School of Engineering and Natural Sciences / Computer Engineering (English)

2023 - 2024 Academic Year

ADVANCED ROBOTICS

Syllabus

Course Description					
Name	**Code**	**Semester**	**T+A Hour**	**Credit**	**ECTS**
ADVANCED ROBOTICS	COE3215372	Spring Semester	3+2	4	8

Prerequisites Courses	LİNEER CEBİR; DİFERANSİYEL DENKLEMLER
Recommended Elective Courses	Linear Algebra and Differential Equations; Introduction to Programming; Linear Algebra; Differential Equations
Language of Instruction	English
Course Level	First Cycle (Bachelor's Degree)
Course Type	Elective
Course Coordinator	Assist.Prof. Elif HOCAOĞLU
Name of Lecturer(s)	Assist.Prof. Elif HOCAOĞLU
Assistant(s)	
Aim	The scope of an advanced robotics course is expansive, delving into intricate aspects of robot motion, control systems, and sensor technologies. It encompasses advanced topics like differential kinematics, path planning, and trajectory generation, offering students a comprehensive understanding of robot dynamics and control. The course also explores cutting-edge control techniques such as force control, and impedance control, along with admittance control. Students gain hands-on experience in robotics software development, utilizing frameworks and programming languages essential for advanced applications.
Course Content	This course contains; Definition of Robotics, Robot components and types ,Derivations of the rotation operators to describe and control the orientation of robotic end-effectors. ,Homogeneous transformations that represent the position and orientation of a robotic system in a unified mathematical framework.,Derivation of Forward Kinematics to determine the end-effector position of a robot given its joint variables,Derivation of Inverse kinematics problems to compute the joint variables required to achieve a desired end-effector position and orientation.,The concept of velocity kinematics and its application to analyze the relationship between joint velocities and end-effector velocities in a robotic system.,Derivation of the equations of motion for robotic systems using the Newton-Euler method: Calculation of inertia properties, including mass, center of mass, and inertia tensor, for individual rigid bodies in a robotic system. Apply the recursive Newton-Euler algorithm to compute velocities and accelerations in a robotic manipulator. ,Analyses joint forces and torques, expressing them in terms of external forces, joint accelerations, and inertia properties. Implementation of dynamic simulations of robotic manipulators using the Newton-Euler method.,Derivation of Lagrange's equations in describing the dynamics of mechanical systems. ,Solving dynamics problems in the presence of constraints using Euler-Lagrange equations, such as closed-loop kinematic structures. ,Force Control Fundamentals: 1)Understanding the principles of force control in robotics. 2)Exploring the role of force sensors and tactile feedback in robotic systems. 3) Analyzing the challenges and applications of force control in various scenarios.,Adaptive Control Techniques: 1) Studying adaptive control techniques applicable to robotic systems. 2) Examining how adaptive control can be utilized to enhance the performance of robots in response to changing environmental conditions. ,Real-time Feedback and Control:Implementing real-time feedback mechanisms for force control.,Examining the importance of closed-loop control systems in adapting to dynamic changes..

Course Learning Outcomes	**Teaching Methods**	**Assessment Methods**
Solve the complexities of robot motion involves understanding and analyzing aspects such as differential kinematics, path planning, and trajectory generation	2, 21	A, D, E, F
Apply force control, impedance control, and admittance control to effectively govern and optimize robotic behaviour.	2, 21	A, D, E, F
Applies the theoretical background acquired in robot dynamics and control in practical scenarios.	2, 21	A, D, E, F
Gain practical experience in robotics software development, utilizing essential frameworks and programming languages for advanced applications and system integration.	2, 21	A, D, E
Apply design principles, including materials, and fabrication methods for prototyping robotic systems.	2	D, F

Teaching Methods	2: Project Based Learning Model, 21: Simulation Technique
Assessment Methods	A: Traditional Written Exam, D: Oral Exam, E: Homework, F: Project Task

Lecture Schedule

Sequence	**Topics**	**Preliminary Preparation**
1	Definition of Robotics, Robot components and types	Course presentation
2	Derivations of the rotation operators to describe and control the orientation of robotic end-effectors.	Course presentation
3	Homogeneous transformations that represent the position and orientation of a robotic system in a unified mathematical framework.	Course presentation
4	Derivation of Forward Kinematics to determine the end-effector position of a robot given its joint variables	Course presentation
5	Derivation of Inverse kinematics problems to compute the joint variables required to achieve a desired end-effector position and orientation.	Course presentation
6	The concept of velocity kinematics and its application to analyze the relationship between joint velocities and end-effector velocities in a robotic system.	Course slides
7	Derivation of the equations of motion for robotic systems using the Newton-Euler method: Calculation of inertia properties, including mass, center of mass, and inertia tensor, for individual rigid bodies in a robotic system. Apply the recursive Newton-Euler algorithm to compute velocities and accelerations in a robotic manipulator.	Course presentation
8	Analyses joint forces and torques, expressing them in terms of external forces, joint accelerations, and inertia properties. Implementation of dynamic simulations of robotic manipulators using the Newton-Euler method.	Course presentation
9	Derivation of Lagrange's equations in describing the dynamics of mechanical systems.	Course presentation
10	Solving dynamics problems in the presence of constraints using Euler-Lagrange equations, such as closed-loop kinematic structures.	Course presentation
11	Force Control Fundamentals: 1)Understanding the principles of force control in robotics. 2)Exploring the role of force sensors and tactile feedback in robotic systems. 3) Analyzing the challenges and applications of force control in various scenarios.	Course presentation

Lecture Schedule

Sequence	Topics	Preliminary Preparation
12	Adaptive Control Techniques: 1) Studying adaptive control techniques applicable to robotic systems. 2) Examining how adaptive control can be utilized to enhance the performance of robots in response to changing environmental conditions.	Course presentation
13	Real-time Feedback and Control:Implementing real-time feedback mechanisms for force control.	Course presentation
14	Examining the importance of closed-loop control systems in adapting to dynamic changes.	Course presentation

Evaluation Methods	Weight(%)
Midterm Exam	30
General Exam	70

Resources

Robot Dynamics and Control, Spong, Vidyasagar, John Wiley and Sons, 1989. • MATLAB Control System Toolbox, SIMULINK (Code Examples)
• Arduino (Built-in Examples) https://www.arduino.cc/en/Tutorial/BuiltInExamples