line at the link given above. This web link is also included in the course web site. Some of you may wish to buy the book (e.g. it's available from Amazon). If you wish to buy a used version of the text, note that there is a second edition with some of the errata from the first edition corrected. Either edition is fine for the course. Course reading material not found in this book will be distributed in class, and copies posted on the course website.