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

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T.A. office hours: TBD
Class Meeting Time: Tentative schedule is Tu/Th 2:30-4:00 p.m.
Class Location: Thomas 206

Intended Scope of ME/CS 132(b)

This second quarter of the two-quarter course ME/CS 132 course will focus on *Robot Motion Planning*. 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(b) 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 ME/CS 132(b) will also introduce students to *sensor-based motion planning*–planning in the presence of a priori unknown or poorly known geometry of the robot's surroundings. This work will complement the brief introduction to SLAM in ME/CS 132(a).

The educational goals of ME/CS 132(b) 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 will consist of 2 homeworks, 1-2 labs (whose goal is to get students familiar with implementing planning algorithms on mobile robots in order to be prepared for the final project), and a final project.

- **Homework:** 20%
- **Labs:** 20%
- **Final Project:** 60%.

Course Prerequisites

Traditionally, this course assumes ME 115(a,b) as a background prerequisite. However, since ME 115 has not been regularly taught in recent 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 most 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:

https://www.cds.caltech.edu/~murray/wiki/index.php/ME/CS_132b,_Spring_2013

This web site will contain copies of homework 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 the final project. 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 the course:

- **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.

The **Probabilistic Robotics** (by *Sebastian Thrun, Wolfram Burgard, and Dieter Fox Lynch*, MIT Press, 2005) used during the first quarter should continue to be a useful reference for this quarter's course, especially for the final project.

4. Interested students may also wish to consult the following classic (but now somewhat dated) text on robotic motion planning:

- **Robot Motion Planning** by *J.C. Latombe*, Kluwer Publishing.

This classic book on robot motion planning is now out of print. It contains good descriptions of some of the foundational motion planning results. A copy is available in the Caltech library, and I have a personal copy that I can loan out for short periods.

Tentative Syllabus of ME/CS 132(b)

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 3 weeks of ME/CS 132 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 2-3 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 be focused on the final project.