**Course Name**: Fundamentals of Robotics and Control

**Course Code:** MDMRB01

**Category:** Multidisciplinary Minor (MDM)

**Preamble:**

This course introduces the foundational principles of robotics, including kinematics, dynamics, and control systems. The course explores real-world robotic applications and the growing role of automation in modern industries. Students will gain hands-on experience with robotic systems and process automation tools. The course integrates Robotic Process Automation (RPA) to bridge physical and digital automation domains.

**Course Objectives:**

- Understand the foundational principles of robotics, including kinematics, dynamics, and control of robotic systems.
- Apply basic control strategies such as PID to robotic manipulators and mobile robots
- Explore the role of Robotic Process Automation (RPA) as a complementary software-based automation technique and build simple RPA workflows.

**Pre-requisites:**

1. Engineering Mathematics-I
2. Engineering Mathematics-II
3. Structured Programming
4. Object Oriented Programming

**Course Outcome:**

The students will be able to:

CO1: Explain the components and types of robotic systems and their applications.
CO2: Derive and apply forward and inverse kinematics for simple manipulators.
CO3: Analyze and implement feedback control systems, including PID controllers
CO4: Simulate basic robotic arm motion and trajectory control using software tools..
CO5: Describe the fundamentals of Robotic Process Automation (RPA) and its uses in industry.
CO6: Develop a basic RPA workflow to automate a simple rule-based software task.

**Course Scheme:**

| Contact Hours | | Credits Assigned |
|---|---|---|
| Theory | Practical | Total |
| 03 | 02 | 04 |

**Assessment guidelines:**

| Head of Learning | ISA | MSE | ESE | Total |
|---|---|---|---|---|
| Theory+ Tutorial | 45 | 30 | 50 | 125 |

The assessment/evaluation guidelines for the courses of different credits are mentioned in the above table. Notwithstanding the above, each course faculty shall have the choice to decide her/his assessment methodology based on the nature of the course. Faculty may propose a revised assessment methodology for his/her course. However, the revised assessment methodology shall be approved by a panel constituted at institute level and published to the learners before the commencement of the semester.

**Detailed Syllabus:**

| Module No. | Module Name | Module Contents | No. of Hours |
|---|---|---|---|
| 01 | Introduction to Robotics | **Learning Objective:**<br>*Introduce types, anatomy, and applications of robotic systems including manipulators, mobile robots, and humanoids*.<br><br>**Contents:**<br>Types of robots: manipulators, mobile robots, humanoids;<br>Robot anatomy: joints, links, actuators, sensors;<br>Applications in manufacturing, healthcare, and services.<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO1.1 Identify the major types of robots and classify them based on structure and mobility.*<br>*(PI 1.1.1, 1.4.1) (CO1)*<br>*LO1.2 Describe the function of key components such as joints, links, actuators, and sensors in robotic systems.*<br>*(PI 1.4.1, 2.1.1) (CO1)*<br>*LO1.3 Explain real-world applications of robotic systems in different industries.* | 06 |

<table>
<tr><th>Module No.</th><th>Module Name</th><th>Module Contents</th><th>No. of Hours</th></tr>
<tr><td></td><td></td><td>(PI 6.1.1, 1.3.1) (CO1)</td><td></td></tr>
<tr><td>02</td><td>Kinematics of Robotic Manipulators</td><td>Learning Objective:<br>Apply coordinate transformation and Denavit–Hartenberg conventions to derive and solve forward and inverse kinematics for basic manipulators.<br><br>Contents:<br>Coordinate systems and transformations,<br>Denavit–Hartenberg (D-H) parameters,<br>Forward and inverse kinematics for 2-DOF and 3-DOF arms.<br><br>Learning Outcomes:<br>A learner will be able to:<br>LO2.1 Apply D-H parameters to model the configuration of 2-DOF and 3-DOF robotic arms.<br>(PI 1.3.1, 2.2.1) (CO2)<br>LO2.2 Derive forward kinematic equations for a planar robotic arm.<br>(PI 2.3.1, 2.4.1) (CO2)<br>LO2.3 Compute inverse kinematics for positioning a robotic end-effector.<br>(PI 2.2.2, 2.2.3) (CO2)</td><td>10</td></tr>
<tr><td>03</td><td>Dynamics and Trajectory Planning</td><td>Learning Objective:<br>Analyze dynamic behavior of robotic systems and apply motion planning using joint and Cartesian trajectories.<br><br>Contents:<br>Basic concepts in robot dynamics (torque, inertia – overview),<br>Joint and Cartesian trajectory planning,<br>Linear and cubic interpolation.<br><br>Learning Outcomes:<br>A learner will be able to:<br>LO3.1 Interpret torque, inertia, and other dynamic effects influencing robotic motion.<br>(PI 1.1.1, 4.3.2) (CO4)<br>LO3.2 Design joint trajectories using linear and cubic interpolation methods.<br>(PI 3.2.1, 3.4.1) (CO4)</td><td>06</td></tr>
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| Module No. | Module Name | Module Contents | No. of Hours |
|---|---|---|---|
| | | *LO3.3 Simulate basic robotic motion trajectories using available tools.*<br>*(PI 5.1.1, 4.1.3) (CO4)* | |
| 04 | Control of Robotic Systems | **Learning Objective:**<br>*Introduce control strategies including PID for robotic motion control and analyze feedback stability concepts.*<br><br>**Contents**:<br>Introduction to control systems,<br>PID control: tuning, implementation, and real-time control,<br>Stability and feedback concepts.<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO4.1 Explain control loops, feedback, and system stability in robotics.*<br>*(PI 1.4.1, 2.1.1) (CO3)*<br>*LO4.2 Tune and implement a PID controller for a robotic joint.*<br>*(PI 2.3.1, 3.4.2) (CO3)*<br>*LO4.3 Analyze system response and stability using control performance metrics.*<br>*(PI 4.3.2, 3.3.1) (CO3)* | 08 |
| 05 | Introduction to Robotic Process Automation | **Learning Objective:**<br>*Understand RPA concepts and differentiate it from physical robotics, including its core components and tools.*<br><br>**Contents:**<br>What is RPA;<br>Difference from physical robotics;<br>Components of an RPA system: bots, orchestrators, recorders;<br>Overview of popular RPA tools (e.g., UiPath).<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO5.1 Define RPA and differentiate it from hardware-based robotic systems.*<br>*(PI 1.1.2, 6.1.1) (CO5)*<br>*LO5.2 Identify components of an RPA system and their roles.*<br>*(PI 1.4.1, 5.1.1) (CO5)* | 06 |

| Module No. | Module Name | Module Contents | No. of Hours |
|---|---|---|---|
| | | *LO5.3 Discuss applications of RPA in sectors such as healthcare, banking, and logistics.*<br>*(PI 6.1.1, 10.2.1) (CO5)* | |
| 06 | RPA Workflow Design and Integration | **Learning Objective:**<br>*Design and simulate RPA workflows for basic automation tasks and explore conceptual integration with physical robotic systems.*<br>**Contents:**<br>Creating simple bots to automate tasks (e.g., Excel, web forms), Control structures, data handling, and triggers in RPA, Conceptual integration with physical robot actions.<br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO6.1 Create and simulate a simple bot workflow using an RPA tool (e.g., UiPath).*<br>*(PI 5.2.1, 3.4.2) (CO6)*<br>*LO6.2 Use control logic, triggers, and data handling in RPA environments.*<br>*(PI 3.4.1, 3.4.3) (CO6)*<br>*LO6.3 Conceptually demonstrate how RPA can integrate with robotic systems (e.g., IoT triggers).*<br>*(PI 3.1.5, 10.2.1) (CO6)* | 09 |
| **Total** | | | **45** |

**Suggested List of Practicals:**

| Sr No. | Suggested Topic(s) |
|---|---|
| 1. | Research a Real-Life Robotic System (e.g., Da Vinci, AGV, Boston Dynamics Spot)<br>**Learning Objective:**<br>Describe the components, sensors, actuators, and control logic of a real-world robotic system and propose improvements for alternate applications.<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO1.1: Identify components and structure of an industrial robotic system. (CO1) (PI 1.1.1, 1.4.1)*<br>*LO1.2: Explain the working of sensors and actuators used in the robotic system. (CO1) (PI 1.4.1, 2.1.1)*<br>*LO1.3: Propose a reconfiguration of the robotic system for a new application. (CO1) (PI 3.2.1, 3.3.1)* |
| 2. | **Design and Simulate 2-DOF/3-DOF Manipulator** |

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| | **Learning Objective:**<br>Model and simulate basic robotic manipulators using kinematic equations.<br>**Learning Outcomes:**<br>A learner will be able to:<br>***LO2.1:*** *Apply coordinate transformations and D-H parameters to a manipulator. (CO2) (PI 1.3.1, 2.2.1)*<br>***LO2.2:*** *Simulate forward kinematics of a robotic arm in MATLAB/Python. (CO2) (PI 2.3.1, 5.1.1)*<br>***LO2.3:*** *Compute inverse kinematics and visualize joint movements. (CO2) (PI 2.2.2, 4.1.3)* |
| 3. | Trajectory Planning for Robotic Painter<br>**Learning Objective:**<br>Generate joint-space trajectories using linear and cubic interpolation techniques.<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO3.1: Define constraints on joint velocity and acceleration. (CO4) (PI 2.4.1, 4.1.2)*<br>*LO3.2: Plan and simulate linear and cubic trajectories. (CO4) (PI 3.2.1, 5.2.1)*<br>*LO3.3: Analyze trajectory efficiency and motion smoothness. (CO4) (PI 4.3.2, 4.3.4)* |
| 4. | Implement PID Controller for Inverted Pendulum<br>**Learning Objective:**<br>Implement PID control logic to stabilize dynamic robotic systems.<br><br>**Learning Outcomes:**<br>A learner will be able to:<br>*LO4.1: Develop the control model of an inverted pendulum. (CO3) (PI 1.4.1, 4.1.1)*<br>*LO4.2: Tune PID parameters for performance optimization. (CO3) (PI 3.4.1, 3.4.3)*<br>*LO4.3: Evaluate system stability and response. (CO3) (PI 4.3.2, 4.3.4)* |
| 5. | Automate a Repetitive Digital Task Using RPA<br>**Learning Objective:**<br>Use RPA tools to automate tasks like data entry, file handling, or notifications.<br>**Learning Outcomes:**<br>**A learner will be able to:**<br>*LO5.1: Identify a repetitive software task suitable for automation. (CO5) (PI 1.1.2, 6.1.1)*<br>*LO5.2: Create a simple RPA workflow using UiPath/Power Automate. (CO5) (PI 5.2.1, 3.4.2)*<br>*LO5.3: Evaluate task efficiency after automation. (CO5) (PI 4.3.4, 10.2.1)* |
| 6. | Event-Triggered RPA Bot<br>**Learning Objective:**<br>Design an RPA bot triggered by external events such as email, file upload, or form submission.<br>**Learning Outcomes: A learner will be able to:**<br>*LO6.1: Configure event-based triggers for RPA workflows. (CO6) (PI 3.4.1, 5.2.1)*<br>*LO6.2: Implement control structures and data handling in RPA tools. (CO6) (PI 3.4.3, 4.1.3)*<br>*LO6.3: Demonstrate integration of RPA bot with external applications. (CO6) (PI 10.2.1, 3.1.5)* |

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| 7. | Voice-Controlled Assistive Robotic Arm for Elderly/Disabled<br>Learning Objective:<br>Design a robotic arm that can perform basic movements controlled by voice commandsto assist the elderly or differently abled.<br><br>Learning outcomes:<br>A learner will be able to:<br>LO1.1: Identify the key components (microphone, actuator, processor) used in voicecontrolled robotic arms. (CO1) (PI 1.4.1, PI 1.1.1)<br>LO1.2: Simulate arm movement using kinematic equations and control logic. (CO2, CO3) (PI 2.3.1, PI 5.1.1)<br>LO1.3: Implement voice control logic and test its reliability through repeated use. (CO4) (PI 3.4.2, PI 4.3.2) |
| 8 | RPA-Based Smart Appointment Scheduler for Public Hospitals<br><br>**Learning Objective:**<br>Automate appointment scheduling and queue management using RPA and form-based input.<br><br>**Learning outcomes:**<br>A learner will be able to:<br>***LO2.1:*** *Identify suitable use-cases of RPA in hospital administration.*<br>*(CO5) (PI 6.1.1, PI 10.2.1)*<br>***LO2.2:*** *Create and deploy an RPA bot to capture form data and assign time slots.*<br>*(CO6) (PI 5.2.1, PI 3.4.2)*<br>***LO2.3:*** *Evaluate improvements in scheduling efficiency post-automation.*<br>*(CO6) (PI 4.3.4, PI 10.1.1)* |
| 9 | IoT-Integrated Sorting Robot for Municipal Waste Management<br><br>**Learning Objective:**<br>Design a robotic system with sensors for automatic waste categorization and real-time analytics via RPA.<br><br>**Learning outcomes:**<br>A learner will be able to:<br>***LO3.1:*** *Integrate sensors (IR, proximity, moisture) into a sorting robot.*<br>*(CO1) (PI 1.4.1, PI 1.1.1)*<br>***LO3.2:*** *Develop logic for waste classification using sensor data.* |

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| | *(CO4) (PI 3.4.1, PI 4.3.2)*<br>***LO3.3:*** *Automate report generation and analytics using an RPA dashboard.*<br>*(CO6) (PI 5.2.1, PI 10.2.1)* |
| 10 | **Gesture-Controlled Smart Home System with RPA Alerts**<br><br>**Learning Objective:**<br>Build a gesture-based robotic interface for smart home control with automation alerts via RPA.<br><br>**Learning outcomes:**<br>A learner will be able to:<br>***LO4.1:*** *Detect gestures using sensor modules and interpret them for control logic.*<br>*(CO1) (PI 1.4.1, PI 2.1.1)*<br>***LO4.2:*** *Program home appliance control using a robotic interface.*<br>*(CO4) (PI 3.4.2, PI 4.3.3)*<br>***LO4.3:*** *Automate safety alerts using an RPA system.*<br>*(CO6) (PI 5.2.1, PI 6.1.1)* |
| 11 | **AI-Powered Medicine Dispenser Robot with Usage Logs via RPA**<br><br>**Learning Objective:**<br>Create an intelligent medicine dispenser that provides reminders and logs dosage through RPA.<br><br>**Learning outcomes:**<br>A learner will be able to:<br>***LO5.1:*** *Design a robotic dispensing system with real-time clock and sensor control.*<br>*(CO1) (PI 1.1.1, PI 3.4.1)*<br>***LO5.2:*** *Implement schedule-based medicine dispensing with feedback confirmation.*<br>*(CO3, CO4) (PI 3.4.3, PI 4.3.4)*<br>***LO5.3:*** *Log user compliance using automated reports via RPA.*<br>*(CO6) (PI 5.2.1, PI 10.2.1)* |
| 12 | **Robotic Stick for Visually Impaired with Terrain Detection**<br><br>**Learning Objective:**<br>Develop a robotic stick that guides users by detecting terrain changes and |

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| | obstacles.<br><br>**Learning outcomes:**<br>A learner will be able to:<br>***LO6.1:*** *Interface terrain-sensing sensors (ultrasonic, LDR, accelerometers). (CO1) (PI 1.4.1, PI 1.1.1)*<br>***LO6.2:*** *Process sensor feedback and simulate response via buzzer/vibration. (CO3) (PI 3.4.3, PI 6.1.1)*<br>***LO6.3:*** *Validate the prototype for obstacle avoidance and direction feedback. (CO4) (PI 4.3.2, PI 4.3.4)* |

**Performance Indicators**

PI 1.1.1 Remembering: Recall components, types, and applications of robotic systems.
PI 1.4.1 Applying: Apply basic principles of mechatronics to robotic structures.
PI 6.1.1 Analyzing: Identify societal applications of robotics.
PI 2.2.1 Analyzing: Reframe robotic arms into joints and links for kinematic modeling.
PI 2.3.1 Applying: Apply transformations and D-H parameters to robot linkages.
PI 5.1.1 Applying: Use MATLAB/Python to simulate robot kinematics.
PI 3.4.1 Applying: Refine high-level robotic motion into joint-level trajectory design.
PI 4.3.2 Analyzing: Analyze trajectory performance under velocity constraints.
PI 4.3.4 Evaluating: Synthesize results from trajectory planning to ensure smoothness.
PI 3.4.3 Applying: Tune and implement PID controllers in dynamic systems.
PI 4.3.2 Analyzing: Evaluate controller response and system behavior.
PI 5.1.1 Applying: Simulate feedback control using digital tools.
PI 5.2.1 Applying: Use appropriate software tools for automation tasks.
PI 6.1.1 Analyzing: Identify administrative processes suitable for RPA.
PI 10.2.1 Evaluating: Present process flows automated via RPA bots.
PI 3.4.2 Creating: Develop rule-based workflows for task automation.
PI 4.1.3 Applying: Select tools and datasets for automation testing.
PI 10.1.1 Creating: Communicate automated processes through reports or dashboards.

**Mapping of Course Outcomes with Learning Outcomes:**

| | **Mapped to Learning Outcomes** |
|---|---|
| **CO1** | 1.1, 1.2, 1.3 |
| **CO2** | 2.1, 2.2, 2.3 |

| | |
|---|---|
| **CO3** | 3.1, 3.2, 3.3 |
| **CO4** | 4.1, 4.2, 4.3 |
| **CO5** | 5.1,5.2 |
| **CO6** | 6.1, 6.2, 6.3 |

CO-PO Mapping

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO 1 | 2/18 | 1/18 | 1/18 | - | - | 1/18 | - | - | - | - | - | - |
| CO 2 | 3/18 | 2/18 | 1/18 | - | 1/18 | - | - | - | - | - | - | - |
| CO 3 | 2/18 | 1/18 | 2/18 | 2/18 | 1/18 | - | - | - | - | - | - | - |
| CO 4 | 2/18 | 1/18 | 2/18 | 2/18 | 1/18 | - | - | - | - | - | - | - |
| CO 5 | 1/18 | - | 1/18 | 1/18 | 2/18 | 1/18 | - | - | - | 1/18 | - | - |
| CO6 | 1/18 | - | 1/18 | 1/18 | 2/18 | 1/18 | - | - | - | 1/18 | - | - |

CO PSO Mapping

| CO | PSO 1 | PSO 2 | PSO 3 | PSO 4 |
|---|---|---|---|---|
| CO 1 | S | - | W | - |
| CO 2 | S | - | W | - |
| CO 3 | S | W | W | - |
| CO 4 | S | W | W | - |
| CO 5 | M | W | M | - |
| CO6 | M | W | M | - |

**Assessment Criteria of Learning Outcomes:**

| **Learning Outcomes:** The Learner will: | **Assessment Criteria:** The Learner can: | **Evaluated under ISA/MSE/ESE/LAB** |
|---|---|---|
| LO1: Introduce types, anatomy, and applications of robotic systems | 1.1 Identify major types of robots and classify them | Quiz, MSE |
| | 1.2 Describe joints, links, actuators, sensors | MSE, LAB |
| | 1.3 Explain applications of robotics in industries | MSE, ESE |
| LO2: Apply coordinate transformation and D-H | 2.1 Apply D-H parameters to 2-DOF/3-DOF arms | MSE, LAB |

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|---|---|---|
| conventions to derive and solve kinematics | 2.2 Derive forward kinematic equations | MSE, ESE |
| | 2.3 Compute inverse kinematics | MSE, LAB |
| LO3: Analyze robot dynamics and trajectory planning | LO3.1 Interpret torque, inertia and motion behavior | ISA,LAB,MSE |
| | LO3.2 Design linear and cubic interpolated trajectories | LAB, ISA |
| | LO3.3 Simulate basic trajectories using tools | LAB, Mini Project |
| LO4: Introduce control systems including PID and stability concepts | LO4.1 Explain feedback loops and stability | MSE, ESE |
| | O4.2 Tune and implement a PID controller | LAB, ISA |
| | LO4.3 Analyze control system response and metrics | MSE, LAB |
| LO5: Understand Robotic Process Automation (RPA) concepts | LO5.1 Define and differentiate RPA from physical robotics | Quiz, MSE |
| | LO5.2 Identify RPA components and their functions | MSE, LAB |
| | LO5.3 Discuss RPA applications in industries | MSE, ISA, ESE |
| LO6: Design and simulate RPA workflows and integration concepts | LO6.1 Create RPA bot for Excel/web form tasks | LAB, Mini Project |
| | LO6.2 Use control logic, data handling in workflows | LAB, ISA |
| | LO6.3 Conceptually demonstrate RPA integration with robotics | Mini Project, Presentation |

**Reference Books / Articles**

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2. John J. Craig, Introduction to Robotics–Mechanics &Control Pearson Education, India, Third Edition, ,2009.
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