गोंय विद्यापीठ
ताळगांव पठार,
गोंय - ४०३ २०६
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(Accredited by NAAC with Grade A+)

GU/Acad –PG/BoS -NEP/2026-27/240 Date: 27.07.2026

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025/386 dated 09.09.2025

In supersession to the above referred Circular, the syllabus for the Courses offered under specialization **Robotics** of **Bachelor of Engineering in Electronics and Computer Engineering/ Bachelor of Engineering in Electronics and Computer Science** Programme for Semester V & VI, approved by the Academic Council in its meeting held on 20th February 2026 and Semester VII approved by the Academic Council in its meeting held on 24th April, 12th & 13th May 2026, is attached.

The syllabus for Semester III & IV approved earlier by the Standing Committee of the Academic Council in its meeting held on 24th & 25th July 2025 is also attached.

The Dean, Faculty of Engineering and the Principals of the affiliated Engineering Colleges are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN V LAWANDE
Digitally signed by ASHWIN V LAWANDE
Date: 2026.07.27 17:13:07 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

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

Copy to:

1. Chairperson, BoS in Electronics and Computer Engineering, Goa University.
2. Controller of Examinations, Goa University.
3. Assistant Registrar Examinations (Technical and Allied), Goa University
4. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

Electronics and Computer Engineering and Electronics and Computer Science

Specialization: Robotics

Sr. No.	Semester	Course Code	Title of the Course	L	T	P	TCr
1	III	ECM-281	Introduction to Robotics and AI	3	0	0	3
		ECM-282	Introduction to Robotics and AI Lab	0	0	1	1
2	IV	ECM-283	Controls of Robotic systems	3	0	0	3
		ECM-284	Controls of Robotic systems Lab	0	0	1	1
3	V	ECM-381	Robot Programming	3	0	0	3
		ECM-382	Robot Programming Lab	0	0	1	1
4	VI	ECM-383	Machine Vision and Machine Learning	3	0	0	3
		ECM-384	Machine Vision and Machine Learning Lab	0	0	1	1
5	VII	ECM-481	Deep Learning for Autonomous Robotic Systems	3	0	0	3
		ECM-482	Deep Learning for Autonomous Robotic Systems Lab	0	0	1	1
			Total	**15**	**0**	**5**	**20**

SEMESTER III

Name of the Programme	**: Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code	**: ECM-281**
Title of the Course	**: Introduction to Robotics and AI**
Number of Credits	**: 3 (T)**
Effective from AY	**: 2024-25**

Pre-requisites for the Course:	Mathematical background, Basic Programming	
Course Objectives:	**The subject aims to provide the student with:** • An understanding of all the subsystems and components of a robot. • An understanding of different drive systems and sensors used in robots. • An understanding of foundational concepts of AI and application of search techniques for effective problem solving. • An understanding of Logic, Planning and learning techniques for effective knowledge representation and intelligent decision making.	
Content:		**No of hours**
Unit - 1	**Fundamentals of robotics:** Automation and robotics, Robot applications. **Different classifications of the robot:** By application, by a coordinate system, by actuation system, by control method and by programming method. **Robot anatomy:** links and joints, Joint notation scheme. Degree of Freedom, Degree of Manipulability, Robot resolution, accuracy and repeatability. Concept of workspace/Work envelope. **Robot End Effectors:** Classification of Grippers, Criteria for selecting Grippers, Robot Grippers: Mechanical, Magnetic, Vacuum and Adhesive and Tools.	**11**
Unit - 2	**Drive systems:** Pneumatic and hydraulic Drives. Electric: Relation between torque and voltage. AC and DC Servo motors, Stepper motors, BLDC motors. Electronic control of motors. L293D **Sensors:** Characteristics of a sensor, Classification of Sensors, Touch sensors, Position Sensors: Potentiometer, LVDT, Optical Encoders, Force/Moment sensors, Range Sensor, Proximity Sensors- Inductive sensor, capacitive sensor, Hall effect sensor, Passive Sensor: RCC. **Advance Sensor Technology:** Smart sensors, MEMS based sensors, Selection of sensors while designing robotic systems.	**11**

Approved by: Standing Committee of the Academic Council on 24th & 25th July 2025

Unit - 3	**Introduction to AI:** What is Intelligence? Problem Solving: Defining a problem. **State Space Search:** Breadth First Search, Depth First Search, **Heuristic Search:** Generate and Test, Simple Hill Climbing, Steepest-Ascent Hill climbing, Best First Search, A* algorithm. **Optimal Search:** Iterative Deepening A*, Recursive Best First Search.	**11**
Unit - 4	**Knowledge Representation:** Representation and Mapping, Approaches to knowledge representation. **Predicate Logic:** Representing simple facts and logic, Representing instance and ISA relationship, Computable functions and predicates. **Logic and Inferences:** Formal Logic, Propositional Logic, Resolution method in Propositional Logic, and First Order Logic, Forward & Backward Chaining. **Planning:** STRIPS, Forward and Backward State Space Planning, Goal Stack Planning, Plan Space Planning. **Game Playing:** Mini-Max Search Procedure, Alpha-Beta Pruning.	**12**
Pedagogy:	Interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills	
References/ Readings:	**TEXTBOOKS:** 1. S. K. Saha; Introduction to Robotics, 2nd Ed.; McGraw Hill. ISBN: 9780070141109 2. M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey; Industrial Robotics: Technology, Programming and Applications; McGraw Hill. ISBN: 9780070221543 3. Saeed B. Niku; Introduction to Robotics: Analysis, Control, Applications, 2nd Ed.; Wiley Publications. ISBN: 9780471743797 4. Elaine Rich, Kevin Knight; Artificial Intelligence; TMH. ISBN: 9780074624755 5. Stuart Russell, Peter Norvig; Artificial Intelligence: A Modern Approach; Pearson. ISBN: 9780134610993	
	REFERENCE BOOKS: 1. John J. Craig; Introduction to Robotics, Mechanics & Control; Pearson Education Inc. ISBN: 9780133157037 2. Mittal, R. & Nagrath, I. J.; Robotics and Control; McGraw Hill, ISBN: 9780074602128 3. Nils J. Nilsson; Artificial Intelligence: A New Synthesis; Harcourt Asia. ISBN: 9781558604674 4. Patrick Winston; Artificial Intelligence; Pearson Education, ISBN: 9780321545892 5. Ivan Bratko; Prolog Programming for Artificial Intelligence; Pearson	

	Education, ISBN: 9780321417460
Course Outcomes:	**Upon completion of the course, students will be able to** CO 1. Explain the basic principles of robotics, including robot classifications, anatomy, and end effectors, and explain their applications in various industries. CO 2. Apply different actuation systems and sensors to design and control robotic systems using platforms like Arduino and Raspberry Pi. CO 3. Analyze and evaluate search algorithms such as BFS, DFS, and A* to solve real-world AI problems and optimize robotic decision-making. CO 4. Create intelligent systems by implementing AI planning techniques, such as STRIPS and Minimax, to enable robots to perform complex tasks autonomously.

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-282**
Title of the Course : **Introduction to Robotics and AI Lab**
Number of Credits : **1 (P)**
Effective from AY : **2024-25**

Prerequisites for the Course:	Mathematical background, Basic Programming	
Course Objectives:	The subject aims to provide students with the ability to: • Understand the architecture and design principles of real-time embedded systems used in IoT applications. • Apply programming skills to interface sensors and actuators using Arduino and Raspberry Pi. • Analyze and evaluate data from IoT devices for edge computing and decision-making. • Develop embedded AI solutions using appropriate search and optimization algorithms for real-time applications	
Content:	**List of programs/ Experiments** ***(Following experiments should be conducted. A certified journal reporting the experiments conducted should be submitted at the end of the term)***	**No of Hours**
	1. Electronic Control of a DC Servo motor 2. Electronic Control of a Stepper motor 3. Electronic control of BLDC motor 4. Interfacing of proximity and range sensors to Arduino/R-Pi 5. Interfacing of Accelerometers and Gyroscopes sensors to Arduino/R-Pi 6. Interfacing of force sensors to Arduino/R-Pi 7. Program to implement breadth first search algorithm. 8. Program to implement depth first search algorithm. 9. Program to implement Best First Search algorithm. 10. Program to implement alpha beta pruning. 11. Program for implementation Hill climbing problem. 12. Program to implement A* search algorithm. 13. Program to solve water jug problem. 14. Program to simulate tic – tac – toe game using min-max algorithm.	**30**
Pedagogy:	Integration of instructional learning, constructive thinking, inquiry-based, collaborative, experiential, and problem-solving approaches.	

Approved by: Standing Committee of the Academic Council on 24th & 25th July 2025

References/ Readings:	**TEXTBOOKS:** 1. S. K. Saha; Introduction to Robotics, 2nd Ed.; McGraw Hill, ISBN: 9780070141109 2. M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey; Industrial Robotics: Technology, Programming and Applications; McGraw Hill, ISBN: 9780070221543 3. Saeed B. Niku; Introduction to Robotics: Analysis, Control, Applications, 2nd Ed.; Wiley Publications, ISBN: 9780471743797 4. Elaine Rich, Kevin Knight; Artificial Intelligence; TMH, ISBN: 9780074624755 5. Stuart Russell, Peter Norvig; Artificial Intelligence: A Modern Approach; Pearson, ISBN: 9780134610993
	REFERENCE BOOKS: 1. John J. Craig; Introduction to Robotics, Mechanics & Control; Pearson Education Inc. ISBN: 9780133157037 2. Mittal, R. & Nagrath, I. J.; Robotics and Control; McGraw Hill, ISBN: 9780074602128 3. Nils J. Nilsson; Artificial Intelligence: A New Synthesis; Harcourt Asia, ISBN: 9781558604674 4. Patrick Winston; Artificial Intelligence; Pearson Education, ISBN: 9780321545892 5. Ivan Bratko; Prolog Programming for Artificial Intelligence; Pearson Education, ISBN: 9780321417460
Course Outcomes:	**Upon completion of the course, students will be able to** CO 1. Implement DC servo, stepper, and BLDC motors using electronic circuits and microcontrollers. CO 2. Implement and analyze BFS, DFS, and Best First Search for solving pathfinding problems. CO 3. Implement and simulate AI algorithms such as A*, Hill Climbing, Alpha-Beta Pruning, Min-Max, and problem-solving strategies like the Water Jug Problem using programming tools. CO 4. Develop sensor-based applications by interfacing proximity, range, accelerometer, and gyroscope sensors with Arduino or Raspberry Pi.

SEMESTER IV

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-283**
Title of the Course : **Controls of Robotic systems**
Number of Credits : **3 (T)**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Nil	
Course Objectives:	**The course aims to provide the students with:** • An ability to solve problems related to kinematics of a robot. • An ability to solve problems related to dynamics of a robot. • An understanding of Trajectory planning and motion planning. • An ability to design and program simple robotic platforms	
Content:		**No of hours**
Unit - 1	**Coordinate frames, mapping and transforms**: description of objects in space, transformation of vectors, Inverting a Homogenous Transform, Fundamental rotation matrices. **Direct Kinematic model:** Kinematic model for Robotic Manipulator (2 DOF and 3 DOF). DH notations. Manipulator Transformation Matrix. **Inverse Kinematics:** Solvability of inverse kinematic models, solution techniques, closed form solution.	**10**
Unit - 2	**Differential Kinematics:** Linear and Angular motion of rigid bodies, Velocity propagation along links, Manipulator Jacobian, Jacobian singularities. **Manipulator Dynamics:** Determination of Robotic Joint Torques, Langrage Euler formulation, Newton Euler formulation, Example with 2 link Manipulator.	**12**
Unit - 3	**Trajectory planning:** Definitions and planning tasks, joint space techniques, Cartesian space techniques, joint space v/s Cartesian space. **Control of Manipulators:** Open and closed loop control, Linear control schemes, PD and PID control schemes, Force control of manipulators, Force control strategies.	**11**
Unit - 4	**Analysis of wheeled robots and Biped robots:** Introduction, Staircase Ascending (SSP), Power Consumption, Dynamic Balances. **Motion planning:** Gross/Free Space Motion Planning	**12**

	Find path problems using: Visibility Graph, Voronoi diagram, Cell Decomposition, Tangent-Graph Technique. **Dynamic Motion Planning Problems:** Path Velocity, Decomposition, Accessibility Graph, Relative velocity scheme, Incremental planning, Artificial Potential field approach, reactive control scheme.	
Pedagogy:	Interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills	
References/ Readings:	**TEXT BOOKS:** 1. S. K. Saha; Introduction to Robotics, 2nd Edition, McGraw Hill Education, ISBN: 9789332902800 2. M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey; Industrial Robotics: Technology, Programming, and Applications, McGraw Hill Education, ISBN: 9781259006210 3. Saeed B. Niku; Introduction to Robotics: Analysis, Control, Applications, 2nd Edition, Wiley Publications, ISBN: 9781119527626 4. Roland Siegwart, Illah R. Nourbakhsh; Introduction to Autonomous Mobile Robots, 2nd Ed.; MIT Press, ISBN: 9780262015356	
	REFERENCE BOOKS: 1. John J. Craig; Introduction to Robotics: Mechanics & Control, Pearson Education Inc., ISBN: 9788131718360 2. Peter Corke; Robotics, Vision and Control, Springer, ISBN: 9783319544120 3. K. S. Fu, R. C. Gonzalez, C. S. G. Lee; Robotics: Control, Sensing, Vision, and Intelligence, McGraw Hill Book Co., ISBN: 9780071002370 4. Mittal, R. & Nagrath, I. J.; Robotics and Control, McGraw Hill Education, ISBN: 9780070482937	
Course Outcomes:	**Upon completion of the course, students will be able to:** CO 1. Explain the use of transformation matrices and coordinate frames in modeling robotic manipulators. CO 2. Compute forward and inverse kinematics for multi-DOF robot arms using DH parameters and matrix transformations. CO 3. Analyze robotic manipulator dynamics using Jacobians and Euler-Lagrange/Newton-Euler formulations to determine joint torques. CO 4. Design and simulate motion planning solutions for mobile robots using techniques like visibility graphs, Voronoi diagrams, and artificial potential fields.	

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-284**
Title of the Course : **Controls of Robotic systems Lab**
Number of Credits : **1 (P)**
Effective from AY : **2024-25**

Prerequisites for the Course:	Mathematical background, Basic Programming	
Course Objectives:	The subject aims to provide students with the ability to: • Understand the fundamental principles of robot kinematics, including forward and inverse kinematic modeling. • Apply path and trajectory planning techniques to control the motion of a robotic arm in different workspaces • Analyze and implement motion control strategies for robotic arms using structured programming techniques. • Design and develop intelligent robotic applications involving obstacle avoidance and real-time sensor integration.	
Content:	**List of programs/ Experiments** ***(Following experiments should be conducted. A certified journal reporting the experiments conducted should be submitted at the end of the term)***	**No of Hours**
	1. Forward Kinematics of a Robot arm (Hardware/Simulation Software) 2. Inverse Kinematics of a Robot arm(Hardware/Simulation Software) 3. Programming a robot arm for straight line paths (Hardware/Simulation Software) 4. Programming a robot arm for Circular Paths (Hardware/Simulation Software) 5. Programming a robot arm for Curved Paths (Hardware/Simulation Software) 6. Programming a robot arm for pick and place operation (Hardware/Simulation Software) 7. Programming a robot arm for Loops (Hardware/Simulation Software) 8. Programming a robot arm for branches and subroutines (Hardware/Simulation Software) 9. Programming a robot arm for external events (Hardware/Simulation Software) 10. Trajectory Planning for Robot Arm (Joint Space and Task Space) (Hardware/Simulation Software)	**30**

	a. Implement joint space and Cartesian space trajectory generation. b. Use linear or cubic interpolation for smooth motion. 11. Obstacle Avoidance Using Robot Arm (Hardware/ Simulation Software) a. Use IR or ultrasonic sensors to detect obstacles. b. Dynamically update path using kinematics and avoid collisions. 12. Velocity and Acceleration Analysis of a Robot Arm (Hardware/ Simulation Software) a. Derive joint velocities and accelerations using Jacobian matrix. b. Simulate or measure for different motions (e.g., pick and place).
Pedagogy:	Integration of instructional learning, constructive thinking, inquiry-based, collaborative, experiential, and problem-solving approaches.
References/ Readings:	**Textbooks** 1. S. K. Saha; Introduction to Robotics, 2nd Edition, McGraw Hill Education, ISBN: 9789332902800 2. M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey; Industrial Robotics: Technology, Programming, and Applications, McGraw Hill Education, ISBN: 9781259006210 3. Saeed B. Niku; Introduction to Robotics: Analysis, Control, Applications, 2nd Edition, Wiley Publications, ISBN: 9781119527626 **Reference Books** 4. John J. Craig; Introduction to Robotics: Mechanics & Control, Pearson Education Inc., ISBN: 9788131718360 5. Peter Corke; Robotics, Vision and Control, Springer, ISBN: 9783319544120 6. K. S. Fu, R. C. Gonzalez, C. S. G. Lee; Robotics: Control, Sensing, Vision, and Intelligence, McGraw Hill Book Co., ISBN: 9780071002370 7. Mittal, R. & Nagrath, I. J.; Robotics and Control, McGraw Hill Education, ISBN: 9780070482937
Course Outcomes:	**Upon completion of the course, students will be able to:** CO 1. Explain the concepts of robot arm kinematics and motion control, including workspace, DOF, and trajectory types. CO 2. Implement forward and inverse kinematics, as well as basic path planning algorithms, using simulation or hardware tools. CO 3. Analyze robotic arm behavior through velocity and acceleration modeling using Jacobian-based calculations. CO 4. Develop autonomous robot arm programs for tasks such as pick-and-place, obstacle avoidance, and event handling using

	appropriate sensors and control logic.

SEMESTER V

Name of the Programme	**: Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code	**: ECM-381**
Title of the Course	**: Robot Programming**
Number of Credits	**: 3 (T)**
Effective from AY	**: 2024-2025**

Pre-requisites for the Course:	Basic knowledge of programming in C or C++	
Course Objectives:	**This course will enable students to:** 1. Understand and use Linux OS and shell scripting for effective system management and automation. 2. Comprehend the ROS framework, including nodes, topics, messages, and parameter handling for robot programming. 3. Develop robot applications using middleware concepts such as publish–subscribe, services, and actions in multi-node systems. 4. Implement and simulate manipulator and mobile robot programs using kinematics, sensors, navigation, and trajectory control in simulation environments.	
Content:		**No of hours**
Unit - 1	**Introduction to Linux:** Linux File System Directories, Basic Linux Commands, Introduction to LinuxShell and Shell Scripting **Introduction to Robot Programming (ROS Basics):** Structure of a ROS Program: Nodes, Master, Topics, Messages **ROS File System**: Packages, Workspaces, catkin build system Writing Publisher and Subscriber Nodes **Message Types**: Standard Messages, Custom Message Creation Parameter Server and Parameter Handling **ROS Tools**: rosnode, rostopic, rosmsg, roslaunch **Introduction to TF**: Coordinate Frames, Broadcasters, Listeners **Debugging Tools**: rqt_graph, roswtf, TF echo	**12**
Unit - 2	**Middleware Programming:** Publish–Subscribe Programming Model; Writing Multi-node **Communication, ROS Services:** Creating Service Servers and Clients, Action Programming: Goal Handling, Feedback, Pre-emption, Recording and Playback of Data using rosbag, Launch **Files and Automated Node Execution, ROS2 Node Model:** Nodes, Executors, QoS Basics, Namespaces and Remapping;	**11**

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	Managing Large Multi-node Systems	
Unit - 3	**Manipulator Programming Basics:** Forward and Inverse Kinematics Coding, Jacobians for Velocity Kinematics; Practical FK/IK Implementation **Mobile Robot Programming:** Differential Drive Kinematics, Odometry, Motion Commands through ROS: Publishing Twist Messages to Control Mobile Robots, Sensor Data Handling: IMU, Laser, Camera Topics; Subscribing to Sensor Streams, Basic Navigation Programming: Sending Navigation Goals using Action Servers	**11**
Unit - 4	**Integrated Robot Applications and Simulation:** Combining Nodes, Parameters, and TF for Full Robot Applications, Simulation Programming: Controlling Robots in Gazebo/ CoppeliaSim, Trajectory Execution and Monitoring in Simulation Environments.	**11**
Pedagogy:	Interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills	
References/ Readings:	**TEXT BOOKS:** 1. Jason M. O'Kane; A Gentle Introduction to ROS, 1st Edition, University of South Carolina Press, ISBN: 9781792854050 2. Morgan Quigley, Brian Gerkey, William D. Smart; Programming Robots with ROS, 1st Edition, O'Reilly Media, ISBN: 9781449323899 3. Peter Corke; Robotics, Vision and Control: Fundamental Algorithms in MATLAB and Python, 2nd Edition, Springer, ISBN: 9783319544120 4. Roland Siegwart, Illah R. Nourbakhsh, Davide Scaramuzza; Introduction to Autonomous Mobile Robots, 2nd Edition, MIT Press, ISBN: 9780262015356	
	REFERENCE BOOKS: 1. John J. Craig; Introduction to Robotics: Mechanics and Control, 4th Edition, Pearson Education, 2021, ISBN: 9781292164953 2. K. S. Fu, R. C. Gonzalez, C. S. G. Lee; Robotics: Control, Sensing, Vision, and Intelligence, 1st Edition, McGraw Hill Book Company, 1987, ISBN: 9780070226258 3. S. K. Saha; Introduction to Robotics, 3rd Edition, McGraw Hill Education, 2024, ISBN: 9789355326461 4. Sebastian Thrun, Wolfram Burgard, Dieter Fox; Probabilistic Robotics, 1st Edition, MIT Press, 2005, ISBN: 9780262201629	
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Explain the ROS framework, including nodes, topics, messages, parameters, and core tools for robot programming. CO 2. Apply Linux commands and shell scripting for effective file, directory, and system management. CO 3. Develop robot applications using publish–subscribe, services, and action-based multi-node communication.	

	CO 4. Implement and simulate manipulator and mobile robot programs, including kinematics, navigation, and integrated applications in simulation environments.

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-382**
Title of the Course : **Robot Programming Lab**
Number of Credits : **01**
Effective from AY : **2024-2025**

Prerequisites for the Course:	Basic knowledge of programming in C or C++	
Course Objectives:	**This course will enable students to:** 1. Understand the principles of ROS/ROS2 middleware including nodes, topics, services, actions, and TF frames. 2. Apply programming techniques to develop robot communication, sensing, and motion control modules using ROS. 3. Analyze robot system behaviour through TF trees, sensor data interpretation, debugging utilities, and simulation outputs. 4. Design and integrate multi-node robotic applications combining sensing, actuation, transforms, and simulation frameworks.	
		No. of Hours
Content:	List of programs/ Experiments 1. Creating and configuring a ROS workspace and package (Linux + catkin environment setup) and Writing basic Publisher and Subscriber nodes in Python 2. Creating custom messages and implementing multi-topic communication 3. Developing ROS Services: Service Server and Service Client programs 4. Implementing Action Programming: Goal, Feedback, and Result handling 5. Using rosnode, rostopic, rosmsg, roswtf, rqt_graph for system debugging 6. Implementing TF Broadcasters and Listeners for coordinate frame transformations 7. Programming robot motion using Twist messages for differential drive control 8. Subscribing to IMU/Laser/Camera topics and performing basic sensor data processing 9. Sending Navigation Goals using Action Servers and monitoring execution 10. Simulation programming in Gazebo/CoppeliaSim: spawning robots and sending commands 11. Trajectory execution and visualization using RViz and simulation tools	**30**

Pedagogy:	Integration of instructional learning, constructive thinking, inquiry-based, collaborative, experiential, and problem-solving approaches.
References/ Readings:	**Textbooks** 1. Jason M. O’Kane; A Gentle Introduction to ROS; 1st Edition; University of South Carolina Press; 2014; ISBN: 9781792854050 2. Lentin Joseph; Learning ROS for Robotics Programming; 2nd Edition; Packt Publishing; 2018; ISBN: 9781783987580 3. Morgan Quigley, Brian Gerkey, William D. Smart; Programming Robots with ROS; 1st Edition; O’Reilly Media; 2015; ISBN: 9781449323899 4. Wyatt Newman; A Systematic Approach to Learning Robot Programming with ROS; 1st Edition; CRC Press; 2017; ISBN: 9781498775381 **Reference Books** 1. Anis Koubaa (Ed.); Robot Operating System (ROS): The Complete Reference, Volume 1; Springer; 2016; ISBN: 9783319260525 2. Bernardo Ronquillo Japón, Víctor Mayoral Vilches; Learning ROS2: Humble Hawksbill; O’Reilly Media; 2023; ISBN: 9781492078006 3. Carol Fairchild, Thomas L. Harman; ROS Robotics By Example; 2nd Edition; Packt Publishing; 2017; ISBN: 9781786463654 4. Lentin Joseph; Mastering ROS for Robotics Programming; 2nd Edition; Packt Publishing; 2018; ISBN: 9781788478953
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Explain ROS programming constructs including nodes, topics, services, actions, and TF frames. CO 2. Implement robot programs for sensing, inter-node communication, and motion control using ROS middleware. CO 3. Analyze multi-node robotics systems by interpreting TF trees, sensor streams, debugging tools, and simulation outputs. CO 4. Develop integrated robotic applications combining sensing, motion commands, transforms, and simulation environments.

SEMESTER VI

Name of the Programme	**: Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code	**: ECM-383**
Title of the Course	**: Machine Vision and Machine Learning**
Number of Credits	**: 3 (T)**
Effective from AY	**: 2024-2025**

Pre-requisites for the Course:	Linear Algebra	
Course Objectives:	**This course will enable students to:** 1. Understand the fundamentals of machine vision, image formation, camera models, and perception systems used in robotics. 2. Apply image processing and feature extraction techniques for robotic perception, inspection, navigation, and scene analysis. 3. Utilize classical machine learning methods for vision-based applications, including classification and clustering. 4. Develop and simulate integrated vision-based robotic applications, combining perception, algorithms, and sensors.	
Content:		**No of hours**
Unit - 1	**Introduction to Machine Vision:** What is vision in robotics? Applications: inspection, localization, grasping, SLAM, navigation **Light & Colour:** Spectral representation of Light, Colour, Human eye. **Image Formation:** Geometric Camera models, image formation, Intrinsic & Extrinsic Parameters, Geometric Camera Calibration,	**11**
Unit - 2	**Image Enhancement & Filtering:** Histograms and histogram equalization, Smoothing filters: mean, Gaussian, Sharpening filters: Laplacian, unsharp masking, Noise removal: median, bilateral filter **Edge & Feature Extraction:** Gradient operators: Sobel, Prewitt, Canny edge detection, Line & circle detection: Hough transforms, Morphological Operations: Erosion and dilation, Opening & closing, Blob detection and connected components	**12**
Unit - 3	**Segmentation:** Thresholding techniques: global, adaptive, Otsu, Region growing, Watershed segmentation, Color-based segmentation **Introduction to ML for Vision:** Supervised & unsupervised learning, Train-test split, cross-validation, Underfitting &	**11**

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	overfitting.	
Unit - 4	**Classical Feature Extraction:** Keypoint detectors: Harris Corner, FAST, Feature descriptors: SIFT, SURF, ORB, Keypoint matching. **Classical ML Algorithms for Vision:** k-NN classifier, SVM classifier Decision trees & Random Forests, Clustering: k-means for image segmentation	**11**
Pedagogy:	Interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills	
References/ Readings:	**TEXT BOOKS:** 1. David Forsyth, Jean Ponce; Computer Vision: A Modern Approach; 2nd Edition (2015); Pearson Education India; 2015; ISBN: 9789332550117 2. Peter Corke; Robotics, Vision and Control; 2nd Edition; Springer; 2017; ISBN: 9783319544120 3. Rafael C. Gonzalez, Richard E. Woods; Digital Image Processing; 4th Edition; Pearson; 2018; ISBN: 9789356067791 4. Richard Szeliski; Computer Vision: Algorithms and Applications; 2nd Edition; Springer; 2022; ISBN: 9783030343691	
	REFERENCE BOOKS: 1. Christopher Bishop; Pattern Recognition and Machine Learning; Springer; 2006; ISBN: 9780387310739 2. Gary Bradski, Adrian Kaehler; Learning OpenCV: Computer Vision with the OpenCV Library; O'Reilly Media; 2008; ISBN: 9780596516130 3. Hartley, R., Zisserman, A.; Multiple View Geometry in Computer Vision; 2nd Edition; Cambridge University Press; 2004; ISBN: 9780521540513 4. Ian Goodfellow, Yoshua Bengio, Aaron Courville; Deep Learning; MIT Press; 2016; ISBN: 9780262035613 5. Jiawei Han, Micheline Kamber, Jian Pei; Data Mining: Concepts and Techniques; 4th Edition; Morgan Kaufmann; 2022; ISBN: 9780123814791 6. Pang-Ning Tan, Michael Steinbach, Vipin Kumar; Introduction to Data Mining; 2nd Edition; Pearson Education; 2018; ISBN: 9780133128907	
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Explain fundamental concepts of light, color, image formation, camera models, and calibration used in robotics. CO 2. Apply image processing, filtering, and feature extraction methods for robotic sensing and perception. CO 3. Analyze segmentation techniques and classical machine learning models for vision-based tasks. CO 4. Develop basic machine-vision applications using classical ML	

	algorithms and feature-based approaches relevant to robotics.

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-384**
Title of the Course : **Machine Vision and Machine Learning Lab**
Number of Credits : **1 (P)**
Effective from AY : **2024-25**

Prerequisites for the Course:	Python Programming, Signal Processing Fundamentals	
Course Objectives:	**This course will enable students to:** 1. Understand image formation principles, camera models, and the fundamentals of digital images used in robotic perception. 2. Apply image preprocessing, enhancement, feature extraction, and segmentation techniques to real-world visual data. 3. Implement classical machine learning algorithms for visual classification, clustering, and pattern recognition tasks. 4. Develop vision-based applications for robotics using Python, OpenCV, and ML libraries, and analyze their performance on real or simulated datasets.	
Content:	List of Mini projects	**No of Hours**
Instructions	The student shall apply Machine Vision & Machine Learning knowledge to any ONE topic given below for a mini project. The list is only indicative; students can choose topics from related / allied areas	
	1. Design and Implementation of a Vision-Based Robotic Inspection and Classification System 2. Vision-Based Perception System for Mobile Robot Navigation Using Image Features 3. Vision-Based Object Detection, Counting, and Classification for Robotic Manipulation 4. Colour-Based Vision System for Robotic Pick-and-Place Operations 5. Feature-Based Object Recognition System for Robotic Perception 6. Vision-Based Scene Segmentation and Understanding for Robotic Applications 7. Vision-Based Traffic Sign Detection and Recognition for Autonomous Robotic Systems 8. Camera Calibration and Vision-Based Measurement System for Robotic Applications 9. Region-Based Vision System for Robotic Inspection and Quality Assessment 10. Vision-Based Object Classification and Decision Support System for Robotics	**30**

Approved by: Academic Council on 20th February 2026

Pedagogy:	Integration of instructional learning, constructive thinking, inquiry-based, collaborative, experiential, and problem-solving approaches.
References/ Readings:	**Textbooks** 1. David Forsyth, Jean Ponce; Computer Vision: A Modern Approach; 2nd Edition (2015); Pearson Education India; 2015; ISBN: 9789332550117 2. Peter Corke; Robotics, Vision and Control; 2nd Edition; Springer; 2017; ISBN: 9783319544120 3. Rafael C. Gonzalez, Richard E. Woods; Digital Image Processing; 4th Edition; Pearson; 2018; ISBN: 9789356067791 4. Richard Szeliski; Computer Vision: Algorithms and Applications; 2nd Edition; Springer; 2022; ISBN: 9783030343691 **Reference Books** 1. Christopher Bishop; Pattern Recognition and Machine Learning; Springer; 2006; ISBN: 9780387310739 2. Gary Bradski, Adrian Kaehler; Learning OpenCV: Computer Vision with the OpenCV Library; O'Reilly Media; 2008; ISBN: 9780596516130 3. Hartley, R., Zisserman, A.; Multiple View Geometry in Computer Vision; 2nd Edition; Cambridge University Press; 2004; ISBN: 9780521540513 4. Ian Goodfellow, Yoshua Bengio, Aaron Courville; Deep Learning; MIT Press; 2016; ISBN: 9780262035613 5. Jiawei Han, Micheline Kamber, Jian Pei; Data Mining: Concepts and Techniques; 4th Edition; Morgan Kaufmann; 2022; ISBN: 9780123814791 6. Pang-Ning Tan, Michael Steinbach, Vipin Kumar; Introduction to Data Mining; 2nd Edition; Pearson Education; 2018; ISBN: 9780133128907
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Explain image formation, camera models, and preprocessing techniques used in robotic vision. CO 2. Apply filtering, edge detection, morphological operations, and segmentation methods to visual data. CO 3. Implement classical machine learning algorithms for classification and clustering of visual features. CO 4. Develop and evaluate vision-based applications relevant to robotics using Python, OpenCV, and ML libraries.

SEMESTER VII

Name of the Programme	**: Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code	**: ECM-481**
Title of the Course	**: Deep Learning for Autonomous Robotic Systems**
Number of Credits	**: 3 (T)**
Effective from AY	**: 2024-25**

Pre-requisites for the Course:	Linear algebra, Probability & Statistics, Soft Computing (preferred)	
Course Objectives:	**This course will enable students to:** 1. Gain knowledge of neural networks and deep learning for robotic perception and decision-making. 2. Explore classical and deep learning approaches for localization, mapping, and environment understanding. 3. Understand planning and navigation strategies, including classical algorithms and learning-based models. 4. Build familiarity with reinforcement learning for autonomous robotic control and behavior learning.	
Content:		**No of hours**
Unit - 1	**Deep Learning Foundations:** What is deep learning? Applications in robotics. Biological neuron vs artificial neuron. Basics of Neural Networks: Perceptron, Multi-Layer Perceptron (MLP), Activation Functions (ReLU, Sigmoid, Tanh), Backpropagation. **Regularization techniques:** weight decay, dropout, batch normalization **Optimization algorithms:** SGD, Adam, Adagrad **Convolutional neural networks:** convolution, pooling, feature extraction.	**10**
Unit - 2	**Localization & Mapping:** Challenges in Localization: Noise & Aliasing, Localization-Based Navigation Versus Programmed Solutions, Belief Representation, Map Representation, Markov localization, Kalman filter localization, SLAM, EKF SLAM. CNN-based place recognition, Deep Visual Odometry, Monocular depth estimation for mapping, Semantic mapping using CNNs, Autoencoders for map representation.	**10**
Unit - 3	**Planning & Navigation:** Path planning: Graph search & Potential field path planning,	**10**

Approved by: Academic Council on 24th April, 12th & 13th May 2026

	Obstacle Avoidance: bug algorithm, Vector field histogram, bubble band technique, curvature velocity techniques. Imitation learning (behaviour cloning) for robot navigation, End-to-end CNN-based navigation, Perception-driven navigation, Neural cost map prediction.	
Unit - 4	**Deep Reinforcement Learning for Robotic Control:** What is Reinforcement Learning? Elements of reinforcement learning. Markov decision processes, state–action–reward models, Policy evaluation and improvement, Temporal-difference learning and Q-learning principles, Policy gradient methods and actor–critic frameworks.	**10**
Pedagogy:	Interactive, reflective, and inquiry-based methods, with a strong emphasis on critical thinking and problem-solving skills	
References/ Readings:	**TEXT BOOKS:** 1. Ian Goodfellow, Yoshua Bengio, Aaron Courville; Deep Learning; MIT Press; 1st Edition; ISBN: 9780262035613 2. Peter Corke; Robotics, Vision and Control: Fundamental Algorithms in MATLAB and Python; 2nd Edition; Springer; ISBN: 9783319544120 3. Roland Siegwart, Illah R. Nourbakhsh, Davide Scaramuzza; Introduction to Autonomous Mobile Robots; 2nd Edition; MIT Press; ISBN: 9780262015356 4. Richard S. Sutton & Andrew Barto; Reinforcement Learning: An Introduction; 2nd Edition; MIT Press; ISBN: 9780262039246 5. Mohamed Elgendy; Deep Learning for Vision Systems; 1st Edition; O'Reilly Media; ISBN: 9781492041382	
	REFERENCE BOOKS: 1. Richard Szeliski; Computer Vision: Algorithms and Applications; 2nd Edition; Springer; ISBN: 9783030343691 2. David A. Forsyth, Jean Ponce; Computer Vision: A Modern Approach; 2nd Edition; Pearson Education; ISBN: 9780136085924 3. Adrian Kaehler, Gary Bradski; Learning OpenCV 3: Computer Vision in C++ with the OpenCV Library; O'Reilly Media; ISBN: 9781491937990 4. Francois Chollet; Deep Learning with Python; 2nd Edition; Manning Publications; ISBN: 9781617296864 5. Sergey Levine, Pieter Abbeel, Chelsea Finn (Editors); Deep Reinforcement Learning for Robotics, Foundations and Trends in Robotics; Now Publishers; ISBN: 9781680835563	
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Explain neural network and deep learning architectures and their applications in robotic perception and feature extraction. CO 2. Apply classical and deep-learning-based techniques for robot localization, mapping, and depth/semantic scene understanding. CO 3. Analyze classical and learning-based navigation strategies including path planning, behaviour cloning, and end-to-end navigation.	

	CO 4. Develop reinforcement-learning-based control strategies for autonomous robotic tasks.

Name of the Programme : **Electronics and Computer Engineering/Electronics and Computer Science (Robotics)**
Course Code : **ECM-482**
Title of the Course : **Deep Learning for Autonomous Robotic Systems Lab.**
Number of Credits : **1 (P)**
Effective from AY : **2024-25**

<table>
<tr><td>Prerequisites for the Course:</td><td colspan="2">Basic programming, introductory robotics</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">This course will enable students to:
1. Implement deep learning models for classification, detection, segmentation, and depth estimation in robotic applications.
2. Train and evaluate deep neural architectures using real-world and synthetic datasets.
3. Develop visual and spatial representations for navigation and mapping tasks.
4. Apply deep reinforcement learning algorithms for robotic control in simulation environments.</td></tr>
<tr><td>Content:</td><td>List of programs/ Experiments</td><td>No of Hours</td></tr>
<tr><td></td><td>1. Implementation of a basic feedforward neural network for image classification.
2. CNN-based image classification using convolution, pooling, and augmentation.
3. Transfer learning using pretrained models (ResNet/MobileNet).
4. Implementation of a single-shot detector (SSD / YOLO-Tiny).
5. Semantic segmentation using U-Net / DeepLab.
6. Instance segmentation using Mask R-CNN
7. Monocular depth estimation using encoder–decoder networks.
8. Learning-based visual odometry using CNN/LSTM models.
9. Autoencoder-based feature learning for scene understanding.
10. Deep Q-Learning for robotic navigation/manipulation tasks.</td><td>30</td></tr>
<tr><td>Pedagogy:</td><td colspan="2">Integration of instructional learning, constructive thinking, inquiry-based, collaborative, experiential, and problem-solving approaches.</td></tr>
<tr><td>References/ Readings:</td><td colspan="2">Textbooks
1. Maxim Lapan, Deep Reinforcement Learning Hands-On, 3rd Edition, Packt Publishing, ISBN: 9781803249902.
2. Adrian Rosebrock, Deep Learning for Computer Vision (PyImageSearch), Digital Edition, PyImageSearch Publishing.</td></tr>
</table>

	3. Anis Koubaa (Editor), ROS: Perception, Deep Learning, and Reinforcement Learning, Springer, Studies in Computational Intelligence, ISBN: 9783030050537. 4. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 2nd Edition, O'Reilly Media, ISBN: 9781492032649. 5. Vishnu Subramanian, Deep Learning with PyTorch, 1st Edition, Packt Publishing, ISBN: 9781788834137. **Reference Books** 1. Mohammed Enamul Hoque, OpenCV 4 with Python Blueprints, 2nd Edition, Packt Publishing, ISBN: 9781788629788. 2. Pradeepta Mishra, Hands-On Reinforcement Learning with Python, Packt Publishing, ISBN: 9781788835721. 3. Joe Minichino, Joseph Howse, Learning Robotics Using Python, 2nd Edition, Packt Publishing, ISBN: 9781788623311. 4. Antonio Gulli, Amita Kapoor, Deep Learning with TensorFlow 2 and Keras, 2nd Edition, Packt Publishing, ISBN: 9781838823412. 5. Valerio Maggio, Ashish Thapliyal, Building Machine Learning Pipelines, O'Reilly Media, ISBN: 9781492053170.
Course Outcomes:	**After going through this course, the students will be able to:** CO 1. Implement deep learning architectures for perception tasks including classification, detection, segmentation, and depth estimation. CO 2. Analyze perception outputs and integrate them into navigation and mapping pipelines. CO 3. Develop learned representations using autoencoders and sequence models for scene understanding. CO 4. Build and evaluate DRL-based controllers for autonomous robots in simulated environments.