Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

National Education Policy (NEP)-2020 Compliant Curriculum

TE - Third Year Engineering (2024 Pattern) in

AUTOMATION & ROBOTICS ENGINEERING

BoS, Mechanical, Automobile and A&R Engineering

(With effect from Academic Year 2026-27)

Contents

Nomenclature

AEC	Ability Enhancement Courses
AICTE	All India Council for Technical Education
AUR	Automation & Robotics Engineering
CO	Course Outcome
CEP	Community Engagement Project
CCE	Comprehensive Continuous Evaluation
HSSM	Humanities, Social Science, and Management
MDM	Multidisciplinary Minor
MEC	Mechanical Engineering
MOOC	Massive Open Online Course
NEP	National Education Policy
NPTEL	National Programme on Technology Enhanced Learning
OEL	Open Elective
PCC	Program Core Course
PEO	Program Educational Objectives
PSO	Program Specific Objectives
SWAYAM	Study Webs of Active-learning for Young Aspiring Minds
UGC	University Grants Commission
VEC	Value Education Course
VSE	Vocational Skill Course
WK	Knowledge and Attitude Profile

Preface by Board of Studies

Dear Students and Teachers,

We, the members of the Board of Studies – Mechanical, Automobile, and Automation & Robotics Engineering, are delighted to present the revised curriculum for Automation & Robotics Engineering under the 2024 Pattern.

The Third Year (TE) syllabus shall be implemented with effect from the Academic Year 2026–27, while the revised curriculum for the Final Year will subsequently be introduced from the Academic Year 2027–28.

Automation & Robotics Engineering is an emerging multidisciplinary field integrating *Manufacturing, Intelligent Automation, Robotics, Artificial Intelligence, Control Systems, Energy Systems, and Smart technologies*. The curriculum has been designed at par with leading universities and global academic standards to provide students with contemporary knowledge, practical skills, and industry-relevant competencies.

The revised syllabus aligns with the vision of NEP-2020 and conforms to the academic frameworks prescribed by Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies. It incorporates *recent technological developments, industrial expectations, and innovative practices* to ensure that students are well prepared for *professional challenges, higher education, research, and entrepreneurial opportunities*.

Wherever applicable, additional learning resources such as NPTEL and SWAYAM links are provided at the end of each course. Students are encouraged to utilize these platforms for self-learning, participate in online certification courses, and undertake additional projects to strengthen their technical knowledge and practical skills.

This curriculum is the outcome of collaborative efforts involving academic experts, industry professionals, and alumni to ensure relevance, quality, and excellence. It is designed not only to meet current industry requirements but also to prepare students for higher studies, research, innovation, and entrepreneurial ventures in the field of Automation & Robotics Engineering.

We hope this curriculum inspires students to become technically competent professionals, responsible citizens, and valuable contributors to the technological and sustainable advancement of society.

Dr. Pradeep A. Patil
Chairman,
Board of Studies - Mechanical, Automobile and Automation & Robotics Engineering

Department of Automation & Robotics Engineering

Program Educational Objectives (PEO)

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

- **PEO1:** The graduates will possess an ability to work in diversified fields along with team work and leadership qualities.
- **PEO2:** The graduates will have successful career with strong technical, research & professional skills.
- **PEO3:** The graduates will continue to learn and to adapt in a society of constantly evolving technological environment.

Program Specific Outcomes (PSO)

Program Specific Outcomes (PSOs) define the specific skills, knowledge, and abilities that students should acquire within a particular program of study at the time of graduation. PSOs are distinct from broader Program Outcomes (POs), which represent general graduate attributes.

- **PSO1:** Design and develop robotic systems from concept to realization for diverse applications by applying analytical thinking, logical reasoning, and problem-solving skills.
- **PSO2:** Develop the AI-powered cutting-edge technologies to create innovative and sustainable automation solutions for industrial and societal needs.
- **PSO3:** Exhibit domain expertise through impactful research in robotics, control systems, and autonomous technologies to solve real-world problems in sectors such as manufacturing, healthcare, and intelligent systems.

Programme Outcomes (PO)

Program Outcomes are statements that describe what students are expected to know and be able to do upon graduating from the program. These relate to the skills, knowledge, attitude and behaviour that students acquire through the program.

On successful completion of B.E. in Automation & Robotics, graduating students/graduates will be able to:

PO No.	Title	Program Outcome Description
PO1	Engineering Knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
PO2	Problem Analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3	Design / Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society and environment. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual and Collaborative Team Work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for, and have the preparation and ability for: (i) independent and life-long learning, (ii) adaptability to new and emerging technologies, and (iii) critical thinking in the broadest context of technological change. (WK8)

Knowledge and Attitude Profile (WK)

WK No.	Focus Area	Description
WK1	Natural Sciences and Social Sciences	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Mathematics and Data Analysis	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	Engineering Fundamentals	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering Specialist Knowledge	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Engineering Design and Environmental Considerations	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Engineering Practice (Technology)	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Role of Engineering in Society	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Research and Critical Thinking	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics and Inclusive Behavior	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability, etc., with mutual respect.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPC V4.0) - (August 2024) Page 55-56

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General Rules and Guidelines

Term	Definition
Course Outcomes (COs)	Course Outcomes are narrower statements that describe what students are expected to know and be able to do at the end of each course. These relate to the skills, knowledge, and behavior that students acquire throughout the course.
Assessment	Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of **Program Educational Objectives (PEOs)** and **Program Outcomes (POs)**.
Evaluation	Evaluation is one or more processes, performed by the **Evaluation Team**, to interpret the data and evidence gathered through assessment practices. It determines how well PEOs or POs are being achieved, and informs decisions for improvement.

Assessment and Evaluation:

Assessment and Evaluation shall be conducted in two parts: 1. Comprehensive Continuous Evaluation (CCE) 2. End-Semester Examination (ESE)		
Component	**Description**	**Marks**
Comprehensive Continuous Evaluation (CCE)	Conducted at institute level, covering all Units of the syllabus. The design and mark allocation follow the Continuous Assessment Sheet structure.	30
End-Semester Examination (ESE)	Conducted at university level, typically covering the entire syllabus through summative examination.	70
	Total Marks per Subject	**100**

A) Comprehensive Continuous Evaluation (CCE) :

CCE to be conducted either on the basis of Mode 1 or Mode 2.

➢ CCE MODE 1:

To design a Comprehensive Continuous Evaluation (CCE) scheme for a theory subject of 15 or 30 marks with the specified parameters, the allocation of marks and the structure can be as per continuous assessment sheet;

Savitribai Phule Pune University

Board of Studies (Mechanical and Automobile Engineering)

Comprehensive Continous Evaluation (CCE) 30 Marks Distribution

Class: TE-Mechanical Engineering — Subject: Refrigeration and Air conditioning

Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Cumulative Sum				30 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Internal Test	Attendance	Field Activity	Quiz	Internal Test	Attendance	
			A	B	C	D	E	F	G	H	I	J	SUM(A+C+E+G+I)	SUM(B+D+F+H+J)			P	Q	R	S	SUM(P:Q)
			10	10	10	10	10	10	10	10	10	10	50	50	100	100	15	5	5	5	30
T9028246474	2016	MAAN PANCHAL	8	8	8	8	8	8	8	8	8	8	40	40	60	75	12	4	3	3.8	22.75

Comprehensive Continous Evaluation (CCE) 15 Marks Distribution

Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4				Cumulative Sum				15 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz			Field Activity	Quiz	Internal Test		Field Activity	Quiz	Internal Test		
			A	B	C	D	E	F	G	H			SUM(A+C+E+G	SUM(B+D+F+H			P	Q	R	S	SUM(P:Q)
			10	10	10	10	10	10	10	10			40	40	100		5	5	5		15
T9970160753	2020	AMOGH SHINDE	8	8	8	8	8	8	8	8			32	32	60		4	4	3		11

Figure 1 Template Comprehensive Continuous Evaluation (CCE) ***Click*** *here to download .*

Field Activities / Home Assignments

Field activities and home assignments are essential components of experiential learning. Under this head, course projects, industrial visits, and guest lectures are to be incorporated. For each unit, one such activity should be designed and executed to reinforce theoretical learning through practical exposure.

1. **Course Projects**

   Course Projects should be framed based on real-world problems relevant to the subject. Each course project must be communicated through one of the following modes. It is recommended to complete all the communication modes across different course projects:

- **Poster Presentation**
- **PowerPoint Presentation**
- **Model Making**
- **Field or Survey Report with Oral Presentation** (e.g., case study)
- **Submission of Digital Content (e.g. Video Summary)**

To evaluate these field activities, **assessment rubrics** should be designed. The rubrics should include criteria such as clarity, innovation, subject relevance, presentation skills, and technical content.

Note: Part of work of any co-curricular activities (relevant to subject contents) like national level project competitions, club activities, paper presentations, startup activities can be accepted as a course projects.

2. **Industrial Visit**

An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the respective field. The purpose is to provide students exposure to actual engineering practices and systems.

Assessment of industrial visits should be carried out using any of the following tools:

- Quiz (based on the visit)
- Interactive video or oral discussion
- Submission of a detailed visit report

3. **Guest Lectures**

Guest lectures should be relevant to the course and highlight advanced topics or recent trends in the field. Subject experts from academia or industry may be invited.

Assessment methods for guest lectures may include:

- Quiz conducted post-lecture
- Attendance monitoring
- Evaluation of attentiveness and participation

Rubrics can be developed, if possible, to objectively assess student involvement in guest lectures.

4. **Quiz**

Unit-wise quizzes should be planned and can be conducted either **online** (via LMS, Google Forms) or

offline. Each quiz should include a **pool of 20 questions**, from which **students are required to attempt any 10**. The quizzes should be diversified across the following question types:

- Simple Multiple Choice Questions (MCQs)
- Numerical MCQs
- Image-based Questions
- Match the Following
- Fill in the Blanks
- Drag and Drop (using images or words)

This variety ensures the assessment caters to different cognitive skills and learning styles.

5. **Internal Tests**

Two major internal tests should be conducted as follows:

1. **Midterm Examination**: This should cover **Unit I and Unit II**, and should include questions targeting **Bloom's Taxonomy Levels 2, 3, and 4** (UNDERSTAND, APPLY, and ANALYZE).
2. **End term Examination**: This should cover the **remaining units** and should also include questions mapped to **BL Levels 2, 3, and 4**.

➢ CCE MODE 2:

Comprehensive Continuous Evaluation scheme in this mode for a theory subject of 30 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	12 Marks	Unit 1 & Unit 2 (6 Marks/Unit)
2	Assignments/Case Study	12 Marks	Unit 3 & Unit 4 (6 Marks/Unit)
3	Seminar Presentation/ Open Book Test/ Quiz	06 Marks	Unit 5

6. CCE of 15 marks based on all the Units of course syllabus to be scheduled and conducted at institute level. To design a CCE scheme for a theory subject of 15 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	10 Marks	Unit 1 & Unit 2 (5 Marks/Unit)
2	Seminar Presentation/ Open Book Test/ Assignments/ Case Studies	05 Marks	Unit 3 & Unit 4

- **Unit Test–**

  Format: Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels

(Remember, Understand, Apply, Analyze, Evaluate, and Create).

Implementation: Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.

- **Sample Question Distribution**–
  1. Remembering (2 Marks): Define key terms related to [Topic from Units 1 and 2].
  2. Understanding (2 Marks): Explain the principle of [Concept] in [Context].
  3. Applying (2 Marks): Demonstrate how [Concept] can be used in [Scenario]
  4. Analyzing (3 Marks): Compare & contrast [Two related concepts] from Units 1 and 2
  5. Evaluating (3 Marks): Evaluate the effectiveness of [Theory/Model] in [Situation].

- **Assignments / Case Study:** Students should submit one assignment or one Case Study Report based on Unit 3 and one assignment or one Case Study Report based on Unit 4.
  – ***Format*:** Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.
  – ***Implementation:*** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.
- **Seminar Presentation: –**
  Format: Oral presentation on a topic from Unit 5, followed by a Q&A session. –
  Deliverables: Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation
  Implementation: Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.

- **Open Book Test: –**
  Format: Analytical and application-based questions to assess depth of understanding. –
  Implementation: Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5

- **Quiz:** –
  Format: Quizzes can help your students practice existing knowledge while stimulating in terest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.
  Implementation: Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc

- **Example Timeline for conducting CCE: –**
  1. Weeks 1-4 : Cover Units 1 and 2
  2. Week 5 : Conduct Unit Test (12 marks)
  3. Weeks 6-8 : Cover Units 3 and 4

4. Week 9 : Distribute and collect Assignments / Case Study (12 marks)
5. Weeks 10-12 : Cover Unit 5
6. Week 13 : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- **Evaluation and Feedback: –**

1. Unit Test: Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
2. Assignments / Case Study: Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
3. Seminar Presentation: Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
4. Open Book Test: Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

B) <u>End-Semester Examination (ESE)</u>

Detailed Scheme for 70 Marks: Unit-Wise Allocation (14 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Detailed Scheme for 35 Marks: Unit-Wise Allocation (08 Marks for Unit 1 , 09 Marks for Unit 2, Unit 3 and Unit 4) : Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation The following structure is to be followed for designing an ESE for a **theory subject of 70 marks** covering **all 5 units** of the syllabus, with **questions set as per Bloom's Taxonomy** guidelines and **14 marks allocated per unit**.

2. Balanced Coverage

Ensure balanced coverage of all units with questions that assess different **cognitive levels of Bloom's Taxonomy**:

a) **Remembering**: Basic recall of facts and concepts.
b) **Understanding**: Explanation of ideas or concepts.
c) **Applying**: Use of information in new situations.
d) **Analyzing**: Drawing connections among ideas.
e) **Evaluating**: Justifying a decision or course of action.
f) **Creating**: Producing new or original work (if applicable).

Curriculum Structure - Semester V

NEP 2020 Compliant Curriculum Structure

Third Year Engineering (2024 Pattern) - Automation & Robotics Engineering

Level 5.5															
Course Code	Course Type	Course Name	Teaching Scheme (Hr/week)			Examination Scheme and Marks						Credit			
			Theory	Tutorial	Practical	CCE	End-Semester	Term Work	Practical	Oral	Total	Theory	Tutorial	Practical	Total
PCC-301-AUR	Major Course-7	Industrial Automation Systems	3			30	70				**100**	3			**3**
PCC-302-AUR	Major Course-8	Robot Kinematics & Dynamics	3			30	70				**100**	3			**3**
PCC-303-AUR	Major Course-9	Robot Operating Systems	3			30	70				**100**	3			**3**
PCC-304-AUR	Major Course-10	Sensors & Vision Systems	3			30	70				**100**	3			**3**
PCC-305-AUR	Major Course-7A	Sensors & Control Lab			2				50		**50**			1	**1**
PCC-306-AUR	Major Course-9A	Robot Standards & Ethics		2						50	**50**		2		**2**
PCC-307-AUR	Major Course-10A	Industrial Automation with PLC/SCADA Lab			2					50	**50**			1	**1**
MDM-311-AUR	Multidisiplinary Course-3	Deep & Reinforced Learning		1	2				50		**50**		1	1	**2**
MDM-312-AUR	Multidisiplinary Course-4A	Measurement and Quality Control Lab		1	2					50	**50**		1	1	**2**
OLE-321-AUR	Open Elective	OE is to be chosen compulsorily from faculty other than that of the Major Discipline.	2			15	35				**50**	2			**2**
		Total =	**14**	**4**	**8**	**135**	**315**	**0**	**100**	**150**	**700**	**14**	**4**	**4**	**22**

CCE: Comprehensive Continuous Evaluation

Note: Students can opt for Open Electives offered by different faculties such as Arts, Science, Commerce, Management, Humanities, or Inter-disciplinary studies.

• **Open Elective III:**

Students may choose courses like Financial *Accounting, Digital Finance, or Digital Marketing* from Commerce and Management faculty.

Curriculum Structure - Semester VI

NEP 2020 Compliant Curriculum Structure

Third Year Engineering (2024 Pattern) - Automation & Robotics Engineering

Level 5.5

Course Code	Course Type	Course Name	Teaching Scheme (Hr/week) Theory	Teaching Scheme (Hr/week) Tutorial	Teaching Scheme (Hr/week) Practical	Examination Scheme and Marks CCE	Examination Scheme and Marks End-Semester	Examination Scheme and Marks Term Work	Examination Scheme and Marks Practical	Examination Scheme and Marks Oral	Examination Scheme and Marks Total	Credit Theory	Credit Tutorial	Credit Practical	Credit Total
PCC-351-AUR	Major Course-11	Smart Factory Technologies	3			30	70				**100**	3			**3**
PCC-352-AUR	Major Course-12	Modeling & Simulation	3			30	70				**100**	3			**3**
PCC-353-AUR	Major Course-13	Actuators and Controllers	3			30	70				**100**	3			**3**
PEC-361-AUR	Program Elective-1	Program Elective -I	3			30	70				**100**	3			**3**
PEC-362-AUR	Program Elective-2	Program Elective -II	3			30	70				**100**	3			**3**
PCC-354-AUR	Major Course-11A	Robot Building Lab		2	2					50	**50**		2	1	**3**
PCC-355-AUR	Major Course-13A	Actuators and Controllers Lab			2				50		**50**			1	**1**
MDM-371-AUR	Multidisiplinary Course-5	Simulation Lab			2					50	**50**			1	**1**
VSE-372	Vocational & Skill Enhancement Course	Robotic Process Automation	1		2	50					**50**	1		1	**2**
		Total =	**16**	**2**	**8**	**200**	**350**	**0**	**50**	**100**	**700**	**16**	**2**	**4**	**22**

CCE: Comprehensive Continuous Evaluation

Note: Students can select any one from the baskets for Program Electives

• Program Elective I	
PEC-361A-AUR	Battery Management Systems
PEC-361B-AUR	Mobile Robotics
PEC-361C-AUR	Additive Manufacturing
PEC-361D-MEC	Industrial Engineering
PEC-361E-AUR	Internet of Things

• Program Elective II	
PEC-362A-MEC	Product Design & Development
PEC-362B-AUR	Agriculture robots
PEC-362C-AUR	Operations Research
PEC-362D-AUR	Warehouse Automation
PEC-362E-AUR	Manufacturing Systems & Simulation

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Automation & Robotics Engineering

2024 Pattern

Semester V Courses

With effect from Academic Year 2026-27

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-301-AUR: Industrial Automation System				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	3 Hr./Week	**3**	**CCE**	30 Marks
Practical	-		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Electrical and Electronics Engineering, Principle of Robotics, Engineering Mathematics

Course Objectives:

1. To understand the fundamentals and architecture of industrial automation systems.
2. To develop the ability to analyze and design hydraulic and pneumatic circuits for automation applications.
3. To study the construction, working and selection of fluid power components such as pumps, valves, actuators and accessories.
4. To develop skills in PLC, SCADA, HMI, and robotic integration.
5. To develop skills for design, troubleshooting, maintenance and performance evaluation of fluid power automation systems used in manufacturing and robotic applications.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Explain the fundamentals, components and working principles of industrial automation systems and line balancing methods

CO2: Analyse and design hydraulic and pneumatic circuits for industrial automation applications using appropriate fluid power components.

CO3: Design PLC-based industrial automation systems with suitable communication interfaces

CO4: Integrate robotics, HMI, and SCADA systems for industrial applications.

CO5: Develop automation solutions for smart manufacturing and Industry 4.0 environments.

Course Contents

Unit 1	**Introduction to Automation System**	**(6 hrs)**

Introduction to Automation System: Concept of automation - mechanisation and automation - classification, balancing of assembly line using available algorithms - Transfer line-monitoring system (TLMS) using Line Status - Line efficiency - Buffer stock Simulation in assembly line.

Real World Assignment:

1. Study and prepare a report on the assembly line automation system used in an automobile manufacturing industry and identify methods used for line balancing and efficiency improvement.
2. Develop a simulation-based case study to analyze the effect of buffer stock on productivity and downtime in a transfer line manufacturing system.

Practical Applications:

1. Transfer Line Monitoring System (TLMS) is used in automated manufacturing plants to monitor machine status, detect faults, and improve production efficiency.
2. Assembly line balancing algorithms are applied in industries to optimize workstation loading, reduce idle time, and increase production output.

Unit 2	**Hydraulics Automation**	**(8 hrs)**

Introduction to Fluid Power Systems, Properties of Hydraulic Fluids, Fluid Power Symbols, Hydraulic Pumps: Gear, Vane, Piston Pumps, Hydraulic Actuators: Cylinders and Motors, Hydraulic Control Valves: Direction, Pressure, and Flow Control Valves, Hydraulic Accumulators and Intensifiers, Hydraulic Circuits, Electro-Hydraulics automation, Design of Hydraulic Systems in Industrial Automation.

Real World Assignment:

1. Study and design a hydraulic press system used in manufacturing industries.
2. Study the hydraulic system used in an industrial automation application such as injection moulding machine, or excavator, and prepare a report explaining the functions of pumps, actuators, control valves, and hydraulic circuits involved in the system.

Practical Applications:

1. Development of hydraulic circuits for industrial automation applications.
2. Analysis of hydraulic cylinder operation for lifting mechanisms

Unit 3	Pneumatics Automation	(8 hrs)

Introduction to Pneumatic Systems, Standard Symbols, Air Compressors and Air Distribution Systems, Pneumatic Control Valves and FRL Units, Pneumatic Actuators and Cylinders, Pneumatic Circuit Design, Electro-Pneumatics automation ,Electro-Pneumatic Systems and Components, Solenoid Valves and Relay Logic, Sequential Control of Pneumatic Systems, PLC Integration with Pneumatic Systems, Industrial Applications of Pneumatics in Automation

Real World Assignment:

1. Design an electro-pneumatic pick-and-place automation system.
2. Study pneumatic automation used in packaging industries.

Practical Applications:

1. Design and simulation of pneumatic circuits using automation software.
2. PLC-based electro-pneumatic control system development.

Unit 4	Programmable Logic Control	(10 hrs)

Automation using Electronics Systems (Introduction - various sensors – transducers - signal processing - servo systems programmable logic controllers, PLC programming languages (Ladder Logic), alarm/interlock design, and PLC networking, Human-Machine Interface (HMI) design, GUI development, and I/O interfacing,

Real World Assignment:

1. Study the PLC-based automation system used in a packaging or conveyor industry.
2. Develop a basic Ladder Logic program for automatic motor control with alarms and interlocks.

Practical Applications:

1. PLC-HMI systems are used in automated production lines for machine monitoring and control.
2. Servo systems with sensors are used in robotic arms and CNC machines for precise motion control.

Unit 5	Communication, Supervisory Control and Automation System Applications	(8 hrs)

Communication and Supervisory system:

Industrial Control Systems & Communication (Distributed Control Systems (DCS) and Supervisory Control and Data Acquisition (SCADA), Industrial standard communication protocols (e.g., Modbus, PROFINET), RTUs, Fieldbus systems and real-time testing

Automation System Applications:

Case studies of Manufacturing automation, Design of FMS, Design of robotic work cell, Design for low-cost automation systems, Recent trends in fluid power automation and Industry 4.0 integration.

Real-World Assignment:

1. Perform a case study on an industrial automation system using fluid power. Analyse system design, automation strategy, maintenance challenges and suggest improvements for energy efficiency and smart monitoring.
2. Robot Arm Modbus TCP/IP Interfacing with SCADA

Practical Applications:

1. Simulation of hydraulic and pneumatic circuits using FluidSIM/Automation Studio
2. Automated robotic arm control using fluid power
3. Smart pneumatic systems with sensors and IoT integration

Books and other resources

Text Books:

1. Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Pearson Education 5th Edition 2019.
2. Oil Hydraulic Systems: Principles and Maintenance S.R. Majumdar Tata McGraw-Hill (TMH),2001
3. Pneumatic Systems: Principles and Maintenance S.R. Majumdar Tata McGraw-Hill (TMH),1995
4. Fluid Power with Applications Antony Esposito, Pearson Education 2009
5. Fluid Power Systems and Control, Prentice Hall,1998
6. Programmable Logic Controllers: Principles and Applications John W. Webb and Ronald A. Reis Pearson Education / PHI Learning 5th Edition (2002 / Reprints available)

References Books:

1. Herbert R Merritt, Hydraulic control systems, John Wiely& Sons, Newyork,1967.
2. Dudley A Peace, Basic fluid power, Prentice hall Inc,1967
3. Servo Pneumatics D Schilz A Zimmermann.
4. Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering W. Bolton Pearson Education 2019.
5. Process Control Instrumentation Technology Curtis D. Johnson Pearson education ,2006
6. Bolton, Programmable Logic Controller, 4th Ed, Newnes, 2006
7. Hydraulic and Pneumatic Power for Production by Harry LStewart.
8. Fundamentals of Fluid Power Control by John Watton.
9. Computer-Based Industrial Control Krishna Kant PHI learning 2008

MOOC Courses Link:

1. https://onlinecourses-archive.nptel.ac.in/noc19_me04/preview
2. https://nptel.ac.in/courses/112106300
3. https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_me67

Savitribai Phule Pune University
Third Year of Automation & Robotics Engineering (2024 Pattern)
PCC-302-AUR: Robot Kinematics and Dynamics

Teaching Scheme		Credits	Examination Scheme	
Theory	03 Hr./Week	**3**	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Engineering Mathematics, Principles of Robotics, Kinematics of Machinery

Course Objectives:

1. To understand the fundamentals of robot manipulator kinematics, workspace analysis, and coordinate transformations using DH parameters.
2. To analyze velocity kinematics and manipulator Jacobian for studying singularities, manipulability, and redundancy resolution in robotic systems.
3. To develop dynamic models of robotic manipulators using Newton-Euler and Lagrange-Euler formulations for motion analysis and control.
4. To study trajectory planning techniques for point-to-point and continuous path motion including collision-free path planning.
5. To understand linear control techniques for robotic manipulators and apply feedback control concepts for trajectory tracking and disturbance rejection.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: APPLY forward and inverse kinematics techniques to analyze robotic manipulators and determine workspace characteristics.

CO2: ANALYZE manipulator Jacobian, singularities, manipulability, and redundancy resolution methods for robotic motion control.

CO3: DEVELOP and SOLVE dynamic equations of robotic manipulators using Lagrange-Euler and Newton-Euler approaches.

CO4: DESIGN and EVALUATE trajectory planning schemes for robotic manipulators in joint space and Cartesian space.

CO5: APPLY linear feedback control techniques for trajectory-following, stability analysis, and disturbance rejection in robotic systems.

Course Contents

Unit 1	Robot Arm Kinematics	(8 hrs)

Introduction, Robot Joints & Work Volume, Transformation Matrices, DH Parameters and Transformation matrix for 3R Planar manipulator, SCARA, PUMA, Forward Kinematics. Inverse Kinematics, Dexterous workspace, Reachable workspace, concept of multiple inverse kinematic solutions. Numericals limited to 4 DOF planar manipulators.

Real World Assignment:

- Kinematic Analysis and Workspace Design of an Industrial Robotic Manipulator for Automated Pick-and-Place Applications.

Exemplar/Practical Applications:

- Model a SCARA robot and determine whether all assembly points are reachable.
- Design a 4-DOF planar manipulator to transfer objects between shelves.
- Build a simple 3R planar robotic arm using servo motors and validate kinematic equations experimentally.

Unit 2	Velocity Kinematics– The Manipulator Jacobian	(8 hrs)

Concept of Jacobian, Jacobian matrix properties, Singularity, types of singularities, minimum energy concept for 2 link planar manipulator, Redundant Robots/Manipulator and Manipulability, conditions for Manipulability Singular Value Decomposition, computing eigen values, Redundancy Resolution of Redundant Manipulators, null space, Moore pseudo inverse, velocity space, joint space, end effector space, Application of Redundancy Resolution.

Real World Assignment:
- Jacobian-Based Motion Analysis and Redundancy Resolution for an Industrial Robotic Manipulator

Exemplar/Practical Applications:
- Simulate a redundant manipulator and optimize joint motion while maintaining end-effector trajectory.
- Develop redundancy resolution algorithms to avoid obstacles while maintaining end-effector trajectory.

Unit 3	Robot Dynamics	(8 hrs)

Robot Dynamics, objectives of robot dynamics, Introduction Lagrange's equation kinetic and potential energy Newton-Euler formulation, Inertia Tensor, Lagrange's equation kinetic and potential energy, Dynamic model of a Two-axis planar robot, Lagrange Euler formulation problems.

Real World Assignment:
- Dynamic Modeling and Motion Analysis of a Two-Link Robotic Manipulator for Industrial Automation

Exemplar/Practical Applications:
- Develop a dynamic model of a 2-link manipulator and calculate actuator torque requirements.
- Model Humanoid robots arm motion and analyze energy-efficient movement strategies.

Unit 4	Trajectory Planning	(8 hrs)

Trajectories for Point to Point Motion, Cubic Polynomial Trajectories, Trajectory planning using linear function with parabolic blends (LSPB trajectory), Minimum Time Trajectories, Trajectories for Paths Specified by Via Points, Cartesian-Space Schemes, Cartesian straight-line motion , Geometric Problems With Cartesian Paths, Collision-Free Path Planning.

Real World Assignment:
- Trajectory Planning and Collision-Free Motion Design for an Industrial Robotic Manipulator

Exemplar/Practical Applications:
- Generate smooth trajectories for transferring objects between two positions while minimizing cycle time.
- Simulate obstacle avoidance and shortest-path trajectory planning.

Unit 5	Linear Control of Manipulators	(8 hrs)

Introduction, Feedback and closed-Loop Control, Second-Order Linear Systems, Control Of second-Order Systems, Control-Law Partitioning, Trajectory-Following Control, Disturbance Rejection, Continuous Vs. Discrete Time Control.

Real World Assignment:
- Design and Analysis of Closed-Loop Control System for a Robotic Manipulator.

Exemplar/Practical Applications:
- Design a feedback controller to maintain accurate positioning during assembly operations.
- Compare continuous and sampled-data control for robotic trajectory tracking.

Books and other resources

Text Books:

1. S. K. Saha, Introduction to Robotics, Second Edition, McGraw Hill Education (India) Pvt. Ltd.
2. Robot Dynamics and Control (Wiley) Mark W. Spong, Seth Hutchinson, and M. Vidyasagar
3. Robotics Control, Sensing, Vision & Intelligence by K.S.Fu, R.C.Gonzalez, C.S.G.Lee
4. Robot Dynamics and Control by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar
5. John J. Craig, Introduction to Robotics Mechanics and Control, Third Edition, Pearson, 2008.

References Books:

1. Robert J. Schilling, Fundamentals of Robotics Analysis and Control, PHI Learning, 2009.
2. Richard D. Klafter, Thomas .A, Chri Elewski, Michael Negin, Robotics Engineering an Integrated Approach, Phi Learning., 2009.
3. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Me Graw Hill Publishing company Ltd., 1995.
4. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1987.

5. Bernard Hodges, Industrial Robotics, Second Edition, Jaico Publishing house, 1993.
6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, MIT Press, 2003.
7. Bijay K. Ghosh, Ning Xi, T.J. Tam, Control in Robotics and Automation Sensor - Based integration, Academic Press, 1999

MOOC Courses Link:

1. https://onlinecourses.nptel.ac.in/e-learning/preview/noc23_me51

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-303-AUR: Robot Operating Systems				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	3	**CCE**	30 Marks
Practical	--------------		**End-Semester**	70 Marks

Prerequisite Courses, if any:
Programming & Problem Solving, Engineering Mathematics, Kinematics of Machinery, Industrial Electronics & Controls, Robot Drives & Systems Lab, Principles of Robotics

Course Objectives:
1. To introduce students to the underlying distributed, peer-to-peer ecosystem architecture of ROS and ROS 2.
2. To familiarize students with the asynchronous and synchronous middleware communication models.
3. To analyze performance indicators of compiled (C++) vs. interpreted (Python) client programming nodes.
4. To model industrial multi-axis robotic arms kinematics through semantic URDF representations.
5. To teach hardware-in-the-loop integration strategies utilizing low-overhead micro-ROS bridges.

Course Outcomes:
On completion of the course the learner will be able to;
CO1: Explain the distributed, peer-to-peer architecture of ROS/ROS2 and analyze the role of DDS middleware in robotic networks.
CO2: Utilize standard command-line tools and visualization suites to monitor, debug, and trace computational graph pathways.
CO3: Critique the engineering trade-offs between high-performance compiled languages (C++) and rapid-prototyping languages (Python) for real-time node design.
CO4: Formulate kinematic representations of multi-degree-of-freedom manipulators using symbolic URDF structural rules and coordinate system transforms.
CO5: Model hardware-in-the-loop interfaces and evaluate execution constraints when microcontrollers are integrated into distributed high-level computing middleware networks.

Course Contents

Unit 1	**Introduction to ROS: Architecture and Terminology**	**(09 hrs)**

The ROS Philosophy: Evolution of ROS (ROS 1 vs. ROS 2 paradigms), peer-to-peer, distributed, and multilingual properties.
Core Architecture: The ROS Master (Name Service), computation graph level, filesystem level, and community level.
Key Terminology: Nodes, Messages, Topics, Services, Bags, Workspace, and Packages.
Environment Setup**:** Setting up a Linux environment, workspace creation (colcon / catkin), structural files (package.xml, CMakeLists.txt), and essential command-line utilities (rosnode, rostopic, rosservice).

Real World Assignment:
- Multi-Vendor Interoperability: A surgical setup where an endoscope camera node stream from Vendor A is fed directly into a haptic feedback arm subscriber node from Vendor B over a single local network.
- Automotive Sensor Fusion: A developmental ADAS system where independent nodes for LiDAR, Radar, and Ultrasonic arrays publish concurrently, allowing an onboard central ECU node to process a synchronized spatial profile.

Practical Applications:

- Heterogeneous Fleet Integration: Providing a shared data framework across manufacturing environments so that mobile platforms, stationary assembly arms, and safety systems share state data effortlessly without custom protocol bridges.
- Modular Prototyping: Allowing research labs to swap out physical sensor packages (like switching from a 2D LiDAR to a 3D Depth Camera) by updating standard package configuration scripts without altering any underlying node code blocks.

Unit 2	ROS Programming in Python and C++	(09 hrs)

Client Libraries: Core language abstractions. Introduction to roscpp / rclcpp (C++) and rospy / rclpy (Python). Choosing between high-performance compiled binaries versus rapid prototyping scripts.
Publish-Subscribe Programming: Writing object-oriented Publisher and Subscriber nodes in Python (rclpy) and C++ (rclcpp). Understanding execution callbacks, spin loops, and custom message definition pipelines (.msg).
Request-Response Programming: Implementing synchronous and asynchronous ROS Services. Writing Service Server and Client nodes in C++ and Python. Designing custom service data types (.srv).
Advanced Communication: Setting up ROS Actions (.action) for feedback-driven, long-duration tasks using goal, feedback, and result structures. Managing configurations via the Parameter Server and organizing complex multi-node systems using Launch files.

Real World Assignment:

- Telemetry Over-the-Air (OTA) Logs: An autonomous sweeping machine continuously streaming raw coordinates to a local station via a telemetry Topic while maintaining a stable internal operational loop.
- Emergency Safe-Stop Routine: A high-speed sorting cell where a light-curtain sensor registers a breach, making an immediate synchronous Service Call that halts all downstream conveyor nodes instantly.

Practical Applications:

- Sortation Line Trajectory Monitoring: Utilizing feedback-driven Actions on an industrial gantry crane to execute long-distance bin transfers while returning continuous positional tracking updates to avoid mechanical overshoot.
- Centralized Recipe Distribution: Utilizing the ROS Parameter Server to instantly change production line operation configurations (such as velocity or orientation parameters) when a new part model variant enters the processing station.

Unit 3	Robot Modeling, Visualisation and Simulation	(09 hrs)

Mathematical foundations of robot kinematics and dynamic modeling.
Unified Robot Description Format (URDF): Designing XML structures for links, joints, visual, collision, and inertial properties. Using Xacro (XML Macros) for modular, parametric robot designs.
Configure and build standardized XML-based robot models (URDF/XACRO).
Utilize advanced visualization tools (RViz) for sensor data and state monitoring.
Spatial Transformations: The tf2 package, static and dynamic transforms, broadcasting and listening to coordinate frames (world → base_link → sensor_frame).
Virtual Simulation Environments: Importing URDF/Xacro models into Gazebo, adding environmental physics, surface friction profiles, and configuring sensor plugins (cameras, LiDAR models).
Deploy and analyze physics-based 3D simulations (Gazebo, Webots, CoppeliaSim) for verification.

Real World Assignment:

- Dynamic Kinematic Coordinate Balancing: A tracking node using the tf2 transformation tree to compute spatial transformations from a moving mobile base coordinate frame (base_link) to a tilting panning camera frame (camera_link) at 100 Hz.
- Closed-Loop Joint Telemetry: A simulated pick-and-place manipulator model using joint state publisher plugins to broadcast real-time internal joint position angles while responding to torque directives within Gazebo.

Practical Applications: • Digital Twin Cell Evaluation: Modeling an entire factory workcell layout (such as a KUKA heavy-payload manipulator arm) to check reach zones and predict potential link collisions before committing to real-world cell deployment. • Synthetic Training Data Generation: Setting up high-fidelity camera and LiDAR physics plugins inside a Gazebo world to extract thousands of training images and scan patterns for training vision models safely.		
Unit 4	**Perception, Mapping, and Navigation Stack**	**(09 hrs)**
Sensory Perception: Interfacing laser rangefinders (sensor_msgs/LaserScan) and point clouds/depth cameras. Simultaneous Localization and Mapping (SLAM): Implementing 2D mapping tools (Gmapping / SLAM-Toolbox) to map dynamic simulated environments. The Navigation Stack: Core architecture of the navigation pipeline (move_base or Nav2 Navigation servers), setting up Global and Local Costmaps, path planning algorithms, and position correction via AMCL (Adaptive Monte Carlo Localization).		
Real World Assignment: • Dynamic Object Evasion: An Autonomous Mobile Robot (AMR) navigating a warehouse path recalculating its local costmap in real time when a human operator steps directly into its sensor array trajectory. • Real-time Map Updating: An inspection vehicle mapping an unknown layout, dynamically populating an ongoing occupancy grid representation over an active network socket using a SLAM toolbox configuration.		
Practical Applications: • Fulfillment Logistics Routing: Running the standard navigation stack (move_base / Nav2) across a fleet of automated guided vehicles (AGVs) to optimize cross-facility parcel delivery layouts. • Automated Layout Digitization: Using autonomous base configurations to map newly acquired facility real estate automatically, outputting portable layout map files (.yaml, .pgm) without manual surveying.		
Unit 5	**ROS Applications, Embedded Deployments, and Hardware**	**(09 hrs)**
Embedded ROS Interfacing: Introduction to rosserial and micro-ROS architectures for low-level resource-constrained systems. Microcontroller Integration: Serial bridge interfacing with hardware platforms (e.g., Arduino, ESP32, STM32, Ardiuno) using C/C++ to capture raw encoder ticks, compute interrupts, and publish sensor data to the main computer. Hardware Deployment: Hardware-in-the-loop (HIL) application layouts; deploying ROS nodes onto single-board computers (SBCs like Raspberry Pi / NVIDIA Jetson) mounted on autonomous mobile platforms. Case Studies: Industrial pick-and-place integration (e.g., KUKA ROS-Industrial nodes) and basic multi-robot orchestration layouts.		
Real World Assignment: • Hardware-in-the-Loop (HIL) Odometry: An ESP32 microcontroller counting motor encoder ticks on hardware interrupts, translating them to step metrics, and publishing a position update to a master Raspberry Pi computer via a micro-ROS agent link. • Physical Robotic Arm Interfacing: Interfacing a hardware industrial controller (such as a KUKA KR series controller) with a ROS-Industrial platform node via TCP/IP to execute immediate kinematic tool path positions.		
Practical Applications: • Edge Deployment for Sorting Robotics: Deploying heavy deep-learning inference models onto high-performance edge computing units (e.g., NVIDIA Jetson) while delegating motor PWM and sensor reading loops to peripheral microcontrollers.		

- Industrial Workcell Migration**:** Converting legacy assembly operations into connected IoT automation architectures by wrapping older PLC networks inside compliant ROS industrial node bridges.

Books and other resources

Text Books:

1. Quigley, Morgan, Gerkey, Brian, and Smart, William D., "Programming Robots with ROS", O'Reilly Media.
2. Joseph, Lentin, "Robot Operating System (ROS) for Absolute Beginners", Apress, Second Edition.
3. Lentin Joseph, *"ROS Robotics Projects: Make your robots see, think, and perceive using ROS2"*, Packt Publishing, 3rd Edition.
4. Anis Koubâa, *"Robot Operating System (ROS): The Complete Reference (Volumes 1 to 5)"*, Springer.
5. Wyatt Newman, *"A Systematic Approach to Learning Robot Programming with ROS"*, CRC Press.

References Books:

1. Yaman, Anis, "Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems", Springer.
2. Joseph, Lentin, "ROS Robotics Projects", Packt Publishing.
3. Martinez, Aaron, and Fernandez, Enrique, "Learning ROS for Robotics Programming", Packt Publishing.
4. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson, 4th Edition.
5. Mark L. Mitchel, "Real-Time Systems Design and Analysis", Wiley-IEEE Press.
6. Morgan Quigley, Brian Gerkey, and William D. Smart, "Programming Robots with ROS", O'Reilly Media.

NPTEL / SWAYAM Course Links:

1. Prof. Asokan Thondiyath (IIT Madras), “Robotics”, NPTEL SWAYAM Portal. Available at: swayam.gov.in
2. Prof. Harshal B. Nemade (IIT Guwahati), “Introduction to Robotics”, NPTEL SWAYAM Portal. Available at: swayam.gov.in
3. Prof. Partha Pratim Das (IIT Kharagpur), “Programming in C++”, NPTEL SWAYAM Portal. Available at: swayam.gov.in

E-Books & Open-Source Digital Libraries:

1. Open Robotics Foundation, “The ROS 2 Documentation Handbook Stack”, Open Robotics. Available at: ros.org
2. Open Navigation Consortium, “The Nav2 Architectural Documentation Stack”.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-304-AUR: Sensors & Vision Systems				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	**3**	**CCE**	30 Marks
Practical	-		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Engineering Physics, Engineering Chemistry, Basics of Electrical and Electronics Engineering, Principles of Robotics

Course Objectives:

1. To enable students to identify suitable sensors for various robotic applications.
2. To develop the ability to compare and classify different types of sensors used in robotics.
3. To introduce the basic principles of robotic vision systems, digital image processing and its applications.
4. To provide knowledge and practical exposure to interface sensors & vision system with robotic systems and interpret their outputs.
5. To develop confidence in students to obtain solution to any one application suitable for Automation and Robotics using sensors and transducers.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: IDENTIFY suitable sensor for robotic applications and COMPARE & CLASSIFY types of sensors

CO2: DEMONSTRATE awareness and a fundamental understanding of all types of robotic sensors

CO3: UNDERSTAND the robotic vision systems and its applications

CO4: APPLY basic principles of digital image processing for different applications

CO5: INTERFACE sensors and vision system with robotic systems and interpret their output

Course Contents

Unit 1	Sensor Fundamentals	(06 rs)

Introduction - Role of sensors in robotics; differences between sensors and transducers; interoceptive vs. exteroceptive classification of sensors used in robotics applications,

Sensor Performance Characteristics - Static and dynamic response; accuracy, precision, sensitivity, resolution, hysteresis, and repeatability, speed of response, delay, dynamic error etc.

Signal Conditioning: Basic principles of sensing (electrical, optical, mechanical); signal amplification and noise reduction.

Real-World Assignment: Study and compare measurement systems used in industrial automation processes

Real World Assignment:

- Study and compare measurement systems used in industrial automation processes.
- Discuss criteria for selection of sensors

Practical Applications:

- Temperature monitoring systems in process industries.
- Pressure and flow measurement in manufacturing plants

Unit 2	Internal State and External Environment Sensors	(10 hrs)

Internal State (Proprioceptive): Potentiometers, LVDTs, and Optical Encoders (absolute/incremental) for position; Hall-effect and MEMS accelerometers for motion; gyroscopes for orientation.

External Environment (Exteroceptive): IR, Ultrasonic, Inductive, and Capacitive proximity sensors; LiDAR and Laser range finders for mapping.

Tactile & Force: Strain gauges, load cells, and piezoelectric transducers for joint torque and collision detection.

Advanced Smart Sensors: Introduction to flexible/wearable e-skin, bio-inspired sensors, and AI-enabled edge sensors
Industrial/Non-industrial Applications - Grasping and manipulation with sensors, Human-robot interaction and sensing, etc.

Real World Assignment:
- Prepare a comparative study of sensors used in autonomous mobile robots.
- Study industrial applications of MEMS and smart sensors

Practical Applications:
- Motion sensing in robotic manipulators
- Smart sensing systems in Industry 4.0 applications

Unit 3	Robotic Vision Systems	(07 hrs)

Vision Foundations: Human vs. machine vision; elements of visual perception; image formation in the human eye.
Camera Models: Pinhole camera geometry; CCD vs. CMOS technology; specialized cameras (SLR, Mirrorless, 360° Panoramic, and depth-sensing RGB-D).
Camera Calibration: Intrinsic and extrinsic parameters; linear methods, Zhang's method, and lens distortion modeling; stereo and multi-camera calibration.
Practical Application: Analysis of camera systems used in industrial machine vision and barcode scanning

Real World Assignment:
- Study camera systems used in industrial machine vision applications.
- Analyse image acquisition techniques for robotic vision systems.
- Prepare a case study on stereo vision in autonomous robots.

Practical Applications:
- Vision-guided robotic inspection systems.
- Barcode and QR code scanning systems.
- Camera-based monitoring and surveillance systems.

Unit 4	Digital Image Processing and Applications	(08 hrs)

Image Transforms: Foundations of 2D signals; Fourier Transform (DFT/FFT); Wavelet transforms and multiresolution analysis.
Spatial Domain Processing: Intensity transformations; histogram equalization; spatial filtering (smoothing and sharpening).
Frequency Domain Processing: Low-pass filters for blurring and high-pass filters for sharpening.
Segmentation & Description: Point, line, and edge detection (Sobel, Canny, Otsu's thresholding); region-based segmentation and boundary descriptors

Real World Assignment:
- Analyze image enhancement techniques used in medical imaging systems.
- Study edge detection methods for defect identification applications.
- Compare spatial and frequency domain filtering techniques.

Practical Applications:
- Noise reduction in digital images.
- Industrial defect detection systems.
- Image enhancement in surveillance applications

Unit 5	Sensor Interfacing, Integration and Calibration	(08 hrs)

Interfacing & Data Acquisition: Communication protocols (I2C, SPI, UART); Analog-to-Digital (ADC) conversion and DAQ systems.
Advanced Robot Vision: Stereo vision geometry (Epipolar geometry, disparity mapping); point cloud processing (Voxel grids, normal estimation).
Intelligent Vision: Object detection (Sliding window, R-CNN, YOLO); K-means and EM clustering for landmark learning; visual SLAM and visual servoing.
System Integration: Integration with Robot Operating System (ROS) camera drivers and computer vision libraries like OpenCV

Real World Assignment:

- Study of Warehouse automation and autonomous robots
- Study of Self-Driving Car Sensor Fusion System

Practical Applications:

- Role Sensor fusion and data integration in autonomous decision making.
- Role of sensor interfacing, ADC, DAC, DAQ in industrial automation e.g conveyor belt automation.

Books and other resources

Text Books:

1. Patranabis D., "Sensors and Transducers", PHI Learning.
2. Ernest O. Doebelin, "Measurement Systems - Applications and Design", Tata McGraw-Hill.
3. Rafael C. Gonzalez & Richard E. Woods, "Digital Image Processing", Pearson.
4. S. K. Saha, "Introduction to Robotics", McGraw Hill
5. Peter Elgar, "Sensors for Measurement & Control", Adison-Wesley Longman Ltd, 1998
6. Ian Robertson Sinclair, “Sensors and Transducers”, Newnes, 2001

References Books:

1. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education.
3. S. R. Ruocco, "Robot Sensors & Transducers", Springer
4. Jon S. Wilson, Sensor Technology Handbook, Elsevier, 2005
5. Toko, K., “Biomimetic sensor technology”, Cambridge Univ Press, Cambridge, 2000
6. Hans Kurt Tönshoff (Editor), Ichiro, “Sensors in Manufacturing” Volume 1, Wiley-VCH, April 2001

MOOC / NPTEL Courses / Other Resources:

1. NPTEL: "Sensor Technologies" by Prof. Mitradip Bhattacharjee.
2. Virtual Labs: Sensors and Instrumentation Lab (COEP).
3. OpenCV and Robot Operating System (ROS) official documentation

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-305-AUR: Sensors and Control Lab				
Teaching Scheme		**Credits**	**Examination Scheme**	
Practical	02 Hr./Week	**1**	**Practical**	50 Marks

Prerequisite Courses, if any:

- Basics of Electronics & Microcontrollers, Control Systems, Linear Algebra, Measurement systems, Software & Programming Prerequisites, C/C++ Programming, Python Programming, Linux Environment Fundamentals, MATLAB

Course Objectives:

The lab course aims to:

1. Enable students to **identify suitable sensors** for various robotic applications and develop the ability to **compare and classify** different types of sensors used in robotics.
2. Provide knowledge and practical exposure to **interfacing sensors** and their integration into robotic systems.
3. Ensure students understand the **core architecture and communication mechanisms** of the Robot Operating System (ROS) in both virtual and hardware environments while learning to interface physical transducers.
4. Develop hands-on skills in using **3D physics simulators (Gazebo)** and **visualization suites (RViz)** to model mechanical systems and tune/benchmark **closed-loop feedback control loops**.
5. Cultivate an engineering mindset toward **autonomous robotics** by integrating sensor networks, localization algorithms, and motor driving loops to solve real-world reactive navigation problems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Identify, compare, and classify suitable sensors for robotic applications.

CO2: Interface sensors with robotic systems, interpret their output, and apply basic principles of **system integration**.

CO3: Model and implement native ROS computation graph communication channels on both virtual and embedded hardware platforms and **parse, filter, and calibrate** multi-dimensional sensor streams (spatial, inertial, and analog) using standard ROS message schemas.

CO4: Design and tune closed-loop dynamic control architectures (such as PID or kinematic steering) to regulate physical and simulated systems and **synthesize perception and actuation algorithms** to execute autonomous mapping, localized navigation, and reactive hazard avoidance loops.

CO5: Demonstrate **awareness and a fundamental understanding** of all types of robotic sensors and the Robot Operating System (ROS)

Course Contents

Section-A - Sensors & Vision Systems (Any 5)

These experiments focus on identifying, comparing, and interfacing various robotic sensors and implementing digital image processing algorithms.

1. Sensor Fundamentals (Ultrasonic): Understand the working of an ultrasonic sensor (HC-SR04) for level measurement by calculating the Time of Flight (ToF).
2. Temperature Sensing: Study the static and dynamic characteristics of RTD or Thermocouple (LM35) sensors and interface them with a microcontroller.
3. Piezoelectric Analysis: Analyze the principle of operation of piezoelectric sensors for pressure or vibration sensing and plot force vs. output voltage.

4. Color Image Segmentation: Develop and implement an algorithm in Python using OpenCV to segment images based on RGB, HSV, or LAB color spaces.
5. Basic Image Processing: Apply image enhancement techniques using OpenCV, including filtering, smoothing, sharpening, and edge/contour detection.
6. Feature-Based Object Recognition: Process and recognize simple objects based on detected features such as color and geometric shapes (circle, square, triangle).
7. Gesture Recognition: Develop a computer vision system to detect hand gestures and use them to control robot movements.
8. DAQ Interfacing: Interface a suitable sensor and actuator with a Data Acquisition System (DAQ) to monitor physical quantities and trigger alarms/signals

Section B – Robot Operating Systems (Any 5)

These experiments are designed to model and implement ROS computation graph communication channels and synthesize perception and actuation algorithms.

1. Workspace and Node Handshaking: Initialize a ROS workspace and establish an asynchronous serial link (rosserial) between a Linux OS and an external Arduino controller.
2. Analog Sensor Publishing: Capture physical continuous voltages using an ADC and broadcast serialized Float32 scalar packets into the ROS network.
3. Actuator Command Subscription: Code a subscriber node to listen to control strings (e.g., /servo/angle) and translate them into physical mechanical movement.
4. LaserScan Representation: Calculate spatial distance using an ultrasonic sensor and wrap the metrics inside a standardized sensor_msgs/Range package for ROS networking.
5. IMU Interfacing over I2C: Configure an Inertial Measurement Unit (MPU6050) to fetch raw acceleration and rotational rates, transmitting them as standard IMU data packets.
6. Wheel Odometry Tracking: Implement hardware interrupt routines to track quadrature encoder ticks and calculate absolute linear travel distance.
7. Differential Drive Teleoperation: Parse multidimensional kinematic velocity targets (/cmd_vel) and map them to individual PWM signals for a mobile robot chassis.

Note:

- The student shall complete the following activity as a Term Work of **total 10 experiments** from the following list for Section-A and Section-B.
- Students must complete following **5 experiments from Section-A** and **5 experiments from Section-B**.
- Term Work of the student is evaluated based on the submission of experiment/assignment completed as individual evaluation and documentation of the assignment assigned to them.

Books and other resources

Textbooks

1. Patranabis, D., *"Sensors and Transducers"*, 2nd Edition, PHI Learning / Prentice Hall India, 2003.
2. Doebelin, Ernest O., *"Measurement Systems - Applications and Design"*, Tata McGraw-Hill, 2009.
3. Gonzalez, Rafael C. & Woods, Richard E., *"Digital Image Processing"*, Pearson, 2009.
4. Quigley, M., Gerkey, B., & Smart, W. D., *"Programming Robots with ROS"*, O'Reilly Media, 2015.
5. Saha, S. K., *"Introduction to Robotics"*, 2nd Edition, McGraw Hill Education, 2014.
6. Elgar, Peter, *"Sensors for Measurement & Control"*, Addison-Wesley Longman Ltd, 1998.
7. Ruocco, S. R., *"Robot Sensors and Transducers"*, Springer, 1987.
8. Sinclair, Ian Robertson, *"Sensors and Transducers"*, Newnes, 2001.

Reference Books

1. Szeliski, Richard, *"Computer Vision: Algorithms and Applications"*, Springer, 2011.
2. Craig, John J., *"Introduction to Robotics: Mechanics and Control"*, 3rd/4th Edition, Pearson Education, 2004/2009.
3. Fraden, J., *"Handbook of Modern Sensors: Physics, Designs, and Applications"*, Springer, 2004.
4. Wilson, Jon S., *"Sensor Technology Handbook"*, Elsevier, 2005.
5. Gonzalez, R. C., Woods, R. E., & Eddins, S. L., *"Digital Image Processing using MATLAB"*, 2nd Edition, Tata McGraw Hill, 2010.
6. Groover, Mikell P., *"Industrial Robotics: Technology, Programming, and Applications"*, McGraw Hill, 2012.
7. Joseph, Lentin, *"Robot Operating System (ROS) for Absolute Beginners"*, Apress, 2018.
8. Martinez, A. & Fernández, E., *"Learning ROS for Robotics Programming"*, Packt Publishing, 2013.
9. Niku, Saeed B., *"Introduction to Robotics – Analysis, Control, Applications"*, Wiley India, 2010.

MOOC / NPTEL / Online Resources

- Sensor Technologies: Prof. Mitradip Bhattacharjee, IISER Bhopal.
- Sensors and Actuators: Prof. Hardik Jeetendra Pandya, IISc Bangalore.
- Computer Vision: Prof. Jayanta Mukhopadhyay, IIT Kharagpur.
- Embedded Sensing & Interfacing: Prof. Banibrata Mukherjee, IIT Kharagpur.
- Robotics: Prof. Asokan Thondiyath, IIT Madras.
- Virtual Labs:
    - Sensors and Instrumentation Lab (COEP).
    - Image Processing Lab (IIIT-H).
- Software Documentation:
    - OpenCV Official: https://opencv.org/.
    - ROS Official: https://www.ros.org/.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-306-AUR: Robot Standards & Ethics				
Teaching Scheme		Credits	Examination Scheme	
Tutorial	02 Hr./Week	2	Oral	50 Marks

Prerequisite Courses, if any: Principles of Robotics

Course Objectives:

1. To enable students to **identify the need for safety considerations** in robot design, installation, and operations.
2. To develop the ability to **compare and classify** different types of robot failures, their causes, and corrective measures aligned with industry standards.
3. To provide knowledge and practical exposure to **roboethics and levels of robomorality**.
4. To introduce the basic principles of **ethical system design** and environmental/governance strategies applicable to robotics.
5. To understand the **social impact and implications** of robotics through domain-specific ethical case studies.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Study and develop **safe procedures** for handling robots.

CO2: Analyze robot failure and reliability and **implement international robot standards**.

CO3: Understand **human-robot interaction (HRI)** consequences and apply ethical principles to robot use.

CO4: Study **ethical system design** and implement environmental and governance strategies.

CO5: Comprehend domain-specific ethical case studies and the **social implications of robotics**.

Course Contents

- The student shall complete the following activity as a Term Work of **any 8 experiments** from the following list.
- Term Work of the student is evaluated based on the submission of experiment/assignment completed as individual evaluation and documentation of the assignment assigned to them.

Unit 1	Foundations of Robot Safety and Standards	(02 hrs)

- **Safety Basics:** Need for safety, the role of engineers, and methods for performing safety analysis of robot systems.
- **Roles & Responsibilities:** Manufacturer and user roles; considerations for installation, operation, and workplace safety.
- **Standardization:** Characteristics and benefits of standards; national and international bodies (ISO).
- **Key Standards:** Introduction to **ISO 10218** (Industrial robots) and **ISO 13482** (Service robots); mechanical and electrical interfaces.

Unit 2	Global Robot Safety Standards - Implementation, Compliance, Testing and Validation	(02 hrs)

- **Reliability Analysis:** Configurations and failure classifications; corrective measures and effectiveness factors.
- **Testing Methods:** Performance testing methods (Ford, IPA-Stuttgart, and NBS methods); start-up safety-related factors.
- **Compliance:** Iterative hazard mitigation following **ISO 12100** principles; safety requirements for collaborative systems (cobots).

Unit 3	Foundations of Roboethics & Morality	(02 hrs)

- **Ethics Theories:** Top-down and bottom-up roboethics approaches; moral theories like Utilitarianism, Deontology, and Virtue ethics applied to AI.
- **Symbiosis:** Robot rights, socialized roboethics, and the psychological impact of human-robot bonding.
- **Professional Conduct:** Analysis of **Asimov's Laws** and the professional code of conduct for robotics engineers.

Unit 4	Ethical System Design and Environmental & Governance	(02 hrs)

- **Design Processes:** Implementing the **IEEE 7000** model to prioritize human values; transparency and explainability in **IEEE 7001**.
- **Data & Bias:** Data privacy processes (**IEEE 7002**) and identifying/mitigating algorithmic bias (**IEEE 7003**).
- **Regulations:** Ethical design frameworks (**BS 8611**) and comparative analysis of global AI/Robotics strategies.

Unit 5	Domain-Specific Ethical Case Studies and Social Impact of Robotics	(02 hrs)

- **Sector Ethics:** Trust and privacy in **healthcare robots**; treaties and control in **military applications**; liability in **autonomous transportation**.
- **Sustainability:** Environmental impacts of manufacturing, battery disposal, and life-cycle assessments.
- **Socio-Economics:** Job displacement metrics, workforce transformation, and economic liability.

Term Work (Tutorial Assignments)

The student shall complete at least any 8 activities from the following list. Individual documentation is required for evaluation.

1. Standards Identification: Study safety requirements of industrial robot cells using ISO 10218 Standards.
2. Safety Evaluation: Document safety requirements for an available fixed-base industrial robot for specific tasks.
3. Service Robot Analysis: Evaluate safety requirements for personal care and commercial collaborative robots.
4. Failure Mode Analysis: Use ISO 12100 principles to identify causes of hardware/software failures in industrial robots.
5. Robomorality Study: Evaluate ethics in specific human-robot interaction scenarios.
6. Professional Responsibility: Identify and document the codes of conduct for robotics developers.
7. IEEE Standard Application: Document an ethical system design process using IEEE 7001, 7002, or 7003.
8. Ethical Design Framework: Perform an ethical risk assessment using the BS 8611 standard.
9. Case Study Analysis: Analyze ethical dilemmas in healthcare or autonomous vehicle domains.
10. Social Impact Report: Evaluate and document the socio-economic impact of robotics on the modern workforce.

Books and other resources

Text Books:

1. **ISO 10218-1/2**, "Robotics - Safety requirements for Industrial robots."
2. **ISO 13482**, "Safety requirements for personal care robots."
3. **IEEE 7000-2021**, "Standard Model Process for Addressing Ethical Concerns during System Design."
4. **BS 8611**, "Ethical design and application of robots and robotic systems."
5. **Lin, P., Abney, K., & Bekey, G. A.**, "Robot Ethics: The Ethical and Social Implications of Robotics," MIT Press.
6. **Dhillon, B. S.**, "Robot System Reliability and Safety: A Modern Approach," CRC Press.

References Books:

1. **Wallach, W., & Allen, C.**, "Moral Machines: Teaching Robots Right from Wrong," Oxford University Press.
2. **Coeckelbergh, M.**, "Robot Ethics," The MIT Press.
3. **ISO/TS 15066**, "Robots and robotic devices - Collaborative robots."

MOOC / NPTEL Courses / Other Resources:

1. Robotics, IIT Kharagpur by Prof. D. K. Pratihar, https://nptel.ac.in/courses/112105249
2. Ethics in Robot Decision-Making and Autonomy, by Course foundry, https://www.coursefoundry.org/courses/professional-certificate-in-ethics-in-robot-decision-making-and-autonomy

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-307-AUR: Industrial Automation with PLC/SCADA Laboratory				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	02 Hr./Week	1	**Oral**	50 Marks

Prerequisite Courses, if any:
- Fluid Mechanics
- Mathematics
- Electrical and Electronics Engineering

Course Objectives:
1. To understand the fundamentals of industrial automation systems, hydraulic and pneumatic components, symbols, and their industrial applications.
2. To develop the ability to design, simulate, and analyze hydraulic and pneumatic circuits using standard industrial components and actuators.
3. To apply electro-pneumatic and PLC-based control techniques for automation of industrial processes and sequential operations.
4. To acquire practical knowledge of HMI/SCADA systems for monitoring, controlling, and integrating automated manufacturing systems.
5. To enhance problem-solving, teamwork, and industrial exposure through mini projects, case studies, and industry visits related to smart manufacturing and automation.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Identify and explain various industrial automation components, hydraulic and pneumatic symbols, valves, actuators, sensors, and control elements.

CO2: Design, simulate, and evaluate hydraulic and pneumatic circuits for industrial applications using appropriate fluid power components.

CO3: Develop electro-pneumatic and PLC ladder logic programs for sequential control, motor automation, safety interlocks, and alarm systems.

CO4: Implement automation solutions integrating PLC, electro-pneumatic systems, HMI/SCADA interfaces, and sensors for process monitoring and control.

CO5: Analyze and develop smart manufacturing or industrial automation systems through mini projects, case studies, and industrial exposure with consideration of real-time industrial practices

List of Practicals

Experiment No 1:

Study of Industrial Automation System Components and Symbols used in Hydraulic & Pneumatic Systems

Exemplars / Practical Applications :

1. Identification and interpretation of hydraulic and pneumatic symbols as per ISO standards.
2. Study and demonstration of industrial automation components such as valves, actuators, FRL unit, pumps, and compressors,
3. Comparative study of hydraulic and pneumatic automation systems used in robotics and manufacturing industries.

Experiment No 2:
Design and Simulation of Basic Hydraulic Circuits using Hydraulic Valves and Actuators
Exemplars / Practical Applications 1. Hydraulic lifting and lowering system used in scissor lifts and elevators. 2. Design of a double-acting cylinder circuit using directional control valves. 3. Development of a hydraulic speed control circuit using flow control valves.
Experiment No 3:
Performance Analysis of Hydraulic Cylinder and Hydraulic Press System
Exemplars / Practical Applications: 1. Analysis of hydraulic cylinder operation in industrial lifting mechanisms. 2. Hydraulic cylinder force and speed evaluation in robotic automation systems.
Experiment No 4:
Design and Simulation of Pneumatic Circuits using FRL Unit, Direction Control Valves and Cylinders
Exemplars / Practical Applications: 1. Pneumatic pick-and-place system used in industrial automation. 2. Pneumatic cylinder-based automatic packaging and sorting system.
Experiment No 5:
Development of Electro-Pneumatic Sequential Control Circuit using Relay Logic
Exemplars / Practical Applications: 1. Electro-pneumatic sequential control system for automatic material handling. 2. Automated bottle filling and packaging system using electro-pneumatics.
Experiment No 6:
PLC Programming using Ladder Logic for Automatic Motor Control with Interlocks and Alarms
Exemplars / Practical Applications: 1. Industrial water pump control system with alarm and protection circuits. 2. PLC-based automatic motor start-stop control system with safety interlocks.
Experiment No 7:
PLC-Based Electro-Pneumatic Automation System for Pick-and-Place Application
Exemplars / Practical Applications 1. PLC-based pick-and-place robotic system for industrial material handling. 2. Simulation of pick-and-place automation using PLC, sensors, and solenoid valves
Experiment No 8:
HMI/SCADA Interface Development for Monitoring and Control of an Automation Process
Exemplars / Practical Applications: 1. Industrial temperature and pressure monitoring using HMI/SCADA 2. HMI interface for automated conveyor and material handling systems.

Experiment No 9:
Mini Project/Case Study on Smart Manufacturing System using PLC, Sensors and Fluid Power Automation
Exemplars / Practical Applications 1. Industry 4.0 enabled fluid power automation system with real-time monitoring. 2. Case study on automated production line using hydraulic and electro-pneumatic automation. 3. Automated robotic assembly workstation using electro-pneumatic control. 4. PLC-based smart conveyor inspection and sorting system using sensors.
Experiment No 10:
Industrial Visit (Mandatory): A Compulsory industrial visit must be arranged to industries/ establishments consisting automation and mechanization during semester to provide awareness and understanding of the course
The Industrial Visit can be done preferably to 1. Manufacturing industries with Assembly-line Automation 2. Automation and robotics industries 3. Process Industries 4. Smart Manufacturing / Industry 4.0 Plants 5. Défense and Heavy Engineering Industries An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the field of hydraulics, pneumatics, PLC, SCADA automation. The purpose is to provide students exposure to actual engineering practices and systems: Student must submit properly documented Detailed Industrial Visit Report in his/her own words
Books and other resources **Text Books:** 1. Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Pearson Education 5th Edition 2019. 2. Oil Hydraulic Systems: Principles and Maintenance S.R. Majumdar Tata McGraw-Hill (TMH),2001 3. Pneumatic Systems: Principles and Maintenance S.R. Majumdar Tata McGraw-Hill (TMH),1995 4. Fluid Power with Applications Antony Esposito, Pearson Education 2009 5. Fluid Power Systems and Control, Prentice Hall,1998 6. Programmable Logic Controllers: Principles and Applications John W. Webb and Ronald A. Reis Pearson Education / PHI Learning 5th Edition (2002 / Reprints available)

References Books:

1. Herbert R Merritt, Hydraulic control systems, John Wiely& Sons, Newyork,1967.
2. Dudley A Peace, Basic fluid power, Prentice hall Inc,1967
3. Servo Pneumatics D Schilz A Zimmermann.
4. Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering W. Bolton Pearson Education 2019.
5. Process Control Instrumentation Technology Curtis D. Johnson Pearson education ,2006
6. Bolton, Programmable Logic Controller, 4th Ed, Newnes, 2006
7. Hydraulic and Pneumatic Power for Production by Harry LStewart.
8. Fundamentals of Fluid Power Control by John Watton.
9. Computer-Based Industrial Control Krishna Kant PHI learning 2008

MOOC Courses Link:

1. https://onlinecourses-archive.nptel.ac.in/noc19_me04/preview
2. https://nptel.ac.in/courses/112106300
3. https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_me67

Savitribai Phule Pune University

Third Year of Automation & Robotics Engineering (2024 Pattern)

MDM-311-AUR: Deep & Reinforced Learning

Teaching Scheme		**Credits**	**Examination Scheme**	
Tutorial	01 Hr./Week	**2**	**Practical**	50 Marks
Practical	02 Hr./Week		**End-Semester**	NA

Prerequisite Courses, if any: Fundamentals of Programming Languages, Engineering Mathematics, Artificial Intelligence & Machine Learning,

Course Objectives:

1. To introduce the theoretical foundations, algorithms, methodologies, and application of deep learning.
2. To design and develop an application-specific deep learning model.
3. To understand the basics of deep reinforcement Learning models.
4. To Describe Reinforcement Learning.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Understand the theoretical foundations, algorithms, and methodologies of Deep Learning.

CO2: Explore Representation Learning and Transfer Learning techniques using variants of CNN architecture.

CO3: To implement and apply deep generative models.

CO4: To Understand Reinforcement Learning Process

Course Contents

Unit 1	**Fundamentals of Deep Learning**	**(06 hrs)**

What is Deep Learning? History of deep learning, Advantage and challenges of deep learning. Learning representations from data, understanding how deep learning works in three figures, Common Architectural Principles of Deep Network, Architecture Design, Applications of Deep learning, Introduction and use of popular industry tools such as TensorFlow, Keras, PyTorch, Caffe, Shogun.

Real World Assignment:

1. Face Mask Detection System
2. Sentiment Analysis on Product Reviews
3. Handwritten Digit Recognition

Practical Applications:

1. AI-based attendance system
2. Emotion recognition from facial expressions
3. Speech-to-text conversion
4. Smart chatbot system
5. AI-powered recommendation system

Unit 2	**Representation Learning**	**(06 hrs)**

Introduction to Representation Learning, Traditional Representation vs Deep Representation, Types of Representation Learning, Greedy Layerwise Pre-training, Transfer Learning and Domain Adaption, Distributed Representation, Embedding Techniques,Variants of CNN: DenseNet, Comparison of CNN Variants

Real World Assignment:

1. **Robotics**
   - Object recognition
   - Navigation systems

2. **Autonomous Vehicles**
   - Lane detection
   - Traffic sign recognition

Practical Applications:
1. Medical Image Feature Representation
2. Recommendation System using Representation Learning

Unit 3	Deep Generative Models	(06 hrs)

Introduction to deep generative model, Boltzmann Machine, Deep Belief Networks, Generative adversarial network (GAN), discriminator network, generator network, types of GAN, Applications of GAN networks

Real World Assignment:
1. GAN for detection of real or fake images
2. Text-to-Image Generation

Practical Applications:
1. Robot Vision and Object Recognition
2. Robot Navigation and Path Planning

Unit 4	Reinforcement Learning	(06 hrs)

Introduction of deep reinforcement learning, Markov Decision Process, basic framework of reinforcement learning, challenges of reinforcement learning, Dynamic programming algorithms for reinforcement learning, Q Learning and Deep Q-Networks, Deep Q recurrent networks, Simple reinforcement learning for Tic-Tac-Toe.
Policy-based methods, Reward engineering concepts, Applications in robotics and autonomous systems, Simulation environments such as OpenAI Gym

Real World Assignment:
1. Self-driving cars
2. Deep learning for chatbots

Practical Applications:
1. Autonomous Robot Navigation
2. Industrial Robot Control

Books and other resources

Text Books:

1. Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media, 2017
2. Ian Goodfellow, YoshuaBengio and Aaron Courville, “Deep Learning”, MIT Press, 2017.
3. Nikhil Buduma, "Fundamentals of Deep Learning Designing Next-Generation Machine Intelligence Algorithms" O'Reilly
4. Nikhil Buduma, “Fundamentals of Deep Learning”, SPD
5. Francois chollet, “Deep Learning with Python”

References Books:

1. Richard S. Sutton and Andrew G. Barto, “Reinforcement Learning: An Introduction”
2. SethWeidman, “Deep Learning from Scratch: Building with Python from First Principles”O’Reily
3. Francois Duval, “Deep Learning for Beginners, Practical Guide with Python and Tensorflow”

MOOC Courses Link:
https://www.my-mooc.com/en/categorie/deep-learning

E Books / E Learning References:
1. Michael Nielsen, “Neural Networks and Deep Learning”, Online book, 2016 (http://neuralnetworksanddeeplearning.com/)
2. Deep Learning for Visual Computing https://onlinecourses.nptel.ac.in/noc22_ee54
3. Deep Learning - IIT Kharagpur https://onlinecourses.nptel.ac.in/noc22_cs22
4. Deep Learning - IIT Ropar https://onlinecourses.nptel.ac.in/noc22_cs35/
5. Introduction to Deep Learning : https://www.coursera.org/learn/introduction-to-deep-learning-

boulder

6. Deep Learning Specialization : https://www.coursera.org/specializations/deep-learning

Guidelines for Practical Conduction

Instruction to students:

1. The student shall complete the following activity as a Practical's
2. Students need to apply the computational algorithms using suitable software / programming language.
3. Experiment 1, 2, 3, 6 & 7 are compulsory. Experiment 2 to 7 to be taken on same data set.

Course Objectives

The laboratory course aims to:

1. Introduce students to implementation aspects of deep learning and reinforcement learning.
2. Develop practical skills in dataset preprocessing, model training, evaluation, and deployment.
3. Enable students to implement CNNs, GANs, transfer learning, and reinforcement learning algorithms.
4. Provide exposure to cloud AI platforms and industry-oriented AI development workflows.
5. Familiarize students with ethical AI practices and explainable AI concepts.
6. Encourage mini-project based learning for robotics and industrial automation applications.

Course Outcomes (COs)

Upon successful completion of the course, students will be able to:

CO1	Implement basic deep learning models using TensorFlow/PyTorch frameworks.
CO2	Perform dataset preprocessing, feature extraction, and representation learning techniques.
CO3	Develop and evaluate CNN and GAN-based applications.
CO4	Design reinforcement learning models using Q-Learning and Deep Q Networks.
CO5	Apply AI techniques for robotics, industrial automation, and autonomous systems.
CO6	Demonstrate ethical AI practices, model explainability, and deployment basics.

List of Experiments/Case Studies/Mini Projects

Experiment 01

Comparative study of deep learning frameworks: (Case Study)

- TensorFlow
- PyTorch
- Keras

Experiment 02

Implementation of a simple Artificial Neural Network (ANN) for classification using TensorFlow / Keras.

Experiment 03

Performance analysis of activation functions: : (Case Study)

- ReLU
- Sigmoid
- Tanh
- Softmax

Experiment 04

Implementation of Deep Neural Network (DNN) for image classification using MNIST dataset.

Experiment 05

Feature extraction and visualization using CNN.
Experiment 06
Ethics and Responsible AI Module Practical should include: • Bias identification in datasets • Fairness evaluation • Explainable AI visualization • Responsible AI case studies • Ethical implications in autonomous systems
Experiment 07
Introduction to Large Language Models (LLMs): • Prompt engineering basics • Transformer-based text generation demo
Experiment 08
Mini Project – 1 Develop a basic industrial fault classification model using sensor dataset. Suggested Applications: • Machine fault detection • Predictive maintenance • Robot sensor monitoring **Mini Project – 2** Develop an AI-based object recognition system for robotic applications. Suggested Applications: • Industrial inspection • Robot vision • Smart surveillance **Mini Project – Unit 3** Develop a GAN-based synthetic industrial defect generation system. Suggested Applications: • Manufacturing defect simulation • Industrial AI training datasets • Smart quality inspection **Any 1 Mini Project**
Experiment 09
Contemporary Topics (Seminars) Students shall prepare seminars/case studies on any one topic: 1. Generative AI Applications 2. Edge AI for Robotics 3. AI for Industrial Automation 4. Autonomous Navigation Systems 5. AI in Manufacturing 6. Predictive Maintenance using Deep Learning 7. Explainable AI (XAI) 8. Responsible AI Practices 9. AI Bias and Fairness 10. Large Language Models in Robotics **Seminar on above topics (Any One) not limited to above topics**

Suggested Learning Resources

Books:

1. Deep Learning – Ian Goodfellow
2. Hands-On Machine Learning – Aurélien Géron
3. Reinforcement Learning – Richard Sutton & Andrew Barto

Online Platforms:

1. TensorFlow Official Website
2. PyTorch Official Website
3. OpenAI Gym Documentation
4. Google Colab
5. GitHub

<table>
<tr><th colspan="4">Savitribai Phule Pune University
Third Year of Automation & Robotics Engineering (2024 Pattern)</th></tr>
<tr><th colspan="4">MDM-312-AUR: Measurements and Quality Controls Lab</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th>Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Tutorial</td><td>01 Hr./Week</td><td rowspan="2">2</td><td>Oral</td><td>50 Marks</td></tr>
<tr><td>Practical</td><td>02 Hr./Week</td><td>End Semester</td><td>NA</td></tr>
</table>

Prerequisite Courses, if any: Basics of Electronics & Microcontrollers, Control Systems, Basic Mechanical/Kinematics, Linear Algebra and Measurement Systems, C/C++ and Python Programming, Linux Environment, MATLAB Programming

Course Objectives:

1. To enable students to **identify and classify suitable sensors** for various robotic applications.
2. To provide practical exposure to **interfacing sensors** and their integration into robotic systems.
3. To understand the core architecture and communication mechanisms of the **Robot Operating System (ROS)**.
4. To develop hands-on skills in using **3D physics simulators (Gazebo)** and visualization suites (RViz) to model mechanical systems.
5. To cultivate an engineering mindset toward **autonomous robotics** by integrating sensor networks and closed-loop feedback control loops.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Identify, compare, and classify suitable sensors and measurement techniques to minimize errors.

CO2: Interface sensors with robotic systems, interpret multi-dimensional sensor streams, and apply principles of system integration.

CO3: Model and implement native ROS computation graph communication channels on virtual and embedded platforms.

CO4: Design and tune closed-loop dynamic control architectures (such as PID) to regulate physical and simulated systems.

CO5: Evaluate the performance of feedback devices and industrial sensors for localized navigation and hazard avoidance.

Course Contents

The student shall complete a total of **09 experiments** from the following list, selecting 4 from Section A (Metrology & Measurement) and 5 from Section B (Controls & ROS).

Section A: Metrology and Measurement

Practical 1: Linear and Angular Measurement

- **Aims & Objectives:** To understand methods for measurement of length and angles using standard instruments like the Sine Bar.
- **Hardware Requirements:** Sine Bar, slip gauges, dial indicator, surface plate.
- **Hybrid Execution Model:**
  - **Simulation Hour:** Virtual lab demonstration of error minimization in alignment.
  - **Hardware Hour:** Physical measurement of a taper angle on a machined component.

- **Assignment:** Calculate the taper angle and discuss sources of measurement error.

Practical 2: Optical Metrology and Surface Inspection

- **Aims & Objectives:** To study the profile of gear teeth and screw threads using an Optical Profile Projector.
- **Hardware Requirements:** Optical profile projector, sample gears, and threaded bolts.
- **Assignment:** Compare measured profiles with design specifications and identify geometric deviations.

Practical 3: Microscopic Geometry Analysis
Aims & Objectives: To study cutting tool geometry and screw threads using a Tool Maker's Microscope.

Hardware Requirements: Tool maker's microscope, various cutting tools.

Assignment: Document the rake and clearance angles of the cutting tool.

Practical 4: Temperature and Load Measurement
Aims & Objectives: To calibrate and measure physical parameters using thermistors/thermocouples and strain gauges.

Hardware Requirements: Thermistor, Whetstone bridge, strain gauge, load cell, DAQ system.

Assignment: Plot the characteristic curve of the sensor and determine its sensitivity.

Section B: Controls and Robotics
Practical 5: PWM-Based Speed Control
Aims & Objectives: To generate a PWM signal to control the speed of a DC motor and observe behavior across duty cycles.

Hardware Requirements: Microcontroller (Arduino/ESP32), DC motor, motor driver.

Assignment: Write a script to vary duty cycles and log the corresponding motor RPM.

Practical 6: Servo Position Control and Interfacing
Aims & Objectives: To interface a servo motor and control its angular position via a microcontroller.

Hardware Requirements: Microcontroller, servo motor, jumper wires.

Assignment: Implement a sweep function from 0° to 180° and back.

Practical 7: Closed-Loop PID Tuning
Aims & Objectives: To design and tune a PID controller for a mechanical system to achieve a desired transient response.

Hardware Requirements: DC motor with encoder, microcontroller OR Matlab/Simulink.

Assignment: Compare the system response with and without the "D" (derivative) component.

Practical 8: ROS Communication and Visualization
Aims & Objectives: To implement native ROS communication channels (topics/services) and visualize sensor data in RViz.

Hardware/Software Requirements: Linux Workstation, ROS, Gazebo.

Assignment: Create a publisher node for a simulated distance sensor and visualize the data stream.

Practical 9: Constructing a Physical 1D Scanning Radar Array

Aims & Objectives: To mechanically synchronize a distance sensor with a rotational actuator to build a custom scanning asset.

Hardware Requirements: Arduino, Servo Motor, Ultrasonic Sensor (HC-SR04).

Assignment: Write a parsing node to convert polar coordinates (r, θ) to standard 2D Cartesian coordinates.

Practical 10: Mapping and Obstacle Avoidance
Aims & Objectives: To combine multi-sensor feedback with path planning rules to steer a robot around hazards.

Hardware/Software Requirements: Mobile robot platform (physical or simulated in Gazebo).

Assignment: Construct a detailed system-wide architectural flowchart tracing data from sensor detection to motor output.

Books and other resources:

- **Text Books:**

1. Patranabis D., "Sensors and Transducers", Prentice Hall India.
2. Ernest O. Doebelin, "Measurement Systems - Applications and Design", Tata McGraw-Hill.
3. Kuo, B. C., "Automatic Control Systems", Wiley.
4. Quigley, M., "Programming Robots with ROS", O'Reilly Media.

- **Reference Books:**

1. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson.
2. S. R. Ruocco, "Robot Sensors & Transducers", Springer.

- **MOOC / NPTEL:**

1. Sensors and Instrumentation Lab (COEP V-Labs).
2. NPTEL Course "Control Systems" by Prof. M. Gopal.

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Automation & Robotics Engineering

2024 Pattern

Semester VI Courses

With effect from Academic Year 2026-27

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-351-AUR: Smart Factory Technologies				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03Hr./Week	3	**CCE**	30 Marks
Practical	---		**End-Semester**	70 Marks

Prerequisite Courses, if any: Artificial Intelligence & Machine Learning, Deep & reinforcement learning, Fundamentals of Programming Languages, Robot Drives & Control Systems, ROS, Robot Kinematics & Dynamics

Course Objectives:

1. To introduce the concepts, architecture, and applications of Industry 5.0 and Industrial Internet of Things (IIoT).
2. To understand smart manufacturing systems, industrial communication, and cyber-physical systems.
3. To design and develop Digital Twin models for industrial automation applications.
4. To explore intelligent, human-centric, and AI-driven industrial systems using Industry 5.0 technologies.

Course Outcomes:

On completion of the course the learner will be able to;
CO1: Understand Industry 5.0 concepts, IIoT architecture, and industrial communication systems.
CO2: Analyze smart manufacturing systems and industrial automation applications using IIoT.
CO3: Design and implement Digital Twin models for real-time monitoring and predictive analysis.
CO4: Apply Industry 5.0 technologies in intelligent industrial automation and smart factories.

Course Contents

Unit 1	**Fundamentals of Industry 5.0 and IIoT**	**(08 hrs)**

Introduction to Industry 4.0 and Industry 5.0, Evolution of Industrial Revolutions, Human-centric Manufacturing, Industrial Internet of Things (IIoT), Smart Sensors and Actuators, Cyber Physical Systems (CPS), Edge Computing and Cloud Computing, IIoT Architecture and Components, Applications of Industry 5.0 in Smart Manufacturing

Real World Assignment:

1. Smart Factory Monitoring System
2. Predictive Maintenance for Industrial Machines
3. Energy Monitoring using IIoT Sensors.

Practical Applications:

1. Sensor-based industrial data acquisition
2. Smart conveyor automation system
3. Industrial environmental monitoring
4. Remote machine monitoring using IoT dashboard
5. AI-based industrial fault detection.

Unit 2	**Smart Manufacturing and Industrial Automation**	**(08 hrs)**

Smart Manufacturing Systems, Industrial Automation Architecture, SCADA and PLC Integration, Industrial Robotics in Smart Factories, Human-Robot Collaboration (Cobots), Industrial Data Analytics, Artificial Intelligence in Manufacturing, Industrial Cyber Security, Big Data in Manufacturing, Case Studies on Smart Industries

Real World Assignment:

1. Automated Warehouse Management System
2. AI-based Quality Inspection System
3. Smart Robotic Assembly Line

Practical Applications:

1. PLC-based smart automation
2. Robot-assisted manufacturing simulation
3. Predictive maintenance analytics
4. Industrial dashboard development

Unit 3	Fundamentals of Digital Twin Technology	(08hrs)

Introduction to Digital Twin, Components of Digital Twin Systems, Physical and Virtual System Integration, Real-time Data Synchronization, Simulation and Modeling Techniques, IoT-enabled Digital Twin, Data Acquisition and Visualization, Predictive Analysis using Digital Twin, Applications in Automotive, Healthcare, and Manufacturing

Real World Assignment:

1. Digital Twin of Smart Manufacturing System
2. Virtual Monitoring of Industrial Motor

Practical Applications:

1. Real-time equipment monitoring
2. Simulation of robotic arm using Digital Twin
3. Machine health prediction system

Unit 4	Advanced Industry 5.0 Applications and Future Trends	(06hrs)

AI-driven Smart Factories, Autonomous Industrial Systems, Collaborative Robotics and Cobots, Augmented Reality (AR) and Virtual Reality (VR) in Industry, Blockchain in Smart Manufacturing, Sustainable and Green Manufacturing, Digital Supply Chain Management, Future Trends in Industry 5.0 Challenges and Opportunities in IIoT and Digital Twin.

Real World Assignment:

1. Smart Healthcare Monitoring System
2. Autonomous Mobile Robot for Industry
3. AI-powered Smart Production System

Practical Applications:

1. AR/VR-based industrial simulation
2. Intelligent robot navigation system
3. Smart factory virtual dashboard

Unit 5	Dark Factories and Autonomous Logistics	(06hrs)

Dark Factory Foundations: Definition and scope of lights-out manufacturing; evolution from Flexible Manufacturing Systems (FMS) to fully autonomous, unattended production environments

Unattended Machining: Technical requirements for independent machine operation; automated tool management, chip disposal, and self-correcting machining cycles

Autonomous Material Handling - Automated Guided Vehicle Systems (AGVS) and Automated Storage and Retrieval Systems (ASRS)

Intelligent Identification & Tracking: Implementation of Automatic Data Capture (ADC) technologies, including RFID, Barcoding, and Optical Character Recognition (OCR), to ensure real-time component traceability in dark environments.

Autonomous Oversight: Use of Digital Twins and IIoT for remote monitoring and real-time synchronization; AI-driven Predictive Maintenance to identify and rectify equipment faults without human intervention

Real World Assignment:

1. Automated Warehouse Design: Develop a conceptual design for an Automated Warehouse Management System using AGVs and ASRS for a lights-out logistics hub
2. Predictive Maintenance Loop: Implement an IoT-enabled system to monitor machine health (vibration, spindle load) for unattended CNC machines to predict failures.
3. Simulation Study: Use discrete event simulation to evaluate the throughput and identify

bottlenecks in a simulated dark factory work-cell

Books and other resources

TextBooks:

1. Industry 4.0: The Industrial Internet of Things – Alasdair Gilchrist
2. Digital Twin Driven Smart Manufacturing – Fei Tao and Ang Liu
3. Industrial Internet of Things – Sabina Jeschke
4. Hands-On Industrial Internet of Things – Giovanni Aloi
5. Smart Manufacturing – Masoud Soroush

ReferencesBooks:

1. Internet of Things: A Hands-On Approach – Arshdeep Bahga
2. Artificial Intelligence for Industry 4.0 – Alok Kumar
3. Digital Twin Technologies and Smart Cities – Mohammad Aazam

MOOC Courses Link:
https://www.my-mooc.com/en/categorie/deep-learning

E Books / E Learning References:

1. IBM – Industrial Internet of Things (IIoT) Fundamentals
   Comprehensive introduction to Industrial IoT architecture, smart manufacturing, sensors, and industrial connectivity.
2. GE Digital – Digital Twin Technology Overview
   Covers Digital Twin concepts, predictive maintenance, industrial monitoring, and real-time analytics.
3. NPTEL – Industry 4.0 and Industrial Internet of Things
   Online learning modules related to smart manufacturing, automation, IIoT, and cyber-physical systems.
4. Coursera – Digital Twin Courses
   Industry-oriented certification courses on Digital Twin applications and smart industrial systems.
5. edX – Smart Manufacturing and Industry 4.0 Courses
   Courses focused on Industry 4.0/5.0 technologies, AI integration, and intelligent manufacturing systems.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
MDM-352-AUR: Modeling and Simulation				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	**03 Hr/Week**	**3**	**CCE**	30 Marks
Practical	--		**End-Semester**	70 Marks

Course Prerequisites: Engineering Mathematics (Statistics and Numerical Methods), Basics of MATLAB/Simulink, Robot Kinematics

Course Objectives:

1. To introduce the fundamentals of system modeling and model-based problem-solving in automation.
2. To teach techniques for data collection, preprocessing, and statistical analysis for input modeling.
3. To enable students to generate random numbers/variates and perform model validation.
4. To apply simulation methodologies to optimize manufacturing systems and robotic workcells.
5. To familiarize students with modern **industrial simulation software** and Digital Twin concepts

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Solve industrial problems based on **simulation principles** and distinguish between various system classifications.

CO2: Perform **input modeling** by identifying probability distributions and generating pseudo-random variables.

CO3: Execute **verification and validation** (V&V) of simulation models using historical data and Turing tests.

CO4: Develop virtual models for **manufacturing throughput analysis**, line balancing, and capacity utilization.

CO5: Utilize **modern simulation tools** (ARENA, MATLAB, ROS-Gazebo) for real-world automation case studies

Course Contents

Unit 1	**Introduction to Simulation & System Simulation**	**6 Hrs**

A review of basic probability and statistics, Definition and concepts of simulation and modeling, steps in a simulation study, Modeling concepts, Advantages, Disadvantages and Applications areas of simulation Basic principles of simulation modeling, Model based problem solving. Component of a system – Continuous and discrete systems – Types of models; Steps in Simulation study; simulation of an event occurrence using random number table – Single server queue. Discrete Event Simulation: Concepts in discreet event simulation

Real World Assignment:

1. Assembly Line Analysis: Study and prepare a report on an automated assembly line system and develop a simulation-based case study to analyze the effect of buffer stock on productivity and downtime.
2. Mechanical Modeling: Formulate and solve a second-order differential equation to model the behavior of a Mass-Spring-Damper system representing a robotic joint

Practical Applications:

1. MATLAB/Simulink Integration: Use MATLAB or Simulink for the mathematical modeling of mechanical and electromechanical components of an automation system.
2. Virtual Environments: Utilize robotics simulation software (e.g., ROS/Gazebo) to create simulated environments for testing autonomous algorithms without the need for physical hardware.
3. Manufacturing Throughput: Apply simulation to solve industrial engineering issues such as line balancing, capacity utilization, and machine loading/unloading efficiency

Unit 2	Simulation Software	7 Hrs
Introduction to Simulation Software, Comparison of Simulation Software with Programming Languages, SLAM and SIMAN Overview, Desirable Features of Simulation Software, Classification of Simulation Software, General Purpose vs. Object-Oriented Simulation Packages, Examples: ARENA, SimFactory, Promodel, Witness		
Real World Assignment: 1. Sensor Interfacing: Interface transducers (Ultrasonic, IR, Temperature) with microcontrollers like Arduino or 8051 and display outputs via LCD or serial monitors. 2. Control Systems: Design and tune closed-loop PID architectures to regulate motor speed and evaluate system stability using root locus or Bode plots. 3. Robot Simulation: Use MATLAB, Gazebo, or RoboAnalyzer to verify forward and inverse kinematics and perform dynamic analysis of serial manipulators		
Practical Applications: 1. Manufacturing: Analyze automated assembly lines to identify methods for line balancing and the effects of buffer stock on productivity. 2. Simulation: Use Monte Carlo techniques to predict outcomes in stochastic inventory models and Petri nets to organize concurrent robot workcell logic. 3. Operations: Analyze the logic of service systems, such as automated parking or supermarket checkouts, using M/M/1 and M/M/s queuing models. 4. Predictive Maintenance: Integrate CNC machine sensors with IoT devices for real-time data acquisition and health monitoring		
Unit 3	**Analysis of Simulation Data**	**7 Hrs**
Nature of simulation, Roots of simulation input modeling, Data collection, Identifying distribution, Histograms, practical methods for testing assumptions Random Number Generation: Introduction, Desired properties, Generation of pseudo random numbers.		
Real World Assignment: 1. Robotic Arm Cycle Time Analysis 2. AGV (Automated Guided Vehicle) Movement Simulation 3. Warehouse Robot Navigation Study		
Practical Applications: 1. Random Number Generator for Robot Task Scheduling 2. Robot Assembly Line Simulation 3. Mobile Robot Path Planning Simulation		
Unit 4	**Random Variate Generation**	**7 Hrs**
Introduction, Factors considered in selecting generator, Generating continuous random variates like Uniform, Exponential, Weibull, Normal Output Data Analysis: Introduction, Types of simulations with regard to output analysis – terminating and nonterminating simulation		
Real World Assignment: 1. Simulation of Robotic Assembly Line Using Continuous Random Variables 2. Mobile Robot Battery Life Simulation 3. AGV Material Handling System Simulation		
Practical Applications: 1. Weibull Distribution for Robot Failure Analysis 2. Autonomous Mobile Robot (AMR) Navigation Simulation 3. Simulation of Robot Cycle Time Using Normal Distribution		
Unit 5	**Industrial Simulation Tools and Manufacturing Systems**	**7 Hrs**
Need of simulation in manufacturing and material handling systems, Components of manufacturing systems – product, resources, demand, control; Downtime, Rework and reentrancy, Random events and performance measures used in manufacturing systems with a case study on any manufacturing system Material Handling Systems – Input parameters for automated material handling systems, Conveyor and vehicle systems, job shop with material handling and flexible manufacturing systems.		

Real World Assignment:

1. Downtime and Rework Analysis in a CNC Manufacturing Cell
2. Flexible Manufacturing System (FMS) Performance Evaluation
3. Simulation Study of an Automated Assembly Line

Practical Applications:

1. Conveyor System Simulation
2. Assembly Line Performance Analysis
3. Machine Downtime and Preventive Maintenance Analysis

Books and other resources

Text Books:

1. Averill M Law, “Simulation Modelling and Analysis”, Fourth Edition, Tata McGraw Hill
2. Education Private Ltd, New Delhi, 2010.
3. Banks, J., J. S. Carson II, and B. L. Nelson. “Discrete-Event System Simulation”, Second Edition, Prentice Hall,
4. Bratley, P., B. L. Fox, and L. E. Schrage “A Guide to Simulation”, 2nd ed., Springer-Verlag, New York
5. Fishman, G.S., “Monte Carlo: Concepts, Algorithms and Applications”, Chapman &Hall, New York.

References Books:

1. System Simulation, Geoffrey Gorden, Prentice Hall of India, 2003.
2. System Simulations and Modeling, Narsingh deo., Prentice Hall of India 2003.
3. Computer simulations and Modeling, Francis Neelamkovil, , john Wiley & Sons, 1987
4. Simulation Modeling with Pascal, Rath M.Davis & Robert M O Keefe, Prentice Hall Inc. 1989

Digital & E-Learning Resources

6. NPTEL Course on "Discrete Event Simulation".
7. https://onlinecourses.nptel.ac.in/e-learning/preview/noc24_me14

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC353AUR: Actuators and Controllers				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	3	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Electrical circuits, semiconductor devices, analog and digital electronics fundamentals.
- Fundamentals of transducers, feedback systems, open-loop and closed-loop control concepts, and PID basics.
- Basic C/C++ programming, microcontrollers, and interfacing concepts.

Course Objectives:

1. To understand the principles, characteristics, and applications of actuation systems used in automation and robotics.
2. Develop knowledge of power electronic devices, amplifiers, and drive circuits for efficient control and operation of industrial actuators and motors.
3. Study the working principles, interfacing techniques, and applications of feedback devices and industrial sensors used for motion, position, force, and process control.
4. Understand open-loop, closed-loop, and PID-based control systems for automation applications.
5. Develop the ability to design and implement industrial and embedded controller.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Explain the operating principles, characteristics, and applications of actuation systems used in industrial automation and robotics.

CO2: Analyze power electronic devices, amplifiers, and motor drive circuits for efficient control and performance enhancement of automation systems.

CO3: Evaluate the performance of feedback devices and industrial sensors for measurement and closed-loop control applications.

CO4: Apply controller architecture, mathematical modeling, and classical control techniques including PID control for automation and robotic systems.

CO5: Design and implement controller-based solutions for industrial automation, robotics, and Industry 4.0 applications.

Course Contents

Unit I	**Fundamental Drives and Actuation Systems**	**(09 Hours)**

Electric Actuators: Brushed and Brushless DC (BLDC) motors, AC servo motors, and stepper motors.
Electromagnetic Fundamentals: Electromagnetism, Lorentz force, commutation, back-EMF, and torque constants.
Fluid Power Actuators: Pneumatic and Hydraulic cylinders, rotary actuators, proportional control valves, and compressor systems.
Specialty Actuators: Piezoelectric actuators, Shape Memory Alloys (SMA), and Series Elastic Actuators (SEAs).
Transmission Systems: Harmonic drives, gear reducers, ball screws, timing belts, and backlash compensation.

Real World Assignment:

1. Compare hydraulic, pneumatic, and electrical actuators based on:
   Speed ,Accuracy, Cost, Load capacity , Maintenance, Prepare industrial application mapping.
2. Actuator Selection for Robotic Arm
   Select suitable actuators for: Base rotation, Elbow movement, Gripper operation

Exemplars / Practical Applications:

1. Industrial robot arm movement systems
2. Automatic door opening systems
3. CNC machine tool positioning
4. AGV (Automated Guided Vehicle) steering control
5. Smart home automation devices
6. Robotic grippers in manufacturing

Unit II	Power Electronics and Amplifiers	(09 Hours)

Power Semiconductor Devices: MOSFETs, IGBTs, and Thyristors used in motor drives.
Drive Topologies: H-bridge circuits, Pulse Width Modulation (PWM) amplifiers, and regenerative braking.
Current and Voltage Control Loops: Cascade control strategies (Position loop \ (\right arrow \) Velocity loop \(\right arrow \) Current loop).
Thermal Management: Heat sinks, thermal dissipation, and drive protection circuits.

Real World Assignment:

- Study hydraulic lift system of automobile service station.

Calculate:
Cylinder force
Pressure requirement
Flow rate

Practical Applications:

1. Hydraulic press machines
2. Excavators and heavy machinery
3. Pneumatic pick-and-place robots
4. Air brake systems
5. Automated packaging systems

Unit III	Feedback Devices and Sensors	(09 Hours)

Position and Velocity Sensors: Optical encoders (incremental and absolute), resolvers, Hall-effect sensors, and tachometers.
Force/Torque Sensors: Strain gauges, tactile array sensors, and 6-axis Force/Torque (F/T) sensors.
Sensor Interfacing & Conditioning: Analog-to-Digital (ADC) conversion, signal filtering, and noise reduction.

Real World Assignment:

CNC Machine Tool Positioning

1. Incremental encoders monitor motor shaft rotation.

Used for:

- Tool positioning
- Axis movement tracking
- Feed control

Practical Applications:

1. 3D printers
2. Industrial robots
3. Elevators
4. Packaging systems
5. Textile machinery

Unit IV	Controller Architecture and Control Theory	(09 Hours)

Classical Control: Proportional-Integral-Derivative (PID) control, tuning methods (Ziegler-Nichols), and lead-lag compensators.
State-Space Modeling: Dynamic equations of actuators, state feedback, and pole-placement techniques.
Advanced Control Strategies: Feed forward control, Computed Torque Control (CTC), and Adaptive Control.
Motion Interpolation and Planning: Trajectory generation, cubic and quantic polynomials, and spline generation

Real World Assignment:

1. PID Controller Tuning:

- Implement PID control for:

- DC motor speed control
- Temperature control system

Practical Applications:
1. Temperature control systems
2. Speed control of motors
3. Autonomous mobile robots
4. Industrial process control
5. Robotic trajectory control

Unit V	Industrial and Embedded Controllers	(09 Hours)

Microcontrollers and DSPs: Real-time processing, interrupt handling, and embedded C/C++ programming.
Programmable Logic Controllers (PLCs): Ladder logic programming, sequential function charts, and industrial automation networks (e.g., Ether CAT, Profinet).
Industrial Robot Controllers: Teach pendant programming, kinematics solvers, and safety-rated controller architectures.
Motion Controllers & Drives: Standalone motion controllers, distributed axis control, and CAN open communication protocols

Real World Assignment:
1. Develop IoT system to monitor:
- Motor temperature
- Speed
- Current

Practical Applications:
1. Arduino-based robotic systems
2. Raspberry Pi automation projects
3. IoT-enabled smart factories
4. Autonomous mobile robots

Books and other resources

Text Books:
1. *Actuators: Design Fundamentals* by J. корф (Korf) and H. J.
2. *Robotics: Modelling, Planning and Control* by Bruno Siciliano, Lorenzo Sciavicco, et al.
3. Robotics-control and programming by J. Srinivas, Narosa Publication 2. Industrial Robotics by M.P. Groover, McGraw Hill Publication
4. Industrial Robotics by Ganesh S. Hegde, Laxmi Publication
5. *Feedback Control of Dynamic Systems* by Gene F. Franklin, J. David Powell, and Abbas Emami-Naeini.
6. *Modern Control Engineering* by Katsuhiko Ogata.

References Books:
1. Fundamental of Robotics: Analysis and Control by Robert J Schilling, Person Publication Education
2. "Industrial Automation and Robotics" by A.K. Gupta and S.K. Arora (Indian Authors)
3. Kuo B.C., Automatic Control Systems, Prentice-Hall of India Pvt Ltd., New Delhi, 6th edition, 1991.

MOOC Courses Link:
1. Prof. Siddhartha Mukhopadhyay, |IIT Kharagpur, “Industrial Automation and Controllers”. https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_me67
2. Prof. Hardik Jeetendra Pandya|, IISc Bangalore, “Sensors and Actuators” https://onlinecourses.nptel.ac.in/e-learning/preview/noc25_ee76
3. Prof. Banibrata Mukherjee |IIT Kharagpur , “Embedded Sensing, Actuation & Interfacing Systems”. https://onlinecourses.nptel.ac.in/e-learning/preview/noc24_ee68

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-361A-AUR: BATTERY MANAGEMENT SYSTEMS				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	3	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

Basic Electrical Engineering, Electronic Devices and Circuits, Sensors and Instrumentation, Control Systems, Introduction to Electric Vehicles (Desirable)

Course Objectives:

1. Understand the architecture and operation of Battery Management Systems (BMS) used in electric vehicles, robots, drones, and energy storage systems.
2. Analyze battery behavior, estimate battery states, and evaluate battery performance under different operating conditions.
3. Design battery protection, monitoring, and balancing systems for lithium-ion battery packs.
4. Develop embedded Battery Management Systems integrating sensors, communication protocols, and IoT technologies.
5. Apply artificial intelligence and predictive algorithms for intelligent battery monitoring, diagnostics, and battery life optimization.

Course Outcomes:

On completion of the course the learner will be able to;

- **CO1:** Explain the construction, characteristics, and operating principles of modern rechargeable batteries and Battery Management Systems.
- **CO2:** Analyze battery performance using State of Charge (SOC), State of Health (SOH), State of Power (SOP), and Remaining Useful Life (RUL) estimation techniques.
- **CO3:** Design battery protection circuits and cell balancing techniques to improve battery safety and lifespan.
- **CO4:** Develop embedded Battery Management Systems integrating sensors, communication protocols, and cloud-based monitoring.
- **CO5:** Evaluate advanced Battery Management Systems using Artificial Intelligence, Digital Twin technology, and industrial case studies.

Course Contents

Unit 1	Fundamentals of Battery Management Systems	(06 hrs)

Introduction: Energy storage technologies, Role of batteries in Electric Vehicles, Robotics, UAVs, AGVs and Energy Storage Systems, Need for Battery Management System, Functions of BMS. **Battery Technologies:** Lead Acid Batteries, Nickel Metal Hydride (NiMH), Lithium-Ion Batteries Lithium Polymer Batteries, LFP, NMC, NCA chemistries, Solid-State Batteries (Overview). **Battery Fundamentals**: Cell construction, Battery terminology, Capacity, C-rate, Energy density, Power density, Battery pack architecture, Series and parallel configuration, Module and pack design, Battery **Failure Mechanisms:** Ageing, Capacity fade, Internal resistance growth, Thermal runaway, Safety concerns, **Applications:** Electric Vehicles, Industrial Robots, AMRs, Drones, UPS, Renewable Energy Storage

Suggested Case Study: Battery Architecture of Tesla Model 3 / Tata Nexon

Unit 2	Battery Characterization and State Estimation	(08 hrs)

Battery Characteristics: Charge-discharge characteristics, Open Circuit Voltage (OCV), Terminal Voltage, Polarization, Battery efficiency, Coulombic efficiency. Battery Parameters: Internal resistance, Capacity estimation, Battery degradation, Temperature effects. **Battery State Estimation:** State of Charge (SOC), State of Health (SOH), State of Power (SOP), Remaining Useful Life (RUL). **Estimation Techniques:** Coulomb Counting, Open Circuit Voltage Method, Equivalent Circuit Model, Kalman Filter, Extended Kalman Filter, Unscented Kalman Filter (Introduction), AI-based estimation methods. **Battery Testing:** Capacity testing, HPPC Test, Charge-discharge cycling, Battery characterization

Suggested Case Study: SOC estimation in Battery Electric Vehicles

Unit 3	Battery Protection and Cell Balancing	(08 hrs)

Battery Protection: Over-voltage protection, Under-voltage protection, Over-current protection, Over-temperature protection, short circuit protection, Reverse polarity protection, Isolation monitoring. **Battery Safety:** Thermal runaway, Fault diagnosis, Safety interlocks, Contactors, Fuse selection, pre-charge circuit, **Cell Balancing:** Need for balancing, Type of Cell Balancing, **Performance Comparison:** Efficiency, Cost, Complexity, Reliability

Suggested Case Study: BYD Blade Battery Safety System

Unit 4	Embedded Battery Management Systems	(08 hrs)

BMS Hardware Architecture: Master-slave architecture, Distributed BMS, Centralized BMS, Modular BMS. **Battery Monitoring:** Voltage sensing, Current sensing, Temperature sensing, Hall Effect sensors, Shunt resistor, Isolation measurement. **Battery Management ICs:** Analog Front End (AFE), Cell monitoring ICs, Protection ICs. **Embedded Controllers:** Microcontrollers, ARM processors, Embedded software, Real-time operating systems. **Communication Protocols:** CAN Bus, LIN, UART, SPI, I^2C, Modbus, Ethernet (Introduction), **IoT Integration:** Cloud monitoring, Remote diagnostics, Data logging, MQTT, Edge Computing

Suggested Case Study: BMS Architecture used in Electric Buses

Unit 5	Intelligent Battery Management Systems and Industrial Applications	(06 hrs)

Artificial Intelligence in BMS: Machine Learning for SOC prediction, Machine Learning for SOH prediction, Fault diagnosis, Predictive maintenance, Neural Networks, Deep Learning (Overview). **Digital Twin:** Digital Twin concepts, Battery simulation, Virtual battery testing, Cloud analytics. **Smart Charging:** Fast charging, Opportunity charging, Battery swapping, Wireless charging, Charging optimization. **Emerging Technologies:** Wireless BMS, Cybersecurity in BMS, Battery Passport, Cloud-connected Battery Systems. **Standards:** AIS-156, AIS-038 Rev 2, UL 2580, IEC 62660, ISO 26262 (Overview). **Industrial Applications:** Electric Cars, Electric Buses, Mobile Robots, Collaborative Robots, AGVs, Warehouse Automation, Drone Battery Management, Grid Energy Storage

Suggested Case Study: CATL Intelligent Battery Management Platform

Real World Assignments:

1. Battery Pack Selection for an Autonomous Mobile Robot (AMR)
2. Design of a Smart Battery Monitoring Dashboard
3. Comparative Study of Commercial Battery Management Systems
4. Battery Health Assessment of an Electric Two-Wheeler

5. AI-Based State of Charge Prediction
6. Battery Safety Audit
7. Design of an IoT-Based Battery Monitoring System
8. Battery Failure Investigation
9. Design of a Battery Management System for an Industrial AGV
10. Life Cycle and Sustainability Assessment of Lithium-Ion Batteries

Practical Applications:

1. Battery Management System for Electric Vehicles
2. Battery Monitoring for Autonomous Mobile Robots (AMRs)
3. IoT-Based Remote Battery Monitoring
4. Cell Balancing System Development
5. Battery Thermal Monitoring and Protection
6. CAN-Based Communication in Battery Packs
7. Battery Fault Diagnosis Using AI
8. Battery Management for Drones
9. Battery Monitoring for Renewable Energy Storage
10. Digital Twin of a Battery Pack
11. Fast Charging Management
12. Battery Health Analytics Dashboard
13. Battery Pack Design for an Automated Guided Vehicle (AGV)
14. Smart Battery Charging Station
15. Predictive Maintenance of Industrial Battery Systems

Books And Other Resources

Text Books:

- Gregory L. Plett, Battery Management Systems, Volume I: Battery Modelling, Artech House.
- Gregory L. Plett, Battery Management Systems, Volume II: Equivalent Circuit Methods, Artech House.
- Gregory L. Plett, Battery Management Systems, Volume III: Battery State Estimation, Artech House.
- Davide Andrea, Battery Management Systems for Large Lithium-Ion Battery Packs, Artech House.
- Rui Xiong, Battery Management Algorithms for Electric Vehicles, Wiley.

Reference Books:

- Mehrdad Ehsani et al., Modern Electric, Hybrid Electric and Fuel Cell Vehicles, CRC Press.
- James Larminie and John Lowry, Electric Vehicle Technology Explained, Wiley.
- Jiuchun Jiang, Fundamentals and Applications of Lithium-Ion Batteries in Electric Drive Vehicles, Wiley.
- Ibrahim Dincer and Halil S. Hamut, Thermal Management of Electric Vehicle Battery Systems, Wiley.
- Texas Instruments, Battery Management System Design Guide.

Learning Resources:

- NPTEL – Electric Vehicles
- NPTEL – Energy Storage Systems
- SWAYAM – Battery Technologies

- MATLAB Academy – Simscape Battery
- Coursera – Battery Management Systems
- MathWorks Onramp – Simscape Battery

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)					
PEC-361B-AUR: MOBILE ROBOTICS					
Teaching Scheme		**Credits**	**Examination Scheme**		
Theory	03 Hr./Week	3	**CCE**	30 Marks	
Practical	NA		**End-Semester**	70 Marks	

Prerequisite Courses, if any:

- Principles of Robotics, Sensors & Vision Systems, Robot Operating System (ROS).

Course Objectives:

1. To introduce the fundamental principles of locomotion for wheeled, legged, and track-based robots.
2. To develop kinematic and dynamic models for various mobile robot configurations.
3. To familiarize students with perception and sensing requirements for autonomous navigation.
4. To teach strategies for localization, mapping, and SLAM (Simultaneous Localization and Mapping).
5. To explore path planning, obstacle avoidance, and the deployment of autonomous systems in real-world environments.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Evaluate and select appropriate mobile robot types for specific industrial and service applications.

CO2: Develop kinematic models for differential drive, holonomic, and legged robotic systems.

CO3: Analyze sensor data and handle uncertainty in robot perception using probabilistic methods.

CO4: Implement localization and mapping algorithms for autonomous spatial awareness.

CO5: Design and simulate navigation stacks for autonomous motion and reactive hazard avoidance

Course Contents

Unit 1	Fundamentals of Locomotion	(06 hrs)

Introduction: Overview of mobile robotics; classification of robots: ground (wheeled, legged, tracked), aerial (UAVs), and underwater (AUVs). Locomotion Mechanics: Key issues in locomotion; stability and configurations of legged robots; design space and mobility issues for wheeled robots. Drive Systems: Differential drive, omnidirectional (Mecanum), and synchronous drive mechanisms.

Unit 2	Kinematic and Dynamic Modeling	(08 hrs)

Kinematics: Representation of robot position; forward and inverse kinematics of wheeled robots; wheel and robot constraints., Mobility: Degrees of mobility and steerability; maneuverability and workspace analysis., Motion Control: Holonomic and non-holonomic constraints; open-loop and feedback motion control; trajectory considerations.

Unit 3	Perception for Autonomy	(08 hrs)

Sensing: Sensors for mobile robots: wheel/motor encoders, heading sensors (gyroscopes, accelerometers, magnetic compass), and GNSS., Active Ranging: Ultrasonic sensors, Laser scanners (LiDAR), and infrared rangefinders., Vision-based Perception: Camera models; feature extraction from range data; visual appearance-based recognition., Handling Uncertainty: Statistical representations and error propagation in sensor data.

Unit 4	Localization and Mapping	(08 hrs)
Foundations: Challenges of localization: sensor noise, aliasing, and belief representation, Techniques: Dead reckoning; beacon-based and landmark-based navigation, Probabilistic Localization: Markov localization; Kalman Filter (EKF/UKF) and Particle Filtering for state estimation, Mapping: Autonomous map building; grid maps, sector maps, and hybrid maps, SLAM: Introduction to Simultaneous Localization and Mapping techniques		

Unit 5	Navigation and Path Planning	(06 hrs)
Path Planning: Point-to-point motion; Dijkstra's algorithm; A*algorithm; and probabilistic roadmaps., Obstacle Avoidance: Reactive behaviors; potential field methods; virtual force field methods., Collaborative Robotics: Introduction to swarm robots and cooperative multi-robot navigation.		

Real World Assignments:

1. Feasibility Study: Evaluate and document the appropriate mobile robot configuration for an automated warehouse application, considering payload and floor constraints.
2. Sensor Fusion Report: Prepare a report on integrating LiDAR and IMU data for a self-driving delivery bot to improve localization accuracy in GPS-denied environments.
3. Kinematic Analysis: Perform a forward kinematic analysis for a differential drive robot and verify it using computational tools.

Practical Applications:

1. Line Following with PID: Build and tune a PID-controlled line-follower robot for warehouse delivery simulation.
2. Autonomous Navigation in Gazebo: Deploy a ROS navigation stack inside a Gazebo maze environment to drive a vehicle toward a coordinate goal while avoiding virtual walls.
3. HIL Odometry: Use an ESP32 or Arduino to capture raw motor encoder ticks and publish serialized odometry packets to a ROS host for travel tracking.
4. Obstacle Avoidance Logic: Program a robot to execute reactive stop-and-turn routines based on real-time ultrasonic distance streams.

Books and other resources

Text Books:

1. Roland Siegwart & Davide Scaramuzza, "Introduction to Autonomous Mobile Robots", MIT Press.
2. Howie Choset et al., "Principles of Robot Motion: Theory, Algorithms, and Implementation", MIT Press.
3. Srikanta Patnaik, "Robot Cognition and Navigation", Springer.

Reference Books:

1. **Peter Corke**, *"Robotics, Vision and Control"*, Springer.
2. **Alonzo Kelly**, *"Mobile Robotics: Mathematics, Models, and Methods"*, Cambridge University Press.
3. **Anis Koubaa**, *"Robot Operating System (ROS): The Complete Reference"*, Springer.

Learning Resources:

1. **NPTEL:** "Wheeled Mobile Robots" by Prof. Asokan Thondiyath, IIT Madras.
2. **Coursera:** "Modern Robotics: Mechanics, Planning, and Control Specialization".
3. **ROS Official:** "ROS 2 Navigation (Nav2) Tutorials".

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-361C-AUR: Additive Manufacturing				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	3	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Manufacturing Technology.
- Engineering Metallurgy and Engineering Materials.
- Product Development Lab.

Course Objectives:

1. To introduce the development, capabilities, and business opportunities of Additive Manufacturing (AM).
2. To familiarize students with various software tools and CAD data formats required for AM.
3. To understand the mechanisms and physics of light-based, laser-based, and extrusion-based deposition processes.
4. To gain knowledge on material selection and Design for Additive Manufacturing (DfAM) principles.
5. To explore hardware construction, post-processing techniques, and quality considerations in AM systems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Classify and evaluate the fundamentals of Additive Manufacturing technologies compared to conventional methods.

CO2: Analyze and select appropriate light and laser-based photo-curing or melting processes for specific applications.

CO3: Demonstrate proficiency in extrusion and inkjet-based deposition technologies.

CO4: Apply DfAM rules, including topology optimization and lattice structure design, to improve part performance.

CO5: Execute post-processing and quality inspection protocols to address common AM defects.

Course Contents

Unit 1	**Introduction to Additive Manufacturing**	**06 hrs**

Foundations: Definition, historical development, and role of AM in the product development cycle.

Classification: Process-based, material-based, and application-based classifications (ASTM/ISO 52900 standards).

Industry 4.0 Relevance: Role of AM in smart manufacturing and the AM process chain.

Application Domains: Case studies in Aerospace, Healthcare (Bio-printing), and Automobile industries.

Unit 2	**Light and Laser-Based Techniques**	**08 hrs**

Photo-curing: Stereolithography (SLA), Digital Light Processing (DLP), and Continuous Liquid Interface Production (CLIP).

Laser Melting: Selective Laser Sintering (SLS), Selective Laser Melting (SLM), and Direct Metal Laser Sintering (DMLS).

Directed Energy: Laser Engineered Net Shaping (LENS), Laser Wire Deposition, and 3D Laser Cladding.

Unit 3	**Extrusion and Energy-Based Deposition**	**08 hrs**

Material Extrusion: Fused Deposition Modeling (FDM), Fused Filament Fabrication (FFF), and Direct Ink Writing (DIW).

Inkjet-Based Fusion: Multi-jet Modeling (MJM), Polyjet printing, Binder Jetting, and Multi-jet

Unit 4	Design and Materials for AM	08 hrs
Materials: Properties and preparation of Metals, Polymers, Ceramics, and Composites for AM. **DfAM Principles**: Topology optimization, generative design, part consolidation, and lattice structure integration. **Process Specifics:** Support structure design, part orientation strategies, and multi-material printing.		
Unit 5	**AM Hardware, Software, and Quality**	**06 hrs**
System Architecture: Construction of basic AM machines; extruder, nozzle, and build platform design considerations. **Data Processing:** AM file formats (STL, AMF); STL error fixing, slicing, and tool path generation. **Post-Processing:** Support removal, sanding, polishing, and heat treatments. **Quality Control:** Inspection methods, testing for defects and error source analysis.		

Assignments and Practical Applications:

Real World Assignments:

1. **Product Feasibility Study:** Identify a conventional industrial component and prepare an AM process plan, justifying the selection of material and technology.
2. **Comparison Report:** Prepare a 2-3 page report comparing the cost, lead time, and strength of a 3D-printed part versus its conventionally machined counterpart.
3. **Industrial Visit:** Visit a facility utilizing advanced manufacturing (SLA/SLS) and document the process parameters and post-processing steps observed.

Practical Applications:

1. **CAD Data Exchange:** Model a single functional part (e.g., a gear or bracket) in CAD software and export it to an error-free STL file.
2. **Slicing and Orientation:** Perform part orientation and support structure generation for a complex geometry to minimize print time and material usage.
3. **Topology Optimization:** Design and print a topology-optimized structure to achieve weight reduction while maintaining structural integrity.
4. **Defect Analysis:** Inspect an additively manufactured product to identify defects (e.g., warping, layer shifting) and propose corrective measures.

Books and other resources:

Text Books:

1. Ian Gibson, David Rosen, & Brent Stucker, "Additive Manufacturing Technologies", 3rd Edition, Springer.
2. Andreas Gebhardt & Jan-Steffen Hötter, "Additive Manufacturing: 3D Printing for Prototyping and Manufacturing", Hanser.
3. Amit Bandyopadhyay & Susmita Bose, "Additive Manufacturing", CRC Press.

References Books:

1. Chua Chee Kai & Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", World Scientific.
2. Milan Brandt, "Laser Additive Manufacturing: Materials, Design, Technologies, and Applications", Woodhead Publishing.
3. Kamrani A.K. & Nasr E.A., "Rapid Prototyping: Theory and Practice", Springer.

MOOC Courses Link:

1. NPTEL: "Fundamentals of Additive Manufacturing Technologies" by Prof. Sajan Kapil, IIT Guwahati.
2. NPTEL: "Rapid Manufacturing" by Prof. Janakarajan Ramkumar, IIT Kanpur.
3. Autodesk Fusion 360 Courses: [Online tutorials for DfAM and STL editing].

Savitribai Phule Pune University Third Year of Mechanical Engineering (2024 Pattern)				
PEC 361D-MEC: Industrial Engineering				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Basic concepts of Mathematics and Mechanical Engineering, Industrial Orientation, Quality Control, Human Psychology, Basic Finance, Passion for Continual Improvement

Course Objectives:

1. To INTRODUCE the concepts, principles, and framework of Industrial Engineering and Productivity enhancement approaches.
2. To FAMILIARIZE the students with different time study and work measurement techniques for productivity improvement.
3. To INTRODUCE various aspects of facility design.
4. To ACQUAINT the students with various components and functions of Production Planning and Control.
5. To ACQUAINT the student about inventory management and approaches to control.

Course Outcomes:

Learner will be able to:

CO1. **EVALUATE** the productivity and various productivity improvement techniques.

CO2. **APPLY** work study techniques and with its importance for better productivity.

CO3. **DEMONSTRATE** the ability to **SELECT** plant location, appropriate layout and material handling equipment.

CO4. **IDENTIFY** various Production planning and control tools for effective planning, scheduling and managing the shop floor control.

CO5. **UNDERSTAND** inventory requirements for effective control on manufacturing requirements.

Course Contents

Unit I	**Introduction to Industrial Engineering and Productivity**	**(07 Hours)**

Introduction to Industrial Engineering, Historical background and scope, Contribution of Taylor, Gilbreth, Gantt, Maynard, Ford, Deming and Ohno. Importance of Industrial engineering. Introduction to Work system design

Productivity: Definition of productivity, Measures of Productivity, Total Productivity Model, need for Productivity Evaluation, Productivity measurement models, Productivity improvement approaches, Principles, Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques. (Numerical on productivity measurement)

Real World Assignment: Understand Productivity Measurement models in a real industrial environment. Select a small-scale industry (Machine shop) 1. Study the Work System and understand Input resources like (labour, material, machine, energy) and Find Output (units produced, value) 2. Calculate Productivity (Labour productivity, Machine productivity, Total productivity)

Exemplars / Practical Applications: Assembly Line Productivity Improvement in an Automobile Industry.

Unit II	Work Study	(07 Hours)
Method Study: Introduction and objectives, Areas of application of work study in industry, Selection and Basic procedure. Recording techniques, Operations Process Chart, Flow Process Chart (Man, Machine & Material) Multiple Activity Chart, Two Handed process chart, Flow Diagram, String Diagram and Travel Chart, Cycle and chronocycle graphs, SIMO chart, Therbligs, Micro motion and macro-motion study: Principles of motion economy, Normal work areas and work place design. **Work Measurement**: Techniques, time study, steps, work sampling, Determination of time standards. Observed time, basic time, normal time, rating factors, allowances, standard time, and standard time determination. (Numerical) Introduction to PMTS, MTM, and MOST		
Real World Assignment: Determine standard time using time study and numerical calculations**.**		
Exemplars / Practical Applications: Material movement analysis in a small manufacturing plant / workshop using Flow Diagram & String Diagram.		

Unit III	Production Facility Design	(07 Hours)
Plant Location: Introduction, Factors affecting location decisions, Multi-facility location **Plant Layout**: Principles of Plant layout and Types, factors affecting layout, methods, factors governing flow pattern, travel chart for flow analysis, analytical tools of plant layout, layout of manufacturing shop floor, repair shop, services sectors, and process plant. Layout planning, Quantitative methods of Plant layout and relationship diagrams. Dynamic plant layout **Material Handling**: Objectives and benefits of Material handling, Relationship between layout and Material handling, Equipment selection		
Real World Assignment 1. Design and Analysis of Plant Layout using Travel Chart & Relationship Diagram, 2. Material Handling System Analysis & Equipment Selection		
Exemplars / Practical Applications: Discuss selection of Plant Location for an Automobile Component Manufacturing Unit.		
Unit IV	**Production Planning and Control**	**(07 Hours)**
Types and methods of Production, and their Characteristics, functions and objectives of Production Planning and Control, Steps: Process planning, Loading, Scheduling, Dispatching and Expediting with illustrative examples, Capacity Planning, Aggregate production planning and Master production scheduling. Introduction to a line of balance, assembly line balancing, and progress control **Forecasting Techniques**: Causal and time series models, Moving average, Exponential smoothing, Trend and Seasonality. (Numerical)		
Real World Assignment: Understand and apply PPC functions (process planning, loading, scheduling, dispatching, expediting) in a real system.		
Exemplars / Practical Applications: Aggregate Production Planning in a Seasonal Product Industry, like Manufacturing of air coolers (seasonal demand product).		
Unit V	**Inventory and Inventory Control**	**(07 Hours)**

Materials: Profit Centre: Role of materials management techniques in material productivity improvement, cost reduction and value improvement.

Purchase Management: Purchase management, incoming material control. Acceptance sampling and inspection. Vendor rating system.

Inventory: Functions, Costs, Classifications, Deterministic inventory models and Quantity discount

Inventory Control: EOQ (Numericals), concepts, type of Inventory models-deterministic and probabilistic, Selective inventory control, Fundamental of Material Requirement Planning (MRP-I), Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP), Just-in-Time system (JIT) and Supply Chain Management (SCM)

Real World Assignment: Economic Order Quantity (EOQ) Analysis for Inventory Control

Exemplars / Practical Applications: Inventory Planning using MRP, ERP & SCM in an Automobile Industry. Managing inventory for car manufacturing (multi-component system).

Learning Resources

Text Books:

1. O. P. Khanna, Industrial engineering and management, Dhanpat Rai publication
2. M Mahajan, Industrial Engineering and Production Management, Dhanpat Rai and Co.
3. Martend Telsang, Industrial Engineering, S. Chand Publication.
4. Banga and Sharma, Industrial Organization& Engineering Economics, Khanna publication.

Reference Books:

1. Askin, Design and Analysis of Lean Production System, Wiley, India
2. Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.
3. H. B. Maynard, K Jell, Maynard’s Industrial Engineering Hand Book, McGraw Hill Education.
4. Zandin K.B., Most Work Measurement Systems, ISBN 0824709535, CRCPress,2002
5. Martin Murry, SAP ERP: Functionality and Technical Configuration, SAP Press.
6. Barnes, Motion and time Study design and Measurement of Work, Wiley India
7. Sumanth, D.J, “Productivity Engineering and Management”, TMH, New Delhi, 1990.
8. Edosomwan, J.A, “Organizational Transformation and Process re- Engineering”, British Cataloging in publications, 1996.
9. Prem Vrat, Sardana, G.D. and Sahay, B.S, “Productivity Management - A systems approach”, Narosa Publications, New Delhi, 1998.
10. Francis, R.L., and White, J.A, “Facilities layout and Location”, Prentice Hall of India, 2002.
11. James A. Tompkins, John A. White, “Facilities Planning”, Wiley, 2013
12. Richard L. Francis, Leon F Mc Ginnes and John A. White, “Facility Layout and Location- An Analytical Approach”, PHI, 1993
13. G. K. Agarawal, “Plant Layout and Material Handling”, Jain Brothers, 2007

MOOC / NPTEL/ YouTube Links: -

1. https://archive.nptel.ac.in/courses/112/107/112107143/#
2. https://nptel.ac.in/courses/112107249
3. https://onlinecourses.nptel.ac.in/noc22_me04/preview
4. https://nptel.ac.in/courses/112107292
5. https://nptel.ac.in/courses/112107142

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-361E-AUR: Internet of Things				
Teaching Scheme		**Credits**	**Examination Scheme**	
Tutorial	03 Hr./Week	3	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Sensors & Vision Systems.
- Fundamentals of Programming Languages.
- Industrial Electronics & Controls.
- Cloud and Network Security.

Course Objectives:

1. To introduce the architecture, physical, and logical design of the Internet of Things (IoT).
2. To teach students how to analyze communication models and protocols for cost-effective IoT system design.
3. To provide hands-on experience in coding and interfacing IoT applications using open-source platforms like Arduino and Raspberry Pi.
4. To understand the role of Cloud Computing, Fog Computing, and Edge Computing in IoT ecosystems.
5. To explore security, privacy, and governance issues within the IoT and Internet of Robotic Things (RIoT).

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Explain the building blocks, communication models, and fundamental characteristics of IoT.

CO2: Identify and interface suitable sensors, actuators, and microcontrollers for IoT-oriented automation.

CO3: Select and implement appropriate communication protocols (MQTT, CoAP, 6LoWPAN) for varying network constraints.

CO4: Utilize cloud offerings and data analytics to remotely monitor and control industrial devices.

CO5: Analyze and evaluate domain-specific applications, including Smart Factories, Healthcare, and Agriculture, while addressing security concerns.

Course Contents

Unit 1	**Fundamentals and Architecture of IoT**	**(06 hrs)**

Foundations: Evolution of IoT, history, definition, and characteristics; IoT vs. M2M (Machine-to-Machine) communication.

Architectural Overview: Physical design (Things in IoT) vs. Logical design (Functional blocks); IoT Levels and Deployment templates.

Frameworks: oneM2M and IoT World Forum (IoTWF) architectures; Simplified IoT Functional Stack; Introduction to **Software Defined Networking (SDN)** for IoT.

Computing Paradigms: Role of **Fog, Edge, and Cloud computing** in distributed IoT systems.

Unit 2	**IoT Hardware: Sensors, Actuators, and Gateways**	**(06 hrs)**

Sensing and Actuation: Overview of sensor working (Analog vs. Digital, Wired vs. Wireless); Types of sensors (Motion, Occupancy, Humidity, Pressure, Gas) and Actuators.

Controller Selection: Role of the microcontroller as a gateway; Microcontroller vs. Microprocessor; Characteristics of Arduino, Raspberry Pi, and Espressif (ESP32) platforms.

Interfacing Basics: Programming interfaces (Serial, SPI, I2C); Accessing GPIO pins; Sending and receiving signals; Basic Embedded C and Python for IoT hardware.

Unit 3	**Networking, Connectivity, and Protocols**	**(08 hrs)**

Connectivity Models: TCP/IP vs. OSI model in IoT; Serial vs. Parallel communication; Wired vs. Wireless technologies (ZigBee, Bluetooth, LoRaWAN, Wi-Fi 6).

Network Layer: IP versions for IoT; Constrained Nodes and Networks; Optimizing IP through 6LoWPAN and serialization using JSON.

Unit 4	Cloud Integration and Data Analytics	(08 hrs)

Cloud Infrastructure: Introduction to cloud models (Public, Private, Hybrid); Cloud service examples (AWS, Google Compute Engine, Windows Azure); API Virtualization.
Data Handling: Data acquisition and synchronization; Structured vs. Unstructured data; Introduction to Big Data analytics and machine learning for IoT.
Visualization: Web servers and posting sensor data; API-based remote monitoring; Designing user interfaces for industrial dashboards

Unit 5	IoT Applications, Security, and Future Trends	(06 hrs)

Industrial IoT (IIoT): Future Factory concepts; Brownfield IoT; Predictive Maintenance and Energy Monitoring using IIoT sensors.
Domain Applications: Smart Cities, Smart Home Automation, Surveillance, Precision Agriculture, and Smart Healthcare.
Security & Governance: Need for security in IoT; Privacy by design; Protecting consumer and industrial devices; Trust in IoT-data-platforms.
Future Trends: Internet of Robotic Things (RIoT); Swarm robotics; Augmented Reality (AR) integration; Blockchain in smart manufacturing.

Practical Applications

1. **Sensor Interfacing & Logging:** Interface a temperature/humidity sensor (DHT11/LM35) with an Arduino and log data to a serial monitor or cloud platform.
2. **Remote Device Control:** Use a web-based dashboard or mobile app to remotely actuate a relay or motor.
3. **Wireless Node Communication:** Establish a communication link between an Arduino and Raspberry Pi using a wireless medium (Bluetooth/Zigbee).
4. **Smart Parking Prototype:** Build a simulation or physical model of an automated parking system that updates slot availability to a cloud database.

Books and other resources:

Text Books:

1. Arshdeep Bahga & Vijay Madisetti, "Internet of Things: A Hands-On Approach", Universities Press.
2. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress.
3. Robert Barton et al., "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for IoT", Cisco Press.
4. Jeeva Jose, "Internet of Things", Khanna Publishing House.

References Books:

1. Francis DaCosta, "Rethinking the Internet of Things: A Scalable Approach to Connecting Everything", Apress.
2. Pethuru Raj & Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press.
3. Adrian McEwen & Hakim Cassimally, "Designing the Internet of Things", Wiley.

MOOC Courses Link:

1. NPTEL: "Industry 4.0 and Industrial Internet of Things" by Prof. Sudip Misra, IIT Kharagpur.
2. Coursera/Udemy: IoT for beginners and System Design.
3. Virtual Labs: Sensors and Instrumentation Lab (COEP).

Savitribai Phule Pune University Third Year of Mechanical Engineering (2024 Pattern)				
PEC 362A-MEC: Product Design and Development				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Basic Engineering Science-Physics, Chemistry, Material Science, Engineering Metallurgy, Manufacturing processes, etc

Course Objectives:

1) To LEARN and UNDERSTAND fundamentals of product design and development process.
2) To UNDERSTAND and LEARN market survey, customer need analysis and product specifications finalization.
3) To UNDERSTAND and LEARN concept generation, evaluation and product architecture.
4) To LEARN and UNDERSTAND Reverse Engineering, Benchmarking and Product optimization.
5) To LEARN and UNDERSTAND Design for X, Prototyping and product life cycle management.

Course Outcomes:

After successful completion of the course, learner will be able to: On completion of the course, learner will be able to

CO1: EXPLAIN and **APPLY** the fundamentals of product design and development process, including design phases, planning, and product lifecycle considerations.

CO2: **ANALYZE** market requirements by conducting customer need analysis, market survey, and formulate product specifications based on Voice of Customer (VoC).

CO3: GENERATE, **EVALUATE**, AND SELECT product concepts and develop product architecture using systematic design methodologies.

CO4: **APPLY** reverse engineering, competitive benchmarking, and optimization techniques to improve existing product designs.

CO5**: IMPLEMENT** Design for X (DfX) principles, prototyping methods, and product lifecycle management (PLM) strategies in product development.

Course Contents

Unit I	**Fundamentals of Product Design & Development**	**(07 Hours)**

- Definition & need of Product Design & Development
- Importance of engineering & industrial design
- Essential factors for product design
- Product design phases and generic product development process
- Product Development Vs Product Design
- Standardization, simplification & specialization in product design
- Steps in Product Development
- Product development team & product development planning
- Modern product development process
- Product testing
- Product validation & product verification

Real World Assignment

1. Product Design Process Case Study:

- Select a real product (e.g., electric kettle, bicycle, smartphone).
- Study product design phases, development process, and role of engineering and industrial design.
- Compare Product Design vs Product Development.
- Submit a structured report with diagrams.

2. Product Redesign & Standardization Study:
- Select an existing product with usability issues.
- Identify design flaws and lack of standardization.
- Propose improved design with testing and validation aspects.
- Present with sketches/models.

Exemplar / Practical Applications/CCE

1. Product Development Planning Exercise:
- Form teams of 3–4 students.
- Select a simple product (e.g., water bottle, chair).
- Prepare product development steps, team roles, and planning.
- Develop timeline using Gantt chart.
- Evaluate based on feasibility and planning.

2. Product Testing & Validation Demonstration:
- Select a small product.
- Conduct functionality, safety, and usability testing.
- Perform verification vs validation comparison.
- Document observations and suggest improvements.

Unit II	Product Development: Customer Need Analysis & Market Considerations	(07 Hours)

Mission statement & technical questioning, Voice of customer (VoC) & customer need identification, Types & models of customer needs, Methods of gathering customer needs, Analysis of gathered data, Technology forecasting & S-curve, Customer population & market segmentation, Establishing engineering characteristics, Quality Function Deployment (QFD) & House of Quality (HOQ),Competitive benchmarking, Economic analysis of product.

Real World Assignment

1. Voice of Customer (VoC) Study:
- Select a product (e.g., backpack, mobile app, home appliance).
- Conduct survey/interviews (minimum 10 users).
- Identify customer needs and pain points.
- Classify needs (basic, performance, excitement).
- Prepare report with charts.

2. QFD & Competitive Benchmarking:
- Select a product category (e.g., electric scooter).
- Perform competitive benchmarking (2–3 products).
- Develop House of Quality (HOQ).
- Map customer needs to engineering characteristics.
- Suggest best design strategy.

Exemplar / Practical Applications/CCE

1. Market Segmentation Exercise:
- Choose a product.
- Identify target customers and segmentation (age, income, usage).
- Analyze customer population.
- Present market positioning.

2. Technology Forecasting & S-Curve Analysis:
- Select a technology (e.g., EVs, smartphones).

- Plot technology growth using S-curve. - Predict future trends and opportunities. - Submit graphical analysis.		
Unit III	**Product Development: Concept Generation, Evaluation & Product Architecture**	**(08 Hours)**
Product information gathering ,Creative thinking & problem solving techniques ,Brainstorming, lateral thinking, Gordon technique, checklist method ,Morphological analysis & attribute listing ,Concept generation technique, Concept selection method (Pugh's method, scoring method), Concept selection design evaluation, estimation & technical feasibility ,Process of concept embodiment ,Product architecture & its types, System modeling, functional modeling & decomposition, FAST method , Subtract & operate procedure		
Real World Assignment **1. Pugh's concept selection** Students will pick a product, generate multiple design concepts, and evaluate them against a reference/datum using criteria like cost, ease of use, safety, etc. Product example:- Foldable Study Table, Helmet for Two-Wheeler Riders, Reusable Water Bottle etc. **2.FAST (Function Analysis System Technique) Method** Students will build a FAST diagram showing **Why → How** function relationships for a product, identifying basic, secondary, and unwanted functions. Product example:- Bicycle, Ceiling Fan , Laptop Bag etc.		
Exemplar / Practical Applications/CCE **Pugh's Concept Selection Matrix** Students select a everyday product they personally use such as a water bottle, backpack, or phone stand conduct brief user interviews with 3–5 peers to identify key needs, generate at least 4 design concepts. **FAST Method** Students disassemble or closely examine a simple household product such as a stapler, hand pump, or electric torch.		
Unit IV	**Reverse Engineering, Benchmarking and Product Optimization**	**(07 Hours)**
Product teardown process and methods, Applications of reverse engineering, Force flow diagrams, Measurement and experimentation techniques, Benchmarking approach and detailed procedure, Tools used in benchmarking, Indented assembly and cost analysis, Function–form diagrams, Trend analysis and product improvement. Product specification setting, Introduction to product portfolio and product architecture.		
Real World Assignment **1.Product teardown & Benchmarking** Students will disassemble or closely examine a simple household product in 3- 4 peers such as Bicycle (complete or subsystem like gear/brake) ,Two-wheeler helmet ,Car wiper mechanism ,Fuel pump (demo model) electric iron, mixer grinder, smartphone charger, or water pump, to understand its construction and working. They will identify components, understand how each part contributes to overall functionality, prepare function–component mapping and block diagrams, and estimate the manufacturing cost by calculating the cost of individual components and comparing it with the market price. **2.Benchmarking** Students will perform benchmarking by selecting at least three similar products and comparing them based on cost, performance, features, material, and efficiency. They will also evaluate product performance by defining parameters such as efficiency, power, and durability, conduct simple experiments, and finally suggest improvements based on the benchmarking analysis.		
Exemplar / Practical Applications/CCE Students will perform reverse engineering of a small component or product, including teardown and benchmarking, and propose an improved design. In this students will able to understand the following process- • Perform **product teardown** to identify components and working • Prepare **function–component mapping and basic diagrams** • Conduct **benchmarking** with similar products • Analyze performance, cost, and materials • Identify limitations of the existing design		

- Propose a **redesign with improved specifications**

Unit V	**Design for X (DFX), Prototyping and Product Lifecycle Management**	**(07 Hours)**

- Design for Manufacturing (DFM) and Design for Assembly (DFA/DFMA)
- Design for reliability, safety and robustness
- Design for environment and sustainability
- Design for serviceability and user-friendly design
- Manufacturing cost analysis
- Life Cycle Assessment (LCA) – basic and weighted method
- Role of computers in product design and manufacturing
- Rapid prototyping techniques: SLA, SLS, FDM, LOM, BPM
- Introduction to 3D printing technologies
- Product Life Cycle Management (PLM): concepts and elements
- Product data management and workflow
- Case studies on product design and development

Real World Assignment

1. Case Study On Product design and development of simple products like e.g., mixer grinder,bicycle, brake system of Two wheeler
2. Reliability & Safety Evaluation of a Mechanical System
3. Sustainable Product Redesign using eco-friendly materials
4. Manufacturing Cost Estimation and cost reduction strategies

Exemplar / Practical Applications

1. Introduction to use simulation tools (FEA/CFD) to test product performance before manufacturing.
2. Introduction to Integration of design, manufacturing, and supply chain data using PLM software. E.g: Windchill

Learning Resources

Text Books:

1. Product Design and Development
   Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang, McGraw-Hill Education.
2. Product Design and Development
   Prof. Mandar M. Bidwe, TechKnowledge Publications.
3. Introduction to Product Design and Development for Engineers
   Ali Jamnia, CRC Press.

Reference Books:

1. Product Design for Manufacture and Assembly
   Geoffrey Boothroyd, Peter Dewhurst.
2. Product Design and Manufacturing
   A. C. Chitale, R. C. Gupta.
3. New Product Development
   Tim Jones, Butterworth-Heinemann.
4. Product Design Fundamentals and Methods

MOOC / NPTEL/ YouTube Links: -

1. NPTEL: Product Design and Development
   Available on NPTEL platform – Covers product lifecycle, design process, QFD, prototyping, and development strategies.
2. NPTEL: Design Thinking
   Focuses on customer-centric product design, innovation, and problem-solving approaches.
3. MIT OpenCourseWare (YouTube): Product Design & Engineering Design Lectures
   Provides real-world case studies and structured engineering design methodologies.
4. Learn Engineering (YouTube Channel)
   Offers visual and conceptual explanations of product design, manufacturing, and engineering fundamentals.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-362B-AUR: Agriculture Robot				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	3	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Principles of Robotics.
- Sensors & Vision Systems.
- Robot Operating Systems (ROS).

Course Objectives:

1. To learn about farming-related machines and the history of mechanized agriculture.
2. To understand Global Positioning Systems (GPS) and information systems in agricultural machines.
3. To study principles of traction, testing, and hitching for agricultural vehicles.
4. To familiarize students with the concepts of autonomous weed management and precision harvesting.
5. To learn the technical criteria for machinery selection and efficiency analysis.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Recognize the areas in agricultural processes where robotics and automation can be applied.

CO2: Integrate sensors and systems for specific processes like soil monitoring and crop health.

CO3: Apply mechanics to design various agricultural robot parameters and drive systems.

CO4: Analyze and select appropriate mechanisms for tillage, planting, and harvesting automation.

CO5: Develop and evaluate suitable robotic systems for specific autonomous agricultural tasks.

Course Contents

Unit 1	Introduction to Mechanized Agriculture	06 hrs

Foundations: History of mechanized agriculture; evolution from traditional tools to agricultural automation.
Farming Operations: Technical overview of machines for tillage, planting, cultivation, and harvesting.
Robotic Platforms: Introduction to Agricultural Vehicle Robots and autonomous tractors.

Unit 2	Precision Agriculture and Sensing	08 hrs

Sensing Systems: Sensor types and agricultural applications: soil moisture, temperature, and nutrient sensors.
Positioning Technologies: Global Positioning System (GPS) foundations; Differential GPS (DGPS), Carrier-phase GPS, and Real-time Kinematic (RTK) GPS.
Information Frameworks: Geographic Information Systems (GIS); Variable Rate Applications (VRA); and Controller Area Networks (CAN) for farm machinery.

Unit 3	Traction, Testing, and Hitches	08 hrs

Hitching Principles: Mechanics of hitching; types of hitches and weight transfer analysis.
Traction Mechanics: Tires and traction performance; interaction between vehicle wheels and various soil types.
Testing Protocols: Methods for testing draft requirements and power output of agricultural robotic bases.

Unit 4	Field Robotics and Crop Management	08 hrs
Autonomous Guidance: Navigation stacks for broad-acre applications; automatic guidance for sowing and spraying. **Automated Weed Control:** Systems for mechanical and chemical weed management; SLAM in agricultural environments. **Horticulture Robotics:** Robotic picking of fruits; automated pruning and crop thinning. **Livestock Automation:** Overview of robot milking, sheep shearing, and livestock health inspection.		
Unit 5	**Machinery Selection and Logistics**	**06 hrs**
Logistics Systems: Automated material handling in farms: screw conveyors, pneumatic conveyors, and bucket elevators. **Selection Criteria:** Determining field capacity and efficiency; draft and power requirements for specific terrains. **Economics:** Analysis of machinery costs, maintenance, and the socio-economic impact of agricultural robotization.		

Assignments and Practical Applications:

Real World Assignments:

1. **Sensor Integration Case Study:** Design a system integrating soil sensors to monitor crop health and optimize irrigation using IoT.
2. **Machinery Cost Analysis:** Prepare a report on the efficiency and field capacity of a traditional tractor versus an autonomous agricultural robot for a 50-acre farm.
3. **Feasibility Report:** Evaluate and document the use of drones for surveillance and multi-spectral imaging in precision agriculture.

Practical Applications:

1. **Smart Monitoring:** Build a greenhouse climate control simulation using temperature and humidity sensors linked to a virtual dashboard.
2. **Autonomous Navigation:** Use ROS and Gazebo to simulate a mobile robot performing a "serpentine" coverage path for autonomous field spraying.
3. **Weed Detection:** Implement an image processing script (OpenCV) to distinguish between crops and weeds based on color or leaf geometry.

Books and other resources:

Text Books:

1. Ajit K. Srivastava et al., "Engineering Principles of Agricultural Machines", ASABE Publication.
2. Qin Zhang & Francis J. Pierce, "Agricultural Automation: Fundamentals and Practices", CRC Press.
3. Myer Kutz, "Handbook of Farm, Dairy and Food Machinery Engineering", Academic Press.

References Books:

1. Stephen L. Young, "Automation: The Future of Weed Control in Cropping Systems", Springer.
2. Guangnan Chen, "Advances in Agricultural Machinery and Technologies", CRC Press.
3. R.A. Kepner et al., "Principles of Farm Machinery", CBS Publishers.

MOOC Courses Link:

1. Udacity: "Decision-Making for Autonomous Systems".
2. NPTEL: "Wheeled Mobile Robots" by Prof. Asokan Thondiyath, IIT Madras.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-362C-AUR: Operations Research				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	**3**	**CCE**	30 Marks
Practical	NA		**End-Semester**	70 Marks

Prerequisite Courses, if any:

- Engineering Mathematics, Theory of Probability and Statistics.

Course Objectives:

1. To develop a conceptual framework for identifying and solving complex decision-making problems.
2. To understand the scope of operational research and its historical development in engineering.
3. To enable students to use optimization techniques under limited resources for industrial and business problems.
4. To sensitize students to the importance of mathematical modeling in real-life environments.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Evaluate and apply Game Theory and Decision Analysis techniques to solve real-world decision-making scenarios.

CO2: Select and solve optimal sequencing and queuing models for industrial service systems.

CO3: Formulate and solve Linear Programming Problems (LPP) using graphical, simplex, and duality methods.

CO4: Model and solve transportation, assignment, and travelling salesman problems for autonomous logistics.

CO5: Plan optimum project schedules using PERT/CPM and implement Dynamic Programming for resource allocation.

Course Contents

Unit 1	**Introduction to OR and Decision Theory**	**06 hrs**

Foundations: Origin, definition, and evolution of Operations Research; phases of an OR study.
Game Theory: Competitive games, two-person zero-sum games, and saddle point theory.
Decision Analysis: Decision-making under certainty, risk, and uncertainty; Decision trees.

Unit 2	**Linear Programming and Duality**	**08 hrs**

LPP Formulation: Identifying objective functions and constraints in automation scenarios.
Solution Methods: Graphical method; Simplex algorithm; Big M and Two-phase methods.
Theory of Duality: Primal to dual conversion and sensitivity analysis.

Unit 3	**Transportation and Assignment Models**	**08 hrs**

Transportation: Formulation; finding basic feasible solutions (VAM, LCM, NWCR); Optimality tests and degeneracy.
Assignment: Formulation; Hungarian method for balanced and unbalanced problems.
Autonomous Logistics: Application to Travelling Salesman Problems (TSP) for robot path optimization.

Unit 4	**Queuing Theory and Sequencing**	**08 hrs**

Queuing Models: Characteristics of queuing systems; Kendall's notation; Single and multi-server models (M/M/1 and M/M/s).
Sequencing: Processing n jobs through 2, 3, or m machines; Johnson's rule.
Service Evaluation: Performance evaluation of engineering and management systems.

Unit 5	**Project Management and Dynamic Programming**	**06 hrs**

Network Models: Project networks; CPM and PERT; critical path scheduling and resource leveling.

Replacement Analysis: Replacement of items that fail suddenly or deteriorate over time.

Assignments and Practical Applications:

Real World Assignments:

1. **Logistics Strategy:** Perform a case study on an industrial automation system using fluid power to analyze resource selection and process flows.
2. **Inventory Analysis:** Conduct an Economic Order Quantity (EOQ) analysis for an automated warehouse to determine safety stocks and reorder points.
3. **Resource Allocation:** Apply the Simplex Method to allocate equipment and raw materials to different plants to improve throughput.

Practical Applications:

1. **Robot Sequencing:** Solve a sequencing problem for processing n jobs through m robotic workstations to minimize total idle time.
2. **Logistics Simulation:** Use Monte Carlo simulation to predict outcomes in stochastic service systems, such as an automated vehicle charging station.
3. **Project Scheduling:** Develop a PERT network for the assembly of a mobile robotic base, identifying the critical path to ensure timely delivery.

Books and other resources:

Text Books:

1. Prem Kumar Gupta & D. S. Hira, "Problems in Operations Research: Principles and Solutions", S. Chand.
2. Hamdy A. Taha, "Operations Research: An Introduction", Pearson Education.
3. J. K. Sharma, "Operations Research: Theory and Application", Laxmi Publications.

References Books:

1. F. S. Hillier & G. J. Lieberman, "Introduction to Operations Research", McGraw Hill.
2. Harvey M. Wagner, "Principles of Operations Research", Prentice Hall.
3. Ravindran, "Engineering Optimization: Methods and Applications", Wiley.

MOOC Courses Link:

1. NPTEL: "Project Management" by Prof. Arun Kanda, IIT Delhi.
2. Coursera: "Optimization Methods for Business Analytics".
3. Virtual Labs: Industrial Automation Laboratory (COEP).

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PEC-362C-AUR: WAREHOUSE AUTOMATION				
Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	03 Hr./Week	**3**	**CCE**	30 Marks
Practical	--		**End-Semester**	70 Marks

Prerequisites Courses:

- Industrial Automation, Sensors and Control, Manufacturing Technology

Course Objectives:

1. Understand warehouse operations and the role of automation in modern logistics.
2. Analyze automated material handling, storage and retrieval systems.
3. Study warehouse robotics including AGVs, AMRs and robotic manipulators.
4. Design PLC-based warehouse control systems integrated with industrial sensors.
5. Evaluate smart warehouse technologies such as WMS, IoT, AI and Digital Twin.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Explain warehouse operations and automation technologies used in logistics.

CO2: Select suitable automated material handling and storage systems for warehouse applications.

CO3: Analyze robotic systems including AGVs, AMRs and industrial robots for warehouse automation.

CO4: Design warehouse control systems using PLC, industrial sensors and HMI.

CO5: Evaluate Industry 4.0 technologies for developing smart warehouses

Course Contents

Unit 1	**Introduction to Warehouse Automation**	**6 Hrs**

Introduction to Logistics and Supply Chain Management, Evolution of Warehousing, Types of Warehouse Functions, Warehouse Layout Planning, Material Flow Analysis, Warehouse Performance Indicators (KPIs), Lean Warehousing, Industry 4.0 in Warehousing

Suggested Case Study

- Amazon Fulfilment Centre
- Flipkart Smart Fulfillment Centre (India)
- Decathlon Distribution Centre
- IKEA Distribution Warehouse

Unit 2	**Automated Material Handling and Storage Systems**	**6 Hrs**

Principles of Material Handling, Conveyor Systems, Sortation Systems, Automated Guided Conveyor Systems, Vertical Lift Modules, Carousel Storage Systems, Automated Storage and Retrieval Systems (AS/RS), Automated Palletizing and Depalletizing, Warehouse Throughput, Storage Capacity Planning

Suggested Case Study

- Daifuku AS/RS System
- AutoStore Cube Storage System
- Dematic Conveyor and Sortation System
- Swisslog PowerStore AS/RS

Unit 3	**Warehouse Robotics and Autonomous Mobile Systems**	**8 Hrs**

Industrial Robots in Warehouses, Pick and Place Robots, End Effectors, Collaborative Robots, Automated Guided Vehicles (AGVs), Autonomous Mobile Robots (AMRs), Navigation Methods, Fleet Management System, Autonomous Forklifts, Robot Safety Standards, Human–Robot Collaboration

Suggested Case Study

- Amazon Robotics (Kiva Systems)
- GreyOrange Butler System (India)
- Geek+ AMR Warehouse
- Boston Dynamics Stretch Robot
- ABB Robotic Palletizing Cell

Unit 4	Warehouse Control Systems and Industrial Automation	8 Hrs

Warehouse Control Architecture, PLC Applications in Warehouse Automation, Conveyor Sequencing, Sensor Technologies, Servo Drives, Variable Frequency Drives, Human Machine Interface (HMI), SCADA, Warehouse Control System (WCS), Safety Interlocking, Functional Safety Standards

Suggested Case Study

- Siemens PLC-Based Conveyor Automation
- Rockwell Automation Distribution Centre
- Schneider EcoStruxure Smart Warehouse
- Mitsubishi Electric e-Factory Warehouse

Unit 5	Smart Warehouse Technologies and Industry 4.0	6 Hrs

Warehouse Management System (WMS), Warehouse Execution System (WES), Internet of Things (IoT), RFID-enabled Inventory Tracking, Cloud-based Warehouse Monitoring, Artificial Intelligence in Warehousing, Machine Learning for Inventory Optimization, Machine Vision Systems, Digital Twin Technology, Predictive Maintenance, Green Warehousing, Cyber Security in Smart Warehouses, Future Trends: Autonomous Warehouses, AI-based Logistics, Hyper Automation

Suggested Case Studies

- DHL Smart Warehouse
- Walmart Distribution Centers
- Swisslog Smart Warehouse
- Ocado Smart Platform (UK)
- Alibaba Cainiao Smart Logistics
- Coca-Cola Automated Warehouse

Real World Assignment

1. Warehouse Layout Design: Design the layout of an automated warehouse for an e-commerce company considering receiving, storage, picking, packing, and dispatch operations. Optimize space utilization and material flow.
2. Material Handling Equipment Selection: Select suitable material handling equipment (conveyors, AS/RS, AGVs, forklifts, etc.) for a warehouse based on product type, storage requirements, and throughput.
3. Warehouse Automation Proposal: Prepare a proposal to convert a conventional warehouse into a smart warehouse by integrating PLCs, sensors, robots, and Warehouse Management Systems (WMS). Include cost-benefit analysis and expected productivity improvements.
4. AGV/AMR Route Planning: Develop an optimal navigation strategy for AGVs/AMRs in a warehouse using shortest-path algorithms while avoiding congestion and collisions.
5. Warehouse KPI Analysis: Collect data from a local warehouse or published case study and calculate key performance indicators such as storage utilization, inventory turnover, order cycle time, picking accuracy, and throughput.
6. RFID-Based Inventory Tracking: Design an RFID-enabled inventory tracking system and explain tag placement, reader configuration, and data flow for real-time inventory management.
7. Conveyor Automation Design: Develop PLC logic and sequence diagrams for an automated conveyor system with package detection, sorting, counting, and emergency stop functionality.
8. Comparative Study of Smart Warehouses: Compare the warehouse automation technologies

used by organizations such as Amazon, Flipkart, DHL, AutoStore, and GreyOrange, highlighting their automation strategies and operational benefits.

9. Digital Twin of a Warehouse: Develop a conceptual Digital Twin model to simulate warehouse operations, identify bottlenecks, and recommend improvements in throughput and resource utilization.
10. Sustainable Warehouse Design: Design an energy-efficient warehouse incorporating renewable energy sources, LED lighting, regenerative drives, and optimized warehouse operations to reduce carbon emissions.

Practical Applications

1. PLC-based conveyor belt control with sensor integration.
2. Barcode and RFID-based warehouse inventory management.
3. Automated package sorting using proximity and color sensors.
4. AGV/AMR path planning and navigation simulation using ROS.
5. Pick-and-place robotic cell for order fulfillment.
6. HMI and SCADA development for warehouse monitoring and control.
7. AS/RS simulation using Factory I/O, FlexSim, or Visual Components.
8. Machine vision-based package identification and sorting.
9. IoT-enabled warehouse monitoring with cloud dashboard for temperature, humidity, and inventory status.
10. Predictive maintenance of conveyor systems using sensor data and analytics.
11. Warehouse throughput and storage capacity analysis using simulation tools.
12. Integration of WMS with PLC and barcode/RFID systems for automated inventory updates.

Text Books

1. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the, Gwynne Richards, Kogan Page Publishers.
2. Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Pearson Education
3. Industrial Automation and Robotics, A. K. Gupta and S. K. Arora, Mercury Learning and Information
4. Material Handling Handbook, Raymond A. Kulwiec, John Wiley & Sons
5. Logistics and Supply Chain Management, Martin Christopher, Pearson Education
6. Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design, Yusuf Altintas, Cambridge University Press

Reference Books

1. Warehouse & Distribution Science, John A. Bartholdi III and Steven T. Hackman, The Supply Chain and Logistics Institute, Georgia Institute of Technology
2. Introduction to Autonomous Mobile Robots, Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza, MIT Press
3. Robot Modeling and Control, Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, John Wiley & Sons

MOOC

1. Introduction to Industry 4.0 and Industrial Internet of Things (IIoT) – NPTEL / SWAYAM
2. Industrial Automation and Control – NPTEL / SWAYAM
3. Robotics – NPTEL / SWAYAM
4. Supply Chain Management Specialization – Coursera
5. Supply Chain Analytics – Coursera
6. Digital Manufacturing and Design Technology – Coursera
7. Industrial Internet of Things (IIoT) – Coursera
8. Supply Chain Fundamentals – MIT OpenCourseWare
9. Fundamentals of Logistics, Supply Chain & Customer Service – edX
10. Warehouse Management and Inventory Control – Alison

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)					
PEC-362E-AUR: Manufacturing Systems and Simulation					
Teaching Scheme		**Credits**	**Examination Scheme**		
Theory	03 Hr./Week	3	**CCE**	30 Marks	
Practical	NA		**End-Semester**	70 Marks	

Prerequisite Courses, if any:

- Engineering Mathematics, Manufacturing Technology, Principles of Robotics.

Course Objectives:

1. To understand the functioning, classification, and performance measures of modern manufacturing systems.
2. To describe the role of facilities, support systems, and material handling in automated production.
3. To introduce various simulation types used in manufacturing.
4. To teach data collection, input modeling, and random number generation for simulation.
5. To familiarize students with industrial simulation software for optimizing line balancing and throughput.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: Classify and analyze different production systems and evaluate their performance metrics.

CO2: Design and evaluate manufacturing layouts and support systems including Group Technology and Cellular Manufacturing.

CO3: Apply simulation methodologies to solve industrial productivity and capacity utilization problems.

CO4: Perform input data analysis and generate random variates for stochastic modeling.

CO5: Develop and validate virtual models using industrial software packages

Course Contents

Unit 1	**Fundamentals of Manufacturing Systems**	**06 hrs**

System Overview: Definition of manufacturing systems; evolution from Industrial Revolution to Industry 5.0.
Classification: Manual, automated, and hybrid systems; Job shop, Batch, and Mass production.
Performance Metrics: Production rate, plant capacity, lead time, and work-in-process (WIP).
Modern Paradigms: Lean manufacturing (Kaizen, 5S, JIT) and Agile manufacturing.

Unit 2	**Facilities and Support Systems**	**08 hrs**

Automated Logistics: Principles of material handling; conveyors, Automated Guided Vehicles (AGVs), and AS/RS.
Layout Design: Plant layout types; Group Technology (GT) and part families; Opitz and MICLASS coding.
Cellular Manufacturing: Design and layout of manufacturing cells; machine cell design and quantitative analysis.
Robotics Integration: Role of industrial robots in assembly lines and workcells.

Unit 3	**Manufacturing Simulation Concepts**	**08 hrs**

Simulation Basics: Definition, purpose, and steps in a simulation study.
Simulation Types: Discrete Event Simulation (DES), System Dynamics (SD), Agent-based modeling, and Monte Carlo simulation.
Problem Formulation: Defining objectives, system boundaries, and performance measures.

Modeling Logic: Organizing logic for inventory and queuing problems (single server systems).

Unit 4	Input Modeling and Random Variates	08 hrs

Data Collection: Sources for input data; preprocessing and identifying distributions (Uniform, Normal, Exponential, Weibull).
Stochastic Processes: Introduction to Random Number Generation; properties of pseudo-random numbers.
Verification & Validation: Face validity; testing model assumptions; validating input-output transformations against historical data.

Unit 5	Output Analysis and Simulation Tools	06 hrs

Performance Evaluation: Output analysis for terminating vs. non-terminating simulations; confidence intervals.
Software Ecosystem: Overview of Arena, ProModel, Witness, and FlexSim; comparison with programming languages.
Digital Twin: Introduction to Digital Twin-based simulation for real-time monitoring and predictive maintenance.

Assignments and Practical Applications:

Real World Assignments:

1. **Assembly Line Analysis:** Study an automobile assembly line and identify methods used for line balancing and efficiency improvement.
2. **Simulation Case Study:** Develop a simulation-based study to analyze the effect of buffer stock on productivity and downtime in a transfer line.
3. **GT Classification:** Identify and categorize daily products using the Opitz coding system and generate a part-family chart.
4. **Logistics Strategy:** Perform a case study on an automated warehouse to determine the optimal number of AGVs required for material handling.

Practical Applications:

1. **FMS Layout Simulation:** Design a flexible manufacturing cell for a family of parts and simulate machine utilization to identify bottlenecks.
2. **Queue Modeling:** Apply Discrete Event Simulation to model a supermarket checkout or parking system using M/M/1 and M/M/s queuing logic.
3. **Monte Carlo Analysis:** Implement a practical case study to predict outcome variations in a stochastic inventory model.
4. **Digital Twin Prototype:** Create a simple digital twin of a CNC machine or conveyor and simulate real-time data exchange.

Books and other resources:

Text Books:

1. Mikell P. Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Pearson.
2. Averill M. Law, "Simulation Modeling and Analysis", Tata McGraw Hill.
3. Banks, J., "Discrete-Event System Simulation", Pearson.

References Books:

1. Christopher A. Chung, "Simulation Modeling Handbook: A Practical Approach", CRC Press.
2. Fei Tao and Ang Liu, "Digital Twin Driven Smart Manufacturing", Elsevier.
3. Al-Aomar, R., "Process Simulation Using Witness", John Wiley & Sons.

MOOC Courses Link:

1. NPTEL: "Discrete Event Simulation".
2. NPTEL: "Industry 4.0 and Industrial Internet of Things".
3. Virtual Labs: "Computer Integrated Manufacturing Lab" (IIT Kharagpur).

Savitribai Phule Pune University
Third Year of Automation & Robotics Engineering (2024 Pattern)

PCC-354-AUR: Robot Building Lab

Teaching Scheme		Credits	Examination Scheme	
Tutorial	02 Hr./Week	3	**Oral**	50 Marks
Practical	02 Hr./Week		**End-Semester**	NA

Prerequisite Courses, if any:

- Mechanical Basics: Engineering Graphics, Manufacturing Processes, Kinematics of Machinery.
- Electronics & Control: Industrial Electronics, Sensors & Vision Systems, Microcontrollers & Interfacing.
- Software: C/C++ or Python Programming, Robot Operating System (ROS).

Course Objectives:

1. To familiarize students with the anatomy and functional elements of various robotic systems.
2. To provide hands-on experience in integrating mechanical hardware with electrical actuators and sensors.
3. To develop proficiency in 3D modeling and additive manufacturing for robot component design.
4. To enable students to program and test autonomous behaviors such as navigation and manipulation.
5. To cultivate skills in system-level troubleshooting and performance evaluation of robotic prototypes.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: IDENTIFY AND SELECT appropriate mechanical links, joints, and drive systems for specific robotic applications.

CO2: DEMONSTRATE proficiency in the design and construction of robotic structures using CAD and fabrication tools.

CO3: INTEGRATE AND INTERFACE microcontrollers, sensors, and actuators to create a functional robotic control loop.

CO4: DEVELOP AND EXECUTE robot programs for tasks such as pick-and-place, line following, and obstacle avoidance.

CO5: EVALUATE the performance of built robots against design specifications for accuracy and reliability

Course Contents

The student shall complete a total of 8 to 10 experiments from the following list.

Practical 1: Anatomy and Component Identification

Aims & Objectives: To study the physical configuration, work envelope, and drive systems of real industrial or mobile robots.

Hardware: PUMA/SCARA configurations, 6-DOF industrial robot, or mobile platforms.

Assignment: Document robot specifications including payload, DOF, and joint types.

Practical 2: CAD Modeling of Robotic Assemblies

Aims & Objectives: To design 3D models of robotic links, joints, and end-effectors.

Software Requirements: Solid Modeling software (e.g., Fusion 360, Blender, or Tinkercad).

Assignment: Create an assembly model of a 2-DOF or 3-DOF robot arm.

Practical 3: Additive Manufacturing of Robot Parts

Aims & Objectives: To fabricate custom enclosures or structural components using 3D printing technology.

Hardware Requirements: FDM or SLA 3D printer.

Assignment: Print a custom gripper or motor mount designed in Practical 2.

Practical 4: Drive System Integration

Aims & Objectives: To select and interface actuators (DC geared, Servo, or Stepper motors) with drivers.

Hardware Requirements: Arduino/ESP32, motor drivers (L298N/L293D), actuators.

Assignment: Implement basic velocity control for a wheel or position control for a joint.

Practical 5: Sensor Feedback and Interfacing

Aims & Objectives: To integrate sensors (Ultrasonic, IR, IMU, or Encoders) for environmental perception.

Hardware Requirements: Sensors, microcontroller, breadboard.

Assignment: Program a system that triggers an alarm or motion stop when an object is detected within a safe boundary.

Practical 6: Simple Autonomous Behavior (Line Following)

Aims & Objectives: To build a robot capable of reactive navigation using simple line-following sensors.

Hardware Requirements: Mobile robot chassis, IR sensor array, microcontroller.

Assignment: Tune a PID loop or simple logic to follow a curved path accurately.

Practical 7: Obstacle Avoidance and Maze Navigation

Aims & Objectives: To program a robot to autonomously steer through a maze or around obstacles.

Hardware Requirements: Mobile robot equipped with ultrasonic or LiDAR sensors.

Assignment: Implement a logic-based or path-planning algorithm to reach a goal without collisions.

Practical 8: Robotic Arm Construction and Pick-and-Place

Aims & Objectives: To assemble a simple robotic arm and program it for material handling tasks.

Hardware Requirements: Multi-DOF robotic arm kit, gripper.

Assignment: Coordinate the joints to pick up an object of a specific color and place it in a designated bin.

Practical 9: ROS-Based Simulation and Hardware-in-the-Loop

Aims & Objectives: To model the built robot in Gazebo and bridge virtual commands to physical hardware.

Software/Hardware Requirements: Linux PC with ROS/Gazebo, physical robot base.

Assignment: Drive the physical robot using a keyboard teleoperation node via a ROS-serial bridge.

Practical 10: Performance Evaluation and Capstone Demo

Aims & Objectives: To test the robot's reliability, accuracy, and payload capacity under varied conditions.

Assignment: Conduct a series of trials, calculate repeatability error, and present a comprehensive final project report.

Books and other resources:

Text Books:

1. S. K. Saha, "Introduction to Robotics", Tata McGraw Hill.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education.
3. Mikell P. Groover, "Industrial Robotics: Technology, Programming, and Applications", McGraw Hill.
4. Gordon McComb, "Robot Builder’s Bonanza", McGraw-Hill.

References Books:

1. Richard D. Klafter, "Robotic Engineering: An Integrated Approach", PHI.
2. S. R. Deb, "Robotics Technology and Flexible Automation", Tata McGraw Hill.

MOOC Courses Link:

1. NPTEL Course "Robotics" by Prof. Asokan Thondiyath, IIT Madras.
2. "Modern Robotics" Specialization by Coursera.
3. Robot Modeling and Simulation Lab (COEP V-Labs).

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)		
PCC-355-AUR: Actuators and Controllers Lab		
Teaching Scheme	**Credit**	**Examination Scheme**
Practical: 02 Hours/Week	**1**	**Oral: 50 Marks**

Prerequisite Courses:

- Basics of **Automation Studio**.
- **Basics of MATLAB/SIMULINK**

Course Objectives:

1. To understand the **operation and characteristics** of electrical, hydraulic, pneumatic, and electromechanical actuators used in industrial automation and robotics systems.
2. To develop practical skills in **interfacing sensors, feedback devices**, and signal conditioning circuits for real-time measurement and control applications.
3. To design and implement **PLC, embedded controller, and PID-based** automation systems using industrial and simulation software tools.

Course Outcomes:

On successful completion of the course, learner will be able to:

1. **CO1:** Operate and analyze the performance of electrical, hydraulic, pneumatic, and robotic actuation systems used in industrial automation.
2. **CO2:** Implement motor control techniques using power electronic circuits, PWM methods, and embedded controllers for automation systems.
3. **CO3:** Develop PLC, PID, and embedded controller-based automation solutions for industrial and robotic applications.

Course Contents

The student shall complete a total of **any 7 experiments** from the following list, including a **mandatory industrial visit**.

Experiment 1: Performance Analysis of DC Servo Motor	**02 hrs.**

Speed control using PWM, direction control, and torque-speed characteristics.

Real World Assignment

Design a servo-based automatic gate opening system with variable speed and angular position control.

Exemplars / Practical Applications

- CNC machine tool feed drives
- Robotic joint position control
- Automatic gate and door systems
- Antenna and camera positioning systems

Experiment 2: BLDC Motor Speed Control	**02 hrs.**
Implement speed control of a Brushless DC (BLDC) motor using Hall-effect sensor feedback and electronic commutation.	
Real World Assignment Design a BLDC motor speed controller for an electric bicycle application.	
Exemplars / Practical Applications • Electric vehicles (EVs) • Industrial drones (UAVs) • Electric bicycles and scooters • Industrial cooling and ventilation systems	
Experiment 3: Pneumatic Actuator Control System	**02 hrs.**
Use Automation Studio Software to operate pneumatic systems (pick-and-place, packaging, or presses).	
Real-World Assignment: Create an electro-pneumatic conveyor diverter system for package sorting.	
Exemplars / Practical Applications: Pick-and-place robots • Packaging and bottling machines • Pneumatic presses • Automatic material handling systems	
Experiment 4: Hydraulic Cylinder Simulation	**02 hrs.**
Simulate hydraulic cylinder operation, pressure-flow control, and speed-force characteristics in Automation Studio.	
Real-World Assignment: Analyze a hydraulic lift system used in automobile service stations.	
Exemplars / Practical Applications: • Hydraulic excavators • Automobile hydraulic lifts • Injection molding machines • Aircraft landing gear systems	
Experiment 5: Motor RPM Measurement	**02 hrs.**
Simulate and measure motor RPM using Hall-effect sensor feedback and magnetic field sensing in MATLAB/Simulink.	
Real-World Assignment: Capture and compare acceleration profiles to minimize motion jerk.	
Exemplars / Practical Applications: • • BLDC motor commutation • Industrial motor condition monitoring • Electric vehicle motor feedback systems • Conveyor speed monitoring systems	
Experiment 6: PID Controller Tuning	**02 hrs.**
Tune a PID controller for dynamic regulation (e.g., speed or position).	
Real-World Assignment: Tune a PID controller for automatic conveyor speed regulation.	
Exemplars / Practical Applications: • Robotic motion control • Servo motor speed regulation • Temperature and process control systems • Industrial conveyor automation	
Experiment 7: Robotic Pick-and-Place System	**02 hrs.**
Design a system using servo motor control and embedded programming.	

Real-World Assignment:
Develop a robotic sorting system for an industrial packaging application.

Exemplars / Practical Applications:
- Assembly line automation
- Packaging and palletizing systems
- Electronics component handling
- Pharmaceutical product sorting

Experiment 8: PID-Based Line Follower Robot	**02 hrs.**

Develop and control a line follower using PID techniques in a MATLAB/Arduino environment.

Real-World Assignment:
Build an autonomous delivery robot for warehouse automation.

Exemplars / Practical Applications:
- Automated Guided Vehicles (AGVs)
- Autonomous Mobile Robots (AMRs)
- Warehouse logistics automation
- Hospital delivery robots

Experiment 9: Industrial Visit	**02 hrs.**

Mandatory visit to an industrial facility to observe automation and actuator integration in practice.

Exemplars / Practical Applications:
- **Industrial robotics integration**
- **PLC and SCADA-based automation systems**
- **Smart manufacturing (Industry 4.0)**
- **Automated production and assembly lines**

Learning Resources

Books and other resources

Text Books:
1. Korf & J., "Actuators: Design Fundamentals".
2. Bruno Siciliano & Lorenzo Sciavicco, "Robotics: Modelling, Planning and Control".
3. M.P. Groover, "Industrial Robotics", McGraw Hill.
4. Katsuhiko Ogata, "Modern Control Engineering".

References Books:
1. Robert J. Schilling, "Fundamentals of Robotics: Analysis and Control".
2. Kuo B.C., "Automatic Control Systems".

MOOC Courses Link:
1) "Industrial Automation and Controllers" by Prof. Siddhartha Mukhopadhyay (IIT Kharagpur).
2) "Sensors and Actuators" by Prof. Hardik Jeetendra Pandya (IISc Bangalore).

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
PCC-371-AUR: Simulations Lab				
Teaching Scheme		**Credit**	**Examination Scheme**	
Practical:	**02 Hours/Week**	**1**	**Oral:**	**50 Marks**

Prerequisite Courses:

PCC-302-AUR: Robot Kinematics & Dynamics

PCC-352-AUR: Modeling & Simulation

Academic Prerequisites: Engineering Mathematics-III (Numerical Methods), Basics of MATLAB / Simulink, and Python Programming.

Course Objectives:

1. To introduce industry-standard software tools for **robotic modeling, kinematic analysis, and physics-based simulation**.
2. To enable students to verify **forward and inverse kinematics** for various serial and parallel robot configurations.
3. To perform **workspace analysis and singularity mapping** in a virtual environment to optimize robot design.
4. To simulate **dynamic equations of motion** and evaluate joint torque requirements using Newton-Euler and Lagrange-Euler formulations.
5. To implement **discrete event simulation** and Monte-Carlo techniques to evaluate the performance of automated manufacturing cells.

Course Outcomes:

On successful completion of the course, learner will be able to:

1. **CO1:** Model and simulate robotic kinematic chains using **DH parameters** and transformation matrices in software like RoboAnalyzer or MATLAB.
2. **CO2:** Perform **velocity kinematics analysis** and identify singular configurations for planar and spatial manipulators.
3. **CO3:** Develop and validate **dynamic models** of robotic systems to compute inertial forces and required joint torques.
4. **CO4:** Design and analyze **collision-free trajectories** for industrial tasks such as pick-and-place or assembly.
5. **CO5:** Apply **discrete event simulation software** (e.g., FlexSim, ARENA) to evaluate the efficiency and throughput of automated production lines.

Course Contents

The student shall complete a total of **8 to 10 experiments** from the following list.

Practical 1: DH Parameter Modeling and Forward Kinematics	**02 hrs.**

1. **Aims:** To model a 3-DOF or 6-DOF manipulator (e.g., PUMA or SCARA) and verify the end-effector position using DH conventions.
2. **Software Requirements:** RoboAnalyzer or MATLAB.

Real World Assignment

Compare analytical link equations with simulation output.

Exemplars / Practical Applications

- • Industrial robotic manipulators (ABB, FANUC, KUKA)
  • CNC machine tool positioning
  • Pick-and-place robotic systems
  • Medical robotic arms

Practical 2: Inverse Kinematics and Multi-Solution Analysis	**02 hrs.**
Aims: To solve the inverse kinematics problem for a given end-effector pose and analyze the concept of multiple solutions	
Real World Assignment Identify reachable vs. dexterous workspace boundaries.	
Exemplars / Practical Applications • • Welding robots • Spray painting robots • Surgical robots • Collaborative robots (Cobots)	
Practical 3: Workspace Visualization and Dexterity Mapping	**02 hrs.**
Ams: To generate a 3D point cloud of the robot's work volume and identify configurations where reachability is limited.	
Real-World Assignment: Map dexterity indices across the work envelope.	
Exemplars / Practical Applications: • • Robot work-cell layout design • Warehouse automation robots • Automated assembly stations • Material handling robots	
Practical 4: Velocity Analysis and Jacobian Singularity Mapping	**02 hrs.**
Ams: To compute the Manipulator Jacobian and identify singular configurations for a 2-link planar robot.	
Real-World Assignment: Plot the determinant of the Jacobian against joint angles.	
Exemplars / Practical Applications: • • High-speed packaging robots • Delta robots in food industry • Precision robotic machining • Motion planning in industrial manipulators	
Practical 5: Trajectory Generation in Joint and Cartesian Space	**02 hrs.**
Aims: To design and simulate Point-to-Point (Cubic Polynomial) and continuous (LSPB) motion profiles.	
Real-World Assignment: Capture and compare acceleration profiles to minimize motion jerk.	
Exemplars / Practical Applications: • • Robotic welding path planning • Laser cutting and engraving robots • Automated painting systems • CNC tool path optimization	
Practical 6: Dynamic Simulation using Lagrange-Euler Approach	**02 hrs.**
To develop a dynamic model for a 2-DOF planar robot considering inertia, gravity, and Coriolis effects. **Software Requirements:** MATLAB/Simulink.	
Real-World Assignment: Calculate the torque requirements for a high-speed pick-and-place cycle.	
Exemplars / Practical Applications: • • Industrial robot dynamic analysis • Electric vehicle robotic assembly • Payload optimization of manipulators • Robot actuator selection	
Practical 7: Stability Analysis and PID Controller Tuning	**02 hrs.**
To perform stability analysis (Root Locus/Bode plots) and tune a PID controller for a simulated joint	

actuator.

Real-World Assignment:
Capture under-damped and critically-damped response profiles.

Exemplars / Practical Applications:

- • Servo motor control systems
  • Robotic joint control
  • CNC machine axis control
  • Autonomous mobile robot speed control

Practical 8: Discrete Event Simulation for an Industrial Work-Cell	**02 hrs.**

To model a robotic assembly line and analyze bottlenecks and machine utilization using simulation data.
Software Requirements: FlexSim, ARENA, or ProModel.

Real-World Assignment:

Exemplars / Practical Applications:

- • Flexible Manufacturing Systems (FMS)
  • Automated production lines
  • Warehouse logistics simulation
  • Industry 4.0 smart factories

Practical 9: Semantic Robot Modeling and Simulation in ROS/Gazebo	**02 hrs.**

To create a Unified Robot Description Format (URDF) and simulate its motion in a physics-based environment.

Real-World Assignment:
Implement a Gazebo plugin to simulate contact forces during gripping.

Exemplars / Practical Applications:

- • Autonomous mobile robots (AMRs)
  • ROS-based warehouse robots
  • Self-driving robot simulation
  • Service and inspection robots

Practical 10: Case Study: Digital Twin and Smart Manufacturing Simulation	

To perform an integrated simulation of a robotic work-cell involving input data analysis and random number generation.

Real-World Assignment:
Mini project on industrial automation performance evaluation.

Exemplars / Practical Applications:

- **Digital Twin for smart factories**
- **Predictive maintenance systems**
- **Virtual commissioning of production lines**
- **Smart manufacturing and Industry 4.0 applications**

Learning Resources

Books and other resources

Text Books:

1. S. K. Saha, "Introduction to Robotics", McGraw Hill.
2. John J. Craig, "Introduction to Robotics – Mechanics and Control", Pearson Education.
3. Averill M Law, "Simulation Modeling and Analysis", Tata McGraw Hill.

References Books:

1. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, "Robot Modeling and Control", Wiley.
2. Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley.

MOOC Courses Link:

1) Robot Modeling and Simulation Lab (COEP V-Labs).
2) NPTEL Course "Mechanism and Robot Kinematics" by Prof. Anirvan Das Gupta.
3) "Modern Robotics" Specialization by Coursera.

Savitribai Phule Pune University Third Year of Automation & Robotics Engineering (2024 Pattern)				
VSE-372: Robotic Process Automation				
Teaching Scheme		**Credits**	**Examination Scheme**	
Tutorial	01 Hr./Week	2	**CCE**	50 Marks
Practical	02 Hr./Week		**End-Semester**	NA

Prerequisite Courses, if any:

- Basic Programming Knowledge (C/C++ or Python), Modeling and Simulation.

Course Objectives:

1. To provide a comprehensive understanding of Robotic Process Automation (RPA) and its development.
2. To master the concepts, tools, and techniques involved in automating business processes.
3. To design, develop, and deploy RPA bots that optimize industrial and business workflows.

Course Outcomes:

On completion of the course the learner will be able to;

CO1: DESCRIBE RPA, its history, implementation strategies, and identifying suitable processes for automation.

CO2: UTILIZE different types of variables, Control Flow logic, and data manipulation techniques in bot development.

CO3: IMPLEMENT Image, Text, and Data Table automation with robust exception-handling strategies.

CO4: DEPLOY and MAINTAIN robots using Server integration and package management utilities.

Course Contents

Unit 1	RPA Foundations, Variables, and Control Flow	(05 hrs)

Introduction: RPA basics vs. traditional automation, types of bots (Attended vs. Unattended), and the RPA Development lifecycle compared to standard SDLC.

Tool Environment: RPA tool interface, variable management (Generic, Text, Number, Array, and Data Table variables), and naming best practices.

Logic Implementation: Sequences and flowcharts; using Control Flow activities such as If-Else statements, loops (While, For Each), and Switch activities to regulate bot behavior.

Unit 2	Advanced Automation, Recording, and Data Handling	(05 hrs)

Data & Scraping: Advanced data manipulation for collections and tables; introduction to screen scraping and data scraping techniques.

Recording & Selectors: Basic, Desktop, and Web recording; configuring and debugging dynamic selectors to handle volatile UI elements.

Information Retrieval: Image-based and keyboard-based automation; automating common office file formats (Excel and PDF) using anchors and specialized extraction tools.

Unit 3	Exception Handling, Events, and Bot Deployment	(05 hrs)

Event Handling: Working with assistant bots and monitoring system triggers (hotkeys, mouse, element, and image triggers).

Error Management: Debugging tools and exception-handling strategies; implementing Try-Catch blocks to solve runtime issues.

Lifecycle Completion: Publishing projects using publish utilities; managing provision robots, server-side bot control, and maintaining package updates.

Term Work (Practical Experiments)

The student shall complete at least **any eight** activities from the following list:

1. **Tool Configuration:** Installing and configuring a standard RPA tool environment (e.g., UiPath, Blue Prism).
2. **Process Analysis:** Analyzing a real-world business process to evaluate its automation potential.
3. **Workflow Design:** Designing and documenting RPA workflows using flowcharts and sequences.
4. **Bot Construction:** Building and testing basic RPA bots using drag-and-drop interfaces.
5. **Data Integration:** Integrating RPA bots with external systems, Excel workbooks, and databases.
6. **Web Automation:** Developing a bot for web-based data extraction (web scraping) from e-commerce or news sites.
7. **File Automation:** Extracting semi-structured data from PDF invoices using anchor-based positioning.
8. **Error Handling:** Implementing Try-Catch blocks and debugging logs to handle network timeouts or UI changes.
9. **Deployment:** Publishing a bot to a central server and managing its execution through a controller/orchestrator.
10. **Cognitive Automation:** Integrating basic AI/ML modules for sentiment analysis or image recognition within a bot.

Books and other resources:

Text Books:

1. Alok Mani Tripathi, "Learning Robotic Process Automation", Packt Publishing.
2. Tom Taulli, "The Robotic Process Automation Handbook: A Guide to Implementing RPA Systems", Springer.

References Books:

1. Frank Casale et al., "Introduction to Robotic Process Automation: A Primer", Institute of RPA.
2. Richard Murdoch, "Robotic Process Automation: Guide To Building Software Robots".
3. Lim Mei Ying, "Robotic Process Automation with Blue Prism Quick Start Guide", Packt Publishing.

MOOC Courses Link:

1. UiPath RPA Academy
2. UiPath Introduction to RPA.

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