ROB 501: Mathematics for Robotics

Fall 2021

Date: 08/24/2021[1]

Instructor: Prof. Necmiye Ozay, *(she/her/hers)*, necmiye@umich.edu

Graduate Student Instructors: TBD

Grader: TBD

Lectures: MoWe, 9:00am-10:30am, FRB 1060.

Discussion: Mo 6:00pm-7:30pm, FRB 1060. There will be an unofficial discussion on We 6:00pm-7:30pm, FRB 1060, where the same material will be covered. By having to discussion sections we aim to reduce to number of students per section to allow more interaction. Feel free to attend whichever you like.

Attendance: Attendance is not required but you are responsible for the material covered in the lectures and discussion sections . Both the lectures and the discussions will be recorded and the recordings will be made available on Canvas. Lectures will also be broadcasted live.

Office hours: Necmiye Ozay: MoWe, 10:35am-11:30am **on Zoom**, or by appointment; GSIs, TBD.

Prerequisites: Graduate standing or permission of the instructor.

I assume (i) you know basic matrix algebra, such as how to multiply and invert matrices, what is the rank of a matrix, and how to compute eigenvectors; (ii) you have had a course in probability and know how to compute means and variances given a density of a continuous random variable, and you have seen what is a conditional probability and how to compute it; (iii) you took vector calculus and will review how to compute gradients of functions and what is the method of Lagrange multipliers; (iv) simple properties of complex numbers; and (v) you know or will learn on your own how to use MATLAB or similar scientific computing package (plotting, various types of multiplication, writing a for loop, using the help command or searching on the web for commands) .

Brief description:

Applied mathematics for robotics engineers. Topics include proof techniques, vectors spaces, orthogonal bases, projection theorem, least squares, recursive least squares, matrix

[1]This is a tentative syllabus and may be modified slightly.

factorizations, Kalman filter and extensions, underlying probabilistic notions, elementary real analysis in $\mathbb{R}$, convergent sequences, contraction mappings, Newton Raphson algorithm, nonlinear constrained optimization, local vs global convergence, convexity, linear and quadratic programs.

Textbook: There is no textbook for the course. Material will be posted on Canvas.

Grading and evaluation: Class work consists of homework sets, one mid-term exam and one final exam. (no absolute scale of 90-100%=A, etc.)

- 15% Homework (weekly)
- 85% Exams

The idea is that exams are worth lots of points (I grade them!), whereas homework is for practice, clarifying certain principles, etc. I will NOT grade them personally.

Topics (approximate schedule)

- Proof techniques (2 Lectures)
- Abstract linear algebra fundamentals (5 Lectures)
- Least squares problems, projection theorem, and the normal equations (3-4 Lectures)
- Some advanced properties of matrices (2 to 3 Lectures)
- Filtering I: (2 Lectures)
- Review of random variables and joint probability distributions (1 to 2 Lectures)
- Filtering II: Kalman filter and extensions (2 to 3 Lectures)
- Introduction to real analysis in $\mathbb{R}^n$ (4 to 6 Lectures)
- Convex sets and functions (1 Lecture)
- Users tour of optimization (1 to 2 Lectures)

Grading and class policies

Please keep in mind that the **Honor Code** is strictly observed. Midterm exam will be outside of lecture hours. Correspondingly one lecture (date to be determined) will be cancelled based on the instructor's travel schedule.

Homework (15%): Homework sets will be assigned every Monday and due the following Monday (to be uploaded on Canvas). Collaboration on homework sets is encouraged. You may consult outside reference materials, other students, the GSI or the instructor but you cannot consult homework solutions from prior years and you must cite any use of material from outside references and list the students you discussed the solutions with. All solutions that are handed in should reflect your understanding of the subject matter at the time of writing/implementation. Students are allowed two grace periods of two days each that can be used at any time (but no more than one grace period per home- work set). Note that if you submit your homework five minutes after the class, this counts as using one grace period. Late homework beyond the grace period will not be accepted. Instructor feedback/help on a homework set during the grace period will be limited. The two lowest homework scores you receive will be dropped in computing your homework average. If you disagree with your HW score, see the GSIs.

HW Scoring: (Each Problem)

a) three (3) points if the problem is perfectly correct or nearly so. Of course, "nearly so" is a subjective evaluation. I don't consider a numerical mistake to be important if it doesn't change the basic problem nor lead to greatly simplified reasoning. I am always concerned about conceptual errors.

b) two (2) points if there are several minor errors or at least one major error, but it is clear that the person had a good idea of how to work the problem

c) one (1) point if the problem was attempted, but the reasoning is quite wrong, quite incomplete, or if the solution was unreadable (illegible writing, undefined notation, etc.)

d) zero (0) points only if the problem was not attempted.

The total number of points for each HW set will vary from week to week because the number of assigned problems will vary. At the end of the term, when computing HW averages, sum of the individual HW scores will be taken and normalized to a score of 15%.

Midterm and final exams (85%): There will be one midterm exam and one final exam. Your lower exam score will account for 40% of your grade and your higher exam score will account for 45%. Approximate dates are as follows:

- Midterm: sometime in 28-30 October, 2021.
- Final: date determined by the registrar's office.

DEI Statement

U-M is committed to a policy of equal opportunity for all persons, and it does not discriminate on the basis of race, color, national origin, age, marital status, sex, sexual orientation, gender identity, gender expression, disability, religion, height, weight, or veteran status.

In this class, I aim to treat everyone with fairness and respect, and I expect you to do the same. I aim to create an environment where we can learn together, freely ask questions, and help each other achieve better, while following the Engineering Honor Code. Please feel free to contact me with any problem, concern, or suggestion.

Mental Health Resources

Given the ongoing pandemic, it is critical to care for your emotional and mental well-being. Resources and support are available for students through the https://care.engin.umich.edu/, https://deanofstudents.umich.edu/ or https://caps.umich.edu/. The University also offers https://umich.silvercloudhealth.com/signup/, an online mental health tool that offers self-guided programs for anxiety, depression, stress, resilience, or insomnia.

COVID Statement

As they have throughout the past year and a half, policies around academic and public health are subject to change as this pandemic evolves. This course will follow all policies issued by the University, which are documented on the Campus Blueprint's FAQ. These policies may change over the course of the term, so please review the Campus Blueprint's FAQ for the most up to date information.

At the time this document is prepared, you are required to wear a mask while in class. You should also refrain from eating or drinking in class as it is not possible with a mask. Since we will make all the lecture material online, please attend remotely if you are feeling sick.