EE/ME 4290/5290 Mechanics & Control of Robotic Manipulators

Course Objectives

Dr. Bob Williams

The objectives of this course are to introduce the student to the modeling, simulation, and control of spatial multi-degree-of-freedom robotic manipulators. In particular we will study the kinematics and dynamics of robotic manipulators. Laboratory exercises will be performed to get an appreciation for the practical side of robotics. A side-objective is to use of MATLAB as a tool in robot system analysis and simulation. This course provides practice in technical writing (via weekly mini-project memos) and practice in technical presentation (one interesting topic in robotics presented orally to the class). Specific topics include:

1. Students will be able to calculate the mobility (number of degrees-of-freedom) of planar and spatial structures, mechanisms, and serial and parallel robots.

2. Students will be able to use the mathematical basis of motion description, including rotation matrices.

3. Students will be able to derive the standard Denavit-Hartenberg parameters for planar and spatial serial robot chains.

4. Students will be able to derive and calculate the forward pose kinematics solution for serial robots.

5. Students will be able to derive and calculate the inverse pose kinematics solution for serial robots.

6. Students will be able to derive and calculate forward and inverse velocity kinematics for serial robots, including Jacobians, static forces/torques, singularities, and simulation of resolved rate control.

7. Students will be able to derive and calculate joint-space trajectory generation polynomials.

8. Students will be able to perform kinematic calculations for example kinematically-redundant serial robots, including simulation of resolved rate control.

9. Students will be able to perform kinematic calculations for example parallel robots.

MATLAB software is required. I am available to help with that during office hours or by appointment. For an extensive introduction to the MATLAB software, please see Dr. Bob's MATLAB Primer (link given later in this document).

EE/ME 4290/5290 Mechanics & Control of Robotic Manipulators

Syllabus and Policy

Dr. Bob, 262 Stocker, 3-1096 williar4@ohio.edu ohio.edu/mechanical-faculty/williams	Fall 2023 Class # 5199 (EE 4290) Class # 5392 (ME 4290) Class # 5200 (EE 5290) Class # 5393 (ME 5290)

Time & Venue

10:45 – 11:40 a.m. M W F 3 credit hours ARC 101

Prerequisites

senior OR graduate student

Description

Classification and applications for mechanical manipulator systems. Manipulator motion description, forward kinematics transformations, and solution of inverse kinematics equations. Velocity kinematics and manipulator dynamics equations. Trajectory generation and control schemes including sensory feedback. Laboratory exercises to augment lecture material.

Office Hours

12:00 – 1:30 p.m. M W and by appointment

Required NotesBook

Robot Mechanics, Dr. Bob Productions, ©2024

Robot Mechanics (lulu.com)

I would NOT use all your Stocker prints for a hardcopy of this required NotesBook.
You must first purchase from lulu.com before making a hardcopy locally.

Required Textbook **none**

EE/ME 4290/5290 Course Website

www.ohio.edu/mechanical-faculty/williams/html/Courses.html

EE/ME 4290/5290 NotesBook Supplement

www.ohio.edu/mechanical-faculty/williams/html/PDF/Supplement4290.pdf

Dr. Bob's MATLAB Primer and Matrices Review

www.ohio.edu/mechanical-faculty/williams/html/PDF/MATLABPrimer.pdf
www.ohio.edu/mechanical-faculty/williams/html/PDF/MatricesLinearAlgebra.pdf

Dr. Bob's Introduction to Robotics

www.ohio.edu/mechanical-faculty/williams/html/PDF/IntroRob.pdf

Robot Animations developed at Ohio University

www.ohio.edu/mechanical-faculty/williams/html/RobotAnimations.html

Mini-Projects

- Seven **mini-projects** must be submitted via hardcopy at the start of class as shown in the schedule on the following two pages. A **Memo** (see sample memo) summarizing the work must be the first page of each mini-project submission. ***NO LATE ASSIGNMENTS WILL BE ACCEPTED!! SOLO WORK ONLY!*** MATLAB use is required. Reports must be complete yet brief. All mini-projects MPi are equally-weighted and worth **20 points each**.

- Six **laboratory exercises** must be submitted via hardcopy at the start of class as shown in the schedule on the following two pages. The laboratory exercises are assigned here: www.ohio.edu/mechanical-faculty/williams/html/PDF/Labs4290.pdf. All laboratory exercises LMPj are equally-weighted and are worth **10 points each** (except for LMP5, which is worth **5 points**). Please choose one partner for the lab assignments all semester, and turn in one report with both names each time.

- Each individual must present a robotics-related video in class (as scheduled on the following pages) and turn in a detailed report on it the same day, worth **5 points** as LMP5.

- Also, each lab team must give an **oral presentation** on an interesting, current topic in robotics worth **10 points** as LMP6. This must be based on a journal article as assigned here: www.ohio.edu/mechanical-faculty/williams/html/PDF/ResPapePres4290.pdf. Your journal article must be approved by Dr. Bob and presented to the class. No journal articles by me or any OU author are allowed.

Graduate Students

As required by Ohio University, graduate students must complete extra work in a dual-listed course. 1. An additional journal paper presentation worth one mini-project (see above) is required; individual-only. 2. A semester-long project assignment worth four mini-projects must be completed by each individual graduate student as assigned here: www.ohio.edu/mechanical-faculty/williams/html/PDF/GradProj5290.pdf. You must define your own project (from your research if possible) and have it approved by Dr. Bob. Graduate students will be evaluated based on 4.5 additional 20-point mini-project scores (80 points for the project and an additional 10-point journal article presentation).

Memos

The first page of all written assignments in this class must be a one-page **memo** giving the highlights, methods, bottom line results, and a short discussion. You should refer to ensuing sections of your report. Assume that I am your boss and you are communicating the results of your recent work to me through this memo. Your mini-project will not be graded without this memo!

Attendance

Full attendance is required. Class participation is expected. No assignment can be made up without a valid written OU excuse. Poor attendance ***will*** affect your grade.

Grading

The weighting for all regular and laboratory mini-projects was stated previously. Based on the following percentages, the following final grades will be assigned:

93.3-100	90-93.3	86.7-90	83.3-86.7	80-83.3	76.7-80	73.3-76.7	70-73.3	66.7-70	63.3-66.7	60-63.3	< 60
A	A–	B+	B	B–	C+	C	C–	D+	D	D–	F

EE/ME 4290/5290 Fall Semester 2023 Schedule

Week	Date	Day	Topic	Notes	MP	Lab
1	28-Aug	Mon	Syllabus and videos, intro	Internet		
		Wed	Introduction to robotics	Internet		
		Fri	Mobility and matrices	1.3-4		
2	4-Sep	Mon	Labour Day Holiday			
		Wed	Vectors, spherical/Cartesian transform	1.5		
		Fri	P-R-T, Rotation matrices steps 1-5	2, 2.1.1		
3	11-Sep	Mon	Rotation matrices steps 6-12	2.1.1		
		Wed	Quaternions	2.1.2		LMP1
		Fri	Homo trans matrices, interps 1 and 2	2.2.1		
4	18-Sep	Mon	Homo trans review, 3rd interp, inv homo	2.2.1		
		Wed	Transform equations & transform graphs	2.2.2		
		Fri	DH parameters; grad proj Signup	3		
5	25-Sep	Mon	DH parameters examples	3	MP1	
		Wed	DH Parameters active learning day			LMP2
		Fri	Neighboring T derivation, screw pairs	4.1		
6	2-Oct	Mon	Forward Pose Kinematics (FPK)	4.2	MP2	
		Wed	FPK examples	4.3		
		Fri	Inverse Pose Kinematics (IPK) intro	5.1		
7	9-Oct	Mon	IPK planar 3R analytical	5.2	MP3	
		Wed	IPK graphical, model, trajectory, MATLAB	5.2		LMP3
		Fri	Wellness Day Holiday			
8	16-Oct	Mon	Trajectory generation - 3rd	6.1	MP4	
		Wed	Trajectory generation - 5th and 2-3rd via	6.2-3		
		Fri	Traj gen - 6th via, control architecture	6.5		

EE/ME 4290/5290 Fall Semester 2023 Schedule (continued)

Week	Date	Day	Topic	Notes	MP	Lab
9	23-Oct	Mon	Grad journal article presentations		MP5	
		Wed	Grad interim project presentations & report			
		Fri	Velocity kinematics intro	7.1		
10	30-Oct	Mon	Velocity deriv, Jacobians, Forward solution	7.2-4		
		Wed	Resolved rate control algorithm	7.5		
		Fri	Sing, static torques, Resolved rate MATLAB	7.6-7		
11	6-Nov	Mon	Kinematically-redundant robots intro	8.1	MP6	
		Wed	KRR particular and homogeneous solns	8.2		LMP4
		Fri	Veteran's Day Holiday			
12	13-Nov	Mon	KRR examples and resolved-rate MATLAB	8.3		
		Wed	Term Project Day	8.3		
		Fri	Introduction to Parallel Robots	9.1		
13	20-Nov	Mon	Thanksgiving Holiday			
		Wed				
		Fri				
14	27-Nov	Mon	Planar 5-bar RRRRR parallel robot FPK/IPK	9.2	MP7	
		Wed	Intersection of 2 circles	9.3		
		Fri	Student Robotics Video Day	YouTube		LMP5
15	4-Dec	Mon	Journal article presentations			
		Wed	Journal article presentations			LMP6
		Fri	Grad final project presentations & report			

OHIO UNIVERSITY

Russ College of Engineering & Technology
Department of Mechanical Engineering

DATE: August 31, 2023

TO: Dr. Bob

FROM: Robo Haptics

SUBJECT: ME 4290 Mini-Project #1 Results

Dr. Williams,

The purpose of this memo is to present the basic results for Mini-Project #1. The assignment was (*briefly summarize here*).

Some sample results are given here: (*give results; not always appropriate or possible here*). My sketches and equation derivations appear on p. 2 (*if appropriate*). For a complete set of results, please see pp. 3-7. The discussion follows on page 8. I obtained the answers using MATLAB file **bob.m**, which appears on p. 9. Sample calculations are presented on p. 10 to demonstrate that the computer code generates the correct results.

(*Summary of roadblocks, issues, or learning here, if appropriate*).

If you have any questions on my work, please contact me.

Sincerely,

Robo Haptics
almosttotallyunintelligibleusername@ohio.edu