

CS 4803/8803
Robot Intelligence: Planning in Action
TR 1:35-2:55, Bunger-Henry 380
Fall 2009

Instructor: Prof. Mike Stilman mstilman@cc.gatech.edu
Office hours: CCB 254 Thursday 12:00 - 1:00 or by appointment.

Summary:

We discuss algorithms for robots and other complex systems that make intelligent decisions in high dimensional or continuous spaces of options. Intelligent decisions take into account both present and future constraints on the system. The course will cover methods for planning with symbolic, numerical, geometric and physical constraints. Topics will range from classical and stochastic planning to continuous robot domains and hybrid control of dynamic systems.

Requirements:

This course has graduate (8803) and undergraduate (4803) sections. Both sections will participate in three group programming projects related to the three covered aspects of planning. The projects will be graded on algorithm implementation, analysis and results for a total of 60% of the course grade.

Classical Planning	(20%)
Motion Planning	(20%)
Dynamic/Stochastic Planning	(20%)

In order to expose students to research in planning, the course will also have a final project that makes up 40% of the grade. This project will involve the design, implementation and validation of a planning algorithm resulting in a conference-style paper and presentation.

- Robot arm planning and control.
- Planning with abstractions.
- Planning for a novel balancing platform.
- Grasp planning for a robot hand.
- Planning or control projects relevant to ongoing research.

8803 Graduate Projects:

Graduate students will work in groups on a project that is relevant to their research goals. The instructor will provide resources such as robot arm/hand hardware and existing algorithms to support this work. Furthermore, students are welcome to use resources or expand on active projects in their own research labs. Final decisions on topics will be made through discussion with the instructor.

4803 Undergraduate Roles:

Undergraduates will take the role of reviewers for the projects. This will expose them to both the research and peer-review. They will be required to review project proposals, final projects, suggest alternative algorithms and find references that back up their claims. They will be graded based on the thoroughness of their reviews, understanding of the project topics and relevance of located references. Undergraduates are given the option to participate in the projects directly and be graded as graduate students.

Tentative Schedule:

- Aug. 18 – 20 Classical Planning
Predicate Logic, STRIPS, Frame Problem, Causal-link planning
- Aug. 25 – 27 Planning Methods
Plan Graph Search, Planning as Satisfiability, Constraint Satisfaction
- Sept. 1 – 3 Extensions of Classical Planning
Heuristics, Hierarchical Task Networks, Resource Scheduling
- Sept. 8 – 10 Grid Based Planning
Search Tools, Dijkstra, Dynamic Environments, Plan Refinement
- Sept. 22 – 24 Motion Planning for Navigation
Cell Decompositions, Trajectory Generation, Potential Fields
- Sept. 29 - Math Tools for Motion
Review of Kinematics, Collision Detection,
Sampling Strategies, Hierarchical Decompositions
- Oct. 6 – 8 Planning for Robot Arms
Configuration Space, Sampling Based Methods, Probabilistic Roadmaps
Random Trees, Sampling Strategies
- Oct. 13 – 15 Kinodynamic Planning
Planning with Primitives, Planning with controllers
- Oct. 20 – 22 Planning With Uncertainty
Adaptive Planning, Markov Decision Processes, HMMs
- Oct. 27 – 30 Dynamic Domains
More MDPs, Controllers, Attractors, Learning Dynamics
- Nov. 3 – 5 Bridging Planning and Control
Trajectories, Relationships between Dijkstra & LQR

Nov. 10 – 27 Further Topics in Planning
Manipulation, Assembly, Navigation Among Movable Obstacles
(TBD: based on student projects and interests)

Dec. 2 – 4 Final Project Presentations

Prerequisites:

The course has no official prerequisites. We will assume some familiarity with programming, algorithm design, linear algebra, complexity and statistics. However, we will also provide the necessary references for students to gain this familiarity in limited scope as required for understanding course material.

Students who are not sure whether they have the necessary background are encouraged to contact the instructor. In some cases we will recommend some background reading – in others we will advise the student on courses that would prepare them.

Books (Recommended):

"Artificial Intelligence: A New Synthesis," Nilsson
"Artificial Intelligence: A Modern Approach," Russel, Norvig
"Reinforcement Learning" Sutton, Barto
"Principles of Robot Motion", Howie Choset et. al
"Planning Algorithms", Steve LaValle
"Robot Motion Planning", Jean-Claude Latombe

Articles will be posted in accordance with topics (Some Examples):

H. Kautz and B. Selman. *Unifying SAT-based and Graph-based Planning*. IJCAI 1999.

A. Blum and M. Furst, "Fast Planning Through Planning Graph Analysis", *Artificial Intelligence*, 90:281--300 (1997).

H. Kautz and B. Selman. *Unifying SAT-based and Graph-based Planning*. IJCAI 1999.

F. Aurenhammer *Voronoi diagrams: A survey of a fundamental geometric data structure*
ACM Computing Surveys, V.23 N.3, 1991.

S. Koenig, M. Likhachev: D*Lite. AAI/IAAI 2002: 476-483

S. LaValle, J. Kuffner *Randomized Kinodynamic Planning* International Journal of Robotics Research, 20(5):378-400, 2001.

P. Maybeck. "Stochastic Models Estimation and Control V.1" Ch. 1: Introduction

Khatib, O. "Motion/Force Redundancy of Manipulators," Symposium on Flexible Automation

Course Websites:

"Planning and Decision Making", S. LaValle: <http://msl.cs.uiuc.edu/~lavalle/cs497/>

"Robot Motion Planning," S. Akella: <http://www.cs.rpi.edu/~sakella/rmp01/>

"Artificial Intelligence Planning" Blythe, Ambite and Gil:

<http://www.isi.edu/~blythe/cs541/>