Introduction to Robotics and Intelligent Control Systems

Course Outline

1.0 COURSE DETAILS			
Course Title	**Introduction to Robotics and Intelligent Control Systems**		
Major	**Computer Science**		
Credits	**4**	**Domain with Course Code**	**CSA334**
Mode	**Theory + Lab (In-person / Simulation-based)**	**Period**	
Academic Year and Semester	**2025-26, Even Semester**	**Category (Core/Audit)**	**Elective**
Instructor	**Dr. Yash Tiwari and Tejas Chavan**	**Office Hours**	**9 hr**
LTP (Lecture-Tutorial-Practical)	**2-0-4**		

2.0 SUBJECT OVERVIEW *The course description should convey to students the intellectual goals of the course -- e.g., the rationale for the course, the guiding questions for the course, the general content of the course.*	
Facilitator's Vision:	**To empower computer science students to understand and build intelligent robotic systems that sense, plan, and act autonomously.**
Relevance for Students:	**Unlike traditional robotics courses, this program emphasizes software simulation, algorithmic intelligence, and ROS2-based control for non-mechanical students.**

Uniqueness of the program	**Prepares learners for the growing fields of automation, AI, and embedded systems through practical, simulation-driven exercises.**
Pre-Requisites:	**Basic programming knowledge in Python. No prior electronics or mechanical experience required.**
Intellectual Goals & Guiding Questions:	**1. How do robots perceive and interpret their environment?** **2. How can we mathematically model robot motion and control?** **3. How do AI and control systems enable autonomy?** **4. How can multiple robots communicate and coordinate?**

3.0 EDUCATIONAL OBJECTIVES	
Objectives	**By the end of this course, students will be able to** **1. Understand the structure and operation of robotic systems.** **2. Apply mathematical foundations to analyze and simulate robot motion.** **3. Implement control and navigation algorithms using ROS2 and Python.** **4. Integrate sensing, planning, and decision-making in a simulated robotic task.** **5. Evaluate the performance of intelligent control systems in practical applications.**

4.0 LEARNING OUTCOMES		
Outcomes	*Identify the learning outcomes based on Skills, Knowledge, Attitudes and Values that will be worked upon during the course.*	
	Skills	1. Simulation and control of robotic systems using Python and ROS2. 2. Algorithm implementation for motion, perception, and planning. 3. Integration of sensors and AI for intelligent behavior.

	Knowledge	1. Kinematics and dynamics of robotic systems. 2. Principles of feedback and control in robotics. 3. AI and machine learning applications in autonomous systems.
	Attitudes/Values	1. Encouraging innovation through experimentation and simulation. 2. Ethical awareness in deploying autonomous systems. 3. Collaboration and teamwork in robotics development.

5.0 PROGRAM OUTLINE

Map the learnings of each week of the course

WEEK	CONTENT	ACTIVITY/OUTCLASS	ASSIGNMENTS/ASSESSMENTS
Week 1	Introduction to Robotics, Components, and Simulation Tools	*Install ROS2 + simulation environment.* *Setup basic robot model in Gazebo/Webots.* *Python refresher for robotics tasks.* *Assignment: Write a script to control a simulated robot wheel or joint.*	*Lab submission: basic robot movement in simulation.*
Week 2-3	Mathematical Foundations, Forward and Inverse Kinematics	*Derive FK for 2-DoF planar robot.*	*Problem-solving worksheet on FK/IK.*

		Implement IK solver in Python. *Lab: simulate robot arm manipulation to reach given target positions.*	*Lab evaluation: reach-target tasks with simulated arm.*
Week 4-5:	Mobile Robotics, Sensors, and Perception	*Publish/subscribe ROS2 topics from LiDAR or camera.* *Sensor fusion project (IMU + Odometry).* *Implement obstacle detection via point cloud filtering.*	*Coding assignment: robot navigation with sensor input.* *Lab test: real-time sensor data visualization and filtering.*
Week 6–7	Localization, SLAM, and Control Systems (PID, Trajectory)	*Simulate robot localization with noisy sensors.* *Implement PID for speed/heading control.* *Run a SLAM pipeline inside ROS2.*	*Assignment: tune PID parameters for a stable trajectory.* *Lab demo: mapping unknown environment in simulation*
Week 8–9	Path Planning, FSMs, and ROS2 Communication	*Path planning on occupancy grids.* *Implement FSM for navigation (idle→move→avoid→goal).* *Create ROS2 service/client structure.*	*Lab submission: robot planning around obstacles.* *Short report on decision-making architecture.*

Week 10–11	Machine Learning, Vision, and Multi-Robot Coordination	*Train a basic ML classifier on sensor/vision data.* *Implement color detection or object tracking using OpenCV.* *Multi-robot communication task in simulation.*	*Mini-project: ML-enhanced perception pipeline.* *Lab evaluation: cooperative robots completing navigation tasks.*
Week 12	Human–Robot Interaction and Final Project Integration	*Robot interface design workshop.* *Final project development and testing.* *Public demonstration session.*	*Capstone project demo.* *Final project documentation + reflection report.*

6.0 EVALUATION CRITERIA

Map the percentage weightage to each category.

Function	% Weightage	Notes
Attendance/Class Participation	**10%**	**Active engagement in lectures and labs**
Assignments	**20%**	**Weekly problem-solving and simulation tasks**
Mid Semester	**30%**	**Practical test on simulation topics**
End Semester	**40 %**	**Capstone project demonstration and evaluation**

7.0 REQUIRED READINGS AND REFERENCES

List of required and suggested material. Can mention week-wise or topic-wise. Can also mention how to access readings.

Readings	**1. Siegwart, Nourbakhsh & Scaramuzza — Introduction to Autonomous Mobile Robots** **2. Peter Corke — Robotics, Vision and Control** **3. Kevin Lynch & Frank Park — Modern Robotics: Mechanics, Planning, and Control** **4. ROS2 Tutorials – official documentation** **5. Webots / Gazebo User Guides, OpenCV Python Tutorials** **6. https://www.amazon.in/Mastering-ROS-Robotics-Programming-prototype-ebook/dp/B0F4WYV5P1**
Videos	*https://onlinecourses.nptel.ac.in/noc21_me37/preview*
Others	

8.0 PROGRAM AUTHORIZATION

(SIGNOFF)

The undersigned acknowledge they have reviewed the course outline. Changes to this course outline will be coordinated with and approved by the undersigned or their designated representatives.

Program Head	Signature: Mr.Abhishek Sharma Date: _____ Print Name: _____ Title: _____ Role: _____
	Signature: _____ Date: _____ Print Name: _____ Title: _____ Role: _____
OAA Office	Signature: _____ Date: _____ Print Name: _____ Title: _____ Role: _____
VC Office	Signature: _____ Date: _____ Print Name: _____

	Title: _____ Role: _____
	Signature: _____ Date: _____ Print Name: _____ Title: _____ Role: _____
Course Owner	Signature: _____ Date: _____ Print Name: _____ Title: _____ Role: _____
	Signature: _____ Date: _____ Print Name: _____ Title: _____ Role: _____
	Signature: _____ Date: _____ Print Name: _____ Title: _____

	Role: