Department of Electronics and Communication Engineering, JNTUH

Course Structure and Syllabus for a Minor Degree in Robotics

Minor Degree *(4 Semesters)*

	Theory (# Credits)	Laboratory (# Credits)	Total Credits
II Year II Sem	Fundamentals of Robotics and Applications In Industry 4.0 & Industry 5.0(3)	--	3
III Year I Sem	Industrial Robotics (Robotic Arm) (3)	Robot Modelling and Simulation Lab (1)	4
III Year II Sem	Autonomous Mobile Robots (Ground, Aerial, And Underwater Vehicles) (3)	Miniaturized Industrial Robotics Lab (1)	4
IV Year I Sem	Haptics and Machine Vision for Social Robots (3)	--	3
IV Year II Sem	Project/ Experiential Learning (4)	--	4
		Total Credits	**18**

FUNDAMENTALS OF ROBOTICS AND APPLICATIONS IN INDUSTRY 4.0 & INDUSTRY 5.0

B.Tech. II Year II Sem **L T P C: 3 0 0 3**

Course Objectives:

1. To provide a broad understanding of industrial revolutions and their transformation of society through robotics.
2. To introduce various types of robots, their components, sensors, actuators, and programming methods.
3. To explain manufacturing and fabrication techniques used in building robotic systems with an applications-first approach.
4. To explore the role of robots in Industry 4.0 with focus on smart manufacturing and digital transformation.
5. To examine emerging applications of robotics in Industry 5.0 including agriculture, healthcare, bionics, and collaborative robots.

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand the evolution of industrial revolutions and classify different types of robots based on architecture, mobility, and application.
2. Explain various sensors, actuators, and programming methods used in robotic systems.
3. Apply appropriate manufacturing and fabrication techniques for building robotic systems based on application requirements.
4. Analyze the role of robots in Industry 4.0 applications across different industrial sectors.
5. Evaluate emerging robotic applications in Industry 5.0 including collaborative robots, agriculture, healthcare, and bionics.
6. Demonstrate knowledge of robotic systems for practical and industrial applications.

UNIT – I: Industrial Revolutions and Classification of Robots

Need for Industrial Revolution and Society Transformation, Industry 1.0: Mechanization, Industry 2.0: Mass Production, Industry 3.0: Automation, Industry 4.0: Smart Manufacturing, Industry 5.0: Human-Centric Era, Looking Ahead: Society 5.0. Introduction to Robotics, Classification Based on Architecture: Articulated, SCARA, Delta, Cartesian, Cylindrical, Polar, Classification Based on Mobility: Fixed, Mobile (Wheeled, Tracked, Legged), Aerial, Underwater, Classification Based on Application: Industrial, Service, Medical, Agricultural, Military, Space, Classification Based on Interaction: Industrial, Collaborative, Teleoperated, Autonomous, Humanoid and Bio-inspired Robots.

UNIT – II: Sensors, Actuators, and Programming

Role of Sensors in Robotics, Position Sensors (Potentiometers, Encoders), Velocity and Acceleration Sensors (Tachometers, Accelerometers, Gyroscopes, IMUs), Proximity and Distance Sensors (Inductive, Capacitive, Ultrasonic, LiDAR, IR), Force and Tactile Sensors (Force Sensing Resistors, Strain Gauges, Tactile Arrays), Vision Sensors (Cameras, Depth Cameras, Thermal Cameras), Other Important Sensors.

Introduction to Actuators, Electric Actuators (DC Motors, Servo Motors, Stepper Motors), Hydraulic Actuators, Pneumatic Actuators, Special Actuators (Piezoelectric, Shape Memory Alloys, Soft Actuators), Motor Drivers and Controllers.

Introduction to Robot Programming Methods (Online vs Offline Programming, Teach Pendant, Lead-through, Simulation-based), Overview of Programming Languages Used in Robotics (Python, C/C++, Block-based languages, Industrial robot languages), Simulation Software for Robotics (MATLAB, Gazebo, CoppeliaSim, Webots, RoboDK, Robot Studio), Sensor and Actuator Integration with Programming.

UNIT – III: Manufacturing and Fabrication of Robots

Robot Design and CAD Modeling, Simulation in Robotics Manufacturing,

Types of Manufacturing Processes: An Overview.

Additive Manufacturing: Applications: Custom grippers, rapid prototyping, lightweight structures, patient-specific parts; Overview of Methods: FDM, SLA, SLS, SLM, MJF, PolyJet, DLP, Binder Jetting, **Subtractive Manufacturing:** Applications: Precision parts, gears, shafts, chassis, enclosures; Overview of Methods: CNC Milling, Turning, Routing, Laser Cutting, Waterjet, EDM, Wire EDM, Grinding), **Forming and Shaping:** Applications: Robot covers, housings, structural frames, high-volume components; Overview of Methods: Sheet metal bending, stamping, forging, extrusion, injection molding, casting, deep drawing, **Joining Techniques:** Applications: Frame assembly, multi-material joining, electronics assembly; Overview of Methods: Welding MIG/TIG/Spot, brazing, soldering, adhesive bonding, mechanical fastening, press fit, snap fit, **Surface Finishing:** Applications: Corrosion protection, wear resistance, aesthetics, color coding; Overview of Methods: Anodizing, powder coating, plating, painting, polishing, sandblasting, heat treatment, **Composite Manufacturing:** Applications: Lightweight arms, drone frames, high-strength components; Overview: Hand lay-up, filament winding, resin transfer molding, pultrusion, compression molding, **Electronics Manufacturing:** Applications: Controller boards, sensor interfaces, compact electronics; Overview of Methods: PCB fabrication, SMT, through-hole assembly, flex circuits, 3D printed electronics

Advanced Manufacturing: Applications : Micro-robots, medical robots, self-assembling structures; Overview of Methods: Micro manufacturing, LIGA, nano manufacturing, 4D printing, biomanufacturing,

Actuator Mounting and Integration, Sensor Mounting and Wiring, Controller and Electronics Assembly, Final Assembly and Integration, Testing and Calibration.

UNIT – IV: Industry 4.0 - Smart Manufacturing and Robotic Applications

Industry 4.0: Definition and Core Principles, Cyber-Physical Systems (CPS), Industrial Internet of Things (IIoT), Cloud Computing and Big Data, Digital Twin, Artificial Intelligence in Industry 4.0, Automotive Manufacturing Applications, Electronics Industry Applications, Material Handling and Logistics, Machine Tending Applications, Quality Inspection and Testing, Food and Pharmaceutical Industry, Warehousing and Fulfillment.

UNIT – V: Industry 5.0 - Human-Centric Robotics and Emerging Applications

Industry 5.0: Definition and Core Values (Human-Centricity, Sustainability, Resilience), Human-Centric Manufacturing, Sustainable and Resilient Robotics, Collaborative Robots (Cobots), Human-Robot Collaboration Levels, Agriculture and Farming Robots (Harvesting, Seeding, Weeding, Monitoring), Bionics and Bio-inspired Robotics, Prosthetics and Assistive Devices, Healthcare and Medical Robotics (Surgical, Rehabilitation), Collaborative Manufacturing, Service and Hospitality Robots, Disaster Response and Rescue, Ethical and Social Considerations.

TEXT BOOKS

1. Niku, S.B. *Introduction to Robotics: Analysis, Control, Applications*, 3rd ed. (Indian Adaptation). Wiley India, 2024.

2. Groover, M.P. *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5th ed. Pearson, 2022.

3. Ustundag, A. and Cevikcan, E. *Industry 4.0: Managing The Digital Transformation*, 1st ed. Springer, 2018.

4. Bartneck, C. et al. *Human-Robot Interaction: An Introduction*, 2nd ed. Cambridge University Press, 2024.

REFERENCE BOOKS

1. Bajd, T. et al. *Robotics* (Intelligent Systems, Control and Automation Series), 1st ed. Springer, 2010.

2. Craig, J.J. *Introduction to Robotics: Mechanics and Control*, 4th ed. Pearson, 2018.

3. Sprague, N. *Just Enough Robotics*

INDUSTRIAL ROBOTICS (ROBOTIC ARM)

B.Tech. III Year I Sem **L T P C: 3 0 0 3**

Course Objectives:

1. To introduce the fundamental concepts, components, and classifications of industrial robotic arms.
2. To explore the diverse applications of robotic arms across various industries.
3. To develop the ability to perform forward kinematic analysis of industrial robots using D-H parameters.
4. To understand inverse kinematics techniques and apply them to standard industrial robots.
5. To introduce trajectory planning and control techniques for industrial robot motion.

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand the anatomy, specifications, and types of industrial robotic arms.
2. Identify and explain robotic arm applications in different industrial sectors.
3. Apply forward kinematics using D-H parameters to compute end-effector position and orientation for PUMA 560 and any 6-DOF industrial robot.
4. Analyze inverse kinematics solutions using analytical and numerical methods for standard industrial robots.
5. Evaluate trajectory planning techniques and control strategies for robotic arm motion.
6. Demonstrate knowledge of robotic systems for practical industrial applications.

UNIT – I: Fundamentals and Types of Industrial Robots

Introduction to Industrial Robots: Definition, history, and evolution. Basic anatomy of a robotic arm: Links, joints, degrees of freedom (DOF), manipulator, wrist, end-effector, and controller. Robot specifications: Payload, reach, repeatability, accuracy, resolution, speed, and IP rating. Work volume and workspace: Reachable vs dexterous workspace.

End effectors: Grippers (mechanical, vacuum, magnetic, soft), tools (welding torch, painting gun, dispensing nozzle), quick-change systems, and Tool Center Point (TCP) concept.

Types of industrial robots: Articulated, SCARA, Delta, Cartesian/Gantry, Cylindrical, Polar/Spherical, and Collaborative robots (Cobots). Other configurations: Mobile robotic arms and humanoid robots. Conveyor systems and robot selection criteria.

UNIT – II: Applications of Robotic Arm in Various Industries

Customized Product Development using Rapid Prototyping: Robotic arms in additive manufacturing (WAAM), laser cutting, and CNC machining for customized components; **Rehabilitation and Prosthetics:** Robotic arms in exoskeletons, myoelectric prosthetics, and assistive robots. **Automotive Industry:** Spot welding, arc welding, painting, assembly, engine manufacturing, and material handling.

.4 Electronics Manufacturing and Assembly: PCB assembly, component insertion, testing, and smartphone assembly. **Agriculture Industry:** Harvesting, seeding/planting, weeding, drone monitoring, precision agriculture, and pest control. **Hotel Industry:** Cooking robots, serving robots, and cleaning applications. **Construction Industry:** 3D printed buildings, bricklaying; **Military and Rescue Operations:** Bunker construction, explosive disposal, search and rescue. **Mining Industry:** Sensor-based inspection, automated drilling, ore sorting, and hazardous environment monitoring. **Space Exploration and Colonization:** Humanoid robots for space missions, debris capture, spacecraft refueling, and planetary exploration.

UNIT – III: Forward Kinematics of Industrial Robots

Coordinate systems: World, Tool, Object frames. Position and orientation representation: Position vectors, Euler angles (Roll, Pitch, Yaw). Rotation matrices about X, Y, Z axes. Homogeneous transformation matrices: Structure and application.Denavit-Hartenberg (D-H) parameters: The four parameters (θ, d, a, α), rules for assigning coordinate frames, D-H parameter table creation.Forward kinematics: Concept and definition. Forward kinematics of PUMA 560: D-H parameters, individual transformation matrices, final transformation matrix ${}^{0}T_{6}$, numerical example. Forward kinematics of any 6-DOF industrial robot (ABB IRB 1200 or equivalent): D-H parameters, transformation matrices, numerical example.

UNIT – IV: Inverse Kinematics and Velocity Analysis

Inverse kinematics: Problem definition, existence of multiple solutions, overview of various types of inverse kinematics techniques: geometrical, analytical, numerical, differential, optimization-based, and intelligent/hybrid techniques.Inverse kinematics of PUMA 560: Analytical solution approach, step-by-step derivation using any one method. Inverse kinematics of any 6-DOF industrial robot.Jacobian matrix and velocity kinematics: Overview of Jacobian matrix, linear and angular velocity relations, and singularity concept.

UNIT – V: Trajectory Planning and Control Techniques

Path planning: Need for path planning, path vs trajectory, joint-space and Cartesian-space planning, overview of point-to-point, continuous path, polynomial, spline-based, graph-based, and optimization-based planning techniques.Cubic polynomial trajectories: Numerical examples involving rest-to-rest motion and motion with non-zero initial velocity.Control systems: Open-loop and closed-loop control, need for feedback, overview of P, PI, PD, PID, feedforward, and adaptive/intelligent control techniques. PID control: proportional, integral, and derivative actions, combined PID structure, effect of each term, and tuning concepts.Robot programming methods: Overview of teach pendant programming, lead-through programming, and offline programming.

TEXT BOOKS

1. Niku, S.B. *Introduction to Robotics: Analysis, Control, Applications*, 3rd ed. (Indian Adaptation). Wiley India, 2024.

2. Jazar, R.N. *Theory of Applied Robotics: Kinematics, Dynamics, and Control*, 3rd ed. Springer, 2022.

3. Groover, M.P. *Automation, Production Systems, and Computer-Integrated Manufacturing*, 5th ed. Pearson, 2022.

4. Groover, M.P., Weiss, M., Nagal, R.N., and Odrey, N.G. *Industrial Robotics: Technology, Programming and Applications*, 2nd ed. (Indian Edition). McGraw Hill Education, 2012.

REFERENCE BOOKS

1. Hegde, G.S. *A Textbook on Industrial Robotics*, 1st ed. Laxmi Publications, n.d.
2. Rajput, R.K. *Robotics and Industrial Automation*, 1st ed. S. Chand, 2013.
3. Nagarajan, R. *Introduction to Industrial Robotics*, 1st ed. Pearson, 2016.
4. Craig, J.J. *Introduction to Robotics: Mechanics and Control*, 4th ed. Pearson, 2018.
5. Fu, K.S., Gonzalez, R.C., and Lee, C.S.G. *Robotics: Control, Sensing, Vision and Intelligence*, 1st ed. McGraw Hill, 1987.

ROBOT MODELLING AND SIMULATION LAB

B.Tech. III Year I Sem **L T P C 0 0 2 1**

Course Objectives:

1. To provide practical exposure to modelling and simulation of different robotic systems using suitable software tools.
2. To enable students to verify forward kinematics, inverse kinematics, and basic trajectory planning of robotic arms through manual and simulation-based approaches.
3. To develop basic understanding of robotic arm control, end-effectors, and hardware interfacing using Arduino/Proteus-based simulation.
4. To expose students to simulation of different robot categories such as articulated robots, SCARA robots, gantry robots, mobile robots, and UAVs.
5. To motivate students to design, import, simulate, and control simple custom robotic systems for future projects, innovation, and interview readiness.

Course Outcomes:

1. **CO1:** Identify suitable software tools for modelling and simulation of robotic systems and understand their features and practical limitations.
2. **CO2:** Verify the forward kinematics, inverse kinematics, and point-to-point trajectory of robotic manipulators through manual calculation and simulation.
3. **CO3:** Simulate basic robotic arm control, industrial operations, and pick-and-place tasks using suitable end-effectors.
4. **CO4:** Demonstrate simulation of SCARA, gantry, mobile robots, and UAVs using appropriate software platforms.
5. **CO5:** Design, import, and simulate a simple custom robotic arm and develop a basic control/interface application for robotic operation.

Note: Any 10 experiments are to be performed.

Suggested software/tools: MATLAB/Simulink, Python, ROS, RoboDK, RobotStudio, Webots, Gazebo, CoppeliaSim, Proteus, or any equivalent open-source/licensed tools depending on institutional facilities.

Hardware Requirements: 15 computers/ Laptops, each equipped with a Core i5 or higher processor, 16 GB RAM, at least 512 GB SSD storage (NVMe SSD preferred), and a dedicated graphics card with a minimum of 4 GB memory.

List of Experiments:

1. Study of various software tools used for robot modelling and simulation, and understanding their features, applications, and practical limitations.

2. Import any 6-DoF or higher DoF robotic arm and verify the forward kinematics through manual calculation and simulation.
3. Import any 6-DoF or higher DoF robotic arm and verify the inverse kinematics through manual calculation and simulation.
4. Import any 6-DoF or higher DoF robotic arm and verify the point-to-point trajectory using cubic polynomial path technique through manual calculation and simulation.
5. PID control of a robotic arm using MATLAB or equivalent software.
6. Control of a robotic arm by actuating motors using Arduino and Proteus interfaced with MATLAB or equivalent open-source software.
7. Import any 6-DoF or higher DoF robotic arm, attach suitable industrial end-effectors such as welding gun or laser cutting tool, and simulate point-to-point motion and closed-path trajectory.
8. Import any 6-DoF or higher DoF robotic arm, attach two-finger or three-finger gripper end-effectors, and simulate pick-and-place operation.
9. Simulate point-to-point trajectory using a SCARA robot.
10. Simulate point-to-point trajectory using a Cartesian/Gantry robot.
11. Simulate a mobile robot with two-wheel drive and four-wheel drive motion.
12. Simulate basic motions of a drone/UAV using suitable open-source or licensed software.
13. Design a custom robotic arm with minimum 3-DoF using SolidWorks or any equivalent open-source CAD tool.
14. Import the custom-designed robot into MATLAB, ROS, or any equivalent open-source software and simulate/control the robotic arm.
15. Create a simple custom software application/interface for robotic arm operation using MATLAB App Designer or equivalent software platform.

AUTONOMOUS MOBILE ROBOTS (GROUND, AERIAL, AND UNDERWATER VEHICLES)

B.Tech. III Year II Sem **L T P C: 3 0 0 3**

Course Objectives:

1. To introduce the fundamental concepts, classifications, and applications of mobile robots.
2. To understand locomotion mechanisms and control of ground mobile robots.
3. To explore the design and operation of aerial vehicles (drones/UAVs).
4. To examine underwater vehicles and their applications.
5. To provide an overview of sensors, localization, mapping, and navigation techniques.

Course Outcomes:

At the end of the course, the student will be able to:

1. Classify different types of mobile robots and identify their applications.
2. Explain ground mobile robot fundamentals and drive mechanisms.
3. Understand aerial vehicle mechanics and control principles.
4. Describe underwater vehicle types and their operational principles.
5. Outline the basic concepts of sensors, localization, mapping, and navigation.

UNIT – I: Introduction, Types, Classification, and Applications

Introduction to mobile robotics: Definition, history, and evolution. Classification of mobile robots based on operating environment: Ground vehicles, Aerial vehicles, and Underwater vehicles.

Ground Vehicle Applications: Industrial material handling and factory logistics, warehouse automation and inventory management, agricultural farming and harvesting, military surveillance and reconnaissance, search and rescue operations in disaster zones.

Aerial Vehicle Applications: Drone photography, cinematography, and surveying, agricultural crop monitoring and pesticide spraying, disaster management and search/rescue operations, military surveillance, target acquisition, and combat, package delivery and logistics.

Underwater Vehicle Applications: Ocean exploration and deep-sea research, underwater pipeline and cable inspection, defense and mine detection operations, environmental monitoring and marine conservation, underwater archaeology and shipwreck exploration.

UNIT – II: Ground Mobile Robot Fundamentals

Introduction to ground mobile robots: Definition, basic concept, types of ground mobile robots based on locomotion mechanism, and key components such as chassis, wheels/tracks, motors and actuators, batteries and power systems, embedded controllers, sensors, and communication modules.

Basic terminologies: Pose, linear and angular velocity, heading, wheelbase, track width, ground clearance, and turning radius. Holonomic and non-holonomic constraints – conceptual understanding only.

Locomotion and drive mechanisms: Wheeled, tracked, legged, and hybrid mobile robots; differential drive, Ackermann steering, skid-steer, omni-wheel, mecanum wheel, and tracked locomotion. Suspension systems: Basic overview of rocker-bogie mechanism. Mobility challenges: Slip, traction, stability, and terrain adaptability.

UNIT – III: Aerial Vehicles – Fundamentals and Flight Mechanics

Introduction to aerial vehicles: Definition, basic concept, types of aerial vehicles – fixed-wing, rotary-wing, and hybrid VTOL; key components of aerial vehicles.

Basic terminologies: Thrust, lift, weight, drag, roll, pitch, yaw, altitude, airspeed, waypoint, loiter, degrees of freedom, and stability concepts.

Multi-rotor configurations: Quadcopter, hexacopter, and octocopter; flight modes – manual, altitude hold, position hold, waypoint navigation, and return-to-home.

Basic flight mechanics: Forces acting on a drone, lift and thrust generation, roll-pitch-yaw control in multi-rotors, and fixed-wing control surfaces – overview only.

UNIT – IV: Underwater Vehicles – Fundamentals and Operational Principles

Introduction to underwater vehicles: Definition, basic concept, types of underwater vehicles, and key components. Basic terminologies: Buoyancy, ballast, trim, depth, heading, surge, sway, heave, roll, pitch, and yaw. Locomotion and control: Thruster configurations, buoyancy control, and stability concepts. Overview of Navigation: Dead reckoning, inertial navigation, DVL, and acoustic positioning .

UNIT – V: Sensors, Localization, Mapping, and Navigation – An Overview

Sensors for mobile robots: Wheel encoders, IMU, GPS, LiDAR, sonar, and cameras – purpose and basic working principle.

Conceptual overview of Localization: Odometry, dead reckoning, GPS-based localization, Kalman filter, and particle filter. Overview of Mapping: Occupancy grid maps, feature maps, and SLAM , Overview of Navigation: Global and local planning, obstacle avoidance, bug algorithms, and potential field method – overview only.

TEXT BOOKS

1. Siegwart, R., Nourbakhsh, I.R., and Scaramuzza, D. *Introduction to Autonomous Mobile Robots*, 2nd ed. MIT Press, 2011.
2. Beard, R.W. and McLain, T.W. *Small Unmanned Aircraft: Theory and Practice*. Princeton University Press, 2012.
3. Antonelli, G. *Underwater Robots*, 4th ed. Springer, 2018.

REFERENCE BOOKS

1. Dudek, G. and Jenkin, M. *Computational Principles of Mobile Robotics*, 2nd ed. Cambridge University Press, 2010.
2. Corke, P. *Robotics, Vision and Control*, 2nd ed. Springer, 2017.
3. Thrun, S., Burgard, W., and Fox, D. *Probabilistic Robotics*. MIT Press, 2005.
4. Choset, H. et al. *Principles of Robot Motion*. MIT Press, 2005.
5. Valavanis, K.P. and Vachtsevanos, G.J. (Eds.). *Handbook of Unmanned Aerial Vehicles*. Springer, 2015.

MINIATURIZED INDUSTRIAL ROBOTICS LAB

B.Tech. III Year II Sem **L T P C 0 0 2 1**

MINIATURIZED INDUSTRIAL ROBOTICS LAB

B.Tech. III Year II Sem. L T P C
0 0 2 1

Course Objectives:

1. To provide practical exposure to implementation and control of miniaturized industrial robotic systems.
2. To enable students to perform robotic arm operations such as teach pendant/PC control, pick-and-place, path planning, and conveyor-based handling.
3. To develop practical skills in mobile robot control using regular, omni, mecanum, and tracked wheel mechanisms.
4. To expose students to industrial robotic applications involving image processing, collaborative robots, warehouse robots, and drone-based monitoring.
5. To motivate students to fabricate, integrate, and control simple robotic systems for industrial and service applications.

Course Outcomes:

1. **CO1:** Operate and control a 5-axis or higher DoF robotic arm using teach pendant or PC-based control.
2. **CO2:** Perform pick-and-place, cubic path planning, conveyor handling, and image-based robotic operations.
3. **CO3:** Demonstrate control of different mobile robot platforms using regular, omni, mecanum, and tracked wheel mechanisms.
4. **CO4:** Implement integrated robotic applications such as robotic arm with mobile robot, collaborative robotic arms, and warehouse robot handling.
5. **CO5:** Fabricate and control a custom robotic arm, and demonstrate basic drone applications for surveillance and inventory tracking.

List of Experiments:

1. Introduce Arduino Mega as DAC Interface for Raspberry PI and create an application to read the temperature sensor , push buttons, potentiometers and joystick values and control the DC Motor and servo motors.
2. Introduce ROS and create an application to read the temperature sensor , push buttons, potentiometers and joystick values and control the DC Motor and servo motors.
3. Control of a 5-axis or higher DoF robotic arm using teach pendant or PC-based interface.
4. Pick-and-place operation using a robotic arm.

5. Cubic path planning / similar technique control a robotic arm for pick-and-place application.
6. Image-based pick-and-place operation for locating and placing objects at desired positions.
7. Pick-and-place of an object from one conveyor belt to another using a robotic arm.
8. Remote Control of a warehouse / Agriculture Mobile Robot using Bluetooth, WIFI & Cloud.
9. Remote control of a warehouse mobile robot with omni wheels using Wi-Fi or Bluetooth.
10. Remote control of a warehouse mobile robot with mecanum wheels using Wi-Fi or Bluetooth.
11. Line-following control of any one mobile robot platform.
12. Pick-and-place of an object from a conveyor belt into a mobile warehouse robot.
13. Collaborative pick-and-place task using multiple robotic arms and multiple conveyor belts.
14. Fabrication or 3D printing of a custom robotic arm with minimum 3-DoF and control of the same.
15. Development of a customized software/application using MATLAB, Android App, or equivalent open-source platform for robotic arm control.
16. use a drone for surveillance and inventory tracking applications.
17. Create an Interface using custom Software / Ros/ Gazebo / any opensource software control the Mobile Robot

Note: Any 10 experiments are to be performed.

Hardware Requirements:

A minimum of 15 computer systems / laptops with Intel Core i5 / AMD Ryzen 5 or higher processor, 16 GB RAM, minimum 512 GB SSD, and dedicated graphics card with at least 4 GB memory.

Software / Tools Suggested:

MATLAB/Simulink may be used as the primary platform wherever required. In addition, exposure may be provided using ROS, Python, RoboDK, RobotStudio, Proteus, SolidWorks, Webots, Gazebo, CoppeliaSim, or any equivalent open-source/licensed software depending on institutional facilities.

Hardware Platforms / Kits Suggested:

S. No.	Item	Minimum Quantity
1	Mini 5-DoF or higher DoF Metal robotic arm Kits with teach pendant / PC-based control interface	3
2	Interchangeable end-effectors for robotic arm such as 2-finger gripper, 3-finger gripper, suction gripper, and magnetic gripper	3 sets
3	Conveyor belt systems with minimum 10 cm width and 40 cm length	6

4	Mobile robot kits with minimum 10 kg payload capacity and interchangeable wheel mechanisms	10
5	Interchangeable wheel sets for mobile robots such as regular wheels, omni wheels, mecanum wheels.	5 sets
6	Wi-Fi / Bluetooth / cloud-enabled control modules for robotic arm and mobile robot operation	3
7	Camera / vision modules for image-based pick-and-place and monitoring applications	3
8	Drone kits for surveillance and inventory tracking applications	3
9	3D Printer for fabrication of robotic components with minimum build volume of 250 × 250 × 250 mm (e.g., Bambu Lab or equivalent).	1
10	Arduino Mega or Raspberry Pi based Training Kit with touch display	6

HAPTICS AND MACHINE VISION FOR SOCIAL ROBOTS

B.Tech. IV Year I Sem **L T P C: 3 0 0 3**

Course Objectives:

1. To introduce the concept of social robots, their classification, and applications.
2. To provide an overview of haptic principles, technologies, and touch-based interaction.
3. To explore machine vision fundamentals and their role in social robots.
4. To examine vision-based perception techniques for social robots.
5. To introduce generative AI and conversational systems in social robotics.

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand social robots, their classification, and applications.
2. Explain haptic principles, devices, and touch interaction in robotics.
3. Describe machine vision fundamentals and camera technologies.
4. Identify vision-based perception techniques for social robots.
5. Discuss the role of generative AI and conversational systems in social robotics.

UNIT – I: Introduction to Social Robots – Classification and Applications

Introduction to social robots: Definition, basic concept, characteristics, and role in human-robot interaction. Basic terminologies in social robotics: Autonomy, teleoperation, embodiment, anthropomorphism, social cues, gesture recognition, speech recognition, and emotion recognition.

Classification of social robots based on appearance: Humanoid robots, animal-like robots, caricature robots, and machine-like social robots. Classification based on function: Companion robots, assistive robots, service robots, educational robots, and therapeutic robots.

Applications of social robots: Healthcare and therapy, elderly care, education, hospitality, entertainment, retail, autism support, public assistance, domestic help, and mental health support.

UNIT – II: Haptics – Principles and Technologies

Definition and concept of haptics. Tactile feedback and kinesthetic feedback. Basic working principle of haptic devices.

Types of haptic actuators: Voice coil motors, eccentric rotating mass (ERM) motors, linear resonant actuators (LRA), piezoelectric actuators, and pneumatic actuators – basic principle and applications.

Haptic sensors: Force sensors, tactile sensors, pressure sensors, and torque sensors – purpose and basic working principle.

Haptic devices and interfaces: Touchscreen feedback, gaming controllers, haptic gloves, exoskeletons, haptic suits, and force-feedback joysticks.

UNIT – III: Machine Vision Fundamentals

Definition and concept of machine vision. Difference between computer vision and machine vision.

Image acquisition: Camera components such as lens, image sensor, and lighting. Types of cameras: Webcam, stereo camera, depth camera, and thermal camera – basic principle and uses.

Image representation: Pixels, resolution, color models, grayscale images, and basic digital image formats.

Basic image processing techniques: Image enhancement, edge detection, image segmentation, and feature extraction – conceptual overview only.

UNIT – IV: Machine Vision for Social Robots

Vision-based perception in social robots: Face recognition, emotion recognition, gesture recognition, and activity recognition – conceptual overview only.

Human detection and tracking: Basic methods for detecting and following humans in a scene.

Vision for interaction and assistance: Person following, obstacle avoidance, and environment awareness for safe navigation.

Applications of machine vision in assistive, service, and social robots: Visual assistance, patient monitoring, fall detection, object recognition, scene understanding, user recognition, social context understanding, and response to non-verbal cues.

UNIT – V: Generative AI and Conversational Systems for Social Robots

Introduction to artificial intelligence in social robotics: Basic concepts and need for intelligence in social robots.

Conversational AI: Overview of speech recognition, natural language understanding, dialogue systems, generative AI, and Large Language Models (LLMs).

Use of generative AI in social robots for conversation, question answering, context understanding, personalized interaction, and natural language generation.

Overview of Multimodal AI: Combining vision and language in social robots.

Examples of AI-enabled social robots.

Ethical considerations: Privacy, data security, trust, bias, safety, and user acceptance.

TEXT BOOKS

1. Bartneck, C. et al. *Human-Robot Interaction: An Introduction*, 2nd ed. Cambridge University Press, 2024.
2. Siciliano, B. and Khatib, O. (Eds.). *Springer Handbook of Robotics*, 2nd ed. Springer, 2016. (Selected chapters)
3. Szeliski, R. *Computer Vision: Algorithms and Applications*, 2nd ed. Springer, 2022. (Conceptual sections only)

REFERENCE BOOKS

1. Jones, L. *Haptics*. The MIT Press Essential Knowledge Series, 2018.

2. Russell, S. and Norvig, P. *Artificial Intelligence: A Modern Approach*, 4th ed. Pearson, 2020. (Selected chapters)

3. Kuffner, J. *Robots and the People Who Love Them*. St. Martin's Press, 2024.

Project

B.Tech IV Yr II Semester **L T P C:** 0 0 4 4

Project Description

The Mini Project is a capstone-style integration task. Students are expected to design and implement a robotic solution that demonstrates **continuity** across the curriculum. This involves combining mechanical design (Anatomy), motion logic (Kinematics), environmental awareness (Machine Vision), and, where applicable, mobility (Mobile Robotics) or human-centric interaction (Haptics).

General Objectives

1. **System Integration:** To synthesize knowledge from the four core robotics subjects into a single, cohesive working model or simulation.
2. **Problem Solving:** To identify a real-world challenge (Industrial or Social) and apply robotic principles to solve it.
3. **Algorithm Implementation:** To move from theoretical equations (DH parameters, PID control, Image filtering) to functional code (Python/C++ or ROS).
4. **Technical Documentation:** To develop the ability to document design iterations, kinematic analysis, and experimental results.

Course Outcomes (COs)

At the end of the project, the student shall be able to:

- **CO1:** Design a robotic mechanism or mobile platform with defined Degrees of Freedom (DoF) and work envelope. (L6)
- **CO2:** Apply kinematic and transformation matrices to control the robot's end-effector or navigation path. (L3)
- **CO3:** Integrate vision-based sensors or haptic feedback to allow the robot to interact with its environment. (L4)
- **CO4:** Utilize software frameworks like ROS, OpenCV, or MATLAB/Simulink for system control. (L3)
- **CO5:** Demonstrate teamwork, project management, and effective technical communication. (L3)