ECE470 Robot Modeling and Control

(Last updated: January 7, 2020)

Course Description

Classification of robot manipulators, kinematic modeling, forward and inverse kinematics, velocity kinematics, path planning, point-to-point trajectory planning, dynamic modeling, Euler-Lagrange equations, inverse dynamics, joint control, computed torque control, passivity-based control, feedback linearization.

Prerequisite: ECE311H1 or ECE356H1
Exclusion: AER525H1

Learning Objective

To model, to perform motion planning, and to control a robotic manipulator.

Teaching Staff

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Lecture Schedule

Section	Day and Time	Location	Dates
LEC 01	Tue 12-13	MS2172	Starts January 7
	Thu 12-13	MS2172	
	Fri 12-13	MS2172	

Tutorial Schedule

Section	TA	Day and Time	Location	Tutorial Dates
TUT 01	Tian Xia	Fri 16-18	BA2185	Jan 24, Feb 7, Feb 28, Mar 13, Mar 27, To reschedule
TUT 02	Tian Xia	Tue 16-18	BA2185	Jan 17, Jan 31, Feb 14, Mar 6, Mar 20, Apr 3

Textbook

- Spong, Hutchinson, Vidyasagar. **Robot Modeling and Control** . Wiley, 2006.

Course Outline

The following table shows the lecture topics. Note that the lecture schedule may be updated as the semester progresses, so it's a good idea to check the file periodically.

Week	Date	Lecture	Topics (scheduled)	Topics (actual)
1	Jan 7	1	Introduction	
	Jan 9	2	Common kinematic configurations	
	Jan 10	3	Rigid motions; Points and vectors; Rotations	
2	Jan 14	4	Rotation matrices; Elementary rotations; Rotational transformations	
	Jan 16	5	Composition of rotations	
	Jan 17	6	Euler angles; Rigid motions	
3	Jan 21	7	Change of coordinates; Composition of rigid motions; Homogeneous transformations	
	Jan 23	8	Elementary homogeneous transformations; Forward kinematics; DH convention	
	Jan 24	9	DH convention exceptions; Examples	
4	Jan 28	10	DH table to homogeneous transformation matrices; Inverse kinematics problem	
	Jan 30	11	Inverse kinematics problem	

	Jan 31	12	Inverse orientation problem; Velocity kinematics	
5	Feb 4	13	Angular velocity	
	Feb 6	14	Instantaneous axis of rotation; Linear velocity; Addition of angular velocities	
	Feb 7	15	Robot Jacobian	
6	Feb 11	16	Inverse velocity kinematics	
	Feb 13	17	Inverse velocity kinematics; End effector forces and torques	
	Feb 14	18	Kinematic singularities	
7	Feb 18		Reading Week	
	Feb 20		Reading Week	
	Feb 21		Reading Week	
8	Feb 25	19	Motion planning; Artificial potential approach	
	Feb 27	20	Attractive potential design; Repulsive potential	
	Feb 28	21	Repulsive potential; Gradient descent	
9	March 3	22	Spline interpolation	
	March 5	23	Decentralized control of robots	

	March 6	24	Robot modeling: mass particle example	
10	March 10	25	Robot modeling; holonomic constraints; Generalized coordinates	
	March 12	26	Virtual displacements; Lagrange D'Alembert principle; Euler-Lagrange equations	
	March 13	27	Euler Lagrange equation; Kinetic energy of a rigid body	
11	March 17	28	Kinetic energy of a rigid body	
	March 19	29	Derivation of robot Lagrangian	
	March 20	30	Equations of motion of a robot; Pendulum on a cart example	
12	March 24	31	Pendulum on a cart example; Double pendulum	
	March 26	32	Double pendulum; Centralized Robot control; Feedback linearization	
	March 27	33	Feedback linearization; Equilibria and stability; Lyapunov's stability theorem	
13	March 31	34	LaSalle's invariance principle	
	April 2	35	PD control with gravity compensation	

	April 3	36	Passivity; passivity-based control	
14	April 7	37	Passivity-based controllers; Adaptive control	
	April 9	38	Adaptive passivity-based control and computer demo	

Homework

Homework problems are turned in online on the dates below. Homeworks are graded based on (seriously) attempted problems, not correctness. Homeworks that are clearly written and complete are given a mark of 1. Poorly written or incomplete or late submission homeworks are given a mark of 0.

Homework	Chapter	Problems	Due Date
1	Chapter 2	1, 2, 10, 11, 12, 13, 15, 23, 37, 38, 39, 41	Feb. 6
2	Chapter 3	2, 3, 4, 5, 6, 7, 13	Feb. 25
3	Chapter 3	15, 18; Chapter 4: 13 (swap phi and psi in problem statement), 15, 18, 20	March 25
4	Chapter 7	7, 8 (use Euler-Lagrange Method), 12, 13	April 8

Laboratories

Labs take place in BA3114 and are performed in groups of two or three students. Lab groups are formed in the first lab. There are no make-up labs. You may not switch lab sections. Lab 0 is an

introduction to the KUKA robots and has no preparation or report. For Labs 1-4, each group submits a preparation at the beginning of the lab. One week after the lab, each lab group submits a lab report.

Section	Day and Time	Lab 0	Lab 1	Lab 2	Lab 3	Lab 4
PRA 01	Mon 15-18	Feb 3	Feb 24	Mar 9	Mar 23	Apr 6
PRA 02	Mon 15-18	Jan 27	Feb 10	Mar 2	Mar 16	Mar 30
PRA 03	Mon 9-12	Feb 3	Feb 24	Mar 9	Mar 23	Apr 6
PRA 04	Mon 9-12	Jan 27	Feb 10	Mar 2	Mar 16	Mar 30
PRA 05	Wed 15-18	Feb 5	Feb 26	Mar 11	Mar 25	Apr 8
PRA 06	Wed 15-18	Jan 29	Feb 12	Mar 4	Mar 18	Apr 1

Grading

Labs	20%	Includes preparation, lab work, and report
Homework	5%	
Midterm	25%	Thursday, March 5, 6-8pm
Final Exam	50%	TBA
