ME224 – Computational Methods for Robotics (4 units)

Lectures: Tu/Th 12:00-1:20
Online via Zoom
Lab: Tu/Th 1:30-2:50
Online via Zoom

Description: Lecture: 3 hours. Laboratory: 3 hours. This is an introductory course providing the students with the mathematical and computational tools used in diverse areas of robotics. Topics include introductions to linear algebra, numerical root finding, convex optimization, and nonlinear programming.

Instructor: Erfan Nozari

Textbook: In addition to provided lecture notes and slides, the following references will be useful during the course:

1. **T1:** Mark W. Spong et al, "Robot Modeling and Control", 2nd Ed.
2. **T2:** C. T. Chen, "Linear System Theory and Design", 3rd Ed.
3. **T3:** Gilbert Strang, "Introduction to Linear Algebra", 5th Ed.
4. **T4:** Timmy Siauw et al, "An Introduction to MATLAB® Programming and Numerical Methods for Engineers"
5. **T5:** Stephen Boyd et al, "Convex Optimization"
6. **T6:** Dimitri P. Bertsekas, "Nonlinear programming", 3rd Ed.

Course objectives: The overall objective of this course is to provide the students with the necessary mathematical knowledge and computational tools to understand and solve various problems in robotics. This class is foundational for any student interested in taking interdisciplinary classes in the areas of controls and dynamical systems, robotics, machine learning, and signal processing. The course content will be motivated by examples from robotics but the focus is on the mathematical concepts.

The specific learning objectives for the student are to:

- understand some of the mathematical and computational foundations of robotics;
- become familiar with numerical methods for matrix manipulation and analysis;
- understand the fundamentals of numerical methods for solving nonlinear systems of equations;
- understand optimization algorithms, their properties, and common solution algorithms;
- be able to use common computational tools and computing languages, particularly MATLAB;
- be able to implement numerical algorithms for data analysis, matrix analysis, and optimization algorithms using MATLAB.

Evaluation method:

1. Homeworks: 20%
2. Midterm: 30/40%
3. Final: 50/40%

Tentative Schedule

Week	Topic	Robotic Context	Math Ref.	Robotic Ref.
1	Vectors and Matrices	Positions and Rotations	T2 Ch. 3 / T3 Ch. 1	T1 Ch. 2
2	Vector Spaces	Coordinate Frames	T2 Ch. 3 / T3 Ch. 3	T1 Ch. 2
3	Change of Basis	Change of Coordinates	T2 Ch. 3 / T3 Ch. 6	T1 Ch. 2
4	Systems of Linear Equations	Inverse Velocity Kinematics	T2 Ch. 3 / T3 Ch. 2	T1 Ch. 3 & 4
5	Matrix Decompositions	Kinematics	T2 Ch. 3 / T3 Ch. 7	T1 Ch. 4
6	Symmetric Matrices, Midterm	Manipulability	T2 Ch. 3 / T3 Ch. 6	T1 Ch. 4
7	Numerical Root Finding	Inverse Kinematics	T4 Ch. 16	T1 Ch. 5
8	Numerical Integration, Least Squares	Robot Dynamics	T4 Ch. 18 & 13	T1 Ch. 6
9	Convex Optimization	Path Planning	T5 Ch. 2-5	T1 Ch. 7
10	Nonlinear Programming	Path Planning	T6 Ch. 1, 2, 5	T1 Ch. 7