Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRICAL ENGINEERING

M. Tech – Control & Automation

ACE Curriculum & Syllabus -2025

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.

Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.

Impactful People: Happy, accountable, caring and effective workforce and students.

Rewarding Co-creations: Active collaboration with national & international industries & universities for productivity and economic development.

Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRICAL ENGINEERING

To offer an education that provides strong fundamental knowledge and skills for employability and creates leaders who provide technological solutions to societal and industrial problems.

MISSION STATEMENT OF THE SCHOOL OF ELECTRICAL ENGINEERING

- To prepare students with strong critical thinking and employability skills through personalized experiential learning.
- To create innovators and entrepreneurs by fostering design thinking, creativity and cross-disciplinary research.
- To generate advanced knowledge leading to the solution of societal and industrial problems.

M. Tech. Control & Automation

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems.

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.

3. Graduates will function in their profession with social awareness and responsibility.

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.

5. Graduates will be successful in pursuing higher studies in engineering or management.

6. Graduates will pursue career paths in teaching or research.

M. Tech. Control & Automation

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications

PO_02: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints

PO_03: Having an ability to design and conduct experiments, as well as to analyze and interpret data

PO_04: Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice

PO_05: Having problem solving ability- solving social issues and engineering problems

PO_06: Having adaptive thinking and adaptability

PO_07: Having a clear understanding of professional and ethical responsibility

PO_08: Having good cognitive load management skills, including the ability to discriminate and filter available data

M. Tech. Control & Automation

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Control and Automation) programme, graduates will be able to

- PSO1: Apply technical knowledge, skills and analytical ability to design and develop controllers as well as employ techniques for automation of systems using modern tools and technologies.

- PSO2: Analyse, interpret and solve problems related to process control, automation, measurement and control etc.

- PSO3: Solve research gaps and provide solutions to socio-economic, and environmental problems.

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M. Tech. Control & Automation: ACE Curriculum 2025

S.No	Category	No. of Credits
1	University Core	39
2	Professional Core	24
3	Professional Electives	14
4	Open Elective	03
Total Credits		80

University Core (39 Credits)

S.No	Course Code	Course Title	L	T	P	C
1	MAENG501	Technical Report Writing	1	0	4	3
2	MASTS503	Qualitative and Quantitative Skills Practice I	3	0	0	3
3	MASTS504	Qualitative and Quantitative Skills Practice II	3	0	0	3
4	MASET697	Project work	0	0	0	10
5	MACOA698	Internship I / Dissertation I	0	0	0	10
6	MACOA699	Internship II / Dissertation II	0	0	0	10

Professional Core courses (24 Credits)

(6 core courses, each 4 credits)

S.No.	Course Code	Course title	L	T	P	C
1	MACOA501	Modern Control Systems	2	1	2	4
2	MACOA502	Process Dynamics and Control	3	0	2	4
3	MACOA503	Smart Sensor Systems	3	0	2	4
4	MACOA504	Embedded Systems Design	3	0	2	4
5	MACOA505	Industrial Automation	3	0	2	4
6	MACOA506	Random Variables and State Estimation	3	1	0	4
Total Credits						**24**

Professional Elective courses (14 Credits)

(Total: 4 Electives, Two 4 credits courses and two 3 credit courses)

S.No.	Course Code	Course title	L	T	P	C
1.	MACOA601	Machine Learning	3	0	2	4
2.	MACOA602	Industrial Robotics	3	0	2	4
3.	MACOA603	Control of Electric Drives	3	0	0	3
4.	MACOA604	Industrial Data Networks	3	0	0	3
5.	MACOA605	Data Analytics in Automation Industries	3	0	0	3
6.	MACOA606	Optimal Control Systems	3	0	0	3
7.	MACOA607	Adaptive and Robust Control	3	0	0	3
8.	MACOA608	Internet of Things: Architecture and Design	2	0	2	3
9.	MACOA609	Digital Twin and Industrial AI	3	0	0	3
10.	MACOA610	Neural Networks and Deep Learning	3	0	0	3
11.	MACOA611	Universal Automation	3	0	2	4
12.	MACOA612	Edge AI in Industrial Automation	3	0	2	4
13.	MACOA613	Modelling and Control of UAVs	3	0	2	4

Semester wise courses

Fall (First) Semester

S.No.	Course Code	Course title	L	T	P	C
1	MACOA501	Modern Control Systems	3	0	2	4
2	MACOA502	Process Dynamics and Control	3	0	2	4
3	MACOA503	Smart Sensor Systems	3	0	2	4
4	MACOA506	Random Variables and State Estimation	3	0	0	3
5	MACOA6xx	Elective –I	3	1	0	4
Total Credits						**19**

Winter (Second) semester

S.No.	Course Code	Course title	L	T	P	C
1	MACOA504	Embedded Systems Design	3	0	2	4
2	MACOA505	Industrial Automation	3	0	2	4
3	MACOA6xx	Elective – II	3	0	2	4
4	MACOA6xx	Elective – III	3	0	2	4
5	MACOA6xx	Elective – IV	3	0	0	3
Total Credits						**19**

Professional Core Courses

VIT
Vellore Institute of Technology
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MACOA501	Modern Control Systems	L	T	P	C
		2	1	2	4
Prerequisite	Nil	Syllabus version			
		v. 1			

Course Objectives:

1. To provide a fundamental understanding of state-space models for representing dynamic systems
2. To develop students' ability to analyze control problems, design solutions, and evaluate system performance effectively
3. To introduce optimal control techniques for dynamic systems

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Formulate state space models of physical systems.
2. Apply controllability and observability tests to determine the feasibility of state feedback and observer design.
3. Design state feedback controllers and observers for dynamical systems
4. Analyse nonlinear system behaviour using phase portraits, describing function methods and Lyapunov stability theory
5. Develop optimal control strategies using LQR and LQG techniques

Module:1	State variable models	9 hours

State models of linear time invariant (LTI) systems, Canonical forms, Transfer function from the state model, State transition matrix and its properties, Solution of the state equation

Module:2	Analysis in state space	9 hours

Controllability; Observability; State transformations such as diagonalization and Jordon canonical forms for controllability and observability tests; Stabilizability and detectability- Model reduction

Module:3	State feedback control and observer design	9 hours

Design of state and output feedback control: Regulation and tracking; Design of full order and reduced order observers; Observer based state feedback control; Simulation tools and case studies

Module:4	Nonlinear systems and stability analysis	9 hours

Nonlinear systems- Types of nonlinearities: saturation, dead-zone, backlash, jump phenomenon- Linearization of nonlinear systems, Singular points and its types- Describing function and Phase plane analysis; Stability analysis: Lyapunov direct and indirect method

Module:5	Optimal control	7 hours

Pontryagin's minimum principle, Linear quadratic regulator (LQR), Riccati Equation, State inequality constraints; Linear Quadratic Gaussian (LQG) control, Loop Transfer Recovery (LTR)

Module:6	Contemporary topics:	2 hours

	Total Lecture hours:	**45 hours**	
Text Book(s)			
1.	Ogata, Katsuhiko. Modern control engineering, Prentice Hall, 5th Edition , 2010.		
2.	Richard Dorf, Robert Bishop, Modern Control Systems, Pearson, 14th Edition, 2022.		
Reference Books			
1.	Farid Golnaraghi, Benjamin C. Kuo, Automatic Control Systems, McGraw Hill, 10th Edition , 2017.		
2.	Norman S. Nise, Control Systems Engineering, Wiley, 8th Edition, 2024.		
3.	Hassan K Khalil, Nonlinear Systems, Pearson Education India, 3rd Edition, 2014.		
4.	Frank L. Lewis, Draguna L. Vrabie, Vassilis L. Syrmos, Optimal Control, 3rd Edition, Wiley, 2012.		
5.	D S Naidu, Optimal Control Systems, CRC Press, 2018.		
Indicative Experiments:			
1.	State modelling and control of double inverted pendulum		
2.	Swing up and stabilization control of single inverted pendulum		
3.	Modelling of flexible joints in robotic arms		
4.	State feedback control design for rotary flexible link systems		
5.	Linear quadratic regulator design for rotary flexible joint systems		
6.	Stability analysis and controller design for magnetic suspension system		
7.	Step response modelling of servo motor		
8.	Partial state feedback controller design for active suspension system		
9.	Parameter estimation of servo motor through hardware in loop testing		
10.	Controllability and observability of magnetic suspension system		
11.	State observer design for inverted pendulum		
12.	Servo motor speed control using full state feedback		
13.	Modelling and controller design for laboratory scale aircraft pitch and yaw tracking		
14.	State estimator design for flexible joint systems		
15.	Pole placement technique for position control of servo motor		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA502	Process Dynamics and control	L	T	P	C
		3	0	2	4
Prerequisite	Nil	Syllabus version			
		1.0			

Course Objectives:

1. Introduce the modelling of various physical processes using first principle
2. Understand various control modes and tuning of controllers.
3. Study advanced control strategies based on process models.

Expected Course Outcome:

On the completion of this course the student will be able to:

1. Develop mathematical models for the dynamic processes.
2. Select suitable controllers for the given processes.
3. Tune PID controllers for the given systems.
4. Design controllers for a process involving multiple variables.
5. Design digital PID controller for the given processes.

Module:1	Process Modelling:	11 hours

Need for Process Control; P&ID diagram; objective of modelling: modelling of level, thermal and flow processes; Integrating and non-integrating systems; Degrees of Freedom; Continuous and batch processes; Self-regulation; Lumped and Distributed parameter models; Dynamic response of a first order process; First order plus dead time process; Second order process; Pure capacitive process; Pure dead time; Higher order process; Inverse response, Linearization of nonlinear systems.

Module:2	Control Actions:	7 hours

Concept of servo and regulatory problems; Selection of manipulated and controlled variables; Types of controller; Characteristic of on-off controller; proportional, integral and derivative controllers; P+I, P+D and P+I+D control modes; anti-reset windup; bumpless transfer; practical forms of PID control; selection of control modes for different processes.

Module:3	Design of feedback controller:	6 hours

Evaluation criteria: IAE, ISE, ITAE and ¼ decay ratio; Tuning methods: Process reaction curve method, Continuous cycling method, Direct synthesis; Overview of final control elements.

Module:4	Enhanced control strategy:	13 hours

Feed forward controller: design with steady state model, design with dynamic model; combination of feed forward-feedback structure; Cascade control: analysis and design; Ratio control; Split range control; Override control; Inferential control; IMC structure – development and design - IMC based PID control – MPC: Dynamic matrix control, Generalized predictive control; Multi-loop Control: Introduction; Process Interaction; Pairing of Inputs and Outputs; The Relative Gain Array (RGA).

Module:5	Sampled Data Controllers:	6 hours

Basic review of Z transforms, Response of discrete systems to various inputs. Open and closed loop response to step, impulse and sinusoidal inputs, closed loop response of discrete systems. Design of digital controllers: Position and Velocity form of PID controllers.		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Seborg, Dale E., Duncan A. Mellichamp, Thomas F. Edgar, and Francis J. Doyle, "Process dynamics and control", 4th edition, John Wiley & Sons, 2016.
2.	Stephanopoulos, George, "Chemical Process Control: An Introduction to Theory and Practice", Pearson India Education Services, 2015

Reference Books

1.	Coughanowr, Donald R., and Lowell B. Koppel, "Process systems analysis and control", McGraw-Hill, 2009.
2.	Johnson, Curtis D, "Process control instrumentation technology", Prentice Hall, 2013.
3.	Lipták, Béla G., ed. "Process Control: Instrument Engineers' Handbook. Butterworth-Heinemann, 2013.
4.	Bequette, B.W., "Process Control Modeling, Design and Simulation", Prentice Hall of India, 2010.

Indicative Experiments:

1.	Modelling and Control of Pressure Process
2	Experimental Study of PID controller on Level process station
3.	Control of liquid level in conical tank
4.	Experimental Study of ON-OFF and PID controller on Temperature Process
5.	Analysis of inherent and installed characteristics of control valves
6.	Experimental Study of Ratio Control for a Level-Flow Process
7.	Performance comparison of PID controller tuning methods using MATLAB
8.	Simulation of nonlinear processes using MATLAB
9.	Performance comparison of single and multi-loop controllers
10.	Design and verification of Feed Forward controller
11.	Design of IMC-PI controller
12.	Realization of PID controllers using LabVIEW
13.	Drum level control using PID controller in LabVIEW
14.	Design of Position and Velocity form of PID controller

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA503	**Smart Sensor Systems**	**L**	**T**	**P**	**C**
		3	**0**	**2**	**4**
Prerequisite	**Nil**	**Syllabus version**			
		v. 1.0			

Course Objectives:

1. To impart knowledge on smart sensing technology and its applications.
2. To introduce the standards and protocols used for smart sensing.

Expected Course Outcome:

On the completion of this course the student will be able to:

1. Select the right sensor for a given application.
2. Design basic building blocks for a Smart sensor.
3. Design compensators and perform calibration for smart sensors.
4. Design, synthesize and layout a VLSI sensor and design micro power generation systems
5. Interpret the standards and protocols used for the smart sensor design and apply smart sensors for Health, Industrial and Home related applications.

Module:1	**Smart Sensor Introduction:**	**7 hours**

Classic vs Smart sensors, Architecture of Smart Sensors: Important components, their features. Monolithic integrated smart sensor, Hybrid integrated smart sensor, Micro Sensors; Impedance sensing system, Smart temperature sensor, Smart Wind sensor, Smart Hall sensor.

Module:2	**Linearization, Calibration and Compensation:**	**12 hours**

Linearization using shunt resistance, Divider circuit, higher order linearizing circuit. Linear interpolation, Piecewise linearization, Lookup table approach, Adaptive filters based approach. Calibration and Self Calibration of smart sensors, Offset compensation, Error and Drift compensation, Lead wire compensation, Temperature effect and compensation. Uncertainties; Sensor fusion

Module:3	**VLSI Sensors and Micro-power Generation:**	**12 hours**

Analog Numerical computation - CORDIC Computation. Adaptive filtering – LMS algorithm, Bit stream multiplication. Analog VLSI based Neural Network. Introduction, Energy storage system, Thermoelectric energy harvesting, Vibration and Motion energy harvesting, Far-Field RF energy harvesting, Photovoltaic.

Module:4	**Standards and protocols:**	**7 hours**

Introduction, IEEE 1451 Standard, Network technologies, LonTalk, CEBUS Communication protocol for smart home, J1850 Bus, Plug-n-Play Smart Sensor Protocol.

Module:5	**Case Studies:**	**5 hours**

Design and Implementation of IoT for Environmental Condition Monitoring, Development of Smart Bed for Health Care Application, Study of Smart City and its Design, Wearable smart sensors, Biosensors and applications.

Module:6	**Contemporary Topics:**	**2 hours**

	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Manabendra Bhuyan, “Intelligent Instrumentation: Principles and Applications”, CRC Press, 2011.	
2.	Gerard Meijer, Kofi Makinwa, Michiel Pertijs, “Smart Sensor Systems: Emerging Technologies and Applications”, IEEE press, Wiley, 2014.	
Reference Books		
1.	Kevin Yallup, Krzysztof Iniewski, “Technologies for Smart Sensors and Sensor Fusion”, CRC Press, 2014.	
2.	Krzysztof Iniewski, “Smart Sensors for Industrial Applications”, CRC Press, 2013.	
Indicative Experiments:		
1.	Interfacing of thermistor sensor using LabVIEW	
2.	Interfacing RTD sensor using LabVIEW.	
3.	Linearization of Thermistor using Matlab	
4.	Linearization of RTD using Feedback Amplifier	
5.	Real time Linearization of Thermistor using LabVIEW	
6.	Perform Linear Interpolation on given sensor data	
7.	Design a Look-Up-Table based calibration of temperature sensor data	
8.	Implement CORDIC computation algorithm using Matlab	
9.	Implement Bit stream multiplication using Matlab	
10.	Energy Storage System : A case study	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		

Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA504	Embedded System Design	L	T	P	C
		3	0	2	4
Prerequisite	**Nil**	**Syllabus version**			
		v. 1.0			

Course Objectives:

1. Acquire hardware and software skills required for the role of embedded system engineer
2. Build automated control systems for real world problems using low cost embedded platforms

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Identify a microcontroller based on application specifications.
2. Develop embedded software using commercial integrated development environments
3. Program microcontroller peripherals using bare metal programming concepts
4. Design and implementation of data acquisition systems for measurement and control applications
5. Design and implement real-time embedded control systems

Module:1	Embedded Controller	8 hours

Embedded system components; Examples of embedded system; Attributes; CPU core: Architecture, Registers, Operating modes; Memory organization; Instructions: Instruction formats, and addressing modes; Exceptions and Interrupts; Commercial ARM Cortex-M microcontrollers

Module:2	Embedded C Programming	8 hours

Number systems, Data types, Data structures, Functions, Bitwise operations; Improving responsiveness: Interrupts, Finite state machines; Concurrency; Real-time operating systems; Scheduling; Context switching; Real-time systems; Embedded software development: Host and target, Compiler, Assembler, Linker, and Loader; Hardware and software debugging, In system programming

Module:3	Peripherals Programming	9 hours

Memory mapped IO; GPIO programming: Push-Pull, Open-Drain modes, Pull up and Pull down modes, Input and output devices; Timing generation and measurements: Timers, and PWM, Input capture; ADC, DAC, Analog comparator; Block data transfer using DMA; Real Time Clock (RTC); Power management; Serial communication protocols: UART, I2C, SPI, and CAN

Module:4	Data acquisition System Design	9 hours

Analog interfacing and data acquisition; Transducers; Current to voltage circuit, Instrumentation amplifier, isolation, Anti-aliasing filters; Nyquist theory to determine sampling rate; Measurement of voltage, current, and temperature; Analysis of noise; Techniques to reduce noise; Optical encoders for speed and position measurement; Data acquisition case studies

Module:5	Embedded Control System	9 hours

Closed loop control system: Set-point control and trajectory tracking; Design process for a PID controller; Fixed point vs. Floating point representation, Implementation of PID controller; Implementation of digital filters, Quantization, Overflow and resource issues; Case studies: DC motor control and process control applications.

Module:6	**Contemporary Topics:**		**2 hours**
	Total Lecture hours:	**45 hours**	

Text Book(s)	
1.	Alexander G Dean, Embedded Systems Fundamentals with Arm Cortex-M based Microcontrollers: A Practical Approach, ARM Education Media, 2021.
2.	Jonathan W. Valvano, Embedded Microcomputer Systems: Real Time Interfacing, Third Edition, Cengage Learning, 2010.
Reference Books	
1.	Yifeng Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, Fourth Edition, 2023.
2.	Daniel Lewis, Fundamentals of Embedded Software with the ARM Cortex-M3, Second Edition, 2012.
3.	Marilin Wolf, Computers as Components: Principles of Embedded Computing Design, Third Edition, Morgan Kaufmann, 2012.
4.	James K Peckol, Embedded Systems: A Contemporary Design Tool, 2ed, An Indian Adaptation, 2024.
Indicative Experiments:	
1.	Implementation of simple C programming concepts in IDE: Bitwise operations, control blocks and functions
2.	GPIO Programming: Interfacing input and output devices
3.	Study of polling and interrupts using a Cortex-M microcontroller
4.	Generation of PWM signals for the given frequency and duty cycle using timers
5.	Implementation of analog interfacing using ADC Programming with suitable sampling rate
6.	Measurement of process variables: Temperature, and level
7.	Measurement of motor speed and position using encoder
8.	Interfacing SPI based devices and signal analysis using logic analyzer
9.	Interfacing I2C based sensors and signal analysis using logic analyzer
10.	Implementation of CAN network and signal analysis using logic analyzer
11.	Porting of FreeRTOS to ARM Cortex Microcontrollers
12.	Pre-emptive task scheduling using RTOS kernel for multitasking applications
13.	Design and implementation of real time PID controller for speed/position control of a DC motor
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar	

Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA505	**Industrial Automation**	**L**	**T**	**P**	**C**
		3	**0**	**2**	**4**
Prerequisite	**Nil**	**Syllabus version**			
		v.1			

Course Objectives:

1. Understand the principles and technologies behind industrial automation, including communication protocols, wireless standards, and the integration of advanced systems such as SCADA, DCS, PLCs, and IoT.
2. Evaluate the role of emerging technologies in industrial automation, such as Industry 4.0, Industrial IoT, and data communication standards, to improve efficiency, control, and monitoring in modern industrial environments.

Course Outcomes:

On the completion of this course the student will be able to:

1. Explain the architecture of Programmable Logic Controllers (PLC) and the operation of basic ladder logic instructions.
2. Demonstrate the use of advanced PLC instructions, along with installation and troubleshooting techniques for efficient system operation.
3. Analyze the architecture and functionality of Supervisory Control and Data Acquisition (SCADA) systems for industrial automation and real-time monitoring.
4. Evaluate the architecture and functionality of Distributed Control Systems (DCS) for process automation and control in industrial environments.
5. Assess the advancements in industrial automation, focusing on data communication protocols, wireless standards, and the building blocks of Industry 4.0 and Industrial IoT.

Module:1	**Programmable Logic Controller (PLC) : Architecture and Programming**	**12 hours**

Evolution of Automation; Automation Components: Discrete Switches, Analog Sensors, Relays, Actuators, and Automation tools. PLC Architecture: input/output modules, power supplies, and isolators, programming device ; Program Scan ; IEC61131-3 Standard programming languages and their selection ; PLC Basic Instructions ; Input and Output Addressing ; Ladder Diagram for Boolean Gates ; Concept of Latching and Unlatching ; Programming Timers and Counters ; Applications

Module:2	**Advanced PLC Instructions, Installation and Troubleshooting**	**10 hours**

Arithmetic functions ; Comparison functions ; Program control Instructions ; Data transfer Instructions ; Sequencer functions ; Shift register functions ; Analog PLC operation ; PLC-PID functions ; Applications ; Networking of PLC ; Design of interlocks and Alarm annunciator sequence (ISA 18.1 Standard); PLC Enclosure; Electrical Noise; Leaky inputs and outputs; Grounding; Voltage Variations and surges ; preventive maintenance ; Troubleshooting: Processor Module, I/O Malfunctions, PLC program

Module:3	**Supervisory Control and Data Acquisition (SCADA)**	**7 hours**

SCADA Components: Human Machine Interface (HMI), Supervisory System, Remote Terminal Unit, Controller, Intelligent Electronic Devices ; Types of SCADA Architectures ; SCADA Communication : IEC61850, Modbus, Distributed Network Protocol (DNP), OPC UA IEC62541 Standard

Module:4	**Distributed Control System (DCS)**	**7 hours**
Evolution of Distributed Control Systems ; Generalized architecture of DCS**:** Local Control unit – Data Input and Output Unit, Operator Interface , Engineering interface ; DCS commissioning and Configuration ; Programming a DCS ; Redundancy concept ; Selection of DCS ; Case Studies: Thermal power plant , Water treatment plant		
Module:5	**Industrial Data Networks**	**7 hours**
Data communication**:** HART Protocol ; Field bus Protocol; Industrial Ethernet ; Wireless MAC Standards– IEEE 802.11- IEEE 802.15.4 , Wireless HART ; ISA 100 Wireless Standard for Automation ; Industry 4.0 ; Building blocks of Industrial IoT.		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Frank D Petruzella, “Programmable Logic Controllers”, McGraw Hill, New York, 2016
2.	Stuart A Boyer, “SCADA: Supervisory Control and Data Acquisition Systems”, ISA Press, 2010
Reference Books	
1.	Lawrence (Larry) M. Thompson and Tim Shaw, “Industrial Data Communications”, 5th Edition ,ISA Press, 2015.
2.	John Park, Steve Mackay, Edwin Wright, “Practical Data Communications for Instrumentation and Control”, Elsevier, 2004
3.	Alasdair Gilchrist, “Industry 4.0: The Industrial Internet of Things” Kindle Edition, Apress, New York, 2016
Indicative Experiments:	
1.	Design a Ladder program to automate the continuous filling system using basic instructions in PLC.
2.	Design a Ladder program to implement an alarm annunciator sequence (ISA 18.1 Standard) using Timer Instructions
3.	Design a Ladder program to implement an automatic parking system using counter instructions in PLC
4.	Design a Ladder/Function Block program to design an Automatic weighing system
5.	Program a ladder/Function Block program to control traffic in four-way Sequencer Output Instruction in PLC
6.	Interface the Analog /Digital Input /Output devices with Standalone PLC.
7.	HMI Configuration and Programming of Discrete Control Sequence Process
8.	DCS commissioning and hardware configuration (AI, AO, DI and DO Modules).
9.	Construct a DCS functional block programming to design an Interlock system

<table>
<tr><td>10.</td><td colspan="4">Interfacing Filed devices with DCS and build PID configuration in DCS</td></tr>
<tr><td>11.</td><td colspan="4">SCADA configuration and programming of Level /Temperature process control and Monitoring</td></tr>
<tr><td>12.</td><td colspan="4">Realization of various closed loop control schemes of Pilot plant (Level/Flow/Temperature/Pressure Process) using DCS</td></tr>
<tr><td>13.</td><td colspan="4">IoT Based Level/Temperature Monitoring System</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar</td></tr>
<tr><td colspan="2">Recommended by Board of Studies</td><td colspan="3">23-05-2025</td></tr>
<tr><td colspan="2">Approved by Academic Council</td><td></td><td>Date</td><td></td></tr>
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MACOA506	Random Variables and State Estimation	L	T	P	C
		3	1	0	4
Prerequisite	**Nil**		**Syllabus version**		
			v. 1		

Course Objectives:

1. Impart knowledge on random processes and the estimation process
2. Explore prediction and identification methods to recognize and control random processes
3. Estimate a system model using parametric and non-parametric approaches

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Understand random variables, random processes and their estimation techniques
2. Analyze the behavior random variables and random processes using statistical tools
3. Design optimal estimators for variables and systems having stochastic nature
4. Apply the concepts of filtering and prediction for a random process
5. Design estimators for dynamic systems using modern techniques and tools

Module:1	Random Variables and Random Processes	14 hours

Probability**:** Sample space, Conditional probability, Bayes theorem; Random variable: Cumulative Distribution Function (CDF), Probability Density Function (PDF), Conditional CDF; Multiple random variable: Joint CDF, Joint PDF; Computation of Expected Values. Random Process Characterization: Densities and Joint densities, Mean, Variance, Expectation of a Random Process; Classification of Random Processes: SSS, WSS, Ergodic, joint stationary; Correlation functions: Autocorrelation, auto-covariance, cross-correlation, cross-covariance; Temporal and Spatial Characteristics; White Noise

Module:2	Parameter Estimation	12 hours

Bayes Performance Measure, Statistical Characterizations of Data; Cramer-Rao bounds; Bayes Estimation: Maximum a posteriori (MAP) estimation, Minimum Mean Square Error (MMSE) Estimate: Linear MMSE Estimation, Nonlinear MMSE Estimation; Estimation of Nonrandom Parameters: Maximum Likelihood Estimation

Module:3	Filters for Estimation	10 hours

Optimum Filter Formulation: Prediction of a Random Process, Filtering out Noise, Interpolation for Random Processes; Wiener Hoff Equation; Wiener filter design: FIR Wiener filter, Linear Time-Invariant Noncausal Filter (IIR), Linear Time-Invariant Causal Filter (IIR). State Dynamics with Random Excitations, Markov Sequence Model, Observation Model; Kalman Filter estimator: Anatomy and Physiology of the Kalman Filter; Prediction: Fixed lead prediction, sliding window; Steady state equivalence of the Kalman and Wiener filter: Kalman filter formulation, Wiener filter formulation

Module:4	Parametric and Non Parametric System Estimation	12 hours

Parametric Model Estimation: Prediction Error Model Structures, parametric estimation using one-step ahead prediction error model structures and estimation techniques for ARX, ARMAX, Box-Jenkins. Nonlinear model estimation: NAR, NARX, NARMA, NARMAX models. Non-Parametric Model Estimation**:** Correlation and spectral analysis, obtaining estimates of the plant impulse, step and frequency responses from identification data

Module:5	**Recursive Estimation Methods and Case Studies**	**10 hours**
Adaptive models: Recursive Least Squares method, Recursive IV method, Recursive prediction-error method, Recursive pseudo-linear regressions. Choice of Updating step. Case Studies: Parameter Estimation in Climate Models, Economic Models, Structural Health Monitoring, Dynamic Models, Robotics, Chemical Kinetics, Biological Systems		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**60 hours**

Text Book(s)	
1.	Ludeman, L. C. (2010). Random processes: filtering, estimation, and detection, John Wiley & Sons, Inc.
2.	Lennart Ljung, (2012). System Identification: A Theory for the User, Prentice-Hall, 2nd edition
Reference Books	
1.	Catak, M., Allahviranloo, T., & Pedrycz, W. (2022). Probability and Random Variables for Electrical Engineering. Springer International Publishing.
2.	Wang, Z., Wang, Y., & Ji, Z. (2023). Filter Design for System Modeling, State Estimation and Fault Diagnosis. Boca Raton, FL, USA: CRC Press.
3.	Tangirala, A. K. (2018). Principles of system identification: theory and practice. CRC Press.

Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	23-05-2025			
Approved by Academic Council		Date		

<table>
<tr><td>MACOA601</td><td>Machine Learning</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td></td><td></td><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>Prerequisite</td><td>Nil</td><td colspan="4">Syllabus version</td></tr>
<tr><td></td><td></td><td colspan="4">v. 1</td></tr>
<tr><td colspan="6">Course Objectives:</td></tr>
<tr><td colspan="6">1. Understand the mathematical foundations, algorithms, and core principles underlying various machine learning paradigms including supervised, unsupervised, and reinforcement learning.
2. Apply machine learning techniques and data preprocessing methods to develop, evaluate, and deploy predictive models on real-world datasets using appropriate tools and libraries.</td></tr>
<tr><td colspan="6">Expected Course Outcome:</td></tr>
<tr><td colspan="6">On completion of this course, the students will be able to:
1. Understand mathematical principles underpinning ML algorithms
2. Perform essential data preprocessing tasks to build accurate Machine learning model.
3. Apply various supervised learning techniques to classification and regression problems.
4. Apply clustering and dimensionality reduction methods to discover patterns and insights in data.
5. Apply reinforcement learning concepts to develop and analyze control strategies for dynamic systems.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Module:1</td><td>Mathematical Foundations and Overview</td><td colspan="4">7 hours</td></tr>
<tr><td colspan="6">Overview of Machine Learning: Definition and scope ,Types of learning: Supervised learning, Unsupervised learning, Reinforcement learning, Real-world applications ; Linear Algebra: Matrix decomposition, Eigenvalues, Singular Value Decomposition (SVD), Calculus: Derivatives, partial derivatives, gradients ; Review of Probability and Statistics: Conditional probability, Bayes' theorem ; Cost functions ; Optimization: Batch gradient descent and Stochastic gradient descent algorithm.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Module:2</td><td>Data Preprocessing</td><td colspan="4">6 hours</td></tr>
<tr><td colspan="6">Data Collection and Understanding ; Sources of data ; Understanding structure and types : structured, unstructured, semi-structured ; Data Cleaning: Handling missing data , Outlier detection and treatment , Data inconsistency resolution , Feature Engineering: Feature selection, extraction, and construction , One-hot encoding, normalization, standardization ; Data Splitting: Train-test split , Cross-validation techniques</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Module:3</td><td>Supervised Learning(SL)</td><td colspan="4">12 hours</td></tr>
<tr><td colspan="6">Regression Algorithms: Linear Regression , Polynomial Regression , Evaluation metrics: MAE, MSE, R^2 ; Classification Algorithms :Logistic Regression , kNN , Decision Trees , Random Forest , Support Vector Machine , Model evaluation: confusion matrix , accuracy , precision , recall , F1-score , ROC-AUC ; Model Selection and Evaluation: Bias-variance tradeoff , Overfitting vs. underfitting ; Ensemble Methods: Bagging , Boosting, AdaBoost , Gradient Boosting ; Applications of SL in Control Systems: Fault detection and classification in control systems, Predictive maintenance ; Overview of Neural Networks (NN) : Perceptron Learning Algorithm and its limitations , Multi layer Perceptron (MLP) Architecture, Back propagation algorithm ; Applications of NN in Control Systems : Nonlinear system modelling, Soft</td></tr>
</table>

sensor design		
Module:4	**Unsupervised Learning (UL)**	**9 hours**
Clustering Algorithms: k-Means, Hierarchical Clustering, DBSCAN, Cluster evaluation metrics: Silhouette Score, Davies-Bouldin Index ; Dimensionality Reduction: PCA (Principal Component Analysis), Overview of t-SNE (introductory) , Association Rule Mining: Apriori, FP, Growth, Key metrics: Support, confidence, lift ; Applications of UL in Control Systems: Anomaly detection in industrial processes		
Module:5	**Reinforcement Learning (RL)**	**9 hours**
Reinforcement Learning fundamentals: Agent-Environment interaction, Reward signals, Policy, Value function, Overview of Markov Decision Processes (MDPs) and Dynamic Programming, Model-Free RL: Q-Learning and Policy Gradient, Exploration vs Exploitation, Overview of Deep Reinforcement Learning ; Applications of RL in Control Systems: Setpoint tracking and Trajectory following, Classical control vs RL-based control.		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, 2nd Edition, MIT Press, 2022.	
2.	Ethem Alpaydin, Introduction to Machine Learning, 4th Edition, Mit Pr, 2020.	
Reference Books		
1.	Stephen Marsland, Machine Learning: An Algorithmic Perspective, Second Edition CRC Press, 2015.	
2.	Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, Elsevier, 3rd Edition 2011	
3.	Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2013.	
4.	Aurelien Geron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow ,3rd Edition, Shroff Publishers, 2022.	
5.	Richard S. Sutton and Andrew G. Barto, Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2015.	
Indicative Experiments:		
1.	Analyze datasets using Exploratory Data Analysis techniques for data visualization and summarize the statistics	
2.	Implement and evaluate simple linear regression models for predictive analysis.	
3..	Apply logistic regression for binary classification and assess model performance.	

4.	Forecast time series data using ARIMA modeling and evaluate prediction accuracy.		
5.	Model complex relationships using Multi-Input and Multi-Output regression techniques.		
6.	Classify multi-class datasets using the K-Nearest Neighbors (KNN) algorithm		
7.	Apply Support Vector Machine (SVM) for Fault Diagnosis in Control Systems.		
8.	Extract key features and reduce dimensionality using Principal Component Analysis (PCA)		
9.	Apply K-Means clustering for unsupervised pattern discovery in control system data		
10.	Build and train a basic feedforward neural network for classification/ regression tasks		
11.	Compare decision tree and random forest algorithms for effective classification		
12.	Implement the Q-learning algorithm for reinforcement learning in control tasks.		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA602	Industrial Robotics	L	T	P	C
		3	0	2	4
Prerequisite	**Nil**	**Syllabus version**			
		v. 1			

Course Objectives:

1. To understand the importance of robotics in scientific and industrial domains.
2. To introduce mathematical aspects of robotics such as spatial transformations. Kinematics and dynamics of the manipulator.

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Demonstrate the classifications, and basic terminologies of robotics and various configurations of industrial robots.
2. Apply the concepts of coordinate transformations for development of homogeneous equations and inverse kinematics models for a given manipulator.
3. Develop the dynamics of the robotic manipulator using Euler Lagrangian approach.
4. Develop and analyze the mathematical model for trajectory planning
5. Explain various types of sensors and their applications in robotic systems.

Module:1	Introduction to Industrial Robotics:	8 hours
Definition and history of robotics; Classification of robots; Links, joints, and degrees of freedom; Robot configurations and work envelopes; End effectors: grippers and tools; Selection criteria for robots; Industrial applications of robots		
Module:2	**Robot Kinematics:**	**9 hours**
Frames and Joint Coordinates; Position and Orientation of objects; Rotation matrix; Homogeneous Transformation; Euler Angles - Quaternion Fundamental, Roll, Pitch and Yaw Angles; Axis angle representation; D H Representation & Homogeneous Matrices for Standard Configurations; Jacobians and velocity kinematics.		
Module:3	**Dynamics of Robotic Manipulators:**	**8 hours**
Introduction; Generalized Robotic Coordinates; Euler and Lagrangian Equations of motion; Lagrangian and Newton-Euler formulations; Application of Lagrange–Euler (LE) Dynamic Modeling of Robotic Manipulators; Computed Torque Control.		
Module:4	**Trajectory Tracking and Planning**	**9 hours**
Point-to-point (PTP) motion; Linear interpolation, Cubic and quintic polynomial interpolation with via points; Linear segment with parabolic blend(LSPB).		
Module:5	**Robot Sensing & Vision:**	**9 hours**
Robotic Sensors and their Classification; Use of Sensors and Sensor Based System in Robotics; Machine Vision System; Description, Sensing, Digitizing, Image Processing analysis and Application of Machine Vision System; Robotic Assembly Sensors and Intelligent Sensors.		

Module:6	**Contemporary Topics:**		**2 hours**
		Total Lecture hours:	**45 hours**
Text Book(s)			
1.	Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Robot Modeling and Control, 2020, 2nd edition, ISBN 9781119524045, Wiley.		
2.	John J. Craig, Introduction to Robotics: Mechanics and Control, 4th Edition, 2022, ISBN13: 9780137848744, Pearson Internationals.		
Reference Books			
1.	M.P. Groover, Industrial Robots: Technology, Programming and applications, McGraw Hill, 2nd Indian edition, 2017.		
2.	S K Saha, Introduction to Robotics, Tata McGraw-Hill, Second Edition, 2017		
3.	Lynch, Kevin M., and Frank C. Park. Modern Robotics: Mechanics, Planning, and Control 1st ed. Cambridge University Press, 2017.		
4.	Lee and Gonzalez Robotics, control vision and intelligence-Fu,. McGraw Hill International, 2nd edition, 2007		
Indicative Experiments:			
1.	Joint-level and Cartesian-level motions in Virtual Robots Module		
2.	Inverse kinematics of a 2-DOF planar robot		
3.	Simulation of robot dynamics using Euler-Lagrange formulation		
4.	Trajectory generation and tracking using computed torque control		
5.	PID control design for a robotic end-effector		
6.	Model predictive control of flexible manipulators		
7.	Trajectory planning using Quintic/Cubic Polynomials		
8.	Vibration control of flexible joints using state feedback control		
9.	Cascade Control of a Robotic Joint		
10.	Adaptive Control of a Robot Arm with Unknown Parameters		
11.	Speed control of servo motor using PIV controller		
12.	Modelling of a servo motor using frequency response test		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA603	**Control of Electric Drives**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
Prerequisite	**Nil**	**Syllabus version**			
		v. 1			

Course Objectives:

1. To introduce the concepts and basic operation of electric drive system
2. To analyse the solid state control of dc, induction and synchronous machine drives
3. To explain the design techniques of drive system

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Identify the need of various, electrical machines, power converters and control systems.
2. Design the phase controlled and chopper controlled DC motor drives.
3. Develop the dynamic model and control of inductor motor drives.
4. Analyse the performance of permanent magnet machines drives and apply intelligent control techniques for control of electric drives.

Module:1	**Introduction to Electrical machines and Power Electronics**	**7 hours**

Fundamental speed and torque equations, multi-quadrant operation, Loads with rotational motion, Loads with translational motion, Various power converters, speed control methods in DC and AC drives.

Module:2	**DC drives**	**10 hours**

Half controlled bridge rectifier fed drive , fully controlled bridge rectifier fed drive, Dual converter fed drive , Time ratio control , current limit control , step down and up chopper , chopper for motoring and regenerative braking, dynamic braking - Closed loop operation of rectifier and chopper fed drive.

Module:3	**Induction Motor Drives**	**10 hours**

Stator- Voltage Control, Slip· Energy Recovery Scheme, V/f control, Dynamic Model of a Three phase Induction Motor, Three phase to two phase transformation, Reference Frames Model, Need for vector control, direct and indirect vector control of induction motor drives.

Module:4	**Special Electric Drives**	**8 hours**

Permanent Magnets and Characteristics, BLDC motor, Unipolar and Bipolar BLDC motor, Sensor based and sensor less control of BLDC Drive. Permanent Magnets synchronous motor drive, Switched Reluctance Motor drive

Module:5	**Intelligent Control of Electric Drives:**	**8 hours**

Fuzzy Logic Control of AC and DC Drives, Artificial Neural Network control of AC and DC Drives, Hybrid Fuzzy/PI Control

Module:6	**Contemporary Topics:**	**2 hours**

		Total Lecture hours:	**45 hours**
Text Book(s)			
1.	Bimal K. Bose, "Power Electronics and Motor Drives: Advances and Trends Academic Press, 2020.		
2.	Ned Mohan, "Electrical Machines and Drives: A First course", Wiley Publications, 2012.		
Reference Books			
1.	Krishnan, Electric Motor Drives: Modelling, Analysis and Control, Pearson Education , 2015		
2.	Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, 2014.		
3.	Orłowska-Kowalska, Teresa, Blaabjerg, Frede, Rodríguez, José ,"Advanced and Intelligent Control in Power Electronics and Drives", Springer, 2014		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA604	Industrial Data Networks	L	T	P	C
		3	0	0	3
Prerequisite	**Nil**	Syllabus version			
		1.0			

Course Objectives

1. Explain the principles, protocols, and standards of industrial data communication systems, including OSI/TCP models, Ethernet technologies, and secure communication mechanisms.
2. Analyze fieldbus and wireless communication protocols, including MODBUS, HART, Profibus, WirelessHART, and Industrial IoT standards, for their applicability in real-time industrial environments.

Course Outcome

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

1. Describe network architectures, protocols, and interface standards used in secure communication.
2. Explain industrial communication protocols such as MODBUS and HART, including their structure, functions, and applications.
3. Summarize the structure and characteristics of OPC communication and Industrial Ethernet across various physical and data link layers
4. Compare Fieldbus architectures and protocols, including Profibus and Foundation Fieldbus, in terms of topology, communication models, and interoperability.
5. Identify wireless communication standards and architectures used in sensor networks and Industrial IoT applications.

Module:1	**DATA NETWORK AND INTERNET FUNDAMENTALS**	**9 hours**

ISO/OSI Reference model – TCP/IP Protocol Stack – UDP – Transport Layer Security [Network security and cryptography] – Virtual Private Network – EIA 232 interface standard – EIA 485 interface standard – CAN [Controller Area Network] and CAN FD – Media access protocol: Command/response, CSMA/CD — IEEE 802.3 – Bridges –Routers –Gateways– Standard ETHERNET configuration

Module:2	**MODBUS AND HART**	**8 hours**

Evolution of industrial data communication standards – MODBUS: Protocol structure, Function codes – HART communication protocol, Communication modes, HART Networks, HART commands, HART applications & Troubleshooting..

Module:3	**OPC AND INDUSTRIAL ETHERNET**	**8 hours**

OPC– Physical layer – Data link layer – Operating characteristics, Industrial Ethernet: Introduction – 10Mbps Ethernet – 100Mbps Ethernet- Gigabit Ethernet.

Module:4	**PROFIBUS AND FOUNDATION FIELD BUS (FF)**	**9 hours**

Fieldbus: Fieldbus architecture, Basic requirements of Fieldbus standard, Fieldbus topology, Interoperability and Interchangeability. Introduction – Profibus protocol stack – Profibus Communication model – Communication objects – Foundation fieldbus versus Profibus.

Module:5	**WIRELESS COMMUNICATION**	**9 hours**

Wireless sensor networks: Hardware components – energy consumption of sensor nodes – Network architecture – sensor network scenario. Wireless MAC Standards– IEEE 802.11- IEEE 802.15.4 – Zigbee Wireless HART – Wireless Standard for Process Industry – ISA100 – Introduction to Industrial IoT – Low Power Wide Area Network (LPWAN), Wi-Fi, low power Bluetooth for IoT and Industrial applications		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Behrouz A. Forouzan, "Data Communications and Networking", Tata McGraw-Hill, 5th edition, 2017.
2.	Sen, Sunit Kumar. Fieldbus and Networking in Process Automation. CRC Press, 2nd Edition, 2021.
Reference Books	
1.	Steve Mackay, Edwin Wright, Deon Reynders, John Park, Practical Industrial Data Networks, Design, Installation and Troubleshooting, Newnes, Elsevier, 2004.
2.	Bela G. Liptak, "Instrument Engineers' Handbook: Process Software and Digital Networks", Third Volume, 4th Edition, CRC Press, 2011.
3.	Theodore S. Rappaport, "Wireless Communications: Principles and Practice", 2nd edition, Pearson, 2009.
4.	Axelsson, Björn, and Geoff Easton, eds. Industrial networks: a new view of reality. Routledge, 2016.
Mode of Evaluation : CAT / Assignment / Quiz / FAT / Project / Seminar	

Recommended by Board of Studies	23-05-2025		
Approved by Academic Council	No.	Date	

MACOA605	Data Analytics in Automation Industries	L	T	P	C
		3	0	0	3
Prerequisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives:

1. Interpret principal techniques of predictive analytics used in decision making
2. Appreciate the impact of predictive maintenance in various sectors

Expected Course Outcome:

On the completion of this course the student will be able to:

1. Explain the principles and significance of predictive analytics and data preparation in automation industries.
2. Apply statistical and probabilistic techniques for analyzing industrial data and building predictive models.
3. Implement machine learning algorithms for predictive analytics and evaluate their performance.
4. Develop and deploy predictive maintenance solutions for industrial applications.
5. Analyze real-world case studies and emerging trends in predictive analytics across various industries.

Module: 1	**Introduction to Predictive Analytics and Data Preparation.**	**10 Hours**

Understanding Predictive Analytics: Definition, concepts, and applications, Maintenance Strategies: Preventive, corrective, predictive, and condition-based maintenance; Benefits of Predictive Maintenance: Cost reduction, increased efficiency, improved reliability. Data Sources: Sensors, PLCs, SCADA systems, and historical data; Data Quality: Cleaning, filtering, handling outliers and normalization; Feature Engineering: Creating relevant features for analysis; Data Visualization: Exploring data patterns and trends.

Module: 2	**Statistical Foundations for Predictive Analytics**	**8 Hours**

Statistical Methods: Descriptive statistics, correlation analysis, hypothesis testing; Uncertainty in Statistics, Randomness and Maximum likelihoods, Probability: Bayesian Reasoning and Estimation, Maximum Likelihood learning models, Naive Bayes Models, Expectation maximum Model, Markov Models.

Module: 3	**Machine Learning Techniques for Predictive Analytics**	**8 Hours**

Machine Learning Algorithms: Regression analysis, time series analysis, classification; Model Selection and Evaluation: Cross-validation, accuracy metrics, and performance evaluation.

Module: 4	**Predictive Modeling for Maintenance**	**10 Hours**

Condition Monitoring: Vibration analysis, temperature monitoring, and oil analysis; Failure Prediction: Developing predictive models for equipment failures; Remaining Useful Life (RUL) Estimation: Predicting the remaining operational life of assets; Anomaly Detection: Identifying abnormal behavior in equipment.

Module: 5	**Implementation and Case Studies**	**2 Hours**

Integration with Existing Systems: Integrating predictive models into automation systems; Alerting and Notification Systems: Implementing real-time alerts for maintenance teams. Case Studies: Analyzing real-world examples of predictive maintenance implementation; Challenges and Best Practices.

Module: 6	**Contemporary Topics:**	**2 Hours**

	Total Lecture hours:	**45 hours**

Text Books	
1.	Kuhn, Max, and Kjell Johnson. Applied Predictive Modeling, 3rd Edition, Springer, 2019
2.	Zhou, Shiyu, and Yong Chen. *Industrial Data Analytics for Diagnosis and Prognosis: A Random Effects Modelling Approach*. John Wiley & Sons, 2021.
Reference Books	
1.	Mobley, R. K. "An introduction to predictive maintenance Butterworth." (2002).
2.	Wang, Jing, Jinglin Zhou, and Xiaolu Chen. Data-driven fault detection and reasoning for industrial monitoring. Springer Nature, 2022.
3.	Cerquitelli, Tania, et al. Predictive Maintenance in Smart Factories. Springer Singapore, 2021.
4.	Shang, Chao. Dynamic modeling of complex industrial processes: Data-driven methods and application research. Springer, 2018.

Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA606	**Optimal Control Systems**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
Prerequisite	**Modern Control Systems (MACOA501)**	**Syllabus version**			
		1.0			

Course Objectives

The course is designed to enable the students to

1. Understand the optimal control theory fundamentals and apply the dynamic programming method for finding the optimal control law
2. Use the variational approach for solving the constrained optimal problem
3. Compare the different iterative methods used for solving the optimal control problems

Course Outcome

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

1. Formulate the optimal control problem for the various control objectives.
2. Find an optimal solution for the functionals with boundary conditions.
3. Determine an optimal control law using dynamic programming techniques for a practical dynamic system.
4. Determine an optimal control law for optimal tracking, regulatory, minimum time and minimum control effort problems using variational approach.
5. Determine an optimal control law using different techniques in MATLAB.

Module:1	**Introduction**	**6 hours**

Optimal Problem formulation: Mathematical model, Physical constraints, Performance measure – Form of optimal control – Performance measures for optimal control problem – Selecting a performance measure.

Module:2	**Calculus of Variations**	**9 hours**

Basic concepts: Function and functionals, Increment, Differential and variation – Functionals of a single function – Functionals involving several independent functions – Piecewise smooth extremals – Constrained extrema: Direct method, Lagrange multiplier method.

Module:3	**Dynamic Programming**	**8 hours**

Optimal control law – Principle of optimality – Dynamic programming: Computational procedure, Interpolation – Recurrence relation of dynamic programming – Characteristics of dynamic programming solution – Hamilton Jacobi Bellman equation – Continuous linear regulator problems.

Module:4	**Variational Approach**	**10 hours**

Variational approach to optimal control problems: Necessary conditions for optimal control. Finite time linear regulator problems – Finite time Linear tracking problems – Solution of general continuous time optimal control problem – Continuous time Linear Quadratic Regulator design – Riccati equation – Pontryagin's minimum principle – state inequality constraints.

Module:5	**Constrained Optimal Control**	**10 hours**

Time optimal control of LTI system – Fuel optimal control systems – Energy optimal control systems – Singular intervals in optimal control problems - Two point boundary value problems – Numerical techniques: Method of steepest decent – variation of extremals – Quasi-linearization – Gradient projection algorithm – Case studies.		
Module:6	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Donald E. Kirk, Optimal Control Theory: An Introduction, Dover Publications, 2004.
2.	Desineni Subbaram Naidu, Optimal Control Systems, CRC Press, 2009.
Reference Book(s)	
1.	Frank Lewis, Draguna L. Vrabie, Vassilis L. Syrmos, Optimal Control, 3rd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2012.
2.	Leonid T Aschepkov, Dmitriy V Dolgy, Taekyun Kim and Ravi P Agarwal, Optimal Control, Springer, 2016.
3.	Suresh P. Sethi, Optimal Control Theory: Applications to Management Science and Economics, 3rd Edition, Springer, 2019.

Mode of Evaluation **:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA607	Adaptive and Robust Control	L	T	P	C
		3	0	0	3
Prerequisite	**Modern Control Systems (MACOA501)**	**Syllabus version**			
		1.0			

Course Objectives:

1. Expose to techniques of system identifications for time varying systems
2. Design of Adaptive Control Systems
3. Analyze uncertain systems and design robust control systems.

Course Outcome:

On the completion of this course the student will be able to:

1. Estimate system parameters and design self-tuning regulators.
2. Apply Lyapunov theory and MIT rule to design Model-Reference Adaptive Control schemes.
3. Utilize vector fields to analyze variable structured systems and design sliding mode control law.
4. Analyze the stability of systems with unstructured uncertainty and design robust control loops satisfying system norms.
5. Utilize simulation tools to design, implement and test adaptive and robust control strategies.

Module:1	**Adaptive Control and Self-Tuning Regulators**	**9 hours**

Background: Linear feedback, Effects of process variations, Adaptive control schemes;
Estimation: Parameter estimation, Least squares and Regression models; Estimating Parameters in Dynamical Systems; Recursive least squares (RLS) estimate. Controller design: Minimum degree pole placement (MDPP) design; Direct and Indirect self- tuning regulators; Continuous-time self-tuners; Stochastic self-tuning regulators; Minimum variance controller design, Minimum average controller design; Linear Quadratic STR

Module:2	**Model-Reference Adaptive Control (MRAC)**	**9 hours**

Series and Parallel MRAC schemes; The MIT Rule, Determination of adaptation gain; Lyapunov Theory: Design of MRAC Using Lyapunov Theory; Bounded-Input Bounded- Output Stability; Applications to Adaptive Control, MRAC via Output Feedback; Relations between MRAS and STR.

Module:3	**Gain Scheduling Control**	**9 hours**

Principle; Design approach: Linearization of nonlinear actuators, Measurement of auxiliary variable, Time scaling based on production rate, Nonlinear transformation of the system dynamics; Application of gain scheduling controllers; Case studies: Industrial adaptive controllers, ship steering

Module:4	**Sliding Mode Control**	**7 hours**

Variable structure systems, Vector field; Sliding surfaces; Continuous approximations of switching control laws; Modeling and Performance Trade-Offs; Relay control for multi-input systems

Module:5	**Robust Control -Model Uncertainty + H2/H∞ Control**	**9 hours**

Unstructured uncertainty and system model; Stability under unstructured uncertainties; Robust stability criteria; Robust performance analysis: Small gain theorem, μ- Analysis and Synthesis, Lyapunov approach.

Norms: Computation of H_2 and H_∞ norms; Standard LQR, LQG control problem; Robust Control Problem as H_2 and H_∞ Control; H_2 and H_∞ control synthesis; LQG as special H_2 controller; Case study on aircraft hovering		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Nguyen, D. T., & Liu, W, Adaptive Control Design and Analysis: A Lyapunov Approach. Springer, 2023.
2.	Wang, H., & Chen, W, Robust Control Design: An Optimal Control Approach, Springer, 2022.
Reference Book(s)	
1.	Sastry, S. & Bodson, M., & Bartram, J. F, Adaptive control: stability, convergence, and robustness. Dover Publications, New York, 2011.
2.	Petros A Ioannou and Jing Sun, Robust adaptive control. Dover Publications, 2013.
3.	D'Andrea-Novel, B., & Xu, X, Robust and $H\infty$ Control: Theory and Applications. CRC Press, 2022.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA608	**Internet of Things: Architecture and Design**	**L**	**T**	**P**	**C**
		2	**0**	**2**	**3**
Prerequisite	**Nil**	**Syllabus version**			
		v.1.0			

Course Objectives:

1. Interpret principal technologies used in an IoT system and the working mechanism
2. Appreciate the impact of IoT in various sectors

Course Outcome:

On the completion of this course the student will be able to:

1. Understand the concept and technologies behind IoT and their applications.
2. Understand IoT Access Technologies and network layer.
3. Design IoT application using development boards and open source IoT platforms
4. Apply the concept of Internet of Things in the real-world scenario
5. Assess different Internet of Things technologies and their applications

Module: 1	**Overview and Architecture of Internet of Things (IoT)**	**Hours: 6**

Definition of IoT; Evolution of IoT over time; Working mechanism of an IoT System, Concepts and Technologies behind IoT, The Past, Present, and Future of IoT. Internet of Things: Architectures, Protocols and Standards; Functional blocks of an IoT ecosystem: Sensors, Actuators, Smart Objects and Connecting Smart Objects; Network Architecture, Device Architecture, Application Architecture, Cloud Architecture

Module: 2	**IoT Communication**	**Hours: 6**

IoT Access Technologies: Physical and MAC layers, topology and Security of communication system, Need for Network protocols; RF, RFID, WIFI, Bluetooth Low Energy, Zigbee; Network Layer: IPv4 & IPv6

Module: 3	**Device Architecture and Application Frameworks**	**Hours: 6**

Embedded system: Architecture, Characteristics and Types of Embedded systems; Examples of Embedded Systems; Embedded System On Chip (SOC), Single Board Computers. IOT applications, Application modeling, Data processing, Data Analytics, Programming Languages, Python libraries and Framework; Machine Learning: Supervised, Unsupervised and Semi-Supervised learning, regression, clustering and classification.

Module: 4	**Development Boards**	**Hours: 6**

Arduino, Raspberry pi, SP8266, selection criteria; Interfacing of sensors, drivers with development boards; Programming, GPIO, USART, ADC, DAC, PWM.

Module: 5	**IoT Platform and Use Cases**	**Hours: 4**

Blynk IoT Platform, ThingSpeak, IBM Watson IoT platform, Introduction to NodeRED, Use Cases: Healthcare, Energy, Smart home, Smart City and Manufacturing Sector

Module : 6	**Contemporary Topics:**	**Hours: 2**

	Total Lecture hours:	**30 hours**

Text Books

1. Arshdeep Bahga, Vijay Madisetti, "Internet of Things: A hands-on Approach", University Press, 2015.
2. Iqbal, M. A., Hussain, S., Xing, H., & Imran, M. A.. Enabling the Internet of Things: Fundamentals, Design and Applications. John Wiley & Sons, 2020.

Reference Books

1. Kamal, R., Internet of Things: Architecture and Design Principles, McGraw-Hill Education, 2017.
2. Cirani, Simone, Gianluigi Ferrari, Marco Picone, and Luca Veltri, *Internet of things: architectures, protocols and standards*. John Wiley & Sons, 2018.
3. Serpanos, Dimitrios, and Marilyn Wolf. *Internet-of-things (IoT) systems: architectures, algorithms, methodologies*. Springer, 2017.
4. Herrero, Rolando. *Fundamentals of IoT communication technologies*. Cham: Springer, 2022.

Indicative Experiments:

1	Measure the light intensity in the room and output data to the web API
2	Control your home power outlet from anywhere using raspberry pi
3	Build a web-based application to automate door that unlocks itself using facial recognition
4	Drinking water monitoring and analytics through cloud and mobile/ web app
5	Develop an IoT based Smart Parking System
6	Draft an IoT based Healthcare application with dashboard
7	Design a Real-time environmental monitoring with IoT based weather prediction and alert
8	Develop an IoT enabled Traffic monitoring and traffic pattern prediction
9	Design of Smart Street light with energy monitoring and control
10	Solve a plant health monitoring problem using IoT based data analytics

Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	23-05-2025			
Approved by Academic Council		Date		

MACOA609	Digital Twin and Industrial AI	L	T	P	C
		3	0	0	3
Prerequisite	**Nil**	**Syllabus version**			
		v. 1			

Course Objectives:

1. To provide a fundamental understanding of Digital Twin and identifying the appropriate Digital Twin solutions for industry applications
2. To develop students' ability to apply fundamental tools within modern artificial intelligence (AI) for industrial analytics

Course Outcome:

On completion of this course, the students will be able to:

1. Understand the fundamental concepts and architecture of Digital Twins.
2. Identify the key components and technologies involved in building and deploying Digital Twins.
3. Explain the role of data acquisition, integration, and management in the context of Digital Twins.
4. Comprehend the principles and applications of Artificial Intelligence and Machine Learning in industrial settings.
5. Evaluate the benefits, challenges, and ethical considerations associated with the adoption of Digital Twins and Industrial AI.

Module:1	**Fundamentals of Digital Twins**	**8 hours**

Evolution of Digital Twins, Introduction to Digital twin, Basic concepts of Digital twins, Growth drivers for digital twin, Product & Process digital twins, Digital Model, Digital Shadow, Digital twin Prototype (DTP), Digital Twin Instance (DTI), Digital Twin Aggregate (DTA), Partial digital twin, Clone digital twin, augmented digital twin, Smart & Connected design, accelerating industry 4.0 using Digital Twin

Module:2	**Enabling Technologies for Digital Twin**	**8 hours**

Sensor Technologies for Digital Twin; Digital Twin Enablement through IoT: IOT Architecture, Communications Protocol, IoT Data Management and Analytics; Cloud Computing and Edge Computing for Digital Twin; Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) usage in Digital Twin Visualization

Module:3	**Digital Twin Development Approaches and Analysis**	**9 hours**

Physics based Approach, Data-driven Methods, Hybrid Approaches, Integrating Physical and Data-Driven Elements, Geometric, Behavioural Data, Historical, Synthetic, and Real-Time Data, Data Acquisition, Storage, and Processing, Data Analytics and Insights: Descriptive Analysis; Diagnostic Analysis; Predictive Analysis; Prescriptive Analysis; Data-Driven Decision-Making

Module:4	**Introduction to Industrial AI**	**9 hours**

Fundamentals of Artificial Intelligence and Machine Learning Relevant to Industry, Types of Machine Learning: Supervised Learning: Regression Techniques(Linear Regression, Polynomial Regression, Support Vector Regression), Classification Techniques (Logistic Regression, Support Vector Machines, Decision Trees, Random Forest), Handling Imbalanced Datasets in Industrial Applications; Unsupervised Learning: Clustering Techniques, Dimensionality Reduction Techniques, Anomaly Detection using Unsupervised Methods; Data Preprocessing and Feature Engineering for Industrial Data; Introduction to Deep Learning and

Neural Networks: CNNs, RNNs, Sequence Modeling in Industrial Processes		
Module:5	**Application of AI in industry**	**9 hours**
Applications of AI in Predictive Maintenance, Anomaly Detection and Fault Diagnosis in Industrial Systems, Process Optimization and Efficiency Improvement through AI-driven Digital Twins, Resource Management and Energy Optimization, Supply Chain Optimization using Digital Twins and AI, Case Studies in Healthcare and Transportation, Ethical Considerations and Societal Impact of AI		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Raj, Pethuru, and Preetha Evangeline David, The digital twin paradigm for smarter systems and environments: The industry use cases, Academic Press, 2020.
2.	Khaled, Nassim, Bibin Pattel, and Affan Siddiqui, Digital twin development and deployment on the cloud: developing cloud-friendly dynamic models using Simulink®/SimscapeTM and Amazon AWS, Academic Press, 2020.
3.	Fernandes, Steven Lawrence, and Tarun K. Sharma, Artificial Intelligence in Industrial Applications, Springer International Publishing, 2022.
Reference Books	
1.	Maryam Farsi, Alireza Daneshkhah, Amin Hosseinian-Far, Hamid Jahankahani, Digital Twin Technologies & Smart Cities, Springer, 2020.
2.	N. Crespi, A. T. Drobot, and R. Minerva, The Digital Twin, Springer International Publishing, 2023.
3.	Jay Lee, Industrial AI: Applications With Sustainable Performance, Springer Singapore, 2020
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar	

Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA610	**Neural Networks and Deep Learning**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
Prerequisite	**Nil**	**Syllabus version**			
		v. 1			

Course Objectives:

1. To master the fundamentals of deep learning
2. To be updated with cutting-edge AI techniques

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Apply the fundamentals of neural networks to build and train deep learning models.
2. Implement deep learning training techniques using optimization algorithms
3. Optimize deep learning models using programming frameworks
4. Analyze advanced convolutional architectures and use transfer learning in real-world image tasks.
5. Develop sequence models and Transformer networks for language modelling

Module:1	**Neural Networks and Deep Learning**	**8 hours**

Introduction to Deep Learning, Neural Network Basics: Perceptron, Activation Functions, Multilayer Perceptrons (MLPs), Backpropagation Algorithm, Shallow vs. Deep Neural Networks, Building Deep Neural Networks

Module:2	**Practical Aspects of Deep Learning and Optimization Algorithms**	**8 hours**

Bias and Variance Trade-off, Regularization Techniques: Dropout, Weight Initialization Strategies, Gradient Techniques: Numerical Approximation of Gradients and Gradient Checking, Optimization Algorithms: Mini-batch Gradient Descent, Exponentially Weighted Averages, Bias Correction in EWAs, Momentum, RMSprop and Adam optimizer

Module:3	**Hyperparameter tuning, Batch normalization and programming frameworks**	**9 hours**

Introduction to Hyperparameters: learning rate, batch size, epochs; Search Strategies: Grid Search, Random Search, Bayesian Optimization; Early Stopping: Preventing overfitting; Automated Hyperparameter Tuning, Learning Rate Scheduling: step decay and exponential decay; Batch normalization in deep networks, Softmax Regression, Introduction to Deep learning frameworks: TensorFlow, Keras and PyTorch

Module:4	**Deep convolutional models**	**9 hours**

Classic Network Architectures: Introduction to Convolutional Neural Networks (CNNs), ResNets, Inception Network, MobileNet, EfficientNet, Transfer Learning techniques, Data Augmentation strategies, Real-world Case Studies

Module:5	**Sequence Models and Transformer Network**	**9 hours**

Recurrent Neural Network Model: Bidirectional RNN, Deep RNNs, Vanishing Gradients with RNNs, Language Model and Sequence Generation: Sampling Novel Sequences, Gated Recurrent Unit (GRU), Long Short Term Memory (LSTM), Attention Mechanisms, Transformer Network, Case Studies

Module:6	**Contemporary Topics:**	**2 hours**

		Total Lecture hours:	**45 hours**
Text Book(s)			
1.	Ian Goodfellow, Yoshua Bengio, and Aaron Courville Deep Learning, Deep Learning, MIT Press, 2016		
2.	Lewis Tunstall, Leandro von Werra, Thomas Wolf , Natural Language Processing with Transformers, O'Reilly Media, May 2022		
Reference Books			
1.	François Chollet, Deep Learning with Python, Manning Publications, 2nd Edition, 2021.		
2.	Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media, 3rd Edition, 2022.		
3.	Michael Nielsen, Neural Networks and Deep Learning, Online Book, 2015.		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA611	Universal Automation	L	T	P	C
		3	0	2	4
Prerequisite	**Nil**	**Syllabus Version**			
		1.0			

Course Objectives

1. To introduce students to the fundamentals of industrial automation, its evolution toward Industry 4.0, and the automation hierarchy including prevailing standards like IEC 61131-3 and IEC 61499.
2. To equip students with the knowledge and skills to design and implement state-machine-based automation logic using the IEC 61499 framework and function blocks.
3. To develop competency in deploying distributed automation systems using Universal Automation practices, and to explore emerging trends such as digital twins, IT/OT integration, and cloud-based control.

Course Outcomes

On completion of this course, the students will be able to

1. Explain the concepts of industrial automation, types of automation systems, and the structure of the automation pyramid in the context of Industry 4.0.
2. Compare IEC 61499 with IEC 61131-3 and describe the architecture and functional components of IEC 61499-based automation using Function Blocks.
3. Design and implement basic and composite function blocks using ECC (Execution Control Chart) and develop state-machine logic using Mealy and Moore models.
4. Demonstrate the ability to configure, deploy, and monitor distributed automation applications using standard event FBs, SIFBs, and UAR in multi-device environments.
5. Analyze advanced concepts in industrial automation such as digital twins, IT/OT convergence, and edge-cloud integration, and assess their implications on future automation architectures.

Module:1	Introduction to Industrial automation	7 hours

Industrial revolution, era of industry 4.0, Automation pyramid and I4.0, types of automation (discrete and process control), introduction to existing implementation standard (IEC 61131 -3), industrial examples – use cases discussions, Introduction to UAO and IEC 61499.

Module:2	IEC 61499 introduction and basics	10 hours

IEC 61499 vs IEC 61131-3(event execution, vendor agnostic capability, distributed automation), Building block of 61499 a basic FB and its components (Interface, ECC, states, algorithm, execution process

Module:3	Automata based programming	11 hours

Types of state machine: Mealy and Moore, State machine: Creating and Programing based on requirements?, time and sequence diagrams, implementation of a designed state machine in ECC. Testing of FBs (debugging and monitoring).

Module:4	Elements of 61499 and Universal Automation in Practice	9 hours

Standard event FBs (E_CYCLE, E_Delay etc), Composite FB, SIFB, application design and system configuration, deployment across devices Building distributed systems across multiple devices, integrating with field devices using SIFBs (e.g., Modbus, OPC UA), use of common runtime (UAR) in different hardware, Plug-and-produce architecture examples, Case studies from UniversalAutomation.org.		
Module:5	**Advanced Topics and Future Trends**	**6 hours**
Digital twins and model-based engineering, IT/OT convergence with IEC 61499, Edge and cloud integration, Security in distributed automation, future roadmap of IEC 61499 and Universal Automation.		
Module:6	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Books		
1	Valeriy Vyatkin, "EC61499 function blocks for embedded and Distributed Control Systems Design", Instrumentation Systems and Automation society, 3rd edition, 2015, ISBN:0979234301	
Reference Books		
1.	Alois Zoiti and Thomas Strasser, "Real-time Execution for IEC 61499", CRC Press, 2017, ISBN: 1934394270	
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar		
Indicative Experiments:		
1.	Introduction to IEC 61499 Development Environment: Ecostuxure Automation Expert.	
2.	Design and Implementation of Basic Function Blocks (FB).	
3.	Programming Finite State machines (FSM) using Execution Control Chart (ECC).	
4.	Composite Function Block design.	
5.	Working with Standard Event FBs (E_Cycle, E_Delay)	
6.	Deployment on distributed devices using Universal Automation Runtime (UAR).	
7.	Integration with Field Devices using Service Interface FBs.	
8.	Debugging and Monitoring FBs.	
9.	Implementing a Plug-and-Produce Use case	
Mode Evaluation : CAT / Assignment / Quiz / FAT / Project / Seminar		

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Recommended by Board of Studies	23-05-2025		
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MACOA612	**Edge AI in Industrial Automation**	**L**	**T**	**P**	**C**
		3	**0**	**2**	**4**
Prerequisite	**Nil**		**Syllabus version**		
			v. 1.0		

Course Objectives

To acquire the specialized skills needed to create embedded AI solutions for industrial applications

Course Outcomes

After completion of the course, students will be able to

1. Identify the challenges in model deployment in edge devices
2. Select the deployable model using key performance metrics
3. Apply suitable compression techniques to reduce memory footprint and latency
4. Compare the trade-off between compression rate, speed, and accuracy
5. Deploy the model in resource constraint embedded targets using suitable tools

Module:1	**Industrial Edge AI**	**9 hours**

Role of AI in industrial automation, Edge AI architecture and components, Pipeline for model deployment in edge devices, Real-world use cases: Predictive maintenance, quality inspection, process optimization, Deployment challenges: latency, memory, connectivity, reliability, Benefits of Edge AI.

Module:2	**Data and Model building**	**9 hours**

Cutting edge sensors, Common industrial protocols: OPC UA, Modbus data, Connectivity, Data loggers, Data preprocessing and cleaning, Assisted and automated labeling, Label noise, Data visualization, Model architecture search, Light weight neural networks,Training and Auto ML, Useful metrics.

Module:3	**Model Compression and xAI**	**9 hours**

Overview of model compression, Key performance indicators: accuracy, model size, and latency, Pruning: structured vs unstructured pruning, Magnitude based pruning, Gradient based pruning, Fine tuning of pruned models, Projection, Low rank factorization, Compression artifacts, Model selection, Model explainability, Pruning frameworks.

Module:4	**Model Quantization**	**9 hours**

Overview of model quantization, Bit-width representations, fixed point vs floating point implementation, Symmetric vs asymetric quantization, Post training quantization techniques, Model calibratrion, Quantization aware training, Trade off between model accuracy and size, Quantization frameworks.

Module:5	**Model deployment in Industrial Computers**	**9 hours**

Overview of industrial computing systems, Hardware targets: Intel x86, ARM based processors, Microcontrollers, and GPUs, SIMD instructions: AVX, NEON, Neural network accelerators, Benchmarking model performace, Hardware accelerated code generation. Case studies: Visual inspection using edge vision for quality control, Process control optimization with reinforcement learning.

Module: 6	**Contemporary Topics**		**2 hours**

		Total Lecture hours:	**45 hours**
Text Book(s)			
1.	Bin Li, Embedded Artificial Intelligence-Principles, Platforms, and Practices, Springer, 2024.		
2	Daniel Situnayake and Jenny Plunkett, AI at the Edge-Solving Real-World Problems with Embedded Machine Learning, O'REILLY publications, 2023.		
Reference Books			
1.	Francois Chollet, Deep learning with Python, Manning Publications, 2017.		
2.	Cen Unsalan, Berkan Hoke, Eren Atmaca, Embedded Machine Learning With Microcontrollers: Applications on Stm32 Development Boards, Springer, 2025.		
3.	Eric Siegel, The AI playbook: Mastering the Rare Art of Machine Learning Deployment, MIT Press, 2024.		
Indicative Experiments:			
1.	Model interoperability and visualization		
2.	Creation and handling datasets with python		
3.	Model training and evaluation using Tensorflow/PyTorch/MATLAB frameworks		
4.	Prune of a ResNet and fine-tune for accuracy recovery using Tensorflow/PyTorch/MATLAB frameworks		
5.	Projection based model compression using Tensorflow/PyTorch/MATLAB frameworks		
6.	Post-training quantization of a pretrained model using Tensorflow/PyTorch/MATLAB frameworks		
7.	Quantization aware training of a tiny CNN model using Tensorflow/PyTorch/MATLAB frameworks		
8.	Reduce the latency time using hardware acceleration		
9.	Deploy the quantized models on a Cortex-A SBC		
10.	Deploy the quantized models on a GPU		
11.	Deploy a tiny word spotting CNN model in Cortex-M microcontroller		
12.	Real-time noise detection using deep signal anomaly detector in embedded targets		
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	

MACOA613	Modelling and Control of UAVs	L	T	P	C
		3	0	2	4
Prerequisite	**Nil**	**Syllabus version**			
		v. 1			

Course Objectives:

1. To understand the fundamentals of drone systems and aerodynamics.
2. To design, assemble, and calibrate a UAV, learn basic drone programming and mission planning.
3. To gain hands-on experience in drone flying and flight simulation.

Expected Course Outcome:

On completion of this course, the students will be able to:

1. Identify and explain the key components and classifications of UAVs and their applications in various industries.
2. Design and assemble a multirotor UAV, including integration of motors, ESCs, propellers, flight controllers, and sensors.
3. Calibrate and configure UAV firmware and hardware systems using tools like Pixhawk/APM and software such as Mission Planner or QGroundControl.
4. Operate a drone safely and efficiently, including manual flight, autonomous missions, and emergency landing protocols.
5. Understand and apply national aviation regulations, including DGCA guidelines, NPNT compliance, and digital flight permissions.

Module:1	**Introduction to UAV Systems**	**7 hours**

Definition of drones/UAVs; History and evolution of drones; Difference between UAV, UAS, and RPAS (Remotely piloted aircraft system); Types and Classifications of Drones; Basic Components of a Drone; Drone Applications; Safety, Ethics & Regulations**.**

Module:2	**Dynamics and Control of Drones**	**9 hours**

Introduction to Drone Dynamics: fixed-wing, rotorcraft, UAVs; Basics of aerodynamics: lift, drag, thrust, weight; Mathematical Modeling of Drone Motion; Drone Stability: Linearization and Stability Analysis; modeling and simulation of drone motion and stability, Flight control systems, including control laws and control allocation.

Module:3	**Drone Components**	**8 hours**

Introduction to Drone components; Motor, Propeller, ESC, Battery, Battery Charger, Power Distribution; Flight Controller, Mission Planner, Telemetry Devices, GPS; Various Sensors and possible payload

Module:4	**Drone Assembly and Drone Flying**	**9 hours**

Frame Assembly; Mounting Motors and Propellers; Electronic Speed Controller (ESC) Wiring; Flight Controller Setup; Power System Installation; Communication & Accessories; Software Configuration and Calibration; Drone Flying Skills: Pre-Flight Checks, Basic Flying, Intermediate Flying, Emergency Handling.

Module:5	**Flight Simulation and Planning**	**9 hours**

Drone Subsystem Development; Firmware Configuration and Mission Planning; Simulation-Based Development; On-Ground Testing and Calibration; Flight Testing Procedures; Troubleshooting and

Iteration; Performance Evaluation and Reporting.			
Module: 6	**Contemporary Topics**		**2 hours**
		Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Beard RW, McLain TW. Small unmanned aircraft: Theory and practice. Princeton university press; 2012
2.	Kabamba PT, Girard AR. Fundamentals of Aerospace navigation and guidance. Cambridge University Press; 2014
Reference Books	
1.	Carrillo LR, López AE, Lozano R, Pégard C. Quad rotorcraft control: vision-based hovering and navigation. Springer, 2012
2.	Fahlstrom PG, Gleason TJ, Sadraey MH. Introduction to UAV systems. John Wiley & Sons, 2022
3.	Austin R. Unmanned aircraft systems: UAVS design, development and deployment. John Wiley & Sons; 2011
Indicative Experiments:	
1.	Manual flight training (Line-of-Sight)
2.	Autonomous Flight Programming
3.	GPS and Telemetry Testing
4.	Sensor fusion using Kalman Filter
5.	GPS integration for position estimation
6.	Multisensor data logging and analysis
7.	Pre-Flight Check and Safety Protocols
8.	System Identification of quadcopter
9.	PID control for altitude stabilization
10.	Adaptive control for load variation
11.	Calibration of electronic speed controller and radio transmitter
12.	Waypoint based autonomous mission

13.	Manual flight control in stabilized mode		
14.	Performing pre-flight checks and propeller direction checks		
Mode of Evaluation**:** CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	23-05-2025		
Approved by Academic Council		Date	