Lahore University of Management Sciences
EE562 / CS5610 – Robot Motion Planning
Fall 2023

Instructors	Dr. Abubakr Muhammad
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Course URL (if any)	

Course Basics				
Credit Hours	3	Tue,Thurs: 2.00pm-3.15pm		
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	1hr-15min each
Labs (per week)	Nbr of Lec(s) Per Week	0	Duration	
Recitation (per week)	Nbr of Lec(s) Per Week	0	Duration	

Course Distribution	
Core	
Elective	Electrical Engineering, Computer Science
Open for Student Category	EE /CS (Juniors, Seniors), EE/CS (Grad)
Close for Student Category	

COURSE DESCRIPTION

Motion planning is the study of models and algorithms that reason about the movement of physical bodies such as humans, robots, and animals. This course focuses on motion planning for industrial manipulators and autonomous mobile robots such as unmanned aerial and ground vehicles. Topics include kinematic representations of movement, potential functions, sampling based probabilistic planners, robot dynamics, multivariable feedback control and learning-based control strategies. Students will implement motion planning algorithms in simulation environments, read recent literature in the field and complete a project that draws on the course material. The course bridges the theoretical gap between low-level regulatory control and higher-level AI in robotics.

COURSE PREREQUISITE(S)

EE-361.Feedback Control Systems OR CS-331 Introduction to Artificial Intelligence.
Course requires mathematical maturity and the ability to program fluently.

Grading Breakup and Policy

Home Works (best 4 of 5 x 3%) : 12%
Quizes (best 3 of 4) : 6%
Midterm Examination: 25%
Final Examination: 30 %
Course Project: 22 %

- Proposal. 2%
- Presentation. 10%
- Paper. 12%

Class Participation : 5%

Examination Detail

Midterm Exams	Duration: 2 hrs Exam Specifications: Open book, open notes, and calculators allowed
Final Exam	Duration: 3 hrs Exam Specifications: Open book, open notes, and calculators allowed

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Course Learning Outcomes	
EE562- CLO1: CLO2: CLO3:	Analyze the motion of robotic mechanisms and mechanical linkages such as manipulators and vehicles using mathematical models Classify the capabilities of robot systems from the point of view of kinematics and dynamics Understand the role of sensors, actuators, computation and control in building an autonomous robot

Relation to EE Program Outcomes

EE-361 CLOs	Related PLOs	Levels of Learning	Teaching Methods	CLO Attainment checked in
CLO1	PLO2-Problem Analysis	Cog-5	Instruction, Tutorial, Assignments	Midterm , Final
CLO2	PLO2-Problem Analysis	Cog-5	Instruction, Tutorial, Assignments	Midterm, Final
CLO3	PLO1-Engineering knowledge	Cog-5	Instruction, Tutorial, Assignments	Midterm, Final

COURSE OVERVIEW

Week	Modules	Topics	Recommended Readings	
1	1 Lecture **Introduction**	Overview of robotics; motion planning setup; joints; manipulator types; vehicles;	Sprong Ch1;	
1-2	3 Lectures **Rigid Body Motion**	Matrix algebra; rotation matrices; compositions; parameterization	Spong Ch2; Corke 2,3	HW 1 due Field Visit (Agricultural Robotics Facility)
3-4	3 Lectures **Forward & Inverse Kinematics**	Kinematic chains; DH-convention; inverse kinematics; examples;	Spong Ch3 Corke 7,8	Quiz 1
5-6	4 Lectures **Velocity Kinematics**	Skew-symmetric matrices; matrix Jacobian; singularities; inverse velocity kinematics; manipulability;	Spong Ch4; Corke 7,8	HW 2 due Visit (Industrial Robotics Research Labs, UET Lahore)
7	2 Lectures **Path & Trajectory Planning**	Trajectory smoothing; potential fields; navigation functions;	Spong Ch5; Choset Ch4	Quiz 2
Midterm				
8-9	2 Lectures **Sampling-Based Planning**	Config Spaces; Probabilistic roadmaps; analysis of PRM; RRT and other variants;	Choset Ch7	HW 3 due International guest speaker (Medical Robotics)
9-11	4 Lectures **Robot Dynamics**	Euler-Lagrange equations; holonomic and non-holonomic constraints; manipulator dynamics;	Spong Ch7; Choset 10; Corke 9;	Quiz 3
12	2 Lectures **Visual Servoing**	Camera motion models; feature interaction matrix; visual feedback;	Spong 11,12; Corke 15, 16	HW 4 due Visit to Local Robotics Industry (Employment and Entrepruenal Opportunities)

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13-14	4 Lectures **Multi-variable robot control**	Independent joint control; inverse dynamics; feedback linearization; passivity;	Spong 8;	Quiz 4
15	2 Lectures **Learning for model-free controllers**	Policy iteration, value iteration, Reinforcement learning, Iterated learning	Notes, papers	HW 5 due Project presentations Guest Speaker (Research Frontiers)

Textbook(s)/Supplementary Readings

Primary Text

- Spong, Mark W., Seth Hutchinson, and M. Vidyasagar. "Robot Modeling and Control." Wiley, 2006.

Secondary Texts

- Choset et al. , “Principles of Robot Motion”. Prentice-Hall, 2005. [available as low-priced edition]
- Steve Lavalle, “Planning Algorithms”, Cambridge University Press, 2006. [available as a free legal download]
- Peter Corke, “Robotics, Vision and Control”, Springer, 2013.

Prepared by:	**Abubakr Muhammad, Aug 1, 2023**