Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore
Shri Vaishnav Institute of Technology and Science
Choice Based Credit System (CBCS) in the Light of NEP-2020
M.Tech. in Robotics and Automation w.e.f. 2024

COURSE CODE	CATE-GORY	COURSE NAME	TEACHING &EVALUATION SCHEME								
			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA311		**Autonomous Mobile Robots**	60	20	20	-	-	3	0	0	3

Legends: L - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):
1. To understand the kinematic and dynamic models of mobile robots.
2. To study localization, mapping, and navigation techniques for autonomous mobility.
3. To learn motion planning algorithms and control strategies for mobile robots.
4. To explore sensor integration, perception, and decision-making in dynamic environments.

Course Outcomes (COs):
After the successful completion of this course, the student will be able:
1. Develop kinematic and dynamic models for different mobile robots.
2. Apply sensor data for localization and mapping in real environments.
3. Implement path planning and obstacle avoidance algorithms.
4. Design motion control strategies for autonomous navigation.

Syllabus:

UNIT I **8 Hrs.**
Introduction to Mobile Robotics: Classification of mobile robots: wheeled, legged, aerial, underwater. Applications in industry, healthcare, defense, agriculture. Concepts of mobile robot locomotion. Challenges of autonomous mobility.

UNIT II **6 Hrs.**
Kinematics and Dynamics in Mobile Robots: Kinematic models of wheeled robots: differential drive, car-like, omni-directional. Non-holonomic constraints and steering mechanisms. Dynamics of mobile robots. Odometry and dead-reckoning methods.

UNIT III **7 Hrs.**
Perception and Localization: Robot perception using sensors: LIDAR, GPS, Inertial Measurement Unit (IMU), cameras, ultrasonic, infrared. Probabilistic methods: Bayes filters, Kalman filter, Particle filter. Localization approaches: global localization, relative localization, Markov localization, Monte Carlo localization.

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			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA311		**Autonomous Mobile Robots**	60	20	20	-	-	3	0	0	3

Legends: L - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

UNIT IV

6 Hrs.

Mapping and Navigation: Basic idea of maps and navigation in mobile robots. Mapping methods: Occupancy grids and Landmark-based maps. Introduction to Simultaneous Localization and Mapping. Path planning: Dijkstra and A* Algorithms. Obstacle avoidance: Bug algorithms. Introduction to motion control using PID controller.

UNIT V

7 Hrs.

Advanced Topics and Applications: Multi-robot systems and swarm robotics. Autonomous decision-making using AI. Human robot interaction in navigation. Case studies: Automated Guided Vehicles (AGVs), warehouse robots, service robots, defense robots, self-driving cars.

Text Books:

1. R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd ed. Cambridge, MA: MIT Press, 2011.
2. R. Subramanian, *Build Autonomous Mobile Robot from Scratch using ROS: Simulation and Hardware*, 1st Ed., Apress / Maker Innovations, October 2023.
3. R. Priyadarshini, R. M. Mehra, A. Sehgal, P. Singh "Robotics and Smart Autonomous Systems: Technology and Applications", Edited by, 1st Ed., CRC Press, 2025.

References:

1. S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*. Cambridge, MA: MIT Press, 2005.
2. B. Siciliano and O. Khatib (Eds.), *Springer Handbook of Robotics*, 2nd ed. Cham: Springer, 2016.
3. B. Siciliano, L. Sciavicco, L. Villani, and G. Oriolo, *Robotics: Modelling, Planning and Control*. London: Springer, 2009.

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COURSE CODE	CATE-GORY	COURSE NAME	TEACHING &EVALUATION SCHEME								
			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTEEE321		Artificial Intelligence and Machine Learning	60	20	20	0	0	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):
The student will have ability to:
1. Know how to build simple knowledge-based systems.
2. Know various AI search algorithms (uninformed, informed, heuristic, constraint satisfaction, genetic algorithms).
3. Ability to apply knowledge representation, reasoning, and machine learning techniques to real world problems.

Course Outcomes (COs):
Upon completion of the subject, students will be able to:
1. Describe the key components of the artificial intelligence (AI) field.
2. Identify and describe artificial intelligence techniques, including search heuristics, knowledge representation, automated planning and agent systems, machine learning, and probabilistic reasoning.
3. Identify and apply AI techniques to a wide range of problems, including complex problem solving via search, knowledge-base systems, machine learning, probabilistic models, agent decision making.
4. Analyze and understand the machine learning and various algorithms.

Syllabus:

UNIT I **7 Hrs.**

Introduction To Al in Robotics
Fundamentals of Artificial Intelligence in Robotics, Problem formulation in robotic tasks (navigation, manipulation, planning), Problem solving methods in robotics: State-space search, Graph-based problem solving, Matching, Indexing, and Heuristic functions for robotic search problems, Search Algorithms: Hill Climbing, Depth-first and Breadth-first Search, A*, D*, and heuristic search for robotic path planning.

UNIT II **7 Hrs.**

Knowledge Representation for Robotics
Issues in representing knowledge for autonomous robots, Representations and Mappings between

COURSE CODE	CATE-GORY	COURSE NAME	TEACHING &EVALUATION SCHEME								
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MTEEE321		**Artificial Intelligence and Machine Learning**	60	20	20	0	0	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.

***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Robotic world models and AI knowledge. Knowledge representation approaches: Predicate Logic, Temporal Logic, and Modal Logic in robotic systems. Structured representation of knowledge for robotic environments (semantic networks, frames, ontologies).

UNIT III **6 Hrs.**

Knowledge inference

Fundamentals of knowledge inferences in autonomous robots. Production-based and Frame-based systems in robotics. Inference mechanisms: Forward and backward chaining for robotic decision-making. Rule-based reasoning, Fuzzy reasoning, Certainty factors, and Bayesian inference in uncertain robotic environments. Applications: Sensor fusion, fault diagnosis, decision-making under uncertainty.

UNIT IV

Machine Learning (ML) **7 Hrs.**

Types of ML and their role in robotics: Supervised, Unsupervised, Semi-supervised, Reinforcement Learning. Reinforcement learning in robot navigation, control, and policy learning. Regression algorithms for robotic perception and control: Linear Regression, Multiple Regression, Polynomial Regression, Support Vector Regression, Decision Tree Regression, Random Forest Regression.

Deep learning basics for robotics: Neural networks, CNNs for vision.

UNIT V

Classification of Algorithms **7 Hrs.**

Supervised ML: K nearest Neighbours, Support Vector Machine (SVM), Kernel SVM, Decision Trees Classification, Random Forest Classification.

Semi-supervised learning with (Expectation - Maximization) EM using labeled and unlabeled data.

Unsupervised Learning: Dimension Reductionality, PCA and LDA, clustering and Association algorithm. Case studies of AI integration in robotic automation (industrial robots, autonomous vehicles, collaborative robots).

Text Books:

1. Rich E and Knight K, "Artificial Intelligence", Third Edition, TMH, 2017.
2. Nelsson N.J., "Principles of Artificial Intelligence", First Edition, Springer Verlag, Berlin.

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COURSE CODE	CATE-GORY	COURSE NAME	TEACHING &EVALUATION SCHEME								
			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTEEE321		Artificial Intelligence and Machine Learning	60	20	20	0	0	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

3. Oliver Theobald, "Machine Learning for Absolute Beginners: A Plain English Introduction", 2nd Edition, 2017.

Reference Books:

1. S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Systems and Evolutionary Algorithms: Synthesis and Applications, 2nd ed., PHI Learning, 2017.
2. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 4th ed. Harlow, UK: Pearson, 2020.
3. E. Alpaydin, Introduction to Machine Learning, 4th ed. Cambridge, MA, USA: The MIT Press, 2020.

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Vishwavidyalaya, Indore	Vishwavidyalaya, Indore		

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			THEORY			PRACTICAL					
			END SEM. University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA331		**Control System for Robotics**	60	20	20	-	-	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.

***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):

1. To provide a deep understanding of control theory as applied to robotic systems.
2. To analyze and design controllers for robotic manipulators and mobile robots.
3. To study modern control techniques including nonlinear, adaptive, and intelligent control.

Course Outcomes (COs):

After the successful completion of this course, the student will be able to:

1. Develop dynamic models of robotic systems using classical methods.
2. Design and analyze controllers for trajectory tracking and stabilization.
3. Apply nonlinear and adaptive control methods to robotic manipulators.
4. Implement force control, impedance control, and compliance in robotic tasks.

Syllabus:

UNIT I **8 Hrs.**

Fundamentals of Control in Robotics: Introduction to control system concepts for robotics, Review of linear control: State-space representation, controllability, observability. Dynamics of robotic manipulators: Euler-Lagrange and Newton–Euler formulations, Properties of manipulator dynamics (linearity, symmetry, passivity).

UNIT II

Classical Control Approaches: Independent joint control, PD and PID controllers for robotic manipulators, Computed torque (inverse dynamics) control, Trajectory tracking with feedback linearization.

UNIT III

Advanced Control Strategies: Adaptive control of robotic systems, Nonlinear control methods for manipulators, Robust control approaches, Sliding mode control.

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			THEORY			PRACTICAL		L	T	P	CREDITS
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*				
MTRA331		Control System for Robotics	60	20	20	-	-	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

UNIT IV
Force and Compliance Control: Interaction control of robots with environment, Force control, hybrid position/force control, Impedance and admittance control, Compliance and redundancy resolution in robotic systems.

UNIT V
Intelligent and Modern Control: Neural network and fuzzy control in robotics, Optimal control approaches (LQR, MPC), Learning-based control strategies, Applications in exoskeletons, cooperative robots, and medical robotics

Text Books:

1. R. Paul, *Robot Manipulators: Mathematics, Programming and Control*, MIT Press, 1981.
2. R. Shilling, *Fundamentals of Robotics*, Prentice-Hall, 2003.
3. L. Behera and I. Kar, *Intelligent Systems and Control*, Oxford University Press, 2009.

Reference Books:

1. B. Siciliano, L. Sciavicco, L. Villani, and G. Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 2009.
2. K. M. Lynch and F. C. Park, *Modern Robotics: Mechanics, Planning, and Control*, 1st ed. Cambridge, UK: Cambridge University Press, 2017.
3. M. W. Spong, S. Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, 2nd ed. Hoboken, NJ, USA: Wiley, 2020.
4. J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 4th ed., Global Edition. Harlow, UK: Pearson, 2021.

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COURSE CODE	CATEGORY	COURSE NAME	TEACHING &EVALUATION SCHEME								
			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA312		Advanced Hydraulics and Pneumatics	60	20	20	0	0	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; **C** - Credit;
***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):
To understand the concept of:
1. Fundamentals of hydraulic and pneumatic power transmission systems.
2. Design and analysis of hydraulic and pneumatic circuits.
3. Selection and application of hydraulic and pneumatic components.

Course Outcomes (COs):
After successfully completing the course students will be able to:
1. Analyze and compare different power transmission systems and their applications.
2. Select appropriate hydraulic fluids, pumps, valves, and actuators for specific applications.
3. Design and troubleshoot basic and industrial hydraulic and pneumatic circuits.
4. Apply electro-hydraulic and electro-pneumatic systems for automation applications.

Syllabus

UNIT I **7 Hrs.**
Basics of Hydraulics, Major advantages and disadvantages of hydraulic systems, Comparison between mechanical, electrical, hydraulic and pneumatic power transmission systems, Applications of hydraulic systems in industry.

UNIT II **8 Hrs.**
Types and properties of hydraulic oils, Functions of hydraulic oils, ISO Viscosity grades, Classification of hydraulic fluids: Mineral based oils, Fire resistant oils, Biodegradable oils, Contamination control, Filters: types, construction and working, Filter rating and Beta ratio, Location of filters in hydraulic systems, Maintenance of hydraulic fluids.

UNIT III **7 Hrs.**
Classification of hydraulic pumps, Gear Pumps: external and internal gear pumps, Vane Pumps: balanced and unbalanced types, Radial piston Pumps: construction and working, Axial piston Pumps: swash plate and bent axis types, Pump performance characteristics, Selection criteria for hydraulic pumps.

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			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA312		Advanced Hydraulics and Pneumatics	60	20	20	0	0	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; **C** - Credit;
***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Linear Actuators: single-acting and double-acting cylinders, telescopic cylinders, Rotary Actuators: hydraulic motors, semi-rotary actuators, Hydrostatic Transmission Systems: open and closed loop systems.

7 Hrs.

UNIT IV

Basic hydraulic circuits include meter-in, meter-out, bleed-off circuits, regenerative circuits, sequencing circuits, and synchronizing circuits. Industrial hydraulic circuits encompass press circuits, injection molding machine circuits, and Power losses in flow control circuits. Circuit design considerations and troubleshooting hydraulic systems are also essential.

8 Hrs.

UNIT V

Basic Requirements for Pneumatic Systems, Advantages and Limitations, Applications of Pneumatic Systems.Air Compressors: Types (reciprocating, rotary screw, centrifugal), Selection criteria for air compressors, Air receiver: sizing and functions.FRL unit: Air filter construction and working, Pressure regulator: construction and working, Lubricator: construction and working, After coolers and air dryers.Pneumatic Actuators: Types of pneumatic cylinders (single acting, double acting, telescopic, rodless), Air motors: vane type, piston type, gear type, turbine type, Cushion assembly in pneumatic cylinders.

Text Books:

1.Anthony Esposito, "Fluid Power with Applications", Pearson Education, Revised 7th Edition, 2024.

2. Andrew Parr, "Hydraulics and Pneumatics: A Technician's and Engineer's Guide", Butterworth-Heinemann, 3rd Edition, 2011.

Reference books:

1.Majumdar S.R., "Oil Hydraulic Systems: Principles and Maintenance", Tata McGraw Hill, 2001.

2. Majumdar S.R., "Pneumatic Systems: Principles and Maintenance", Tata McGraw Hill, 1995.

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			THEORY			PRACTICAL		L	T	P	CREDITS
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*				
MTRA322		**Human Robot Interaction**	60	20	20	-	-	3	0	0	**3**

Legends: L - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.

***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):

1. To provide fundamental knowledge of human perceptual, cognitive, and motor systems relevant to HRI.
2. To familiarize students with modalities of interaction (speech, gesture, haptic, gaze, AR/VR) and their applications in robotics.
3. To equip students with the ability to design, prototype, and evaluate human–robot interfaces.
4. To sensitize students to ethical, safety, trust, and social implications of HRI.

Course Outcomes (COs):

After the successful completion of this course, the student will be able to:

1. Demonstrate the principles, goals, and challenges of human robot interaction.
2. Analyze human cognitive and perceptual capabilities and apply them in designing robot interfaces.
3. Apply multimodal interaction methods (speech, gesture, gaze, haptic feedback, AR/VR) in robotic systems.
4. Evaluate usability, trust, and safety aspects of HRI systems using suitable metrics.

Syllabus:

UNIT I **8 Hrs.**

Introduction to Human Robot Interaction: HRI vs HCI vs HMI: Definitions and scope, Importance of HRI in Robotics and Automation, Applications: industrial, medical, assistive, social, defense, teleoperation.

UNIT II

Human Factors and Cognitive Foundations: Human sensory systems: vision, audition, haptics, Perception, cognition, motor control, memory, attention, Mental workload, cognitive load, and human limitations, Implications for robot design and control.

UNIT III

Interaction Modalities: Speech recognition & natural language interfaces, Gesture recognition, body tracking, gaze and eye-tracking, Touch and haptic interfaces, multimodal interaction, Sensors and hardware: cameras, microphones, IMU, depth sensors, tactile sensors.

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			THEORY			PRACTICAL		L	T	P	CREDITS
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*				
MTRA322		Human Robot Interaction	60	20	20	-	-	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

UNIT IV

Design, Social Aspects, Trust and Ethics: Robot Embodiment and Anthropomorphism, Non-verbal communication, affordances, motion design, social acceptance, human trust in robots, safety protocols, Ethical, cultural, and legal aspects of human robot, collaboration.

UNIT V

Evaluation Methods and Case Studies: Usability metrics: effectiveness, efficiency, satisfaction, Experimental design for HRI, statistical testing. Adaptive HRI: shared autonomy, intention recognition. Case Studies: Collaborative Robots (cobots), Assistive Robots, Telepresence, Social Robots.

Text Books

1. C. Bartneck, E. Croft, D. Kulic, and S. Zoghbi, *Human Robot Interaction: An Introduction*, 2nd ed. Cambridge, U.K.: Cambridge Univ. Press, 2020.
2. R. Vinjamuri, Ed., *Human Robot Interaction: Perspectives and Applications*. London, U.K.: IntechOpen, 2023.
3. M. G. Ang, J. Virk, and P. W. Tsang, Eds., *Advances in Human Machine Interaction, Artificial Intelligence, and Robotics*. Basel, Switzerland: MDPI, 2024.

Reference Books

1. Goodrich, M. A., & Schultz, A. C. *Human Robot Interaction: A Survey*. Foundations and Trends in Human Computer Interaction, Now Publishers, 2007.
2. B. Siciliano and O. Khatib, Eds., *Springer Handbook of Robotics*, 2nd ed. Cham, Switzerland: Springer, 2016.
3. Esposito, M. Faundez-Zanuy, A. Hussain, and C. A. Avizzano, Eds., *Discovering the Frontiers of Human Robot Interaction: Insights and Innovations in Collaboration, Communication, and Control*. Cham, Switzerland: Springer, 2024.

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			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA332		Cyber Physical Systems in Automation	60	20	20	-	-	3	0	0	3

Legends: L - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.
***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

Course Educational Objectives (CEOs):

1. Understand CPS concepts, modeling, and real-time operation.
2. Design stable, safe, and reliable CPS controllers.
3. Explore advanced CPS methods in estimation, learning, and security.

Course Outcomes (COs):

After the course, students will be able to:

1. Explain CPS fundamentals and real-time constraints.
2. Model, analyze, and control CPS.
3. Apply stability, safety, and optimization techniques.
4. Implement estimation and security methods in CPS.

Syllabus:

UNIT I **7 Hrs.**

Fundamentals of Cyber-Physical Systems

Introduction to CPS: Motivational examples in robotics, manufacturing, autonomous vehicles. CPS architecture and compute platforms. Real-time sensing and communication: Sensor/actuator interfacing, communication protocols (CAN, Ethernet, Wireless). Real-time task scheduling: Scheduling algorithms (Rate Monotonic, EDF), resource management.

UNIT II **6 Hrs.**

Modeling and Control of CPS

Dynamical system modeling for CPS, Stability concepts and controller design, Delay-aware design: effect of delays on stability and performance, co-design of control and computation.

UNIT III **6 Hrs.**

Hybrid System Modeling and Analysis

Hybrid automata-based modeling of CPS, Discrete-continuous dynamics in robotic CPS. Reachability analysis for safety verification and autonomous navigation.

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Shri Vaishnav Institute of Technology and Science
Choice Based Credit System (CBCS) in the Light of NEP-2020
M.Tech. in Robotics and Automation w.e.f. 2024

COURSE CODE	CATEGORY	COURSE NAME	TEACHING & EVALUATION SCHEME								
			THEORY			PRACTICAL					
			END SEM University Exam	Two Term Exam	Teachers Assessment*	END SEM University Exam	Teachers Assessment*	L	T	P	CREDITS
MTRA332		Cyber Physical Systems in Automation	60	20	20	-	-	3	0	0	3

Legends: **L** - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** – Practical; C - Credit.

***Teacher Assessment** shall be based on the following components: Quiz/Assignment/ Project/Participation in Class, given that no component shall exceed more than 10 marks.

UNIT IV

Stability and Safe Control Design **7 Hrs.**

Lyapunov stability theory for CPS, Barrier functions and safety guarantees, Quadratic Program (QP) based safe controller design. Robust Control Methods: $H\infty$ control, sliding mode control for uncertain CPS.

UNIT V

Advanced Topics in CPS **6 Hrs.**

Neural Network (NN) based controllers in CPS, State estimation using Kalman Filters and Extended Kalman Filter (KF, EKF). Security in CPS: attack detection and mitigation (sensor spoofing, actuator attacks, resilience).

Text Books:

1. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
2. Houshang Darabi, Cyber-Physical Systems: Design and Application, Springer, 2022.
3. Karl J. Åström and Richard M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press, 2010.

Reference Books:

1. Magnus Egerstedt and Paulo Tabuada, Control of Cyber-Physical Systems, Springer, 2015.
2. Rajeev Alur, Formal Methods for Cyber-Physical Systems, Springer, 2019.
3. João P. Hespanha, Linear Systems Theory, Princeton University Press, 2009.

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