NIRMA UNIVERSITY

Institute:	Institute of Technology
Name of Programme:	M.Tech. in Electronics & Instrumentation Engineering (Robotics and Artificial Intelligence)
Semester:	I
Course Code:	6EI801CC25
Course Title:	Control systems for Robotics
Course Type:	Core
Year of introduction:	2025 - 26

L	T	Practical component				C
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Course Learning Outcomes (CLOs):

After successful completion of the course, student will be able to –

1. explain the fundamental principles of control systems and their applications in robotics (BL2)
2. apply control techniques for position, velocity, and force control in robotic systems (BL3)
3. decide the control strategies for robotic systems (BL5)
4. design and implement control algorithms for autonomous robotic applications. (BL6)

Unit	Contents	Teaching Hours (Total 30)
Unit I	**Introduction to control systems in robotics** Fundamentals of control systems: Open-loop and closed-loop control, feedback principles and importance in robotics, examples of control systems in robotic applications, historical development of control systems in robotics, challenges in implementing control systems in robotic platforms.	03
Unit II	**Mathematical modelling of robotic systems** Modelling of robotic dynamics: Kinematics and dynamics equations, transfer functions and state-space representation, stability analysis using pole-zero concepts, controllability and observability in robotic systems, frequency response analysis: Bode plot, Case study: modelling of a two-wheel balancing robot, introduction to simulation tools for control system analysis e.g., MATLAB/Simulink.	07
Unit III	**Control strategies for robotics** Proportional, Integral, and Derivative (PID) control and tuning methods, adaptive control and its application in dynamic environments, feedforward and feedback control, introduction to robust control methods, implementation of cascaded PID control in robotic systems. case study: PID control implementation for robotic arm motion, practical considerations in PID tuning for robotic actuators, nonlinear control strategies for complex robotic systems, introduction to AI-driven control methods: fuzzy logic and neural networks in control, case study: fuzzy control for obstacle avoidance in mobile robots.	10

Unit IV	**Feedback in control systems** Role of sensors in robotic control: Position, velocity, and force feedback, sensor fusion techniques for control applications, implementation of control algorithms with sensor feedback, data acquisition and filtering techniques in control systems, case study: force control in robotic grippers, real-time feedback loop design and challenges.	05
Unit V	**Applications and case studies** Real-world examples of control systems in robotics: Drones, robotic arms, and mobile robots, challenges in implementing control systems in industrial robots, case study: Autonomous navigation using control algorithms, case study: path tracking control in unmanned ground vehicles (UGVs).	05

Self – Study: The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

Suggested Readings/References:

1. Katsuhiko Ogata, Modern Control Engineering, Pearson.
2. Benjamin C. Kuo, Automatic Control Systems, McGraw-Hill.
3. Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Robot Modeling and Control, Wiley.
4. Roland Siegwart, Introduction to Autonomous Mobile Robots, MIT Press.
5. Kevin M. Lynch, Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press.

Suggested List of Experiments:

Sr No	Title	Hours
1.	To implement open-loop and closed-loop control for a DC motor.	02
2.	To study of PID control for a robotic arm joint.	02
3.	To understand force control implementation using a force sensor.	02
4.	To observe balancing a two-wheel robot using feedback control.	02
5.	To determine adaptive control for a robotic gripper with varying loads.	02
6.	To study of fuzzy control algorithm for obstacle avoidance.	02
7.	To understand implementation of advanced control for a robotic arm.	02
8.	To observe sensor integration and feedback control for a mobile robot.	02
9.	To determine path-following control of an autonomous vehicle.	02
10.	To describe control of an omnidirectional robot various techniques.	02
11.	To determine sensor control for UGV navigation control.	02
12.	To determine sensor control for outdoor robot application.	02

L = Lecture, T = Tutorial, P = Practical, C = Credit

w.e.f. the academic year 2025 - 26 and onwards