ME/CS 133(b): Robotics

Lecturer: Prof. Joel Burdick, Gates-Thomas 245, x4139, *jwb@robotics.caltech.edu*
T.A.s: Amanda Bouman, Anushri Dixit, Andrew (Drew) 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(b)

ME/CS 133(b) is the second quarter of the two-quarter introduction to *Robotics*. While the first quarter was primarily devoted to the study of *robot kinematics*, this second quarter will focus mainly on *robot navigation*, which includes *robot motion planning*, *robotic perception for navigation*, *localization*, and *map making*.

We will first review *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, which allow a robot to operate in the presence of an a priori unknown or poorly known geometry of the robot's surroundings. This work will motivate the need for robot perception, which provides the data needed by a sensor-based planning algorithm to execute its plan.

We will study a few basic robot sensing modalities, such as laser range finders, accelerometers and gyroscopes, and RGB-D vision. Finally, we will study how robot's use this sensory information to localize their position, and to build maps of their environment.

This course will try to strike a balance between a review of the basic philosophies underpinning motion planning, practical algorithms, and a few theorems/proofs underlying important motion planning results.

In summary, the educational goals of ME/CS 133(b) are to:

- 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.
- Review the basic sensing modalities used by robots for localization and mapping.
- Enable interested students to read and understand the robot motion planning and navigation research literature after completing this course.
- 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, sensor-based planning, localization, and mapping algorithms on a mobile robot.
- Expose students to practical issues involved in implementing robot motion planning

Course Mechanics and Grading

The course work will consist of two traditional problem sets and four 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 first lab will familiarize students with quadrotor robots. The second lab will cover inertial navigation. The third lab will focus on robot sensing with laser range finders and RGB-D cameras. The final lab will involve simple motion planning techniques and SLAM.

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. The final project could build upon material from ME/CS 133(a), or it could frocus on a completely fresh topic. It is intended to be a more in-depth project than the final project option in ME/CS 133(a).

- **Homework:** 20%
- **Labs:** 40%
- **Final Exam or Project:** 40%.

See the course website for the collaboration, extension, and late homework policies.

Course Prerequisites

There are no formal course prerequisites. It is expected that students have successfully completed ME/CS 133(a), or its equivalent. Some of the homeworks, and all of the labs, will require programming. For programming the laboratory robots, a minimal amount of knowledge of C++ or python programming languages is required. Students will extend their knowledge of the ROS programming environment, and learn the OOMPL motion planning tool.

Course Web Site:

We will continue to use the web site for ME/CS 133(a):

http://robotics.caltech.edu/wiki/index.php/ME_CS_133_2018-19

Like ME/CS 133(a), this site will contain copies of homeworks and lab assignments, homework solutions, 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.

<u>Course Reference Texts:</u>
While we will occasionally use some material from the Murray, Li, Sastry text (used in ME/CS 133(a)), much of the course material in the first portion of the course will come from:

- **Planning Algorithms** by *Steve LaValle* (Cambridge Univ. Press, New York, 2006).

This book is strong on classical motion planning theory and algorithms. It also includes excellent reference material on information-space approaches to planning, and evasion-pursuit algorithms. While these subjects are beyond the immediate scope of this class (but some of them will be touched upon in ME/CS/EE 134), they are accessible to interested students. For those of you interested in motion planning, I would recommend buying this book (on Amazon for example) as a reference. Fortunately, the book is available freely on line at: *http://msl.cs.uiuc.edu/planning/*. A link to this text can be found on the course web site.

The following two texts are *optional*

- **Principles of Robot Motion: Theory, Algorithms, and Implementations**, by *Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun*, Bradford Books, MIT Press, 2007.
- **Probabilistic Robotics** (by *Sebastian Thrun, Wolfram Burgard, and Dieter Fox Lynch*, MIT Press, 2005).

The first text is strong on sensor-based motion planning algorithms, while the second text is strong on localization and SLAM (Simultaneous Localization and Motion Planning) theory and algorithms. While ME/CS 133(b) will use concepts from these texts, students can successfully complete all of the course assignments without purchasing them.