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ताळगांव पठार,
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(Accredited by NAAC with Grade A+)

GU/Acad –PG/BoS -NEP Engg. /2025-26/504 Date: 18.10.2025

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP Engg. /2024-25/764 dated 21.01.2025

In supersession to the above referred Circular, the Syllabus of Semester III & IV of the **Master of Engineering (Industrial Automation and Robotics)** Programme approved by the Standing Committee of the Academic Council in its meeting held on 24th & 25th July 2025 is attached. The Syllabus of Semester II approved earlier by the Academic Council in its meeting held on 06th December 2024 and the Syllabus of Semester I approved by the Academic Council on 22nd August 2024 is also attached.

The Dean, Faculty of Engineering and Principals of affiliated Colleges offering the **Master of Engineering (Industrial Automation and Robotics)** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2025.10.18 15:21:55 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, Faculty of Engineering, Goa University.
2. The Principals of affiliated Engineering Colleges.

Copy to,

1. The Director, Directorate of Technical Education, Govt. of Goa
2. The Chairperson, BoS in Electronics & Telecommunication Engineering.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar Examinations (Prof.), Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

MASTER OF ENGINEERING (INDUSTRIAL AUTOMATION & ROBOTICS) (RC 2024-25)

TWO YEAR PROGRAMME STRUCTURE						
Semester I						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-500	Industrial Robotics	2	0	0	2
2	ETC-501	Industrial Robotics Lab	0	0	2	2
3	ETC-502	Communication Networks	3	0	0	3
4	ETC-503	Communication Networks Lab	0	0	1	1
5	ETC-504	Introduction to Embedded Computing systems	3	0	0	3
6	ETC-505	Embedded Computing systems Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
7	ETC-531	Artificial Intelligence and Fuzzy Logic	3	1	0	4
OR						
8	ETC-532	Process Control Instrumentation	3	1	0	4
Research Specific Elective (RSE) Courses						
9	REC-561	Engineering Research & Publications	3	1	0	4
OR						
10	REC-562	Literature Review & Technical Writing for Engineers	3	1	0	4
		Total	**14**	**2**	**4**	**20**
Semester II						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-506	Industrial Automation with Programmable Logic Controllers	3	0	0	3
2	ETC-507	Programmable Logic Controllers and SCADA Lab	0	0	1	1
3	ETC-508	Industrial IoT and Edge AI	3	0	0	3
4	ETC-509	Industrial IoT and Edge AI Lab	0	0	1	1
5	ETC-510	Mobile Robotics	3	0	0	3
6	ETC-511	Mobile Robotics Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
7	ETC-533	Deep Learning	3	0	0	3
8	ETC-534	Deep Learning Lab	0	0	1	1
OR						
9	ETC-535	Advanced Control Systems	3	0	0	3
10	ETC-536	Advanced Control Systems Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
11	REC-563	Statistics and Data Analysis for Engineering Research	2	0	0	2
12	REC-564	Statistics and Data Analysis Lab	0	0	2	2
OR						
13	REC-565	Statistical Techniques for Engineering Research	2	0	0	2
14	REC-566	Probability and Statistical Analysis Lab	0	0	2	2
		TOTAL	**14**	**0**	**6**	**20**

Semester III						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-600	Introduction to Real-Time Operating System	3	0	0	3
2	ETC-601	Real-Time Operating System Lab	0	0	1	1
3	ETC-602	Machine Vision	3	0	0	3
4	ETC-603	Machine Vision Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
5	ETC-631	Wireless Sensor Networks	3	0	0	3
6	ETC-632	Wireless Sensor Networks Lab	0	0	1	1
OR						
7	ETC-633	Rapid Prototyping	3	0	0	3
8	ETC-634	Rapid Prototyping Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
9	ETC-661	System Modeling and Simulation Techniques	2	0	0	2
10	ETC-662	System Modeling and Simulation Techniques Lab	0	0	2	2
OR						
11	ETC-663	Optimization Techniques for Engineering Research	2	0	0	2
12	ETC-664	Optimization Techniques for Engineering Research Lab	0	0	2	2
General Elective (GE) Courses						
13	GEC-681	Sustainability - Principles & Practices	3	0	0	3
14	GEC-682	Sustainability - Principles & Practices Lab	0	0	1	1
OR						
15	GEC-683	Project Management	3	0	0	3
16	GEC-684	Project Management Lab	0	0	1	1
		TOTAL	**14**	**0**	**6**	**20**
Semester IV						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
General Elective (GE) Courses						
1	GEC-685	Financial Management	4	0	0	4
OR						
2	GEC-686	Entrepreneurship	4	0	0	4
Program Specific Dissertation or Internship						
3	**ETC-698**	Dissertation	0	0	0	16
OR						
4	**ETC-699**	Internship	0	0	0	16
		TOTAL	**4**	**0**	**0**	**20**

THREE YEAR PROGRAMME STRUCTURE						
Semester I						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-500	Industrial Robotics	2	0	0	2
2	ETC-501	Industrial Robotics Lab	0	0	2	2
Programme Specific Elective (PSE) Courses						
3	ETC-531	Artificial Intelligence and Fuzzy Logic	3	1	0	4
OR						
4	ETC-532	Process Control Instrumentation	3	1	0	4
Research Specific Elective (RSE) Courses						
5	REC-561	Engineering Research & Publications	3	1	0	4
OR						
6	REC-562	Literature Review & Technical Writing for Engineers	3	1	0	4
		Total	**8**	**2**	**2**	**12**
Semester II						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-506	Industrial Automation with Programmable Logic Controllers	3	0	0	3
2	ETC-507	Programmable Logic Controllers and SCADA Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
3	ETC-533	Deep Learning	3	0	0	3
4	ETC-534	Deep Learning Lab	0	0	1	1
OR						
5	ETC-535	Advanced Control Systems	3	0	0	3
6	ETC-536	Advanced Control Systems Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
7	REC-563	Statistics and Data Analysis for Engineering Research	2	0	0	2
8	REC-564	Statistics and Data Analysis Lab	0	0	2	2
OR						
9	REC-565	Statistical Techniques for Engineering Research	2	0	0	2
10	REC-566	Probability and Statistical Analysis Lab	0	0	2	2
		TOTAL	**8**	**0**	**4**	**12**

Semester III						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-502	Communication Networks	3	0	0	3
2	ETC-503	Communication Networks Lab	0	0	1	1
3	ETC-504	Introduction to Embedded Computing systems	3	0	0	3
4	ETC-505	Embedded Computing systems Lab	0	0	1	1
Programme Specific Elective (PSE) Courses						
5	ETC-631	Wireless Sensor Networks	3	0	0	3
6	ETC-632	Wireless Sensor Networks Lab	0	0	1	1
OR						
7	ETC-633	Rapid Prototyping	3	0	0	3
8	ETC-634	Rapid Prototyping Lab	0	0	1	1
		TOTAL	**9**	**0**	**3**	**12**
Semester IV						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-508	Industrial IoT and Edge AI	3	0	0	3
2	ETC-509	Industrial IoT and Edge AI Lab	0	0	1	1
3	ETC-510	Mobile Robotics	3	0	0	3
4	ETC-511	Mobile Robotics Lab	0	0	1	1
General Elective (GE) Courses						
5	GEC-681	Sustainability - Principles & Practices	3	0	0	3
6	GEC-682	Sustainability - Principles & Practices Lab	0	0	1	1
OR						
7	GEC-683	Project Management	3	0	0	3
8	GEC-684	Project Management Lab	0	0	1	1
		TOTAL	**9**	**0**	**3**	**12**

Semester V						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
Programme Specific Core (PSC) Courses						
1	ETC-600	Introduction to Real-Time Operating System	3	0	0	3
2	ETC-601	Real-Time Operating System Lab	0	0	1	1
3	ETC-602	Machine Vision	3	0	0	3
4	ETC-603	Machine Vision Lab	0	0	1	1
Research Specific Elective (RSE) Courses						
5	ETC-661	System Modeling and Simulation Techniques	2	0	0	2
6	ETC-662	System Modeling and Simulation Techniques Lab	0	0	2	2
OR						
7	ETC-663	Optimization Techniques for Engineering Research	2	0	0	2
8	ETC-664	Optimization Techniques for Engineering Research Lab	0	0	2	2
		TOTAL	**8**	**0**	**4**	**12**
Semester VI						
Sr. No.	**Course Code**	**Title of the Course**	**L**	**T**	**P**	**Credits**
General Elective (GE) Courses						
1	GEC-685	Financial Management	4	0	0	4
OR						
2	GEC-686	Entrepreneurship	4	0	0	4
Program Specific Dissertation or Internship						
3	**ETC-698**	Dissertation	0	0	0	16
OR						
4	**ETC-699**	Internship	0	0	0	16
		TOTAL	**4**	**0**	**0**	**16**

Semester I

Programme Specific Core (PSC) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-500
Title of the Course : Industrial Robotics
Number of Credits : 02 (2L)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basics of Control Systems	
Course Objectives:	The course aims to provide the student with: 1. An understanding of the components of an industrial robot, including their functions and operational principles. 2. Knowledge of control algorithms for industrial robots based on mathematical modeling. 3. An understanding to assess the suitability of mechanical and electrical components for specific industrial robot applications. 4. Knowledge of optimizing control and motion algorithms for enhancing robot performance.	
Content:		**No of hours**
Unit -1	Industrial Robots and their applications. Actuators and Grippers. Sensors and Sensor Selection. Transformations: Robot architecture, Pose, Coordinate transformations, DH parameters. DH parameterization of Euler angles. Kinematics: Forward and Inverse position analysis. Velocity analysis. Link Velocities. Jacobian Computation. Forward and Inverse Velocity analysis. Acceleration analysis.	**8**
Unit -2	Statics and manipulator design: Forces and moments balance, recursive calculations. Equivalent joint torques. Role of Jacobian in statics. Manipulator design. Functional requirements of a Robot. Kinematic and Kinetostatic measures. Structural measures.	**6**
Unit -3	Dynamics: Inertia properties. Euler-Lagrange formulation. Newton-Euler formulation. Recursive Newton-Euler formulation. Dynamic Algorithms. Control: A robotic joint. PID Control of moving block. Selection of PID gains. Joint Controllers. Multivariable robot control: Linearized control, PD position control, computed torque control. Feedforward control.	**8**
Unit- 4	Motion Planning: Joint space planning – Cubic polynomials, Cubic polynomials with intermediate points, Quintic Polynomials. Trajectory with given initial and final points. Trajectory with given initial intermediate and final points. Linear segments with parabolic blend. Cycloidal trajectory. Cartesian space planning. Path primitives. Cartesian trajectories. Point to Point v/s continuous path planning.	**8**

Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning
References/ Readings:	1. S. K. Saha, "Introduction to Robotics", 2nd Ed. McGrawHill Education. ISBN-13: 978-0070140011 2. John J. Craig, "Introduction to Robotics Mechanics and Control", 3rd Ed. Pearson Education International, ISBN-13: 978-0201543612 3. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, "Robotics: Modelling, planning and Control", Springer 2011, ISBN-13: 978-1846286414
Course Outcomes:	The student shall have the ability to CO 1. Explain different parts and their working, mathematical model and real-world applications of an industrial robot. CO 2. Apply mathematical tools to model, control and plan trajectories for a given industrial robot. CO 3. Evaluate mechanical and electrical components, robot model and parameters and control algorithms for a given robot and application. CO 4. Develop robot models, control and motion algorithms and allied systems for a given application.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-501
Title of the Course : Industrial Robotics Lab
Number of Credits : 02 (2P)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basics of control systems and basic programming in C/Python	
Course Objectives:	The course aims to provide the student with: 1. An understanding of the foundational concepts of ROS, UDRF, XACRO, Rviz and its architecture. 2. Capacity to execute simple programs to start and move the KUKA robot. 3. Knowledge of tools to perform mastering, tool calibration, and base calibration on KUKA robots for accurate operation work 4. Capacity to implement KUKA robot programs for pick-and-place operations in various applications.	
Content:		**No of hours**
	List of Experiments (Any ten to be performed): 1. Introduction to ROS, ROS Topics, Services, Actions and Nodes. 2. Introduction to ROS URDF, XACRO, Rviz, Gazebo. 3. Introduction to ROS MoveIt and Simulations 4. KUKA Robot Programming – Introduction, starting and moving the robot 5. KUKA Robot Programming – Mastering, Tool calibration and Base Calibration 6. KUKA Robot Programming – Executing Robot Programs, PTP, Linear and curved motions 7. KUKA Robot Programming – Program for tracing a given path 8. KUKA Robot Programming – Program for Pick and Place operation 9. KUKA Robot Programming – Programs using logic functions 10. KUKA Robot Programming – Programs using variables 11. KUKA Robot Programming – Programs using control functions, loops, switch-case and jumps 12. KUKA Robot Programming – Interrupts and I/O	**60**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. S. K. Saha, “Introduction to Robotics”, 2nd Ed. McGrawHill Education. ISBN-13: 978-0070140011 2. John J. Craig, “Introduction to Robotics Mechanics and Control”, 3rd Ed. Pearson Education International, ISBN-13: 978-0201543612 3. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, “Robotics: Modelling, planning and Control”, Springer 2011, ISBN-13: 978-1846286414	

Course Outcomes:	The student shall have the ability to CO 1. Explain ROS fundamental concepts such as nodes, topics, services, messages and parts and functions of KUKA industrial manipulator. CO 2. Develop models in ROS, visualize in Rviz and simulate in Gazebo and MoveIt. CO 3. Perform mastering, calibration and manual jogging of KUKA industrial robot CO 4. Develop programs for a given task using teach pendant for KUKA industrial robot

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-502
Title of the Course : Communication Networks
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basics of Networking Protocols	
Course Objectives:	The course aims to provide the student with: 1. An Introduction to the OSI reference model, Ethernet cabling, and the three-layer hierarchical model. 2. An Understanding of networking devices and IP addressing schemes, including subnetting and VLSM. 3. A capacity to configure routers and implement IP routing protocols, including IPv6. 4. Knowledge of Layer 2 switching, VLANs, and associated protocols.	
Content:		**No of hours**
Unit -1	OSI reference model, Ethernet Cabling, Three Layer Hierarchical Model: Core layer, Distribution layer, Access layer. Networking devices: Hubs, Switches, Routers, Repeaters, and Bridges, 4 layers protocols. IP addressing: class A, B, C, D, E, Private/Public IP Addresses, IPV4 Address types: Unicast, broadcast, multicast.	**13**
Unit -2	IP Subnetting: Subnet masks, Classless Inter-Domain Routing (CIDR), Subnetting Class C Addresses, Subnetting Class B Addresses, and Subnetting Class A Addresses. Variable Length Subnet Masks (VLSM): VLSM Design, Implementing VLSM Networks. IPv6: Benefits and Uses, IPv6 Address types, IPv6 Routing Protocols: Static, RIPv6, EIGRPv6, OSPFv6.	**12**
Unit -3	Router Fundamentals: Hostnames, Banners, Setting passwords. IP Routing: Routing Basics; IP Routing Process; Configuring IP Routing: Static Routing: Static, Default Routing; Dynamic Routing: Routing Protocols Basics, Distance-Vector Routing Protocols, Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF); Introduction to Access Control Lists (ACLs): Standard, Extended; Network Address Translation (NAT), HSRP, DHCP, Ether Channels.	**10**
Unit- 4	Layer 2 Switching: Switching services, Types of switches, Spanning Tree Protocols (STP), Configuring Catalyst Switches: Basic Commands, Port security, Virtual LANs (VLANs): VLAN Basics, Routing between VLANs, VLAN Trunking Protocol (VTP): Modes of operation, Configuring VTP.	**10**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	

References/ Readings:	1. Todd Lammle, CCNA Routing and Switching Study Guide, Wiley-India, Seventh Edition, 2011. ISBN-13: 978-1119288282 2. Wendell Odom, Cisco CCNA Routing and Switching ICND2 200-101, Official Cert Guide, Cisco Press, 2013. ISBN-13: 978-9332520950 3. CCNA Routing and Switching Portable Command Guide by Scott Empson, Cisco Press, 2016. ISBN-13: 978-1587205880 4. Computer Networking: A Top-Down Approach by James F. Kurose and Keith W. Ross, Pearson Education, 2013. ISBN-13: 978-0133594140
Course Outcomes:	The student shall have the ability to: CO 1. Explain the OSI reference model, Ethernet cabling standards, and the three-layer hierarchical model. CO 2. Describe the functions of various networking devices and apply IP addressing schemes, including subnetting and VLSM. CO 3. Configure routers with basic and advanced settings, and implement both static and dynamic routing protocols, including IPv6. CO 4. Design Layer 2 switching services, VLANs, and VTP in network environments.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-503
Title of the Course : Communication Networks Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basic programming in C/Python	
Course Objectives:	The course aims to provide the student with: 1. Knowledge of Networking software like Cisco Packet Tracer. 2. An Understanding of networking devices and IP addressing schemes, including subnetting and VLSM. 3. Knowledge to configure routers and implement IP routing protocols, including IPv6. 4. An Understanding of Layer 2 switching, VLANs, and associated protocols.	
Content:		**No of hours**
Unit -1	List of Experiments (Any ten to be performed): 1. To build and configure a network using Static Routing using Packet Tracer software. 2. To build and configure a network using Default routing using Cisco Packet Tracer software. 3. To build and configure a network using rip routing using Cisco Packet Tracer Software. 4. To build and configure a network using EIGRP routing using Cisco Packet Tracer Software. 5. To build and configure a network using OSPF routing protocol using Cisco Packet Tracer software. 6. To use VLSM and manage Extended Access Control List using Cisco Packet Tracer software. 7. To study different types of NAT techniques using Cisco Packet Tracer Software. 8. To build and configure a network using static IPv6 routing using Cisco Packet Tracer Software. 9. To build and configure a network using IPv6 RIP routing using Cisco Packet Tracer Software. 10. To build and configure a network using IPv6 EIGRP routing using Cisco Packet Tracer Software. 11. To build and configure a network using ipv6 ospf routing using Cisco Packet Tracer Software. 12. To create, transfer ports, range of ports and to delete a VLAN using Cisco Packet Tracer. 13. To enable trunking on inter-switch connection and verify the configuration using Cisco Packet Tracer. 14. To build and configure a network using different types of Trunk-based inter-VLAN routing using Cisco Packet Tracer software.	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive	

	learning and Collaborative learning
References/ Readings:	1. Todd Lammle, CCNA Routing and Switching Study Guide, Wiley-India, Seventh Edition, 2011. ISBN-13: 978-1119288282 2. Wendell Odom, Cisco CCNA Routing and Switching ICND2 200-101, Official Cert Guide, Cisco Press, 2013. ISBN-13: 978-9332520950 3. CCNA Routing and Switching Portable Command Guide by Scott Empson, Cisco Press, 2016. ISBN-13: 978-1587205880 4. Computer Networking: A Top-Down Approach by James F. Kurose and Keith W. Ross, Pearson Education, 2013. ISBN-13: 978-0133594140
Course Outcomes:	The student shall have the ability to: CO 1. Demonstrate the working of Networking software like Cisco Packet Tracer. CO 2. Configure various networking devices and apply IP addressing schemes, including subnetting and VLSM. CO 3. Configure routers with basic and advanced settings, and implement both static and dynamic routing protocols, including IPv6. CO 4. Configure Layer 2 switching services, VLANs, and VTP in network environments.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-504
Title of the Course : Introduction to Embedded Computing Systems
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of Basics of Microprocessors	
Course Objectives:	The course aims to provide the student with: 1. Knowledge of the ARM processor architecture, including exceptions and exception handling schemes. 2. Capacity to summarize and compare the ARM and THUMB instruction sets, highlighting their features and applications. 3. Knowledge to Analyze and write assembly language programs for ARM and THUMB modes, with a focus on coding, debugging, and optimization. 4. Knowledge to design and implement embedded systems using ARM7 architecture.	
Content:		**No of hours**
Unit -1	ARM architecture and Processor fundamentals: Types of computer Architectures, ISA's and ARM History, RISC and ARM Design, architectural inheritance, ARM Programmer's model, memory system, memory formats and data types, ARM core data flow model, Processor modes, registers: General purpose and Program status, flags, Overview of Endianness, unaligned access support, ARM 3 and 5 stage Pipeline, hazards, ARM7TDMI block, core and functional diagrams, memory interface, bus Interface signals and bus cycle types, Exceptions, interrupts and vector table.	**13**
Unit -2	ARM Instruction set: Branch, data processing, comparison, SIMD, Multiply, miscellaneous data processing, status register transfer, load store, coprocessor, exception-generating instructions, Elementary assembly level programs. Thumb state: Thumb Programmers model, Thumb exceptions, Implementation and applications. Thumb Instruction set, Elementary assembly level programs.	**12**
Unit -3	Exception handling: ARM processor exceptions and modes, vector table, exception priorities, link offset registers. Interrupt handling: Assigning interrupts, interrupt latency, IRQ and FIQ exceptions, basic interrupt stack design, Interrupt handling schemes: non-nested and nested interrupt handler.	**10**
Unit- 4	ARM Coprocessor Interface: Coprocessor availability, interface signals, handshaking, connecting coprocessors. Vector Floating Point Processor (VFP) architecture: Overview, floating point model, registers, floating-point exceptions, compliance with IEEE 754 standard, VFP and ARM interactions. Advanced Microcontroller Bus Architecture (AMBA): Overview, Typical	**10**

	AMBA Based Microcontroller, AHB bus features, components, bus interconnection, AHB Bus transfers, APB bus transfers, APB Bridge.	
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Andrew N. Sloss, Dominic Symes, Chris Wright; ARM System Developers Guide, Designing and Optimizing System Software; Elsevier, 2004, ISBN-13: 978-1558608740 2. Steve Furber; ARM System-on-Chip Architecture, 2nd Edition;Pearson Education, 2000, ISBN-13: 978-0201675191 3. J.R. Gibson "ARM Assembly Language – an Introduction" Dept. of Electrical Engineering and Electronics, The University of Liverpool, 2007, ISBN-13 9781447717157 4. Online Resources: a. ARM7TDMI-S Technical Reference Manual, ARM Inc. b. Embedded System Design with ARM, Prof. Indranil c. Sengupta Prof. Kamalika Dutta Computer Science and Engineering IIT Kharagpur, NPTEL Course	
Course Outcomes:	The student shall have the ability to CO 1. Explain the architecture of ARM processor, concept of Exceptions and exception handling schemes, ARM coprocessor interface, Vector floating point processor architecture and AMBA bus architecture. CO 2. Summarize the ARM and THUMB instruction sets. CO 3. Analyze Assembly language programs for ARM and THUMB mode CO 4. Design embedded systems with ARM7 architecture	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-505
Title of the Course : Embedded Computing systems Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basic programming in C/Python	
Course Objectives:	The course aims to provide the student with: 1. Knowledge to interface various sensors and actuators with the Raspberry Pi. 2. Knowledge to control LED intensity using Pulse Width Modulation (PWM) and interfacing with DC and servo motors. 3. Skills to interface the Raspberry Pi with sensors such as fire sensors, TSOP sensors, and ultrasonic distance sensors. 4. Hands-on experience in writing and executing assembly language programs on an ARM processor using the Raspberry Pi.	
Content:		**No of hours**
	List of Experiments: 1. Interfacing Raspberry Pi with LEDs and generating a pattern on them. 2. Interfacing Raspberry Pi with 7 Segment display 3. Interfacing Raspberry Pi with the fire sensor 4. Interfacing Raspberry Pi with the TSOP sensor 5. Varying the intensity of the LED by using Pulse Width Modulation on Raspberry-pi 6. Interface two DC motors and rotate 1st clockwise and 2nd anti-clockwise then revert the polarity-stop and repeat 7. Interface Raspberry-pi with Servo motor 8. Interfacing Raspberry-pi with Ultrasonic Distance Sensors (ultrasonic sensor HC-SR04) 9. Assembly Language Codes on ARM processor in Raspberry-pi	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Andrew N. Sloss, Dominic Symes, Chris Wright; ARM System Developers Guide, Designing and Optimizing System Software; Elsevier, 2004, ISBN-13: 978-1558608740 2. Steve Furber; ARM System-on-Chip Architecture, 2nd Edition;Pearson Education, 2000, ISBN-13: 978-0201675191 3. J.R. Gibson “ARM Assembly Language – an Introduction” Dept. of Electrical Engineering and Electronics, The University of Liverpool, 2007, ISBN-13 9781447717157 4. ARM7TDMI-S Technical Reference Manual, ARM Inc.	

Course Outcomes:	The student shall have the ability to CO 1. Interface Raspberry Pi with LEDs, 7-segment displays, fire sensors, TSOP sensors, and ultrasonic distance sensors. CO 2. Implement Pulse Width Modulation to vary LED intensity and control the rotation of DC and servo motors. CO 3. Connect and manage various sensors and actuators with the Raspberry Pi for practical applications. CO 4. Write and analyze assembly language programs for the ARM processor on the Raspberry Pi platform.

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Programme Specific Elective (PSE) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-531
Title of the Course : Artificial Intelligence and Fuzzy Logic
Number of Credits : 04(3L+ 1T)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basic Mathematics, Linear Algebra	
Course Objectives:	The course aims to provide the student with: 1. An introduction to basic principles of AI and fuzzy sets, operations, and properties of fuzzy sets, fuzzy relations, features of membership functions, and the processes of fuzzification and defuzzification. 2. Skills for evaluating various search strategies, knowledge representation techniques, and fuzzy systems to solve complex AI problems. 3. Knowledge of different fuzzy inference systems to determine their suitability for various practical applications. 4. Skill to design fuzzy rule-based systems.	
Content:		**No of hours**
Unit -1	Introduction, Propositional logic Search: Uninformed strategies (BFS, DFS, Dijkstra), Informed strategies (A* search, heuristic functions, hill-climbing), Adversarial search (Minimax algorithm, Alpha-beta pruning).	**10 + 3T**
Unit -2	Predicate logic: Knowledge representation, Resolution Rule-based systems: Natural language parsing, Context free grammar, Constraint satisfaction problems Planning: State-space search, Planning Graphs, Partial order planning.	**11 + 4T**
Unit -3	Classical sets: Operations and properties of classical sets, Mapping of classical sets to the functions. Fuzzy sets - Membership functions, Fuzzy set operations, Properties of fuzzy sets. Classical and Fuzzy relations: Cartesian product, crisp relations-cardinality, operations and properties of crisp relations. Fuzzy relations-cardinality, operations, properties of fuzzy relations, fuzzy Cartesian product and composition, Fuzzy tolerance and equivalence relations, value assignments and other format of the composition operation. Logic vs Crisp Logic Fuzzification and Defuzzification: Features of the membership functions, various forms, fuzzification, defuzzification to crisp sets, - cuts for fuzzy relations, Defuzzification to scalars. Fuzzy logic and approximate reasoning, other forms of the implication operation.	**12+4T**
Unit- 4	Fuzzy Systems : Natural language, Linguistic hedges, Fuzzy (Rule based) System, Aggregation of fuzzy rules, Graphical techniques of inference, Membership value assignments: Intuition, Inference, rank ordering, Fuzzy Associative memories.	**12 + 4T**

	Fuzzy Inference System: Construction and working principle of FIS, Methods of FIS: Mamdani FIS, Takagi-Sugeno Fuzzy Model, Comparison between Mamdani and Sugeno methods. Design examples of FIS to solve day to day life problems .	
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Artificial Intelligence – A Modern Approach. Second Edition, Stuart Russel, Peter Norvig, PHI/ Pearson Education, ISBN-13: 978-8120323827 2. Artificial Intelligence, Kevin Knight, Elaine Rich, B. Shivashankar Nair, 3rd Edition, 2008, McGraw Hill Education, ISBN-13:978-0070087705 3. Timothy J.Ross - Fuzzy logic with engineering applications, 3rd edition, Wiley, 2010, ISBN-13: 978-8126531264 4. Fuzzy sets and Fuzzy logic theory and Applications, George J.Klir, Bo Yuan - PHI, New Delhi,1995, ISBN-13: 978-9332549425 5. Principles of Soft Computing , SN Sivanandan , S N Deepa, 3rd edition, Wiley, ISBN-13: 978-8126577132 6. Neural Networks and Fuzzy logic and Genetic Algorithms, Synthesis and Applications, S.Rajasekaran, G.A.Vijayalakshmi - PHI, New Delhi, 2003, ISBN-13: 978-8120321861	
Course Outcomes:	The student shall have the ability to CO 1. Describe and apply the basic principles of AI and fuzzy sets, operations and properties of fuzzy sets, fuzzy relations, features of membership functions, fuzzification process and defuzzification process. CO 2. Analyse search strategies, knowledge representation techniques, and fuzzy systems to solve complex problems in artificial intelligence CO 3. Compare different fuzzy inference systems to determine their suitability for various practical applications. CO 4. Design fuzzy rule-based systems.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-532
Title of the Course : Process Control Instrumentation
Number of Credits : 04 (3L+ 1T)
Effective from AY : 2024-25

Pre-requisites for the Course:	Knowledge of basics of control systems	
Course Objectives:	The course aims to provide the student with: 1. Understanding of the principles of process control. 2. Knowledge of the principles and workings of process control, controllers, process loops, and data acquirement systems. 3. Understanding of the mechanisms of process control, controllers, process loops, and data acquisition. 4. Knowledge of a given application's process control, controller mechanism, process loop, and data acquisition logic.	
Content:		**No of hours**
Unit -1	**Introduction to Process Control:** Introduction; control systems; process control block diagram; servomechanisms; control system evaluation; on-off control; analog and digital control; process characteristics. **Discrete state process control:** Introduction; definition; characteristics of the system; relay controllers.	**10 + 3T**
Unit -2	**Controller Principles:** Introduction; overview of control system parameters, Continuous controller modes: proportional, integral, derivative control modes. **Analog Controllers:** Introduction; Electronic controllers: Error Detector, Single Mode (P, I & D), Composite controller modes (PI, PD & PID); Pneumatic controllers (PI, PD, PID)	**11 + 4T**
Unit -3	**Final Control:** Operation, Signal conversion, Power electronics - Switching devices, SCR and TRIAC **Telemetry:** Pneumatic telemetering system; electronic telemetry system; electrical electronic telemetering system. **Introduction to process loops**: simple control schemes for level, flow, temperature as applied to reactor, heat exchanger.	**12 + 4T**
Unit- 4	**Computer in process control:** Data logging; supervisory control; computer- based controller; digital controller for a turbine and generator. **Data logger:** basics, Advantages, anatomy, types, factors to be considered in selecting a data logger. **Data-Acquisition Systems**: Working, Advantages.	**12 + 4T**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Curtis D. Johnson; Process Control Instrumentation Technology, 7th Edition; Pearson Education ISBN-13: 978-0131194571 2. Alan S. Morris; Principles of Measurement and Instrumentation, 3rd Ed.; Butterworth-Heinemann (Reed Educational and Professional Publishing Ltd) 2001 ISBN-13: 978-0750650816	

	3. S. K. Singh; Industrial Instrumentation and control; TMH ISBN-13: 978-0070678200
Course Outcomes:	The student shall have the ability to CO 1. Explain the principles of process control, controllers, process loops, and data acquisition methods. CO 2. Analyze the mechanisms of process control, controllers, process loops, and data acquisition. CO 3. Evaluate the workings of a given application's process control, controller mechanism, process loop, and data acquisition logic. CO 4. Design a control system for an industrial process.

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Research Specific Elective (RSE) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : REC-561
Title of the Course : Engineering Research & Publications
Number of Credits : 4 (3L +1T)
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable the students to 1. Understand the importance of literature review, defining the research objectives. 2. Explain qualitative and quantitative methods of data analyses and its importance. 3. Classify research publications, select appropriate journals based on research areas. 4. Practice ethics in publication and academic integrity	
Content:		**No of Hours**
Unit -1	**Overview of scientific research in engineering**, foundational and fundamental concepts like types of research and considerations for research in specific domains, motivation to do research, critical thinking, assumptions and hypotheses, basic and applied research, importance of formulation of broad research objectives	**11 + 4T**
Unit -2	**Purpose and Methodology of Literature Search and Review** of the scientific and engineering publications. Sources such as scholarly databases, public domain, open access, current literature, review articles, critical review and gap analysis, defining research objectives	**11+ 4T**
Unit -3	**Quantitative and qualitative Data –** importance of data in research, types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, mathematical modeling, simulation, experimental data, optimization methods; Qualitative data collection, preparing questioners, rating scale, conducting survey, validation of models.	**12+ 4T**
Unit- 4	**Preparation of Publications-** Elements of research publications, types of publications, writing for journal publications, basic requirements for publication, selection of journals, journal quality indicators, peer review, reply to comments and responses, publication ethics, references, citations, authorship, plagiarism, academic integrity	**11 + 3T**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Herman Tang, 'Engineering Research-Design, Methods and Publications', John Wiley and Sons, 2021, ISBN:9781119624486. 2. Michael Jay Katz, 'From Research to Manuscript', Springer	

	Publication, 2009, ISBN:9781402094668. 3. Rob Dekkers, Lindsey Casey, Peter Langhorne, 'Making Literature Review Work', Springer Publications, 2022, ISBN:9783030900243 4. Meikang Qiu, Han Qiu, Yi Zeng, 'Research & Technical Writing for Science and Engineering', Taylor & Francis Publications, 2022, ISBN:9781003139058.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of literature review, defining the research objectives. CO 2. Explain qualitative and quantitative methods of data analyses and its importance. CO 3. Classify research publications, select appropriate journals based on research areas. CO 4. Practice ethics in publication and academic integrity

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Name of the Programme : Industrial Automation & Robotics
Course Code : REC-562
Title of the Course : Literature Review & Technical Writing For Engineers
Number of Credits : 4 (3L +1T)
Effective from AY : 2024-25

Pre-requisites for the Course:	Nil	
Course Objectives:	The course will enable the students to 1. Understand the importance of literature review and writing a review paper. 2. Explain the method to be followed to write a review paper. 3. Classify data for qualitative and quantitative analysis 4. Demonstrate technical writing for conference.	
Content:		**No of Hours**
Unit -1	**Overview on Literature Review**, difference between objectives of literature review and research objectives; types of literature review, qualitative and quantitative reviews, search strategies, primary and secondary sources, database search strategies, field search, root search, complimentary search, meta-analysis	**12 + 4T**
Unit -2	**Database management of literature reviews**, bibliometric analysis, importance of writing a review paper, reply to comments and responses, publication ethics, references, citations, authorship, plagiarism, academic integrity; public domain, open access, current literature.	**11 + 4T**
Unit -3	**Technical writing on a specific research topic**, structure of the paper, abstract, introduction, experimental, simulation, analysis, discussion, inferences, title, acknowledgment, referencing, presentation of tables, figures, graphs, equations; comparison between technical writing for conference papers and journal paper	**11 + 4T**
Unit- 4	**Importance of data in research**, types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, mathematical modeling, simulation, experimental data, optimization methods; Qualitative data collection, preparing questioners, rating scale, conducting survey, validation of models.	**11 + 3T**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Rob Dekkers, Lindsey Casey, Peter Langhorne, 'Making Literature Review Work – Multidisciplinary Guide to Systematic Approaches', Springer Publications, 2022, ISBN:9783030900243. 2. Michael Jay Katz, 'From Research to Manuscript', Springer Publication, 2009, ISBN:9781402094668. 3. Herman Tang, 'Engineering Research-Design, Methods and Publications', John Wiley and Sons, 2021, ISBN:9781119624486.	

	4. Meikang Qiu, Han Qiu, Yi Zeng, 'Research & Technical Writing for Science and Engineering', Taylor & Francis Publications, 2022, ISBN:9781003139058.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of literature review and writing a review paper. CO 2. Explain the method to be followed to write a review paper. CO 3. Classify data for qualitative and quantitative analysis CO 4. Demonstrate technical writing for conference.

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Semester II

Programme Specific Core (PSC) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-506
Title of the Course : Industrial Automation with Programmable Logic Controllers
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. An Introduction to PLC Programming with the skills to create and execute both basic and advanced PLC programs using a wide range of instructions and functions. 2. An Understanding of Field Device Integration, empowering students with the ability to effectively interface and troubleshoot various field devices connected to PLCs, ensuring operational efficiency and reliability. 3. An Introduction to HMI/SCADA Systems, equipping students with the skills to design, program, and utilize these systems for real-time monitoring and control of industrial processes. 4. An Understanding of AC Drives and Servo Systems to configure, program, integrate, and troubleshoot these systems for diverse industrial applications with PLCs.	
Content:		**No of hours**
Unit -1	Need of Automation, Role of PLC in automation, Introduction to the field devices attached to PLC, PLC fundamentals: Block diagram, PLC components, Power supply, CPU, Input Output modules, Types of input and outputs, Source sink concept in PLC, Scan cycle execution, Introduction of PLC software, Addressing concepts. Factors to consider while selecting a PLC.	**11**
Unit -2	Basic PLC Programming: Programming ON-OFF inputs to produce ON-OFF outputs, Concepts of latching, interlocking, jogging outputs via ladder programing. Programming instructions, Arithmetic & logical, Compare, Add/Sub/Or-block, Leading edge / trailing edge instructions, Move block application, Timer Block programming, Counter Block programming, Advance instructions, Comment functions, Master control /set / reset function.	**11**
Unit -3	HMI (HUMAN MACHINE INTERFACE)/ SCADA : Scada Fundamentals, Working principle and types of HMI, Programming techniques for Text display, Variable parameter display and setting, Alarm messages, Page generation ,Sequence of pages, Graphic display, Communication of SCADA to PLC AC DRIVES (VFD): Basic principle of AC drives, Types of load: Constant torque / Constant power, Programming of AC drives,	**12**

	Selection criteria of the Drives, Configuration of parameters, Communication with PLC.	
Unit- 4	SERVO: Multiple control points speed (velocity), position. Digital and Analog i/o points, High speed output, Home positioning of servo, Encoder concept and its i/o points, MODBUS communication with PLC, RS 485, RS 232 communication. Interfacing of above devices. Fundamentals of Modbus, Profibus, fieldbus and Industrial Internet.	**11**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. John Webb, Ronal Weiss; "Programmable Logic Controllers: Principles & Applications", 5th Edition; Prentice Hall of India; ISBN-13: 978-8120323087 2. Gordon Clarke, Deon Reynders; "Practical Modern SCADA Protocols DNP3, 60870.5 and Related Systems", 1st Edition, Newnes , An imprint of Elsevier;ISBN-13: 978-0750657990 3. Frank D. Petruzella;" Programmable Logic Controllers" ,5th Edition, McGraw Hill; ISBN-13: 978-9353167271 4. Stuart A Boyer; "SCADA: Supervisory Control and Data Acquisition", Fourth Edition 4th Edition, International Society of Automation; ISBN-13: 978-1936007097 5. Deon Reynders, Steve Mackay, Edwin Wright ;"Practical Industrial Data Communications Best Practice Techniques". Publisher: Newnes , An imprint of Elsevier; ISBN-13: 978-0750663953	
Course Outcomes:	The student shall have the ability to: CO 1. Develop basic and advanced PLC programs using a variety of instructions and functions to control industrial processes. CO 2. Explain the operation of various field devices connected to PLCs, ensuring smooth and efficient operations. CO 3. Design HMI and SCADA systems for effective real-time monitoring and control of industrial automation processes. CO 4. Write programs for AC drives and servo systems for various industrial applications, including troubleshooting and integration with PLCs.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-507
Title of the Course : Programmable Logic Controllers and SCADA Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. An understanding of PLC Programming methodologies to create and execute both basic and advanced PLC programs using a wide range of instructions and functions. 2. Knowledge of Field Device Integration, to effectively interface and troubleshoot various field devices connected to PLCs, ensuring operational efficiency and reliability. 3. An understanding of HMI/SCADA Systems to design, program, and utilize these systems for real-time monitoring and control of industrial processes. 4. An Understanding of AC Drives and Servo Systems to configure, program, integrate, and troubleshoot these systems for diverse industrial applications with PLCs.	
Content:		**No of hours**
	List of Experiments (Any ten to be performed): 1. Wiring of PLC with input (Switches/Sensors) and output devices (AC Load). 2. Control of output devices using timers using PLC. 3. Counting operations using various sensors using PLC. 4. Interfacing analog sensors to PLC. 5. Control of AC motors using only VFD (2 Experiments),(Interfacing and writing programs) 6. Control of AC motors using VFD and PLC (2 Experiments),(Interfacing and writing programs) 7. Interfacing of HMI to PLC(2 Experiments),(Interfacing and writing programs) 8. Introduction to SCADA software. 9. Interfacing of PLC and SCADA software to control various tasks. 10. Interfacing of servo to PLC(2 Experiments),(Interfacing and writing programs)	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. John Webb, Ronal Weiss; “Programmable Logic Controllers: Principles & Applications”, 5th Edition; Prentice Hall of India; ISBN-13: 978-8120323087 2. Gordon Clarke, Deon Reynders; “Practical Modern SCADA Protocols DNP3, 60870.5 and Related Systems”, 1st Edition, Newnes , An imprint of Elsevier;ISBN-13: 978-0750657990	

	3. Frank D. Petruzella;"Programmable Logic Controllers" ,5th Edition, McGraw Hill; ISBN-13: 978-9353167271 4. Stuart A Boyer; "SCADA: Supervisory Control and Data Acquisition", Fourth Edition 4th Edition, International Society of Automation; ISBN-13: 978-1936007097 5. Deon Reynders, Steve Mackay, Edwin Wright;"Practical Industrial Data Communications Best Practice Techniques". Publisher: Newnes , An imprint of Elsevier; ISBN-13: 978-0750663953
Course Outcomes:	The student shall have the ability to: CO 1. Develop and execute both basic and advanced PLC programs using a variety of instructions and functions to control industrial processes. CO 2. Interface and troubleshoot various field devices connected to PLCs, ensuring smooth and efficient operations. CO 3. Design, program, and operate HMI and SCADA systems for effective real-time monitoring and control of industrial automation processes. CO 4. Configure, and program AC drives and servo systems for various industrial applications, including troubleshooting and integration with PLCs.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-508
Title of the Course : Industrial IoT and Edge AI
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. Introduction to evolution of Industry 4.0 and Industrial internet of things and its applications. 2. Knowledge of IIoT reference architecture and impact of IIoT. 3. Introduction to Edge AI technology and its applications. 4. Knowledge of various algorithms, hardware involved in Edge AI.	
Content:		**No of hours**
Unit -1	Overview of Industry 4.0 and Industrial Internet of Things : Introduction , Industry 4.0: Industrial revolution: Phases of development, Evolution of Industry 4.0, Environmental impacts of industrial revolution, Industrial Internet, Applications of Industry 4.0, IIoT: Industrial IoT: Business Model and Reference Architecture, Prerequisites of IIoT Basics of CPS, CPS and IIoT, Applications of IIoT.	**12**
Unit -2	Industrial Internet of Things: Introduction: IIoT and Industry 4.0, IIC, Industrial Internet Systems: Design of industrial internet systems, Impact of industrial internet, Benefits of industrial internet, Industrial sensing: Traditional sensing, Contemporary sensing, Industrial Processes: Features of IIoT for industrial processes, Industrial plant–The future architecture, Viewpoint of industrial processes, Digital Enterprise, Applications of Industry 4.0.	**13**
Unit -3	A Brief Introduction to Edge AI: The Edge (and the Internet of Things), Artificial Intelligence, machine learning and Edge AI, Need for edge AI, benefits of edge AI. Common Uses cases of Edge AI The Hardware of Edge AI: Sensors, Signals, and Sources of Data, Processors for Edge AI, Edge AI Hardware Architecture	**10**
Unit- 4	Algorithms for Edge AI: Working with Data Streams, Artificial Intelligence Algorithms, The Edge AI Workflow, Brief overview of designing Edge AI Applications. Evaluating, Deploying, and Supporting Edge AI Applications	**10**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. S. Misra, C. Roy, and A. Mukherjee, 2020. Introduction to Industrial Internet of Things and Industry 4.0. CRC Press; ISBN-13: 978-0367644710 2. S. Misra, A. Mukherjee, and A. Roy, 2020. Introduction to IoT. Cambridge University Press; ISBN-13: 978-1108959742	

	3. Daniel Situnayake, Jenny Plunkett, AI at the Edge, January 2023, O'Reilly Media, Inc, ISBN: 9781098120207. 4. Raj Kamal, INTERNET OF THINGS Architecture and Design Principles, McGraw Hill Education (India) Private Limited, 2017; ISBN-13: 978-9390727384
Course Outcomes:	The student shall have the ability to: CO 1. Explain the evolution of Industry 4.0 and Industrial internet of things and its applications. CO 2. Describe the IIoT reference architecture and impact of IIoT. CO 3. Analyze different Edge AI technologies and their applications. CO 4. Write programs for various algorithms, hardware involved in Edge AI.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-509
Title of the Course : Industrial IoT and Edge AI Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. Knowledge of Edge AI Fundamentals: 2. An understanding of the Implementation of Edge AI Solutions: 3. An understanding of the Optimization of AI Models for Edge Devices. 4. Knowledge of various parameters determining Edge AI Performance	
Content:		**No of hours**
	List of Experiments (Any ten to be performed): 1. Object Detection 2. Speech Recognition 3. Predictive Maintenance 4. Facial Recognition with Privacy Filters 5. Agricultural Monitoring 6. Environmental Sound Classification 7. Real-time Human Activity Recognition 8. Smart Home Automation 9. Gesture Recognition 10. Smart Alarm Systems 11. Traffic Control Suggested Software for AI Edge Impulse studio Suggested Microcontrollers: Raspberry Pi, Arduino Nicla Sense ME, Arduino Nano 33	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. John Webb, Ronal Weiss; "Programmable Logic Controllers: Principles & Applications", 5th Edition; Prentice Hall of India; ISBN-13: 978-8120323087 2. Gordon Clarke, Deon Reynders; "Practical Modern SCADA Protocols DNP3, 60870.5 and Related Systems", 1st Edition, Newnes , An imprint of Elsevier;ISBN-13: 978-0750657990 3. Frank D. Petruzella;"Programmable Logic Controllers" ,5th Edition, McGraw Hill; ISBN-13: 978-9353167271 4. 4. Stuart A Boyer; "SCADA: Supervisory Control and Data Acquisition", Fourth Edition 4th Edition, International Society of Automation; ISBN-13: 978-1936007097 5. Online resources: https://docs.edgeimpulse.com/experts https://edgeimpulse.com/	
Course Outcomes:	The student shall have the ability to: CO 1. Comprehend Edge AI Concepts and Limitations CO 2. Implement Lightweight AI Models on Edge Devices	

	CO 3. Evaluate Model Performance on Edge Devices CO 4. Develop Custom Edge AI Solutions for Real-World Applications

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-510
Title of the Course : Mobile Robotics
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. An understanding of the fundamental concepts and classifications of mobile robots 2. Knowledge of ground robots (wheeled and legged), aerial robots, and marine robots based on their design and functionality. 3. An understanding of the functions of various sensors used in mobile robot navigation 4. Knowledge to develop autonomous map-building techniques to enable mobile robots to create and update maps of their environment in real-time	
Content:		**No of hours**
Unit -1	Introduction to mobile robots. Principle of locomotion and types of locomotion. Types of mobile robots: ground robots (wheeled and legged robots), aerial robots and marine robots. Mobile Robot Kinematics: Kinematic Models and Constraints. Mobile Robot Manoeuvrability. Mobile Robot Workspace. Degrees of freedom. Holonomic robots. Path and trajectory considerations. Motion Control (Kinematic Control).	**10**
Unit -2	Dynamics of mobile robot: Lagrange-Euler and Newton-Euler methods. Examples: Dubins car, differential drive car, unicycle, pendulum, cartpole, quadcopter, surface and underwater vehicle. Holonomic vs. non-holonomic systems.	**10**
Unit -3	Control: PID Control Tuning, cascading PID, advantages and drawbacks. Linear Quadratic Regulator (LQR) Computing optimal actions for linear dynamical systems with quadratic cost-to-go functions. Sensors for mobile robot navigation: magnetic and optical position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, tactile and proximity sensors, ultrasound/RADAR rangefinder, laser scanner/LiDAR, infrared rangefinder, GPS, visual and motion sensing systems.	**13**
Unit- 4	Localization: Error propagation model, Probabilistic map-based localization. State estimation: Bayesian localization**,** Kalman Filter, Extended Kalman Filter, Particle Filter. Map Representations and Map Alignment: Occupancy grids, Octrees, Voronoi Graph. Iterative Closest Point (ICP). Autonomous map building, Simultaneous localization and mapping (SLAM). Path planning: Configuration space, Road map path planning, Cell decomposition path planning, Potential field path planning. Dijkstra, A*, Rapidly-exploring Random Trees (RRT), Probabilistic	**12**

	Road Maps (PRM). Obstacle avoidance: Bug algorithm, Vector field histogram, The bubble band technique, Dynamic window approaches.	
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. R Siegwart, IR Nourbakhsh, D Scaramuzza, Introduction to Autonomous Mobile Robots, MIT Press, USA, 2011; ISBN: 9780262015356 2. SG Tzafestas, Introduction to Mobile Robot Control, Elsevier, USA, 2014; ISBN: 9780124170490 3. S Thrun, W Burgard, D Fox, Probabilistic Robotics, MIT Press, USA, 2005; ISBN-13: 978-0262201629 4. A Kelly, Mobile Robotics: Mathematics, Models, and Methods, Cambridge University Press, USA, 2013; ISBN-13: 978-1107031159 5. Steven M. LaValle, Planning Algorithms, Cambridge University Press; Illustrated edition (29 May 2006); ISBN-13: 978-0521862059	
Course Outcomes:	The student shall have the ability to CO 1. Explain different types of mobile robots, their components, models and control and planning algorithms CO 2. Apply mathematical tools to model, control and plan trajectories for a given mobile robot. CO 3. Evaluate mechanical and electrical components, robot model and parameters and control algorithms for a given robot and application. CO 4. Develop robot models, control and motion algorithms and allied systems for a given application.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-511
Title of the Course : Mobile Robotics Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. Knowledge of the components and functions of different parts of a mobile robot. 2. An understanding of various models available in Robot Operating System (ROS), visualize them in Rviz, and simulate autonomous behaviors in Gazebo. 3. Knowledge on interfacing various sensors, actuators, and control electronics with a mobile robot. 4. An understanding to develop and implement programs for specific tasks using ROS and hardware integration.	
Content:		**No of hours**
	List of Experiments: 1. Computer based dynamic (numerical) simulation of different wheeled mobile robots. 2. ROS – Setting up simulation environment with Gazebo 3. ROS – SLAM examples 4. Hardware – Setting up hardware robot 5. Hardware – Program for manual control of robot 6. Hardware – Setting up PID Control 7. Hardware – Setting up odometry, Range and LIDAR sensors 8. Hardware – Setting up IMU sensors 9. ROS + Hardware – Interfacing hardware with ROS and Rviz 10. Hardware – SLAM example 11. ROS – Path planning examples 12. ROS + Hardware – Autonomous Navigation	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. R Siegwart, IR Nourbakhsh, D Scaramuzza, Introduction to Autonomous Mobile Robots, MIT Press, USA, 2011; ISBN: 9780262015356 2. SG Tzafestas, Introduction to Mobile Robot Control, Elsevier, USA, 2014; ISBN: 9780124170490 3. S Thrun, W Burgard, D Fox, Probabilistic Robotics, MIT Press, USA, 2005; ISBN-13: 978-0262201629 4. A Kelly, Mobile Robotics: Mathematics, Models, and Methods, Cambridge University Press, USA, 2013; ISBN-13: 978-1107031159	

Course Outcomes:	The student shall have the ability to CO 1. Explain different parts of a given mobile robot and their functions. CO 2. Develop models in ROS, visualize in Rviz and simulate autonomous behaviours in Gazebo. CO 3. Interface different sensors, actuators and control electronics for a given mobile robot. CO 4. Develop programs for a given task through ROS and hardware.

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Programme Specific Elective (PSE) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-533
Title of the Course : Deep Learning
Number of Credits : 03 (3L)
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course aims to provide the student with: 1. An introduction to the fundamental concepts and architecture of deep learning, including the functioning of various neural networks such as CNNs, RNNs, and LSTMs, through historical context and key success stories. 2. Knowledge of various optimization and regularization methods, including momentum-based GD, Stochastic GD, AdaGrad, RMSProp, Adam, and techniques to prevent underfitting and overfitting in deep learning models. 3. An understanding of the performance of deep learning models by adjusting model parameters and architecture, covering advanced topics such as better activation functions, weight initialization methods, and normalization techniques. 4. An understanding of the ethical and societal impacts of deep learning applications, teaching students to develop models considering fairness, accountability, transparency, and the correction of distribution shifts in various environments.	
Content:		**No of hours**
Unit -1	History and success stories of Deep Learning, McCulloch Pitts Neuron, Thresholding Logic, Perceptrons, Perceptron Learning Algorithm and Convergence, Multilayer Perceptrons (MLPs), Representation Power of MLPs, Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, Backpropagation, Gradient Descent (GD), overfitting-underfitting.	**10**
Unit -2	Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Basic concepts of Linear and Logistic Regression, Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Dropout Greedy Layerwise Pre-training, Better activation functions: ReLU, Leaky-ReLU, ELU, SELU, Swish, GELU, SILU, Maxout, Better weight initialization methods, Batch Normalization, Instance Normalization, Group Normalization.	**11**
Unit -3	Convolutional Neural Networks: Padding, Stride, Pooling, LeNet, AlexNet, ZF-Net, VGGNet, GoogLeNet, ResNet, MobileNet-v1, MobileNet-v2, EfficientNet, Visualizing Convolutional Neural Networks, Guided Backpropagation, Deep Dream, Deep Art.	**12**

	Recurrent Neural Networks, Backpropagation Through Time (BPTT), Vanishing and Exploding Gradients, Truncated BPTT, Gated Recurrent Units (GRUs). Long Short Term Memory (LSTM) Cells, Solving the vanishing gradient problem with LSTMs, Encoder Decoder Models, Attention Mechanism, Attention over images, Hierarchical Attention.	
Unit- 4	Natural Language Processing and Word Embeddings, Sequence-to-Sequence Models, Transformers: Multi-headed Self Attention, Cross Attention, Generative Adversarial Networks: Generate Some "Real" Data, Generator, Discriminator, Training. Environment and Distribution Shift: Types and examples of Distribution Shift, Correction of Distribution Shift, A Taxonomy of Learning Problems and Considering the Environment, Fairness, Accountability, and Transparency in Machine Learning.	**12**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Ian Goodfellow and Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press, 2016; ISBN: 9789353675974 2. Michael A. Nielsen, Neural Networks and Deep Learning, Determination Press, 2015 3. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006; ISBN-13 978-1493938438 4. Charu C. Aggarwal, Neural Networks and Deep Learning, Springer Cham, Second Edition, 2023; ISBN-13: 978-3319944623 5. Zhang, Aston and Lipton, Zachary C. and Li, Mu and Smola, Alexander J. Dive into Deep Learning,Cambridge University Press, 2023; 978-1009389433 6. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, John Wiley & Sons Inc., 2012; ISBN-13: 978-8126511167 7. Coursera Course by Andrew Ng, Younes Bensouda Mourri and Kian Katanforoosh on Deep Learning Specialization, https://www.coursera.org/specializations/deep-learning	
Course Outcomes:	The student shall have the ability to CO 1. Explain Deep Learning Concepts including the architecture and functioning of various neural networks such as CNNs, RNNs, and LSTMs. CO 2. Implement and compare various optimization and regularization methods to enhance the training of deep learning models and prevent problems like underfitting, and overfitting. CO 3. Analyze the performance of deep learning models, using adjustment model parameters and architecture to improve outcomes. CO 4. Develop deep learning models considering ethical and societal impacts of deep learning applications.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-534
Title of the Course : Deep Learning Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	1. Programming skills in Python 2. Knowledge of Python libraries e.g., NumPy, Pandas, Matplotlib	
Course Objectives:	The course aims to provide the student with: 1. Ability to describe the fundamental concepts and architectures of deep learning, including various neural networks such as CNNs, RNNs, and LSTMs, and their applications in industrial automation and robotics. 2. Ability to apply deep learning techniques to train and implement neural network models for solving problems in industrial automation and robotics, using appropriate algorithms and methods. 3. Ability to Evaluate the performance of deep learning models, optimizing parameters and architectures to improve outcomes in industrial applications. 4. Ability to develop deep learning solutions, including novel architectures and approaches, for complex industrial automation and robotics tasks, integrating ethical considerations and societal impact into the development process.	
Content:		**No of hours**
	List of Experiments: 1. Implementing Perceptron for Defect Detection for Quality Control in the Manufacturing Process: Implement a single-layer perceptron to classify defective and non-defective products on a manufacturing line, while considering the ethical implications of misclassification. 2. Training Multilayer Perceptron (MLP) for Robotic Sensor Data Interpretation: Build an MLP with backpropagation using gradient calculations and weight updated to classify or predict states based on robotic sensor data (e.g., accelerometers, gyroscopes). 3. Optimization Algorithms in Robotic Control Systems: Train a network model using optimization algorithms like SGD, Momentum-based GD etc. to predict control signals for a robotic arm and evaluate convergence rates and the stability of each algorithm. 4. Regularization in Predictive Maintenance: Modify a neural network that predicts equipment failures based on sensor data, incorporating L2 regularization, early stopping dropout layers, and data augmentation to analyze the effects on overfitting. 5. Implementing Convolutional Neural Network for Object Recognition in Robotic Vision Systems: Understand	**30**

	parameter sharing, padding, stride, and pooling in convolutional networks for robotic vision tasks. 6. Activation Functions and Weight Initialization in Autonomous Navigation: Explore different activation functions and weight initialization methods in a network that predicts navigation paths based on environmental inputs. 7. Normalization Techniques in Robots: Add Batch Normalization etc. to models that predict robot movements in shared workspaces with humans. 8. Transfer Learning for Automated Defect Detection in Manufacturing: Apply transfer learning using pre-trained convolutional neural networks (CNNs) such as ResNet or EfficientNet to create an automated visual inspection system that will detect surface defects like cracks, inclusions, and porosity on a manufacturing line. 9. Implementing RNNs for Robot Motion Prediction: Build a model to predict the next state or position of a robot based on previous movements. 10. Implementing LSTMs for Predictive Maintenance Scheduling: Build LSTM models to predict equipment failures over time, enabling proactive maintenance scheduling. 11. Encoder-Decoder Models with Attention for Industrial Process Optimization: Build a model that takes sequences of process parameters and predicts optimal settings, using attention mechanisms to focus on critical parameters. 12. Implementing Transformers for Robotic Language Understanding: Build a transformer model that interprets natural language commands and translates them into robotic actions. 13. Building GANs for Synthetic Industrial Data Generation: build a GAN to generate synthetic sensor data or images of industrial components, which can be used to augment training datasets.	
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Ian Goodfellow and Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press, 2016; ISBN: 9789353675974 2. Michael A. Nielsen, Neural Networks and Deep Learning, Determination Press, 2015 3. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006; ISBN-13 978-1493938438 4. Charu C. Aggarwal, Neural Networks and Deep Learning, Springer Cham, Second Edition, 2023; ISBN-13: 978-3319944623 5. Zhang, Aston and Lipton, Zachary C. and Li, Mu and Smola, Alexander J. Dive into Deep Learning, ,Cambridge University Press, 2023; 978-1009389433 6. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, John Wiley & Sons Inc., 2012; ISBN-13: 978-8126511167	

	7. Coursera Course by Andrew Ng, Younes Bensouda Mourri and Kian Katanforoosh on Deep Learning Specialization, https://www.coursera.org/specializations/deep-learning
Course Outcomes:	The student will be able to: CO 1. Describe the fundamental concepts and architectures of deep learning, including various neural networks such as CNNs, RNNs, and LSTMs, and their applications in industrial automation and robotics. CO 2. Apply deep learning techniques to train and implement neural network models for solving problems in industrial automation and robotics, using appropriate algorithms and methods. CO 3. Evaluate the performance of deep learning models, optimizing parameters and architectures to improve outcomes in industrial applications. CO 4. Develop deep learning solutions, including novel architectures and approaches, for complex industrial automation and robotics tasks, integrating ethical considerations and societal impact into the development process.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-535
Title of the Course : Advanced Control Systems
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	1. Fundamental control system course 2. Fundamental signals and systems course	
Course Objectives:	The course aims to provide the student with: 1. An Ability to explain applications, advantages, disadvantages, modeling and control approaches in digital domain 2. An Ability to develop models for systems in the digital domain using z transform and state variable methods. 3. An Ability to evaluate stability, time response characteristics, controllability and observability of sampled continuous time plants 4. An Ability to design compensators using frequency response plots, root locus and pole placement approaches.	
Content:		**No of hours**
Unit -1	Digital Control: Introduction, Advantages and Challenges, basic digital control scheme, Basic discrete time signals, State variable models and impulse response models. Z-transform, ideal sampler and z-transforms of useful functions. Shifting theorems and inversion. Jury stability criterion. Model of sample and hold system. Aliasing and sampling theorem. Reconstruction of analog signals.	**11**
Unit -2	Discretization methods: Impulse invariance, step-invariance, finite difference and bilinear transformation. Z-domain description of sampled continuous time plants. Implementation of digital controllers. Digital PID controllers. Digital temperature and position control system. Digital compensator design using frequency response plots and root locus.	**12**
Unit -3	State variable methods: State variable representation. State variable to transfer function and transfer function to state variable conversion. Cayley-Hamilton theorem. Eigen value and Eigen vectors. Solution to state equations. Concepts of controllability and observability. Multivariable systems. State description of digital processes. State description of sampled continuous time plants. Solution of state difference equations.	**12**
Unit- 4	Stability improvement by state feedback. Conditions for arbitrary pole placement. State regulator design. Design of state observer. Compensator design by separation principle. Feedforward control. State feedback with integral control. Digital control systems with state feedback. Deadbeat control. Introduction to LQR design.	**10**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	

References/ Readings:	1. M. Gopal, "Digital Control and State Variable Methods", 4th Ed., McGrawHill 2011. ISBN:978-0071333276 2. K. Ogata, "Discrete-Time Control Systems", 2nd Ed, Pearson, 2015. ISBN: 9789332549661 3. K. Moudgalya, "Digital Control", Wiley India, 2009. ISBN:978-8126522064
Course Outcomes:	The student shall have the ability to CO 1. Explain applications, advantages, disadvantages, modeling and control approaches in digital domain CO 2. Develop models for systems in the digital domain using z transform and state variable methods. CO 3. Evaluate stability, time response characteristics, controllability and observability of sampled continuous time plants CO 4. Design compensators using frequency response plots, root locus and pole placement approaches.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-536
Title of the Course : Advanced Control Systems Lab
Number of Credits : 01 (1P)
Effective from AY : 2024-25

Pre-requisites for the Course:	1. Programming skills in Python 2. Knowledge of Python libraries e.g., NumPy, Pandas, Matplotlib	
Course Objectives:	The course aims to provide the student with: 1. An ability to implement digital temperature and position controllers 2. An ability to design and implement digital compensators using frequency and time domain techniques 3. An ability to design and implement digital controllers and observes using state space methods 4. An ability to design and implement digital PID, Deadbeat, feedforward and LQR controllers.	
Content:		**No of hours**
	List of Experiments: 1. Introduction to Digital Control Design (Matlab/Python/Scilab etc) 2. Digital PID Controller design 3. Digital Temperature Control 4. Digital Position Control 5. Digital Compensator Design using Root Locus 6. Digital Compensator Design using Bode plot 7. Controller Design using Pole Placement 8. Observer Design 9. Compensator Design using Separation Principle 10. Deadbeat Control 11. Feedforward control 12. LQR Controller Design	**30**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. M. Gopal, "Digital Control and State Variable Methods", 4th Ed., McGrawHill 2011. ISBN:978-0071333276 2. K. Ogata, "Discrete-Time Control Systems", 2nd Ed, Pearson, 2015. ISBN: 9789332549661 3. K. Moudgalya, "Digital Control", Wiley India, 2009. ISBN:978-8126522064	
Course Outcomes:	The student will be able to: CO 1. Understand Digital Control System Fundamentals CO 2. Apply Digital Control Design Techniques such as PID, pole placement, feedforward, and LQR CO 3. Analyze and Evaluating Controller Performance CO 4. Design and Implementing Advanced Control Solutions	

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Research Specific Elective (RSE) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : REC-563
Title of the Course : Statistics and Data Analysis for Engineering Research
Number of Credits : 2
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic Knowledge of Statistics	
Course Objectives:	The course will enable the students to 1. Explain the different types of data and parameter estimations 2. Explain standard probability distributions 3. Select the appropriate parameter estimation & distribution method 4. Co-relate different Hypotheses	
Content:		**No of Hours**
Unit -1	**Data Analysis:** Types of data, data collection techniques, Quantitative methods for analysis of data – statistical tools, experimental data, Qualitative data collection, questioners, rating scale, conducting survey. Statistical Modeling and Graphical Diagnostics - Scatter Plot, Stem-and-Leaf Plot, Histogram, Box Plot **Correlation and Regression Modeling:** Basic concept and numericals.	**9**
Unit -2	**Probability distributions and Sampling distributions:** Basic introduction to Bernoulli, Binomial and Normal distribution. Basic introduction to Sampling distributions- Normal, t-distribution, Chi-square and F- distributions.	**7**
Unit -3	**Parameter estimation:** Point Estimation – Concept, unbiased estimator, method of maximum likelihood. Parameter estimation of standard distributions- Binomial and Normal. Confidence Interval Estimation - Concept, Confidence interval on mean of single normal population with variance known, Confidence interval on the ratio of variances of two normal distributions	**7**
Unit- 4	**Tests of Hypotheses:** Introduction, Type I and type II errors, significance level and power of the test, Test of hypotheses - on mean of single normal population with variance known, on variance of single normal population.	**7**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. D. V Thiel, 'Research Methods for Engineers', Cambridge Press, 2014, ISBN:978-110-70-3-488 2. T. Mustafy, T. U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 3. D. C. Montgomery, C. G. Runger, 'Applied Statistics and Probability for Engineers', 6th Edition, Wiley India, 2016, ISBN 0-471-20454-4	

	4. R. E. Walpole, R. H. Myers, S. L. Myers, K. E. Ye; Probability and Statistics for Engineers and Scientists ,9th Edition, Pearson Education India, 2013, ISBN 978-0-321-62911-1 5. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Explain the different types of data and probability distributions. CO 2. Select the appropriate parameter estimation & distribution method CO 3. Apply estimators for the given situations. CO 4. Evaluate Hypotheses based on the statistical considerations.

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Name of the Programme : Industrial Automation & Robotics
Course Code : REC-564
Title of the Course : Statistics and Data Analysis Lab
Number of Credits : 2
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic Knowledge of Statistics	
Course Objectives:	The course will enable the students to 1. Apply the different types of data and parameter estimations 2. Analyze standard probability distributions 3. Demonstrate parameter estimation & distribution methods 4. Co-relate different Hypotheses	
Content:		**No of Hours**
	Using open-source software like libreoffice or any proprietary software perform following experiments: 1. Obtain measures of central tendency and dispersion. 2. Obtain Quartiles, Percentiles and prepare Box-and-Whisker Diagram 3. Develop Pie chart, Bar Chart, Histogram and Stem-and-Leaf Plot, 4. Develop correlation using Pearson's Correlation Coefficient and showing Scatter Diagrams and Trendlines 5. Develop Linear and Nonlinear Regression Models 6. Obtain probability values involving probability distributions – Binomial and Normal 7. Obtain values of Normal, t-distribution, Chi-square and F-statistic. 8. Develop confidence interval for single population and two populations with variance known. 9. Develop confidence interval on the ratio of variances of two normal distributions. 10. Perform test of hypotheses on mean/variance of single/ two population(s).	**60**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. D. V Thiel, 'Research Methods for Engineers', Cambridge Press, 2014, ISBN:978-110-70-3-488 2. T. Mustafy, T. U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 3. D. C. Montgomery, C. G. Runger, 'Applied Statistics and Probability for Engineers', 6th Edition, Wiley India, 2016, ISBN 0-471-20454-4 4. R. E. Walpole, R. H. Myers, S. L. Myers, K. E. Ye; Probability and Statistics for Engineers and Scientists ,9th Edition, Pearson Education India, 2013, ISBN 978-0-321-62911-1	

	5. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Apply the different types of data and parameter estimations CO 2. Analyze standard probability distributions CO 3. Demonstrate parameter estimation & distribution methods CO 4. Co-relate different Hypotheses

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Name of the Programme : Industrial Automation & Robotics
Course Code : REC-565
Title of the Course : Statistical Techniques for Engineering Research
Number of Credits : 2
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of Statistics and Probability	
Course Objectives:	The course will enable the students to 1. Understand the importance of statistical methods for research 2. Select the appropriate factorial design method for a given set of experimental plan. 3. Apply basic probability theorems and draw relevant inferences. 4. Analyze suitable probability model for given set of data	
Content:		**No of Hours**
Unit-1	**Overview on Statistical methods**, collection of data, one dimensional and two-dimensional statistical analysis, computation of central tendency and dispersion for grouped and ungrouped data, correlation preliminary, understanding variability in data.	**6**
Unit-2	**Design of Experiments**, Preparation of experimental plan, full factorial design, fractional factorial design, identification of parameters and levels, randomization, replication, blocking, interaction; numerical; Optimization methods for two parameters.	**9**
Unit-3	**Probability Preliminary**: Introduction to Probability, definition, Sample Space, Events, Conditional Probability, Theorem on total probability, Bayes' theorem. Random Variable: Introduction, Discrete and Continuous distribution, Characteristics- Mean, Variance and distribution function.	**8**
Unit-4	**Probability and Sampling Distribution**: Bernoulli, Binomial, Exponential, Normal, distribution. Mean, variance and distribution function, important properties, approximations and applications. Statistic and Sampling Distribution: Population and Sample. Statistic, Sampling distributions- Normal, t-distribution, Chi-square and F- distributions.	**7**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Tahvir Mustafy, Tauhid U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 2. Jiju Antony, 'Design of Experiments for Engineers & Scientists', Elsevier, 2023, ISBN 978-044-315-1736 3. Douglas Montgomery, 'Design and Analysis of Experiments', Wiley India, Eighth Edition, 2013, 9788126540501	

	4. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010, ISBN: 9788126523504 5. R. Johnson, Probability and Statistics for engineers, Eighth Edition, Prentice Hall of India, New Delhi, 2015, ISBN 978-1-292-17601-7 6. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Understand the importance of statistical methods for research CO 2. Select the appropriate factorial design method for a given set of experimental plans. CO 3. Apply basic probability theorems and draw relevant inferences. CO 4. Analyze suitable probability model for given set of data

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Name of the Programme : Industrial Automation & Robotics
Course Code : REC-566
Title of the Course : Probability and Statistical Analysis Lab
Number of Credits : 2
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of Statistics and Probability	
Course Objectives:	The course will enable the students to 1. Apply basic probability theorems and draw relevant inferences. 2. Analyze suitable probability model for given set of data 3. Demonstrate factorial design methods 4. Synthesize fractional and full factorial experimental design data	
Content:		**No of Hours**
	Using open-source software like libreoffice or any proprietary software perform following experiments: 1. Obtain probability values involving discrete probability distributions - Bernoulli, Binomial. 2. Obtain probability values involving continuous probability distributions - Exponential and Normal distributions. 3. Obtain values of Normal, t-distribution, Chi-square and F-statistic. 4. Obtain values of Mean, Variance and distribution function of Bernoulli and Binomial distribution. 5. Obtain values of Mean, Variance and distribution function of Exponential and Normal distributions. 6. Obtain values of central tendency of grouped and ungrouped data. 7. Obtain values of dispersion of grouped and ungrouped data. 8. Analyse experimental output using full factorial design. 9. Analyse experimental output using fractional factorial design. 10. Analyse a full case study in involving full factorial design or fractional factorial design.	**60**
Pedagogy:	Inquiry based learning, Integrative, Reflective Learning, Constructive learning and Collaborative learning	
References/ Readings:	1. Tahvir Mustafy, Tauhid U Rahman, 'Statistics & Data Analysis for Engineers and Scientists', Springer, 2024, ISBN:9789819946600. 2. Jiju Antony, 'Design of Experiments for Engineers & Scientists', Elsevier, 2023, ISBN 978-044-315-1736 3. Douglas Montgomery, 'Design and Analysis of Experiments', Wiley India, Eighth Edition, 2013, 9788126540501 4. J. Ravichandran, Probability and Statistics for Engineers, Wiley India, 2010, ISBN: 9788126523504 5. R. Johnson, Probability and Statistics for engineers, Eighth Edition, Prentice Hall of India, New Delhi, 2015, ISBN 978-1-292-17601-7	

	6. J. Schmuller, Statistical Analysis with Excel for Dummies, 5th Edition, John Wiley & Sons, 2022.
Course Outcomes:	After taking this course, student will be able to: CO 1. Apply basic probability theorems and draw relevant inferences. CO 2. Analyze suitable probability model for given set of data CO 3. Demonstrate factorial design methods CO 4. Synthesize fractional and full factorial experimental design data

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SEMESTER III

Programme Specific Core (PSC) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-600
Title of the Course : Introduction to Real-Time Operating System
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic Programming skills	
Course Objectives:	The course will enable the students to: 1. Appreciate the difference between hard and soft real-time constraints. 2. Gain knowledge of real-time embedded applications, considering performance constraints, timing requirements, and resource limitations. 3. Gain knowledge of memory management techniques, synchronization techniques between different processes. 4. Develop an understanding of real-time system performance through practical case studies and industry-relevant scenarios.	
Content:		**No. of Hours**
Unit-1	**Basics Of Developing For Embedded Systems:** Introduction, Overview Of Linkers And The Linking Process, Executable And Linking Format, Mapping Executable Images Into Target Embedded Systems. **Embedded System Initialization:** Introduction, Target System Tools And Image Transfer, Target Boot Scenarios, Target System Software Initialization Sequence, On-Chip Debugging, **Introduction To Real-Time Operating Systems:** A Brief History Of Operating Systems, Defining An RTOS, The Scheduler, Objects, Services, Key Characteristics Of An RTOS, Points To Remember.	**10**
Unit-2	**Tasks:** Introduction, Defining A Task, Task States and Scheduling, Typical Task Operations, Typical Task Structure, Synchronization, Communication, and Concurrency. **Semaphores:** Introduction, Defining Semaphores, Typical Semaphore Operations, Typical Semaphore Use, Message **Queues:** Introduction, Defining Message Queues, Message Queue States, Message Queue Content, Message Queue Storage, Typical Message Queue Operations, Typical Message Queue Use.	**12**

Unit-3	**Other Kernel Objects:** Introduction, Pipes, Event Registers, Signals, Condition Variables. **Other RTOS Services:** Introduction, Other Building Blocks. Component Configuration. **Exceptions And Interrupts:** Introduction, What Are Exceptions And Interrupts?, Applications Of Exceptions And Interrupts, A Closer Look At Exceptions And Interrupts, Processing General Exceptions, The Nature Of Spurious Interrupts.	**13**
Unit-4	**Timer And Timer Services:** Introduction, Real-Time Clocks And System Clocks,Programmable Interval Timers, Timer Interrupt Service Routines, A Model For Implementing The Soft-Timer Handling Facility, Timing Wheels, Soft Timers And Timer Related Operations, I/O Subsystem: Introduction, Basic I/O Concepts, The I/O Subsystem.	**10**
Pedagogy	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.	
References/ Readings:	**Text Books:** 1. Qing Li and Caroline Yao, "Real-Time Concepts for Embedded Systems", CRC Press, India, 1st Edition, 2003, ISBN: 978-1578201242. 2. Jane W. S. Liu, "Real-Time Systems", PHI, 1st Edition, 2000, ISBN: 978-0130996510. **Reference Readings:** 1. Xiaocong Fan, "Real-Time Embedded Systems: Design Principles and Engineering Practices, Newnes (an imprint of Butterworth-Heinemann Ltd.), 2015, ISBN: 978-0128015070. 2. Brian Amos, “Hands-On RTOS with Microcontrollers”, Packt Publishing, 1st Edition, United Kingdom, 2020, ISBN: 978-1838826734. 3. Daniele Lacamera, “Embedded Systems Architecture”, Packt Publishing, 1st Edition, United Kingdom, 2023, ISBN: 978-1803239545.	
Course Outcomes:	After taking this course, student will be able to: 1. Define real-time systems and describe their characteristics, types, and typical applications. 2. Explain the architecture of an RTOS and illustrate task management, scheduling, and synchronization concepts. 3. Apply task scheduling algorithms and inter-process communication techniques to real-time system scenarios. 4. Analyze task interactions and synchronization issues in real-time systems using semaphores, mutexes, and message queues.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-601
Title of the Course : Real-Time Operating Systems Lab
Number of Credits : 01
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Programming in C.	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of the fundamental principles of real-time systems. 2. Gain hands-on experience with RTOS. 3. Gain knowledge on the development of interrupt-driven applications. 4. Explore the design and development of various real-time applications.	
Content:		**No. of Hours**
	List of Experiments: 1. RTOS Setup on an Embedded board (Raspberry pi, STM32, etc.) 2. Write a c program and run all the basic commands of the RTOS 3. Write a program to demonstrate Task Creation 4. Write a program to demonstrate Task Priorities and Preemption on a RTOS 5. Write a program to demonstrate Task Synchronization Using Semaphores 6. Write a program to demonstrate Task Communication Using Queues 7. Write a program to demonstrate Timers in RTOS 8. Write a program to demonstrate Interrupt Handling in RTOS 9. Write a program to demonstrate Real-Time Performance Monitoring 10. Write a program to demonstrate Dynamic Memory Allocation and Stack Monitoring	**30**
Pedagogy	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	
References/ Readings:	**Text Books:** 1. Qing Li and Caroline Yao, "Real-Time Concepts for Embedded Systems" , CRC Press, India, 1st Edition, 2003, ISBN: 978-1578201242. 2. Jane W. S. Liu, "Real-Time Systems", PHI, 1st Edition, 2000, ISBN: 978-0130996510. **Reference Readings:**	

	1. Xiaocong Fan, "Real-Time Embedded Systems: Design Principles and Engineering Practices, Newnes (an imprint of Butterworth-Heinemann Ltd.), 2015, ISBN: 978-0128015070. 2. Brian Amos, "Hands-On RTOS with Microcontrollers", Packt Publishing, 1st Edition, United Kingdom, 2020, ISBN: 978-1838826734. 3. Daniele Lacamera, "Embedded Systems Architecture", Packt Publishing, 1st Edition, United Kingdom, 2023, ISBN: 978-1803239545.
Course Outcomes:	After taking this course, student will be able to: 1. Define the structure and characteristics of real-time operating systems. 2. Explain the working of task scheduling, synchronization, and communication mechanisms in RTOS. 3. Implement multitasking applications using FreeRTOS or similar RTOS. 4. Analyze the behavior of RTOS-based applications under various scheduling strategies and inter-task communication methods.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-602
Title of the Course : Machine Vision
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Image Processing	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of camera geometry and image formation. 2. Get familiarized with geometric and analytical image features. 3. Gain knowledge of segmentation and motion analysis techniques. 4. Explore various classification and fitting techniques.	
Content:		**No of hours**
Unit -1	**Camera Geometry:** Camera Projections, Projective Geometry, Reconstruction from more than one view, Three and Four-view Geometry and n-view Reconstruction, Transfer, Euclidean Reconstruction, Auto-Calibration1, Stereopsis. **Image Formation:** Radiometry – Measuring Light: Light in Space and at Surfaces, Important Special Cases, Sources, Shadows and Shading: Radiometric Properties of Light Sources, Qualitative Radiometry, Sources and their Effects, Local Shading Models, Photometric Stereo, Interreflections.	**11**
Unit -2	**Geometric Image Features:** Differential Geometry: Curves, Surfaces, Contour Geometry: The Occluding Contour and the Image Contour, The Cusps and the Inflections of the Image Contour, Koenderink's Theorem. **Analytical Image Features:** Analytical Euclidean Geometry: Coordinate Systems and Homogeneous Coordinates, Coordinate System Changes and Rigid Transformations, Geometric Camera Parameters: Intrinsic, Extrinsic, Characterization of Perspective Projection Matrices, Calibration Methods.	**11**
Unit -3	**Segmentation Using Clustering Methods:** Shot Boundary Detection, Background Subtraction, Simple Clustering Methods, Segmentation using Simple Clustering Methods, Clustering and Segmentation using K-Means. **Affine Structure from Motion:** Elements of Affine Geometry, Affine Structure from Two Images, Affine Structure from Multiple Images, From Affine to Euclidean Images, Affine Motion Segmentation	**12**
Unit- 4	**Fitting:** The Hough Transform, Fitting Lines, Fitting Curves, Fitting to the Outlines of Surfaces.	**11**

	Finding Templates using Classifiers: Classifiers, Feature Selection, Neural Networks, Support Vector Machines, Ethics in Machine Vision.	
Pedagogy:	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.	
References/ Readings:	**Text Books:** 1. Richard Hartley, Andrew Zisserman, "Multiple View Geometry in Computer Vision", 2nd Edition, Cambridge University Press, United Kingdom, 2003, ISBN: 978-0521540513. 2. David Forsyth and Jean Ponce, "Computer Vision: A Modern Approach", Pearson Education India, 2nd Edition, 2015, ISBN: 978-9332550117. 3. Rosalie A. Waelen, "The Ethics of Computer Vision: An Overview in Terms of Power", Springer, March 2023, DOI: https://doi.org/10.1007/s43681-023-00272-x. **Reference Readings:** 1. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer Nature Switzerland AG, 2nd Edition, 2021, ISBN: 978-3030343712. 2. Simon J. D. Prince, "Computer Vision: Models, Learning and Inference", Cambridge University Press, United Kingdom, 2011, ISBN: 978-1107011793. 3. Emanuele Trucco, Alessandro Verri, "Introductory Techniques for 3-D Computer Vision", Prentice Hall, United Kingdom, 1998, ISBN: 978-0132611084.	
Course Outcomes:	After taking this course, student will be able to: CO 1. Describe and apply the basic principles of Machine Vision. CO 2. Analyse the relationships and transformations in Machine Vision. CO 3. Compare various Image Analysis techniques in Machine Vision. CO 4. Develop pseudocode for a given Machine Vision task.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-603
Title of the Course : Machine Vision Lab
Number of Credits : 01
Effective from AY : 2024-25

Pre-requisites for the Course:	1. Programming Skills in Python 2. Python libraries relevant to image processing and machine learning, e.g., NumPy, matplotlib	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of digital image processing fundamentals. 2. Get familiarized with vision system calibration and spatial analysis. 3. Explore various machine vision algorithms and parameters. 4. Gain knowledge of the design and implementation of machine vision systems.	
Content:		**No of hours**
	List of Experiments: 1. Camera Calibration: Implement different methods to calibrate a camera using a chessboard pattern, understanding intrinsic and extrinsic parameters. 2. Basic Image Manipulations with OpenCV: Perform image resizing, rotating, and flipping techniques to understand OpenCV's basic image handling capabilities. 3. Projective Transformations: Apply projective transformations to images and analyse the geometric changes. 4. Stereo Vision and Depth Mapping: Construct a stereo vision system to calculate depth maps from stereo image pairs. 5. Radiometry – Light Measurement: Simulate the light intensity and colour measurement using different light sources in a controlled environment. 6. Shadow and Shading Effects: Analyse the effects of various lighting conditions on object shadows and shading to understand local shading models. 7. Photometric Stereo: Implement a basic photometric stereo setup to reconstruct the surface details of an object from images taken from multiple light sources. 8. Image Contour and Shape Analysis: Use differential geometry concepts to detect and analyse images' contours, cusps, and inflections. 9. Homography and Image Registration: Align two images using homography, focusing on coordinate system transformations. 10. Ethics and Bias in Machine Vision: Analyse bias in facial recognition systems, discussing ethical considerations and potential mitigation strategies.	**30**
Pedagogy:	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	

References/ Readings:	**Text Books:** 1. Richard Hartley, Andrew Zisserman, "Multiple View Geometry in Computer Vision", 2nd Edition, Cambridge University Press, United Kingdom, 2003, ISBN: 978-0521540513. 2. David Forsyth and Jean Ponce, "Computer Vision: A Modern Approach", Pearson Education India, 2nd Edition, 2015, ISBN: 978-9332550117. 3. Rosalie A. Waelen, "The Ethics of Computer Vision: An Overview in Terms of Power", Springer, March 2023, DOI: https://doi.org/10.1007/s43681-023-00272-x. **Reference Readings:** 1. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer Nature Switzerland AG, 2nd Edition, 2021, ISBN: 978-3030343712. 2. Simon J. D. Prince, "Computer Vision: Models, Learning and Inference", Cambridge University Press, United Kingdom, 2011, ISBN: 978-1107011793. 3. Emanuele Trucco, Alessandro Verri, "Introductory Techniques for 3-D Computer Vision", Prentice Hall, United Kingdom, 1998, ISBN: 978-0132611084.
Course Outcomes:	After taking this course, student will be able to: CO 1. Perform coding of fundamental tasks related to basic Digital Image Processing. CO 2. Construct and calibrate vision systems to perform tasks related to spatial analysis. CO 3. Contrast and evaluate parameters and algorithms related to machine vision. CO 4. Design a machine vision system for a given task.

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Programme Specific Elective (PSE) Courses

Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-631
Title of the Course : Wireless Sensor Networks
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course will enable the students to: 1. Get familiarized with the architecture, hardware components, enabling technologies, and design principles of WSNs for various applications. 2. Explore physical layer design, MAC protocols, routing strategies, and transport control mechanisms tailored for energy-efficient WSN operation. 3. Gain an introduction to sensor tasking, data aggregation, and network database management for optimized information processing in WSNs. 4. Examine operating system design, simulation tools, performance modeling, and emerging applications in WSN research.	
Content:		**No of hours**
Unit -1	Introduction and overview of Wireless Sensor Networks (WSN), Commercial and Scientific Applications of WSN, Category of Applications of WSN, Challenges for WSN, Enabling Technologies for WSN. Single node Architecture: Hardware Components, Energy Consumption of Sensor nodes, Operating Systems and Execution Environments, Examples of Sensor Nodes, Network Architecture: WSN Scenarios, Optimization Goals and figures of Merits, Design principles for WSNs, Service Interfaces for WSNs, Gateway Concepts.	**11**
Unit -2	**Physical Layer:** Wireless Channel and Communication Fundamentals, Physical Layer & Transceiver Design Considerations in WSN, MAC Protocols: Fundamentals, MAC Protocols for WSNs, Low duty cycle protocols and wakeup concepts, Contention-based protocols, Schedule-based protocols, IEEE802.15.4 MAC Protocol.	**11**
Unit -3	**Routing Protocols for Wireless Sensor Networks :** Introduction, Data Dissemination and Gathering, Routing Challenges and Design Issues in Wireless Sensor Networks, Routing Strategies in Wireless Sensor Networks, WSN Routing Techniques, Flooding and Its Variants, Sensor Protocols for Information via Negotiation, Low-Energy Adaptive Clustering Hierarchy, Power-Efficient Gathering in Sensor Information Systems, Directed Diffusion, Geographical Routing.	**12**

	Transport Control Protocols: Traditional Protocols, Design Issues, Examples of Transport Protocols, Performance of Transport Control Protocols.	
Unit- 4	**Sensor Tasking and Control:** Information-Based Sensor Tasking, Joint Routing Information Aggregation, Sensor Network Databases: Challenges, Query Interfaces, In-Network Aggregation, Data Centric Storage, Data Indices and Range queries, Distributed Hierarchical Aggregation, Temporal Data. **Operating Systems for Sensor Networks:** Introduction, Design Issues, Examples of Operating Systems, Node Level Simulators, Performance and Traffic Management Issues: WSN Design Issues, Performance Modelling of WSNs, Emerging Applications and Future Research Directions.	**11**
Pedagogy:	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.	
References/ Readings:	**Text Books:** 1. Kazem Sohraby,Daniel Minoli,Taieb Znati, "Wireless Sensor Networks: Technology, Protocols, and Applications", John Wiley & Sons, USA, 1st Edition, 2007, ISBN: 978-8126527304. 2. Holger Karl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley & Sons, 1st Edition, USA, 2005, ISBN: 978-0470519233. 3. Feng Zhao, Leonidas Guibas, "Wireless Sensor Networks; An Information Processing Approach", Elsevier India, 1st Edition, 2005, ISBN: 978-8181476425. **Reference Readings:** 1. C. S. Raghavendra, Krishna M. Shivalingam, Taieb Znati, "Wireless Sensor Networks", Springer Verlag, New York, 1st Edition, 2006, ISBN: 978-0387352695. 2. H. Edgar, Jr. Callaway, "Wireless Sensor Networks, Architectures and Protocols", CRC Press, 1st Edition, 2005, ISBN: 978-0849318238.	
Course Outcomes:	After taking this course, student will be able to: 1. Describe the fundamental concepts of Wireless Sensor Networks including their architecture, communication protocols, routing strategies, and data management techniques. 2. Implement and compare various MAC and routing protocols, network architectures, and data aggregation methods to optimize WSN performance under different constraints. 3. Assess the efficiency of transport control protocols, sensor tasking methods, and operating systems to enhance WSN reliability, energy efficiency, and data processing capabilities. 4. Design and develop WSN-based solutions by integrating hardware components, communication protocols, and data management techniques to address real-world challenges and emerging applications.	

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Name of the Programme : **Industrial Automation & Robotics**
Course Code : **ETC-632**
Title of the Course : **Wireless Sensor Networks Lab**
Number of Credits : **01**
Effective from AY : **2024-25**

Pre-requisites for the Course:		
Course Objectives:	The course will enable the students to: 1. Develop an understanding of the basic WSN technology and configuring of the network. 2. Explore key routing protocols for sensor networks and main design issues. 3. Get familiarized with sensor management, sensor network middleware, operating systems. 4. Appreciate various applications of WSN in real life applications.	
Content:		**No of hours**
	List of Experiments: 1. Prototyping the Network model using packet tracer. 2. Configuring the Network using distance vector and link state routing protocols. 3. Configuring DHCP and NAT on a multifunction device. 4. Configuring VLAN and PAP using packet tracer. 5. Configuring wireless topology and VoIP. 6. Detection and measurement of gases using sensors and microcontrollers. 7. Proximity estimation using sensors. 8. Control of Home Appliances using Sensors. 9. Object counting for Smart Industries 10. Measurement of Parameters like temperature, pressure, humidity, light and distance using sensors.	**30**
Pedagogy:	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	
References/ Readings:	**Text Books:** 1. Kazem Sohraby,Daniel Minoli,Taieb Znati, "Wireless Sensor Networks: Technology, Protocols, and Applications", John Wiley & Sons, USA, 1st Edition, 2007, ISBN: 978-8126527304. 2. Holger Karl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley & Sons, 1st Edition, USA, 2005, ISBN: 978-0470519233. 3. Feng Zhao, Leonidas Guibas, "Wireless Sensor Networks; An Information Processing Approach", Elsevier India, 1st Edition, 2005, ISBN: 978-8181476425. **Reference Readings:**	

	1. C. S. Raghavendra, Krishna M. Shivalingam, Taieb Znati, "Wireless Sensor Networks", Springer Verlag, New York, 1st Edition, 2006, ISBN: 978-0387352695. 2. H. Edgar, Jr. Callaway, "Wireless Sensor Networks, Architectures and Protocols", CRC Press, 1st Edition, 2005, ISBN: 978-0849318238.
Course Outcomes:	After taking this course, student will be able to: CO 1. Prototype the network and configure it using simulators. CO 2. Demonstrate the use of various sensors to measure quantities like temperature, pressure, light, humidity etc. CO 3. Implement a complete sensor node with sensors and microcontroller. CO 4. Design a prototype of WSN for applications like home automation, healthcare, agriculture, weather monitoring, object counting.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-633
Title of the Course : Rapid Prototyping
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of product fundamentals and prototyping. 2. Explore additive and subtractive manufacturing for rapid prototyping and production. 3. Get familiarized with reverse engineering techniques for product analysis and reproduction. 4. Gain PCB design skills by applying layout principles, routing techniques, and multilayer board configurations.	
Content:		**No of hours**
Unit -1	**Product fundamentals:** Product definition, Engineering design process, product prototyping and its impact, product prototyping and product development. Need for prototyping. Common mistakes. How to conduct prototyping? Physical prototype design procedure. Prototype design methods. Paper prototyping. Prototyping materials. Material Properties and Characterization.	**11**
Unit -2	**Additive manufacturing:** Introduction, Fundamentals, advantages and classification of additive manufacturing systems3. Additive manufacturing process. STL File format. Liquid based system: Stereo lithography Apparatus (SLA)- Principle, process, advantages and applications. Solid based system: Fused Deposition Modelling (FDM) - Principle, process, advantages and applications. Powder based additive manufacturing systems: Selective Laser Sintering - Principles, Process, advantages and applications, 3D Printing –Principle, process, advantages and applications. Electron Beam Melting.	**12**
Unit -3	**Subtractive manufacturing:** Prototyping and manufacturing using CNC machining: Machine codes for process control, CAD/CAM for digital manufacturing. Postprocessor. Subtractive Rapid Prototyping. CNC Process overview. CNC safety. CNC tools. CNC operation overview.	**11**
Unit- 4	**Reverse Engineering:** Non-contact and Contact based systems. **PCB Design:** Introduction, Layout, Power and Ground trace routing, Ground return and shields, multilayer boards, Soldering techniques.	**11**
Pedagogy:	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.	
References/ Readings:	**Text Books:**	

	1. Fuewen Frank Liou, "Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development", 2nd Edition, CRC Press, 2019, ISBN: 978-1498798921. 2. Kamrani A.K. and Nasr E.A., "Rapid Prototyping: Theory and Practice", Springer-Verlag New York, 1st Edition, 2015, ISBN: 978-1461498421. 3. Chee Kai & K F Leong Chua, "Rapid Prototyping: 3D Printing and Additive Manufacturing Principles and Applications", 5th Edition, World Scientific, Singapore, 2019, ISBN: 978-0000987570. **Reference Readings:** 1. "Desk Copy-Fundamentals of CNC Machining: A Practical Guide for Beginners", Autodesk, USA, 2014. 2. R.G. Kaduskar, V.B. Baru, "Electronic Product Design", 2nd Edition, Wiley India, 2011, ISBN: 978-8126580576.
Course Outcomes:	After taking this course, student will be able to: CO 1. Explain the engineering design process, different prototyping steps and prototyping methods. CO 2. Compare the operation of additive and subtractive prototyping processes such as FDM, SLA, CNC. CO 3. Select appropriate material and prototyping process for a given application. CO 4. Develop appropriate CAD models for prototyping given an application.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-634
Title of the Course : Rapid Prototyping Lab
Number of Credits : 01
Effective from AY : 2024-25

Pre-requisites for the Course:	NIL	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of the fundamental concepts and processes involved in CAD modeling, additive and subtractive manufacturing, and PCB design and fabrication. 2. Gain knowledge of 2D and 3D CAD models, generate STL files for slicing, operate FDM and SLA 3D printers, perform CNC milling, and create PCB layouts using appropriate software tools. 3. Explore different manufacturing and prototyping techniques, assess slicing parameters, optimize milling and printing processes, and evaluate PCB circuit performance after assembly. 4. Gain knowledge of the design and fabrication of a fully functional prototype by integrating CAD modeling, 3D printing, CNC milling, and PCB fabrication techniques to meet a specific engineering requirement.	
Content:		**No of hours**
	List of Experiments: 1. CAD modelling – 2D Sketching and 3D Modelling. 2. Slicing and STL Export 3. FDM 3D Printing – Setup, printing, post processing 4. SLA 3D Printing - Setup, printing, post processing 5. CNC Milling – Setup, milling and post processing 6. PCB CAD Modelling – Circuit Schematic Design & Custom symbols and footprints 7. PCB CAD modelling – Netlist and PCB layout 8. PCB CAD modelling – Routing 9. PCB circuit milling 10. Circuit Assembly, soldering and testing.	**30**
Pedagogy:	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	
References/ Readings:	**Text Books:** 1. Fuewen Frank Liou, “Rapid Prototyping and Engineering Applications A Toolbox for Prototype Development”, 2nd Edition, CRC Press, 2019, ISBN: 978-1498798921. 2. Kamrani A.K. and Nasr E.A., “Rapid Prototyping: Theory and Practice”, Springer-Verlag New York, 1st Edition, 2015, ISBN: 978-1461498421. 3. Chee Kai & K F Leong Chua, “Rapid Prototyping: 3D Printing and Additive Manufacturing Principles and Applications”, 5th Edition, World Scientific, Singapore, 2019, ISBN: 978-0000987570.	

	Reference Readings: 1. "Desk Copy-Fundamentals of CNC Machining: A Practical Guide for Beginners", Autodesk, USA, 2014. 2. R.G. Kaduskar, V.B. Baru, "Electronic Product Design", 2nd Edition, Wiley India, 2011, ISBN: 978-8126580576.
Course Outcomes:	After taking this course, student will be able to: CO 1. Design 3D CAD models of prototypes in CAD software. CO 2. Setup and use FDM, SLA and CNC processes for prototyping. CO 3. Design schematics and PCB layouts in CAD software. CO 4. Assemble and develop physical prototype solutions for given applications.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-661
Title of the Course : System Modelling and Simulation Techniques
Number of Credits : 02
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Probability Theory and Linear Algebra.	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of different system models and modeling methodology. 2. Explore different methods for selecting input models. 3. Get familiarized with modeling requirements and find appropriate tool for simulation. 4. Gain knowledge of measures of system performance through estimation techniques.	
Content:		**No. of Hours**
Unit-1	**Introduction to Modeling and Simulation:** Definition of Basic Terms and Concepts, Modeling and Simulation Development Process Cycle, Modeling and Simulation Attributes- Fidelity, Resolution and Scale, Model Types- Physics Based Modeling, Finite Element Modeling (FEM), Data Based Modeling, Agent - Based Modeling (ABM), Aggregate Modeling, Hybrid Modeling, Modeling and Simulation Categories- Type, Application, Randomness, and Domain.	**7**
Unit-2	**Statistical Concepts for Discrete Event Simulation:** Common Theoretical Distribution Functions- Uniform, Triangular, Exponential, Normal, Generation of Random Variates- Linear Congruential Generators (LCG), Input data modelling- Direct Use of Sample Data, Use of Empirical Distributions, Use of Theoretical Distributions, Categorization of input data modeling situations, Output Data Analysis- Confidence Interval Estimate of the Mean.	**8**
Unit-3	**Discrete Event Simulation (DES):** Queueing System Model Components- State Variables, Events, and Attributes, Simulation Methodology- Time Advance Mechanism, Main Components- Common terminology associated with DES, Simulation Flowchart.	**7**
Unit-4	**Modeling Continuous Systems:** System Class, Modeling Approach- State Variables, Equations, Output Equations, Simulating Continuous Systems- General Solution Approach, Numerical Solution Techniques- Euler's Method, Runge-Kutta Methods, Adaptive Time Step.	**8**

	Monte-Carlo Simulation: Monte Carlo Method, Sensitivity Analysis.	
Pedagogy	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.	
References/ Readings:	**Text Books:** 1. John A. Sokolowski, Catherine M. Banks, "Modeling and Simulation Fundamentals", John Wiley & Sons, Inc, USA, 1st Edition, 2010, ISBN: 978-0470486740. 2. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol, "Discrete-Event System Simulation", 5th Edition, Pearson Education India, 2014, ISBN: 978-1-292-02437-0. **Reference Books:** 1. Averill M. Law, "Simulation Modeling and Analysis", 5th Edition, McGraw-Hill, New York, 2013, ISBN: 978-0073401324. 2. Lawrence M. Leemis, Stephen K. Park, "Discrete – Event Simulation: A First Course", Pearson Education, USA, 2006, ISBN: 978-0131429178. 3. Ernest O. Doebelin, "System Modelling and Response", John Wiley & Sons Inc, USA, 1980, ISBN: 978-0471032113.	
Course Outcomes:	After taking this course, student will be able to: CO 1. Identify and differentiate different system models. CO 2. Analyse different methods for selecting different input models. CO 3. Analyse requirements and find appropriate tool for simulation. CO 4. Evaluate different measures of system performance through estimation techniques.	

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-662
Title of the Course : System Modelling and Simulation Techniques Lab
Number of Credits : 02
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Probability Theory, Linear Algebra and Programming in Python/Matlab.	
Course Objectives:	After taking this course, student will be able to: 1. Identify and differentiate different system models. 2. Analyse different methods for selecting different input models. 3. Analyse requirements and find appropriate tool for simulation. 4. Evaluate different measures of system performance through estimation techniques.	
Content:		**No. of Hours**
	List of Experiments: 1. Simulation of Mathematical System Model. 2. Simulation of Random Number Generator. 3. Simulating a Pseudo-random Number Generator. 4. Simulation of specified empirical distribution using Histogram. 5. Fitting a theoretical distribution to sample data. 6. Simulation for Parameter Estimation and Goodness-of-Fit tests. 7. Simulation of a Single-Server Queue. 8. Simulation of a Multi-Server Queue. 9. Simulation of Eulerian Method. 10. Simulation of Runge-Kutta Method. 11. Monte Carlo Simulation. 12. Simulation of Time-series data models. 13. Simulation for determining the transfer function for the network. 14. Simulation of a Reliability Problem. 15. Simulation program for State Space model.	**60**
Pedagogy	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	
References/ Readings:	**Text Books:** 1. John A. Sokolowski, Catherine M. Banks, "Modeling and Simulation Fundamentals", John Wiley & Sons, Inc, USA, 1st Edition, 2010, ISBN: 978-0470486740.	

	2. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol, "Discrete-Event System Simulation", 5th Edition, Pearson Education India, 2014, ISBN-13: 978-1-292-02437-0. **Reference Books:** 1. Averill M. Law, "Simulation Modeling and Analysis", 5th Edition, McGraw-Hill, New York, 2013 ISBN: 978-0073401324. 2. Lawrence M. Leemis, Stephen K. Park, "Discrete – Event Simulation: A First Course", Pearson Education, USA, 2006, ISBN: 978-0131429178. 3. Ernest O. Doebelin, "System Modelling and Response", John Wiley & Sons Inc, USA, 1980, ISBN-13: 978-0471032113
Course Outcomes:	After taking this course, student will be able to: CO 1. Design mathematical models to characterize engineering systems. CO 2. Analyse requirements and find appropriate tool for simulation. CO 3. Implement different system models and simulation techniques using software tools. CO 4. Demonstrate system performance using estimation techniques.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-663
Title of the Course : Optimization Techniques for Engineering Research
Number of Credits : 02
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Calculus and Linear Algebra.	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of mathematical concepts used to solve optimization problems. 2. Explore different optimization methods. 3. Recognize problem constraints and select appropriate tools for simulation. 4. Gain knowledge of algorithm development for optimization problems.	
Content:		**No. of Hours**
Unit-1	**Introduction to Optimization:** Optimal problem formulation, Engineering applications of optimization, Classification of optimization techniques. **Linear programming:** Formulation of the problem, Graphical method, General LLPs- Canonical and Standard Forms, Simplex Method, Artificial variable techniques- Big M Method, Two-phase Method.	**7**
Unit-2	**Single-variable Nonlinear Optimization:** Classical method for single-variable optimization, Exhaustive search method, Bounding phase method, Interval halving method, Fibonacci search method, Golden section search method, Bisection method, Newton-Raphson method, Secant method, Successive quadratic point estimation method.	**8**
Unit-3	**Multivariable Unconstrained Non-linear Optimization:** Classical method for multivariable optimization, Unidirectional search method, Evolutionary search method, Simplex search method, Hooke-Jeeves pattern search method, Conjugate direction method, Steepest descent method, Newton's method, Marquardt's method.	**8**
Unit-4	**Multivariable Constrained Non-linear Optimization:** Classical methods for equality constrained optimization- Solution by direct substitution, Solution by the method of constrained variation, Solution by the method of Lagrange multipliers, Classical methods for inequality constrained optimization, Random search method, Complex method.	**7**

Pedagogy	The teaching-learning process shall integrate interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills.
References/ Readings:	**Text Books:** 1. Sukanta Nayak, "Fundamentals of Optimization Techniques with Algorithms", Academic Press, 1st Edition, United Kingdom, 2020, ISBN: 978-0128211267. 2. Kalyanmoy Deb, "Optimization for Engineering Design- Algorithms and Examples", 2nd Edition, PHI Learning Private Limited, India, 2012, ISBN: 978-8120346789. **Reference Books:** 1. Edwin K. P. Chong and Stanislaw H. Zak, "An Introduction to Optimization", Wiley India, 4th Edition, 2017, ISBN: 978-8126567898. 2. Mykel J. Kochenderfer, Tim A. Wheeler, "Algorithms for Optimization", The MIT Press, USA, 1st Edition, 2019, ISBN-13: 978-0262039420. 3. Stephen Boyd and Lieven Vandenberghe, "Convex Optimization", Cambridge University Press, United Kingdom, 1st Edition, 2004, ISBN: 978-0521833783.
Course Outcomes:	After taking this course, student will be able to: CO 1. Analyze problems using programming algorithms. CO 2. Use search techniques methods to find optimal solutions of linear and non-linear problems. CO 3. Solve various multivariable optimization problems. CO 4. Formulate mathematical models of real-world problems.

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Name of the Programme : Industrial Automation & Robotics
Course Code : ETC-664
Title of the Course : Optimization Techniques for Engineering Research Lab
Number of Credits : 02
Effective from AY : 2024-25

Pre-requisites for the Course:	Fundamentals of Calculus, Linear Algebra and Programming Basics in Matlab/Python.	
Course Objectives:	The course will enable the students to: 1. Develop an understanding of modeling and simulation methodology for optimization. 2. Gain an introduction to simulation software tools for optimization. 3. Get familiarized with typical algorithms used for optimization problems. 4. Explore methods to evaluate performance of optimization techniques.	
Content:		**No. of Hours**
	List of Experiments: 1. Simulation and comparison of derivative estimates. 2. Simulation to implement Simplex Method. 3. Simulation to implement Exhaustive Search Method. 4. Simulation to implement Bounding Phase Method. 5. Simulation to implement Interval Halving Method. 6. Simulation to implement Fibonacci search. 7. Simulation to implement Golden section search. 8. Simulating to implement Quadratic fit search. 9. Simulation to implement the Bisection method. 10. Simulation to implement the Newton-Raphson method. 11. Simulation to implement the Secant Method. 12. Simulation to implement Box's Evolutionary Optimization. 13. Simulation to implement the Nelder-Mead Simplex Method. 14. Simulation to implement the Hooke-Jeeves Method. 15. Simulation to implement the Gradient Descent Method.	**60**
Pedagogy	The teaching-learning process shall combine instructional learning, constructive thinking, inquiry-based and collaborative learning, experiential learning, and problem-solving approaches.	
References/ Readings:	**Text Books:** 1. Sukanta Nayak, "Fundamentals of Optimization Techniques with Algorithms", Academic Press, 1st Edition, United Kingdom, 2020, ISBN: 978-0128211267. 2. Kalyanmoy Deb, "Optimization for Engineering Design- Algorithms and Examples", 2nd Edition, PHI Learning Private Limited, India, 2012, ISBN: 978-8120346789.	

	Reference Books: 1. Edwin K. P. Chong and Stanislaw H. Zak, "An Introduction to Optimization", Wiley India, 4th Edition, 2017, ISBN: 978-8126567898. 2. Mykel J. Kochenderfer, Tim A. Wheeler, "Algorithms for Optimization", The MIT Press, USA, 1st Edition, 2019, ISBN-13: 978-0262039420. 3. Stephen Boyd and Lieven Vandenberghe, "Convex Optimization", Cambridge University Press, United Kingdom, 1st Edition, 2004, ISBN: 978-0521833783.
Course Outcomes:	After taking this course, student will be able to: CO 1. Develop mathematical models to implement optimization techniques. CO 2. Analyse requirements and find appropriate technique for a specified optimization problem. CO 3. Implement simulation techniques using software tools for optimization problems. CO 4. Demonstrate performance of various algorithms for optimization.

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Generic Elective (GE) Courses

Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-681
Title of the Course : Sustainability - Principles & Practices
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	Undergraduate level knowledge of any branch of engineering	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of importance of Sustainability Practices 2. Explanation of Assessment, Planning and Implementation of Sustainability Principles 3. Description of the steps involved in implementing sustainable solutions 4. Apply the knowledge of sustainability practices to real life situations.	
Content:		**No. of Hours**
Unit-1	**Overview on Global Sustainability Goals (SDGs):** Industry-Innovation-Infrastructure, Health & Well Being, Clean Water & Sanitation, Education, Responsible Consumption and production, Climate Action, Quality Education, Economic growth, sustainable community living,	**10**
Unit-2	**Sustainability:** Requirements for Sustainability, Approaches towards Sustainable Engineering, Sustainability Challenges, Environmental Challenges; **Reasons for Un-sustainability** – Economics and Environment, Corporate View of Sustainability, Social Attitude, Approach, Cultural Narratives, Political Aspects, Ethics and Morals. Steps in life cycle impact assessment	**13**
Unit-3	**Sustainability Assessment:** Steps in assessing life cycle, data availability, process network analysis, Input-Output Analysis, Hybrid Models; Carbon footprint, Water footprint, Energy analysis of technologies, processes and its economics; Concept of Exergy and Emergy Analysis; Ecosystem Services in Sustainability Assessment; Case Studies	**10**
Unit-4	**Solutions for Sustainability:** Designing sustainable processes and products; Techno-Economic Analysis; Energy Ecosystem and its dynamic characteristics; Circular Economy; Nature based solutions, Green infrastructure, Techno-ecological synergy; Economic Policies, Societal Developments; Case Studies.	**12**
Pedagogy	Interactive learning, reflective thinking, critical analysis, and problem-solving.	

References/ Readings:	1. Raj Gaurang Tiwari, 'Sustainability Principles and Applications in Engineering Practices', Nova Science Publishers, 2024, ISBN:9798891136403 2. Bhavik R Bakshi, 'Sustainable Engineering', Cambridge University Press, 2019, ISBN:9781108420457 3. Margaret Robertson, 'Sustainability – Principles & Practices', Routledge Publishers, 2017, ISBN: 97811138650244
Course Outcomes:	After going through this course, student will be able to: CO 1. Understand the importance of sustainability practices CO 2. Assess, Plan and Suggest basic sustainability practices CO 3. Explain the steps involved in implementing sustainable solutions CO 4. Prepare a plan for sustainability practices to real life situations.

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Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-682
Title of the Course : Sustainability - Principles & Practices Lab
Number of Credits : 01
Effective from AY : 2024-25

Pre-requisites for the Course:	Undergraduate level knowledge of any branch of engineering	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of importance of Sustainability Development Goals (SDG) 2. Explanation on Assessment, Planning and Implementation of SDG 3. Description of the steps involved in order to achieve the SDG. 4. Apply the knowledge of sustainability practices to real life situations.	
Content:		**No. of Hours**
	The United Nations has promulgated Sustainable Development Goals (SDG)s. Every student has to prepare a detail report and presentation, based relevant literature, field visits and data collection, interaction with experts, on ANY TWO topics of SDG as applied to the local region or State of Goa. (1) No Poverty (2) Zero Hunger (3) Good Health & Well Being (4) Quality Education (5) Gender Equality (6) Clean Water & Sanitation (7) Affordable & Clean Energy (8) Decent Work and Economic Growth (9) Industry, Innovation and Infrastructure (10) Reduce Inequalities (11) Sustainable Cities & Communities (12) Responsible Consumption and Production (13) Climate Action (14) Life Below Water (15) Life on Land (16) Peace, Justice & Strong Institutions	**30**
Pedagogy	Instructional learning, Inquiry based learning, Constructive learning, Collaborative learning and problem solving	
References/ Readings:	1. Raj Gaurang Tiwari, 'Sustainability Principles and Applications in Engineering Practices', Nova Science Publishers, 2024, ISBN:9798891136403 2. Bhavik R Bakshi, 'Sustainable Engineering', Cambridge University Press, 2019, ISBN:9781108420457	

	3. Margaret Robertson, 'Sustainability – Principles & Practices', Routledge Publishers, 2017, ISBN: 97811138650244
Course Outcomes:	After going through this course, student will be able to: CO 1. Understand the importance of sustainability Development Goals (SDGs) CO 2. Assess, Plan and Suggest basic sustainability practices CO 3. Explain the steps involved in order to achieve the SDG CO 4. Prepare a plan for sustainability practices to real life situations.

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Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-683
Title of the Course : Project Management
Number of Credits : 03
Effective from AY : 2024-25

Pre-requisites for the Course:	Undergraduate level knowledge of any branch of engineering	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of the various features of project management 2. Explanation of the relevance of human resource planning and management 3. Describes the importance of procurement planning, cost estimation, and quality management. 4. Detailed explanation on time and risk management.	
Content:		**No. of Hours**
Unit-1	**Overview on Project Management**: Need for Project Management, Project Life Cycle and its Phases, Scope of the project, requirements and scope, Organizational Influences, Project Management Plan, Integrated Change Control Plan, Agile Project Management and Lean Project Management, Project selection and portfolio management. **Economics & Cost Management**: Time Value of Money, Cost-Benefit Ratio, Cost estimation, methods of preparing estimates, budgeting, Cost monitoring and Control, cost on completion.	**10**
Unit-2	**Human Resource Management,** Planning Human Recourses, Acquiring human resources, developing and strategizing deployment of resources, leadership qualities, team management – motivation, monitoring and control, conflict management and interpersonal relationship management. Importance of Communication and communication management – tools and techniques; basic human fundamentals, ethics and professional conduct,	**12**
Unit-3	**Procurement Management**- Planning, Implementation – Monitoring and control of goods and services; Stakeholders Management, Contracts drafting, preparation, approval, implementation and closure. **Quality Management:** Introduction, quality planning tools and techniques, quality monitoring and control, tools and techniques,	**13**
Unit-4	**Time Management**: Purpose of Time Management, Time Planning, different methods of activity planning, milestones, resource assignment and time lines. Time monitoring and	**10**

	control - different types of charts; Path Planning – forward, backward, critical, lag and lead time lines. **Risk Management** – Risk Identification, Risk Qualitative Analysis, Risk Quantitative Analysis, Risk Response, Monitoring and Control	
Pedagogy	Interactive learning, reflective thinking, critical analysis, and problem-solving.	
References/ Readings:	1. J.Michael Bennet, Danny S.K.Ho, 'Project Management for Engineers', World Scientific Publishing, 2014, ISBN: 13-978-981444-7928. 2. J. M. Nicholas, Herman Steyn, 'Project Management for Engineering, Business and Technology, 6th Edn, Taylor & Francis Publications, 2021, ISBN: 978-0-367-277730-7 3. Neil G Siegel, Engineering Project Management, Wiley Publications, 2019, ISBN: 9781119525769. 4. Khanna.R.B., Project Management, PHI Publishing, 2011, ISBN: 978-81-203-4288.	
Course Outcomes:	After going through this course, student will be able to: CO 1. Explain the importance of Project Management CO 2. Describe the various components of Project Management CO 3. Analyze the importance of cost, human resource, procurement, quality, time and risk management CO 4. Apply project management knowledge in their professional life.	

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Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-684
Title of the Course : Project Management Lab
Number of Credits : 01
Effective from AY : 2024-25

Pre-requisites for the Course:	Undergraduate level knowledge of any branch of engineering	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of the various features of project management 2. Explanation of the relevance of applying project management knowledge to any one domain 3. Describes the advantages of applying project management tools & techniques to address specific problems 4. Ability to prepare reports and presentation on specific areas by applying knowledge of Project Management	
Content:		**No. of Hours**
	Project Management is applicable to all types of Human Activities. Every Student has to choose ANY TWO topics, prepare a detail report and presentation, based relevant literature, field visits and data collection, interaction with experts in the local region or State of Goa. The student shall apply project management knowledge to any ONE topics given below, the list is only indicative, students can choose topics from related / allied areas: (1) Large construction site (on-going projects) – residential, commercial, highways, ports, airports (2) Large Manufacturing Industry in any of the Industrial Areas in Goa, scaling up production, sales / marketing. (3) Waste Management; Water Management; (4) Application of Project Management to Law Enforcement (5) Project Management in Education – infrastructure, skill training (6) Project Management as applied to consumer goods / supplies (7) Manpower Management in the context of AI in software industry (8) Project Management – Global markets for local products using Digital Marketing platforms (9) Project management for Logistics and Transportation (10) Project management for Hospital & Health Management	**30**

Pedagogy	Instructional learning, Inquiry based learning, Constructive learning, Collaborative learning and problem solving
References/ Readings:	1. J.Michael Bennet, Danny S.K.Ho, 'Project Management for Engineers', World Scientific Publishing, 2014, ISBN: 13-978-981444-7928. 2. J. M. Nicholas, Herman Steyn, 'Project Management for Engineering, Business and Technology, 6th Edn, Taylor & Francis Publications, 2021, ISBN: 978-0-367-277730-7 3. Neil G Siegel, Engineering Project Management, Wiley Publications, 2019, ISBN: 9781119525769. 4. Khanna.R.B., Project Management, PHI Publishing, 2011, ISBN: 978-81-203-4288.
Course Outcomes:	After going through this course, student will be able to: CO 1. Understanding of the various features of project management CO 2. Explanation of the relevance of applying project management knowledge to any one domain CO 3. Describes the advantages of applying project management tools & techniques to address specific problems CO 4. Ability to prepare reports and presentation on specific areas by applying knowledge of Project Management

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Semester IV

Generic Elective (GE) Courses

Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-685
Title of the Course : Financial Management
Number of Credits : 04
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of Finance, Economics	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of Financial Systems and Its Management 2. Explanation of Financial Planning, Fund Flow and Cost Analysis 3. Analysis of Capital & Working Capital Management, Valuation, Long Term Financing 4. Description of product cost analysis, break even analysis and investment management.	
Content:		**No. of Hours**
Unit-1	**Financial Management: An Overview –** Types of Business organizations, Fundamental principle of finance. **The Financial System-** Functions, Financial Assets and Markets, **Financial Statements, Taxes, and Cash Flow**- Balance Sheet, Profit and loss Account, Profits Vs Cash Flow, Taxes; Financial decision making.	**15**
Unit-2	**Financial Statement Analysis**- Financial Ratios- Liquidity Ratios, Leverage & Profitability Ratios; **Fund Flow Analysis** - Fund Flow Statement; **Breakeven Analysis and Leverages**- Cost Volume Profit Analysis; **Financial Planning & Forecasting-** Financial Planning, Sales Forecast; **Cost Analysis-** Determination of product cost, overhead cost, volume and profits, planning and control on costs and decision making using costs.	**16**
Unit-3	**Fundamental Valuation Concepts -**The Time Value of Money, Risk and Return. **Capital Budgeting -**Techniques of Capital Budgeting – Capital Budgeting Process, project classification; cash flows, risk analysis, cost of capital; **Investment Criteria**- Net Present value, Benefit Cost Ratio, Internal Rate of return, Payback Period, Accounting rate of Return.	**15**
Unit-4	**Working Capital Management** -Working Capital Policy, Cash and Liquidity Management, Credit Management, Inventory Management, Working Capital Financing; **Corporate Valuation:**	**14**

	Debt analysis and management, Leasing, Hire Purchase, Valuation, Mergers, acquisitions and Restructuring; **Long Term Financing:** Sources of Long Term Finance, Raising Long Term Finance.	
Pedagogy	Interactive learning, reflective thinking, critical analysis, and problem-solving.	
References/ Readings:	1. Prasanna Chandra "Financial Management: Theory and Practice" 11th Edition, McGraw Hill Education Publishers, 2023, ISBN: 978-9355-322-203 2. Pandey I.M., Finance- A Management Guide for Managing Company Funds and Profits, Prentice Hall India Publications, 1995, ISBN:978-8120-309-180 3. Van Horne, J.C, "Fundamentals of Financial Management", 13th Edition, Pearson Publications, 2015, ISBN:978-933-255-8670. 4. Khan, M.Y. and Jain, P.K., "Financial Management", 8th Edition, McGraw-Hill Education Publishers, 2018, ISBN:978-9353-1622-184	
Course Outcomes:	After going through this course, student will be able to: CO 1. Understand the Financial Systems and Its Management CO 2. Explain Financial Planning, Fund Flow and Cost Analysis CO 3. Analyze Capital & Working Capital Management, Valuation, Long Term Financing CO 4. Describe product cost analysis, break even analysis and investment management.	

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Name of the Programme : Master of Engineering (Data Sciences)
Course Code : GEC-686
Title of the Course : Entrepreneurship
Number of Credits : 04
Effective from AY : 2024-25

Pre-requisites for the Course:	Basic knowledge of Creative Thinking, Innovation, Finance, Economics	
Course Objectives:	The course aims to provide the student with an: 1. Understanding of entrepreneurial skill sets and different types of entrepreneurship. 2. Explanation of Differences between New Enterprise, Social Enterprise and Family Business 3. Describes the process of preparing business plan, operational plans to start an enterprise 4. Apply the knowledge of market analysis, product planning, customer requirements, costing and finance	
Content:		**No. of Hours**
Unit-1	**Entrepreneurial Characteristics:** Overview on Entrepreneurship, Broad classification of entrepreneurs; Leadership, Goal Setting, Time and resource Planning, Communication, Networking, Knowledge & Skill Upgradation; Awareness of Social and Industrial Eco-system; Awareness of Government Policies and Schemes; Digital marketing and business promotion; Local and global market; Basic understanding of Legal and regulatory system, Intellectual Property Rights; Financial Literary; Decision making and risk taking abilities	**18**
Unit-2	**Creation of New Enterprise:** Creativity, Innovation, technology, wealth creation, social impact, Team building, Business Plan, project formulation and feasibility analysis; business simulation; designing and configuring business models and customers, Enterprise management tools and techniques; Launching and managing enterprises; Sales & Marketing Strategies; Human Resources; Incubation, Costing and Financial Plans, Case Studies	**14**
Unit-3	**Social Entrepreneurship:** Overview**,** project formulation and feasibility analysis; understanding customer needs, positioning the firm for social change and strategic advantage; social business model; participatory development; stakeholders; social impact assessment; networking; regional economic models; banking and loans; Women Entrepreneurship; Case Studies	**14**

Unit-4	**Family Business Management :** Small and Medium Business Enterprises; Growth plan formulation; Vision, Values and Strategies, Turn around strategies, cost management, finance and liquidity, family to corporate culture; Case Studies;	**14**
Pedagogy	Interactive learning, reflective thinking, critical analysis, and problem-solving.	
References/ Readings:	1. Nagasubba Rayudu, 'A Textbook on Entrepreneurship & Incubation', Mahi Publications, 2023, ISBN: 978811949282 2. Balasubramanya. M.H., 'Entrepreneurial Ecosystems for Tech Startup in India', Verlag Max Publications, 2021, 9783110679298. 3. Kenji Uchino, 'Entrepreneurship for Engineers', CRC Press, 2010, ISBN: 978143980063 4. Ryszard Praszkier, Andrzej Nowak, 'Social Entrepreneurship', Theory and Practice, Cambridge University Press, 2011, ISBN 9781139504331 5. Peter Leach, Tatwamasi Dixit, 'Indian Family Business Mantras', Rupa Publications, 2016, ISBN: 9788129136945 6. Bill Bolton, John Thompson, 'Entrepreneurs – Talent, Temperament, Opportunity', Elsevier Publications, 2004, ISBN:0750661283 7. John Bessant, Joe Tidd, 'Entrepreneurship', John Wiley Publications, 2015, ISBN: 9781118993095	
Course Outcomes:	After going through this course, student will be able to: CO 1. Understand entrepreneurial skill sets and different types of entrepreneurship. CO 2. Classify New Enterprise, Social Enterprise and Family Business CO 3. Explain process of preparing business plan, operational plans to start an enterprise CO 4. Apply the knowledge of market analysis, product planning, customer requirements, coting and finance	

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