ENSC-887: Computational Robotics
2012 (Draft - Jan 5; to be revised further)
Course Description

A main goal of computational robotics is to automatically synthesize robot motions to achieve a given task. This course discusses geometric and algorithmic issues that arise in such an endeavour. Examples of a few sub-problems that need to be addressed are: how can a robot plan its own collision-free motions? How does it grasp a given object? How does one account for uncertainty in sensing and control? The course employs a broad range of tools from basic graph algorithms, computational geometry, mechanics and control theory. The material covered also finds applications in designing devices for automation and in computer animation. The course involves a substantial project which exposes the students to some practical and implementation issues involved in building such automatic motion planning capabilities for robotic systems.

A major emphasis is normally placed on the motion planning problems. The first part of the course will cover fundamental topics and will be lecture oriented. The second part will consist of readings from the research literature and in the final part students will present their projects.

The course involves a substantial project. It is generally an individual undertaking, but small groups may be allowed with prior permission of the instructor. The projects should be chosen and work started on them early (by the end of the first month). There will be considerable flexibility in selecting projects within the broad theme of robotics. Students can also propose their own projects. An in-house developed library, the Motion Planning Kernel, or MPK (written in C++ and runs on Windows) is available for student use. It provides a nice geometric modelling and simulation environment. Students are encouraged to develop their projects within this environment, but it is not mandatory to use it.

Part I: Algorithmic Fundamentals of Robotics

elementary notions from algorithms and geometry: computational complexity, O notation, graph search techniques: A^* etc.; convex hull, intersection detection, algorithms for distance calculations.

elementary notions from basic mathematics: affine space, connectedness, closure, compactness, inner product, distance, etc.

representing rigid bodies, polyhedral models; representing rotations; notion of configuration space; basic kinematics. Representation of orientations, Jacobians.

Part II: Selected Topics in Robot Motion Planning. These will be student led presentations. Each student will present a prescribed paper(s) covering various motion planning algorithms. [1]

gross motion planning: global motion planning, local collision avoidance, planning with non-holonomic constraints, movable objects, planning with moving obstacles etc.

Planning under uncertainty: Navigation and Path Planning with sensing and localization uncertainty.

Mobile Manipulation: Integrating Mobility and Manipulation

Planning with Sensing: incorporating 3D range sensors within Motion Planning

Part III: Projects

In past few years years students have implemented local motion planners, global motion planners, and have presented surveys of research areas such as potential field based approach to motion planning.

Grading

There will be a small number of assignments and one exam. Approximately half of the grade will be based on the term project. You should submit a project proposal and a final project report. The other half will be based on class participation, homework assignments and the final exam.

Assignments: There is a small number of homework assignments.

Participation: Each student (in turn) will either lead discussion(s) or present short, informal lecture(s) on research paper(s) from recent research literature.

Main References

There is no required text for the course. Course handouts and papers will be given. Following texts will serve as our references.

- *Robot Motion Planning* by J.-C. Latombe, Kluwer, 1991. For more than a decade, this was the main reference book in the field. We will certainly be using it. More recently, two more texts (the next two on the list) have appeared on the scene and we will use material from them as well.
- *Planning Algorithms.* Steven Lavalle. Cambridge University Press, 2006. This book has a strong algorithmic focus on motion planning. Available free at http://msl.cs.uiuc.edu/plannin

[1]We may not be able to cover them all; our main emphasis is on gross motion planning.

- *Principles of Robot Motion: Theory, Algorithm and Implementation.* Choset et al. MIT Press, 2005. This book covers both mobile robots and manipulator arms is relatively broad.
- *Introduction to Robotics: Mechanics and Control.* John J. Craig. Addison-Wesley. Second Edition. 1989. This is a basic undergraduate text that covers the mechanics and control of manipulator arms.

Supplementary References

Following books cover some of the basic mathematical and algorithmic background that we will need in this course.

- *Introduction to Algorithms.* Cormen, Leiserson and Rivest. MIT Press.
- *An Introduction to Solid Modelling.* Martti Mantyla. Computer Science Press. 1988
- *Computational Geometry in C.* Joseph O'Rourke. Cambridge University Press. 1994.

Prerequisites

Graduate standing or permission of instructor. An undergraduate level background in linear algebra, geometry or graphics, and data structures and algorithms is helpful. ENSC 488 is a desirable but not required prerequisite.

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I have open office hours. So please feel free to drop by my office if you have any questions. The topics covered in the course are somewhat open-ended, so your learning depends a lot on how much you put into it!