CSCI-534: Robot Planning & Manipulation (RPM)

Colorado School of Mines

Spring 2020

This course will introduce planning algorithms in the context of robotics. The first half of the course will cover classical planning using symbolic, heuristic, and constraint-based methods. The second half of the course will cover motion planning with emphasis on sampling-based algorithms.

1 General Course Information

Instructor: Dr. Neil T. Dantam
TA: Matthew Schack

Textbooks

- Steve LaValle. *Planning Algorithms*. http://planning.cs.uiuc.edu/
- Russell and Norvig. *Artificial Intelligence: A Modern Approach*.

Supplemental References

- Kevin M. Lynch and Frank C. Park. *Modern Robotics*. http://hades.mech.northwestern.edu/index.php/Modern_Robotics
- Murray, Li, and Sastry. *A Mathematical Introduction to Robot Manipulation* http://www.cds.caltech.edu/~murray/mlswiki/index.php/Main_Page.

Lisp References

- Peter Siebel. *Practical Common Lisp*. http://www.gigamonkeys.com/book/
- Paul Graham. *ANSI Common Lisp*.
- *Common Lisp HyperSpec*. http://www.lispworks.com/documentation/HyperSpec/Front/
- Paul Graham. *On Lisp*. http://www.paulgraham.com/onlisp.html
- David S. Touretzky. *COMMON LISP: A Gentle Introduction to Symbolic Computation* https://www.cs.cmu.edu/~dst/LispBook/book.pdf

Who should I email/contact?

- **Miscellaneous basic policy questions** (when is the midterm? when is an assignment due?): Re-read the syllabus, check Canvas for announcements and assignments, check the course website, and ask any additional questions on Piazza.
- **Help with assignments or course topics:** Piazza, TA office hours, or instructor office hours. Private post on Piazza if the matter should be hidden from other students (e.g., something about your code or questions about your grade)
- **Solutions to in-class exercises:** Slides with completed exercises will be posted to Canvas after the lecture.
- **Anything sensitive or confidential** (e.g., a health issue) Email the instructor about the issue and/or to schedule a meeting to discuss the issue.

2 Grading and Evaluation

The final course grade will primarily be project-based. Letter grades will be based on a *rough* curve. It is expected (but not required) that course grade distributions will correspond to university and department norms.

Planned Projects Two projects, plus a final project are planned.

Project 0	Warm-up project (symbolic reasoning / differential calculus)
Project 1	Task Planning
Final Project	Applications / Research Project

Class Participation During most lectures, you will have a worksheet to practice the material. After the lecture is complete (i.e., we finish the set of slides corresponding to the worksheet), scan or photograph the worksheet and submit it on Canvas. Your participation grade will be based on making an honest effort on the exercises. You may omit submitting the greater of 2 worksheets or 10% of the total number of worksheets and still receive full credit for participation. Late worksheets will not be accepted.

Course Score The course score (percentage) will be computed as a weighted average of scores (points received over points possible). Assuming two projects plus a final project, the point distribution will be as follows:

Class Participation	6% (p)
Project 0	12% (a)
Project 1	24% (b)
Final Project	48% (f)
Research Paper Presentation	10% (r)

$$\texttt{score} = .06\left(\frac{\texttt{p}_{\text{recv.}}}{\texttt{p}_{\text{poss.}}}\right) + .12\left(\frac{\texttt{a}_{\text{recv.}}}{\texttt{a}_{\text{poss.}}}\right) + .24\left(\frac{\texttt{b}_{\text{recv.}}}{\texttt{b}_{\text{poss.}}}\right) + .48\left(\frac{\texttt{f}_{\text{recv.}}}{\texttt{f}_{\text{poss.}}}\right) + .1\left(\frac{\texttt{r}_{\text{recv.}}}{\texttt{r}_{\text{poss.}}}\right)$$

Fairness It is import to evaluate all students as evenly as possible. We will accommodate disabilities and extenuating circumstances (physical/mental health, school-related travel, and similar) to the greatest possible extent. However, aside from such reasonable accommodations, it would be unfair to offer any special treatment.

Grading Corrections Grading changes will only be made for grading errors. It is not possible to change grades is response to disagreements about point allocation, partial credit, letter grade cutoffs, etc., because such changes would be unfair to the rest of the class. Grading corrections will only be made for the following errors:

1. *Arithmetic:* The grader incorrectly summed your points.
2. *Code:* An error in the grading environment or scripts incorrectly tested your code.
3. *Written:* The grader incorrectly understood your answer.

Projects Expectations and Grading

- Projects will include a coding portion and a report portion.
- Code will be graded objectively. Code must produce the correct output to receive credit. Incorrect output, no output, compilation errors, or runtime errors will not receive credit. **Please double-check your submitted code to ensure that minor errors will not result in major test failures.**
- Code tests will include edge cases. Think through all possible conditions for your program.
- Report grading will evaluate your overall understanding for the project area.

Written Work Format and submit your written work as follows. Improper submission or formatting may result in a penalty on assignments.

- For FERPA compliance, include a cover sheet on all written work that contains only your name and no answers or other work.
- Write your name on *every page* of all written work. If the work cannot be matched to you, you cannot receive credit for it.
- Include page numbers and total page count in written reports to ensure pages are properly ordered and no pages are overlooked.
- Handwritten work must be *clearly legible* to receive credit.
- Submit electronic reports, homeworks, etc. in PDF format. Do not submit word processor files because these are inconsistently formatted by different software.
- Work must be readable when printed in black and white.

3 Laptop and Smartphone Policy

- Lecture slides will typically be posted in advance. You are welcome and encouraged to use your laptop or phone to follow along on the slides.
- Note-taking on laptops, tablets, etc. is welcome if you find it useful.
- Please refrain from using laptops, phones, etc. for non-class activities, e.g., email, web browsing, games, during classtime, as it is distracting to other students.

4 Tentative Schedule

(updated 2020-01-06)

Week	**Date**	**Topic(s)**
Week 1	Jan 7	Introduction
Week 2	Jan 14	Symbolic Reasoning
Week 3	Jan 21	Lisp Introduction
Week 4	Jan 28	Search
Week 5	Feb 4	Informed Search
Week 6	Feb 11	Propositional Calculus
Week 7	Feb 18	Predicate Calculus
Week 8	Feb 25	Situation Calculus
Week 9	Mar 3	SATPlan
Week 10	Mar 10	GraphPlan
Week 11	Mar 17	FastForward Planner
Week 12	Mar 24	(Spring Break)
Week 13	Mar 31	Rotations
Week 14	Apr 7	Configuration Space
Week 15	Apr 14	Sampling-based planning
Week 16	Apr 21	Differential Kinematics
Week 17	Apr 28	Project Presentations
Week 18	May 5	Finals Week

5 CS Department Policies

DEPARTMENT OF COMPUTER SCIENCE

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We follow the Colorado School of Mines Student Honor Code and Policy on Academic Integrity. Work submitted for grading should not be derived from or influenced by work of others. The programming assignments are an integral part of the Computer Science learning experience. These projects will be fun, challenging, illuminating, time consuming, frustrating, and rewarding. Your sense of pride upon finishing is well deserved and your efforts earn your powerful skills and deep understanding. Don't cheat yourself out of this opportunity!

The Honor Code is a powerful community statement that asserts our shared values of integrity. This is a community we are committed to be a part of – please join us! Below are some additional guidelines that apply to CS courses. However, in every course, the instructor has the final say about expectations of academic honesty.

There are various ways to use a resource for assigned work and we distinguish them in two ways:

- **What kind of source is it?** Is it a general resource that you are drawing on to do the assigned work, or is it a solution to the assigned work? Does the resource trivialize the assigned task?
- **How is the source used?** Do you consult the source, or do you copy from it more or less verbatim?

For homework assignments and projects, the following policy is fairly common (but should not be assumed as the default, be sure to consult with your instructor for the course specific policy):

	Resources	Solutions
Consulting	**Cite**	**Not Allowed**
Copying	**Consult with instructor & Cite**	**Not Allowed**

For example, if your assignment is to write a function that implements selection sort:

	Resources	Solutions
Consulting	You discuss selection sort with other students and leave the conversation with "empty hands" – without an artifact of your discussion. You then implement the solution discussed. You add a comment listing the students you consulted with and the content of your discussion. You forget how to swap two variables and the TA reminds you. You add a comment listing the TA's name that assisted you.	You Google "selection sort" and find a pseudocode implementation of selection sort. You model your solution on this implementation. You look at another student's pseudocode or implementation. You model your solution on the other student's solution.
Copying	You forget how to swap two variables. After asking your instructor if online resources are allowable for this task, you look on StackOverflow and reuse code you find there. You add a comment to your code giving a citation and link to the original source.	You Google "selection sort", find an implementation of selection sort, and retype it in your source file. You look at another student's implementation and retype it in your source file.

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Assistance that is allowed for consultation but must be cited
These activities are encouraged and allowed for all students:

- Asking/answering questions about general course topics, programming languages, libraries, and tools.
  - For example: “Does strcmp compare strings case insensitively?”
- Clarifying the assignment specifications.
  - For example: “Do the results have to be sorted?” “What is the expected response if the input is empty?”
- Sharing generic advice and techniques for coding or debugging.
  - For example: “When my program crashes, I first look at the stack trace in the debugger.”

Whereas the general background assistance above is freely allowed, if you receive assistance that is assignment-specific or that influences your submitted work, it must be cited. Some examples:

- Discussing the design of an assignment.
  - Design is a crucial part of the programming process. You should only compare and contrast with a peer after you both have completed your own independently conceived designs. You both must cite this discussion and note any ideas taken away from it.
- Advising another student’s assignment debugging.
  - A student could describe symptoms to a peer who helps analyze the situation and offers recommendations. This collaboration must be cited. Debugging aid should not involve sharing code.

How to make a proper citation
A citation must be specific, complete, and truthful. It should

1. Identify the source (name of person, book title, URL, etc.)
2. Describe the nature and extent of assistance (what information was given/received, how it was communicated)
3. Indicate the influence on your work

A misleading, incomplete, or untruthful citation can be considered an aggravating factor when a case is referred to the Dean of Students. Failing to make a necessary citation can be charged as an Honor Code violation. Some former students have acknowledged they were unsure about the appropriateness of the assistance and chose not to cite to avoid drawing scrutiny. If in doubt, cite. If the assistance you cite was in fact impermissible, your honest representation of it allows us to adjust the potential Honor Code violation.

Assistance that is NOT allowed
These activities are never allowed for any student:

- Submitting or copying solutions from other students.
  - For example (not allowed): When I get stuck on a problem, I ask another student to provide me with their solution as a reference to compare against my solution.
- Sharing your solution with other students.
  - For example (not allowed): I took the class in the Spring and passed my code to another student who will take the class in the Fall.
  - For example (not allowed): I took the class in the Spring and publicly broadcasted the solution on a website.
- Using public resources for assignment-specific code.
  - For example (not allowed): I found code on a website that directly solves a problem in the assignment, and I used the full or partial code in my solution.

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Student Absences All students are advised to be familiar with university policy regarding the make-up of work missed due to excused absences. This policy may be found in the Bulletin.

Disabilities Accommodations The Colorado School of Mines is committed to ensuring the full participation of all students in its programs, including students with disabilities. The website http://disabilities.mines.edu outlines the university's disability services. Any student requiring accommodations must request Student Disability Services deliver each professor a *Confidential Letter of Required Accommodations* to ensure accommodations are met.

Discrimination & Harassment This course and all learning opportunities at Mines require a safe environment for everyone to be productive, develop professional practices, and to be able to share and learn without fear of discrimination or harassment. Discrimination or harassment of any type will not be tolerated. Sometimes harassment is unintentional, but regardless of intent the instructor will address any language or behaviors that might discriminate, stereotype, or promote harassment. If you witness discrimination or harassment of others, please bring it to the attention of Mines faculty so it can be addressed immediately.

Title IX is a federal law that protects individuals from discrimination based on sex and gender in educational programs or activities. Mines takes its Title IX obligations seriously and is committed to providing a campus community free from gender-based discrimination. Gender-based discrimination, including sexual harassment, sexual violence, stalking, and domestic violence, is prohibited within the Mines campus community. If these issues have impacted you or someone you know, you can appropriate resources here: http://inside.mines.edu/POGO-Title-IX. You can also contact the Mines Title IX Coordinator, Karin Ranta-Curran, at 303.384.2558 or krcurran@mines.edu for more information.

Learning Environment Fundamentally, I expect and require respect in this course for yourself, your classmates, and your instructor and TAs.

- Respect for yourself includes taking care of yourself physically and mentally and advocating for an environment that facilitates learning for you.
- Respect for your classmates includes recognizing and appreciating the diversity of backgrounds and experiences of your classmates and making it your interest to foster a learning environment for everyone; all are welcome.
- Respect for your instructors (as well as your classmates) includes not participating in disruptive or distracting behavior: talking, playing games, or web surfing during lecture, for instance, make it difficult for others to focus on the reason we are all here.
- Respect must be mutual to be effective; we (your instructors) and your TAs will be held to the same standards of respect.

Please let your instructor know if you become aware of an issue with the classroom (or out-of-classroom) environment with regards to these policies.