ROB310 Mathematics for Robotics

Syllabus and Course Information, Fall 2018

Objective

The course addresses advanced mathematical concepts that are particularly relevant for robotics. Topics include optimization, probability theory, complex analysis, advanced linear algebra, and numerical methods. Concepts will be studied in a mathematically rigorous way but will be motivated by robotics examples.

The objective of this course is to provide a solid foundation of the mathematical methods used in subsequent robotics courses (for example, Control Systems, Mobile Robotics and Perception, Computer Vision, and Machine Learning). The mathematical tools covered in this course are fundamental for understanding, analyzing and designing robotics algorithms that solve tasks such as robot path planning, robot vision, robot control, and robot learning.

Instructor

– Prof. Angela Schoellig, University of Toronto Institute for Aerospace Studies (UTIAS), e-mail: schoellig@utias.utoronto.ca, phone: 416-667-7518, web: `https://schoellig.name`

Teaching Assistant

– Alan Li, e-mail: alanli.li@mail.utoronto.ca

Schedule

– Lecture: Mon 9h00–11h00, BA1200; Wed 10h00–12h00, BA1210.

– Office hours: after class on Wednesdays 12h00–13h00 (please come to Prof. Schoellig right after class) and by appointment (please send an e-mail to Prof. Schoellig); additional office hours will be offered before the midterm and final exam.

Website

We will use Quercus for course administration: `https://q.utoronto.ca`.

Reference Material

Since we cover a wide range of mathematical topics tailored to robotics, reference material will be provided for each topic separately. A list of references, including a table pointing to the relevant chapters for each lecture, is provided in a separate handout. A good reference book that provides a broad overview over advanced mathematical methods and can also be used to refresh important prerequisites (such as linear algebra) is: *Advanced Engineering Mathematics (**Tenth** Edition)* by Erwin Kreyszig, Wiley, 2011.

Hand-written class notes will be made available on Quercus; notes will typically be available for download shortly before the lecture.

Matlab/Simulink will be used for some of the exercises. The software is available to students for free at: `http://sites.utoronto.ca/ic/software/detail/matlabStudent.html`.

Course Topics and Syllabus

A rough outline of the topics covered in class is provided below. Each topic will include robotics examples that show how the learned content is applied in robotics.

Week	Dates	Topic	Problem Set
1	Sep 10, 12	**Introduction and Motivation, System Models**	
2	Sep 17, 19	**Numeric Methods**	#1 due Sep 27
3	Sep 24, 26	**Numerics for Ordinary Differential Equations (ODEs)**	#2 due Oct 4
4	Oct 1, 3	**ODEs in Practice, Introduction to Optimization**	#3 due Oct 11
5	Oct 8, 10	➢ *Thanksgiving Day on Oct 8* **Unconstrained Optimization**	#4 due Oct 23
6	Oct 15, 17	**Unconstrained and Constrained Optimization Problems**	#5 due Oct 28
7	Oct 22, 24	**Convex Optimization, Advanced Linear Algebra**	#6 due Nov 15
8	Oct 29, 31	➢ *Review Session on Oct 29* ➢ *Midterm Exam on Oct 31 during regular class hours, covers Weeks 1–7, takes place in EX320*	
9	Nov 5, 7	**Singular Value Decomposition**	#7 due Nov 22
10	Nov 12, 14	**Probability Theory Review, Bayes' Theorem**	#8 due Nov 29
11	Nov 19, 21	**Bayesian Tracking**	#9 due Dec 5
12	Nov 26, 28	**Extracting Estimates from Probability Distributions, Gaussian Probability Density Functions**	#10 due Dec 5
13	Dec 3, 5	**Complex Numbers and Functions** ➢ *Review Session on Dec 5*	

Problem Sets

Problem sets will be handed out at the beginning of each section and are due about 1.5 weeks later. Problem sets must be submitted online at `https://gradescope.com` by 23h59 of the due date. Mobile apps such as *CamScanner* are recommended to scan handwritten solutions for the purpose of uploading. For late submissions, 25% of the points will be deducted each day of late submission.

Students must hand in their own solution but are encouraged to discuss the problems with their peers. Questions can also be asked in the office hours.

Grading

Grades will be assigned according to the following scheme:

- Problem Sets, 20%
- Midterm Exam, 30%
- Final Exam, 50%

Allowed aid for the midterm exam is a single sheet of paper (letter size). Students may enter on both sides of the aid sheet any information they desire, without restriction, except that nothing may be affixed or appended to it. Allowed aid for the final exam are two (2) single sheets of paper (letter size) and a non-programmable calculator.

"Education is not the filling of a pail, but the lighting of a fire."
– Plutarch