

Syllabus

EN.530.663: Robot Motion Planning

Spring, 2022 (3 credits)

Description

This course provides a graduate-level introduction to robot motion planning. Topics include geometric representation of rigid bodies, configuration space of robots, graph search algorithms, shortest-path motion, and various approaches to motion planning problems (e.g., combinatorial and sampling-based motion planning algorithms, and potential field method). The emphasis is both on mathematical aspects of motion planning (which provides fundamentals in understanding the state-of-the-art planning techniques) and computational implementation of algorithms.

Prerequisites

Recommended course background: multivariable calculus, geometry, linear algebra, differential equations.
Programming: Knowledge of the Matlab programming language.

Instructor

Dr. Jin Seob Kim (email: jkim115@jhu.edu)

- Office: Latrobe Hall 102
- Office hours: Wednesday 10:00-11:00 am and by appointment.
- Zoom link: <https://wse.zoom.us/j/98726986322>
Zoom link is for those who cannot attend the office hours in-person, who should notify to the instructor in prior (same as in the TAs' office hours).

Teaching Assistants

- Mr. Mingxu Liu, mliu90@jhu.edu
 - Office hours: TBD
 - Zoom link: TBA
- Mr. Michael Xu, mxu46@jhu.edu
 - Office hours: TBD

- Zoom Link: TBA

Class Time

- In-person classes
 - Monday, Wednesday, 4:30–5:20 pm, Shaffer 303 ~~Maryland 409~~
 - Friday, 1:30–2:20 pm, Hodson 311
- Lecture recordings will be uploaded on Blackboard (for those who cannot make it to the class due to some reasons, e.g., sickness).

Textbook

Required Text:

- Steven M. LaValle, *Planning Algorithms*. Cambridge University Press, 2006.
Freely available online: <http://planning.cs.uiuc.edu>
errata: <http://planning.cs.uiuc.edu/errata.pdf>

Optional Texts:

- Howie Choset, et al., *Principles of Robot Motion: Theory, Algorithms, and Implementations*. MIT Press, 2005.
- Jean-Claude Latombe, *Robot Motion Planning*. Kluwer, 1991.
- Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*. Cambridge University Press
(preprint version: <http://hades.mech.northwestern.edu/images/7/7f/MR.pdf>).
- G. S. Chirikjian and A. B. Kyatkin, *Harmonic Analysis for Engineers and Applied Scientists*, Dover, 2016.
- R. M. Murray, Z. Li, and S. Shankar Sastry. *A Mathematical Introduction to Robotic Manipulation*. CRC Press, 1994
(Freely available online: <https://www.cds.caltech.edu/murray/books/MLS/pdf/mls94-complete.pdf>)

Online Resources

Please log in to Blackboard for all materials related to this course.

Course Topics

1. Mathematical formulation of motion planning of robots, including geometric representation of rigid bodies, kinematics, configuration space of robots, graph theory, etc.
2. Graph search algorithms.

3. Sampling-based and combinatorial planning algorithms.
4. Potential field method
5. Planning under kinematic constraints; Nonholonomic systems; Density function approach

Tentative Schedule

- *Week 1:* Introduction; Mathematical Preliminaries
- *Week 2:* Discrete Planning (Graph Search Algorithms)
- *Week 3–4:* Geometric Representation
- *Week 4–6:* Configuration Space
- *Week 7–10:* Sampling-Based Planning
- *Week 11–12:* Combinatorial Planning, Potential Field Method
- *Week 12–13:* Systems with Nonholonomic Constraints
- *Week 13–14:* Planning under Kinematic Constraints, Density Function Approach

Course Expectations & Grading

- All email communications should have “[530.663 RMP]” in the subject line.
- Course work includes weekly homework assignments which includes theoretical problems and computational assignments (numerical implementation) using the Matlab (30% of the final grade), a mid-term examination and a final project (35% each of the final grade). Class attendance and active participation is expected.
- *No credit will be given for late homework submission unless previously approved by the instructor.*

Key Dates (tentative)

- Midterm : Week 8 or 9 (we will do the poll in the class)
- Final Project: Given in the last week, and submitted in two weeks.

Ethics

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition. Report any suspected violations to the instructor. You can find more information about university misconduct policies on the web at these sites:

- Undergraduates: <http://e-catalog.jhu.edu/undergrad-students/student-life-policies/>

- Graduate students: <http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/>

In addition, specific ethics guidelines for this course are as follows.

1. Working together on problem sets is encouraged, but it must be acknowledged on your homework problem set. **DO NOT COPY.** Your problem set writeup should directly come from your brain not your friend's papers or anything.
2. Matlab / computational Writeups: Your final writeups for computational problem sets must be done independently without reference to any notes from group sessions, the work of others, or other sources such as the internet. **DO NOT share any source code via email or other sharing means (dropbox, git, thumb drive, etc).** **Doing so is an academic violation for both parties.**
3. While working on your final write-ups for assignments, you may refer to your own class notes, the textbook, internet, etc.
4. Disclosure of Outside Sources: If you use outside sources other than your class notes and your textbook to solve problems especially in the computational homework assignments (i.e. if you have used sources such as your roommate, study partner, the Internet, another textbook, a file from your office-mate's files) then you must disclose the outside source and what you took from the source in your writeup. In other words, disclose your sources properly.
5. *Importantly, the followings are considered ethics violations:*
 - (a) students share their own homework assignments with other students;
 - (b) students uploading or downloading from sites like coursehero, and that ethics violations **WILL** be reported and may result in their termination from JHU.

Personal Wellbeing

- Because of the ongoing COVID-19 pandemic special requirements will be in effect this term, and these may vary during the term. Please keep updated with these at the following sites:
 - University information: <https://covidinfo.jhu.edu/>
 - Whiting School of Engineering information: <https://engineering.jhu.edu/covid-19/>
- As of the start of the term all students, instructors and staff must complete health screening daily using the ProDensity app before coming to campus. **Masks must be worn properly at all times while in the classroom and other indoor spaces.** Vaccination is required unless an exception has been granted by the university for health or religious reasons. Periodic asymptomatic testing may be required. Please follow the university guidance faithfully.
- The Johns Hopkins COVID-19 Call Center (JHCCC), which can be reached at 443-287-8500 seven days a week from 7 a.m. to 7 p.m., supports all JHU students, faculty, and staff experiencing COVID-19 symptoms. Primarily intended for those currently within driving distance of Baltimore, the JHCCC will evaluate your symptoms, order testing if needed, and conduct contact investigation for those affiliates who test positive. More information on the JHCCC and testing is on the [coronavirus information website](#).

- If you are sick please notify me by email so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. The [Student Health and Wellness Center](#) is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action. See also <https://studentaffairs.jhu.edu/student-life/student-outreach-support/absences-from-class/illness-note-policy/>
- All students with disabilities who require accommodations for this course should contact me at their earliest convenience to discuss their specific needs. If you have a documented disability, you must be registered with the JHU Office for Student Disability Services (385 Garland Hall; 410-516-4720; <http://web.jhu.edu/disabilities/>) to receive accommodations.
- Students who are struggling with anxiety, stress, depression or other mental health related concerns, please consider connecting with resources through the JHU Counseling Center. The Counseling Center will be providing services remotely to protect the health of students, staff, and communities. Please reach out to get connected and learn about service options based on where you are living this fall at 410-516-8278 and online at <http://studentaffairs.jhu.edu/counselingcenter/>.
- Student Outreach & Support helps students manage physical and mental health concerns, personal and family emergencies, financial issues, and other obstacles that may arise during their college experience. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please visit this website: <https://studentaffairs.jhu.edu/student-life/student-outreach-support/> or email deanofstudents@jhu.edu, call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and filling out a referral form online.

Classroom Climate

As your instructor, I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade. You may also share concerns with the Mechanical Engineering Department Head (Gretar Tryggvason <mailto:gtryggv1@jhu.edu>), the Director of Undergraduate Studies (Mike Bernard, <mailto:me-academic@jhu.edu>), the Assistant Dean for Diversity and Inclusion (Darlene Saporu, <mailto:dsaporu@jhu.edu>), or the Office of Institutional Equity (<mailto:oie@jhu.edu>). In handling reports, people will protect your privacy as much as possible, but faculty and staff are required to officially report information for some cases (e.g. sexual harassment).

Family Accommodations Policy

You are welcome to bring a family member to class on occasional days when your responsibilities require it (for example, if emergency child care is unavailable, or for health needs of a relative). In fact, you may see my children in class on days when their school is closed. Please be sensitive to the classroom environment, and if your family member becomes uncomfortably disruptive, you may leave the classroom and return as needed.

University Policy on Incompletes

Students who are confronted with compelling circumstances beyond their control which interfere with the ability to complete their semester's work during the normal course of a term may request an incomplete grade from the instructor. This must be requested by the last day of class. Approval of such a request is neither automatic nor guaranteed, but it is expected that faculty will make every effort to accommodate students dealing with illness in the family and other pandemic-related hardships. The instructor and student must establish a timetable for submitting the unfinished work with a final deadline no later than the end of the third week of the subsequent semester. Exceptions to this deadline require a petition from the instructor to the student's academic advising office before this date. When entering an Incomplete grade in SIS, faculty must include a reversion grade which represents the grade the student will receive if they do not complete the missing work by the agreed-upon deadline.

Deadlines for Adding, Dropping and Withdrawing from Courses

Students may add a course up to **February 4, 2022**. They may drop courses up until **March 6, 2022** provided they remain registered for a minimum of 12 credits. Between **March 7, 2022** and **April 15, 2022**, a student may withdraw from a course with a W on their academic record. A record of the course will remain on the academic record with a W appearing in the grade column to indicate that the student registered and then withdrew from the course.

For more information on these and other academic policies, see <https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policies/grading-policies/>