ME/CS 132(b): Advanced Robotics: Navigation and Vision (Introduction to Robot Motion Planning & Perception)

Lecturer: Prof. Joel Burdick, Gates-Thomas 245, x4139, *jwb@robotics.caltech.edu*
T.A.s: TBD
T.A. office hours: TBD
Class Meeting Time: To Be Determined (at the Organizational Meeting)
Class Location: Tentatively, Gates-Thomas 115

Intended Scope of ME/CS 132(a,b)

ME/CS 132 is a two-quarter dedicated to *Robot Motion Planning* (or *Navigation*) and *Robotic Perception* (which is often based on *computer vision*). The first quarter of the two-quarter course ME/CS 132 course will focus mainly on the robot motion planning problem. A robot motion planning algorithm enables an autonomous mobile robot to determine its movements in a cluttered environment so as to achieve a variety of goals while avoiding collisions. The ability of a robot to plan its motions without explicit human guidance is a basic prerequisite for robotic autonomy. This course will try to strike a balance between a review of the basic philosophies underpinning motion planning, practical algorithms, and theorems/proofs underlying important motion planning results.

ME/CS 132(a) will first focus on the basic theories underlying *classical* robot motion planning–planning when the geometry of the robot's stationary surroundings is known in advance. Next we will consider *sensor-based motion planning*–planning in the presence of a priori unknown or poorly known geometry of the robot's surroundings. This work will motivate the need for robot perception, which will be addressed at the end of ME/CS 132(a), and in ME/CS 132(b). The robot's perception system provides the data needed by a sensor-based planning algorithm to execute its plan.

The educational goals of ME/CS 132(a) are to:

- introduce basic robotic motion planning problems.
- provide students with a basic review of *classical* motion planning theory and an introduction to the most widely used classical motion planning algorithms.
- introduce sufficient terminology and concepts so that interested students can independently read the robotic motion planning research literature.
- introduce the basic concepts behind *sensor-based motion planning algorithms*.
- enable students (via laboratories) to implement sensor-based planning algorithms on a mobile robot, and expose them to practical issues involved in implementing a motion planner

- have students (possibly in teams) carry out a significant final project in the area of robotic motion planning.

Course Mechanics and Grading

The course-work in the first quarter will consist of 4 homeworks, 1-2 labs (whose goal is to get students familiar with implementing planning algorithms), and a final project or final exam.

- **Homework:** 50%
- **Labs:** 20%
- **Final Project:** 30%.

ME/CS 132(b) will have a much more substantial final project, accounting for at least 50% of the grade. This project, which can be tackled in teams, will allow students to integrate material from both quarters to realize a significant real-world deployment of a planning system.

Course Prerequisites

Traditionally, this course assumes ME 115(a,b) as a background prerequisite. However, since ME 115 is now taught in alternate years, it is not a prerequisite this year. A review of basic rigid body kinematics will be provided as needed. The lectures will also be presented in a style which doesn't require much knowledge from ME 115.

Some of the homeworks, and all of the labs, will require programming. There is no preferred programming language for the course, though Mathematica or MATLAB should suffice for many of the homeworks. For programming the laboratory robots, a minimal amount of knowledge of C or C++ programming languages is required.

Course Web Site: The web site for this course can be found at:

http://robotics.caltech.edu/wiki/index.php/ME_CS_132_2017

This web 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 information about the class, such as changes in due dates, homework errata, etc. can be found in the "Announcements" section. You should visit this site if you miss class.

References

1. The following text will provide the main background for the first half of the course:

- **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, 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/*.

2. The following *optional* text covers some of the same material as the LaValle book, but is strong on sensor-based motion planning algorithms, which is the subject of the second half of ME/CS 132(a).

- **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.

ME/CS 132(b) will likely use **Probabilistic Robotics** (by *Sebastian Thrun, Wolfram Burgard, and Dieter Fox Lynch*, MIT Press, 2005). It may be desirable to acquire this text before the end of the ME/CS 132(a), in preparation for next quarter, and as a possible support for the ME/CS 132(a) final project.

Tentative Syllabus of ME/CS 132(a)

The course lectures and content will roughly follow this tentative outline:

- An overview of robot motion planning problems.
- The configuration space of a rigid body.
- The classical motion planning paradigms: (1) roadmaps; (2) potential fields; (3) cellular decomposition and approximate cellular decomposition.
- Graph search and discrete planning algorithms.
- Sensor-Based Motion Planning Algorithms: (1) the "Bug" algorithms; (2) the TangentBug algorithm; (3) the incremental Voronoi Graph; (4) the D^* algorithm.

The first 4 weeks of ME/CS 132(a) will focus on the *classical motion planning* framework, where the geometry of the environment is a priori known. With this theory in mind, the next 4 weeks of the course will focus on *sensor-based motion planning* problems, where the geometry of the robot's environment is either a priori unknown, or poorly known. The final weeks of the course will begin the transition to the perception portion of the course.