RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

New Scheme Based On AICTE Flexible Curricula

Robotics and Artificial Intelligence, VII Semester

RA 701 -Edge AI and Embedded ML for Robotics

Course Objectives:

1. To introduce the fundamentals and significance of Edge AI and Embedded ML in robotics applications.
2. To develop an understanding of embedded hardware platforms suitable for deploying AI models on robots.
3. To train students in designing, training, and deploying lightweight machine learning models for edge devices.
4. To integrate ML-based perception and decision-making within robotic systems for autonomy.
5. To expose students to practical challenges, emerging trends, and ethical issues in Edge AI for robotics.

Course Outcomes:

After completing this course, students will be able to:

CO1: Explain the principles and need for Edge AI and Embedded ML in robotics systems.
CO2: Select suitable embedded hardware platforms for ML-based robotic tasks.
CO3: Train and optimize lightweight ML models for deployment on edge devices used in robotics.
CO4: Implement ML-based perception and control tasks on embedded robotic systems.
CO5: Demonstrate practical skills in building and deploying embedded ML applications for robotics.

Syllabus

Unit 1: Introduction to Edge AI and Embedded Machine Learning

Introduction of Edge AI, Advantages of Edge AI in Robotics, Embedded ML concepts, Comparison with Cloud AI, Case studies: Mobile robots, drones, and IoT-based robots

Unit 2: Embedded Hardware Platforms for Edge AI

Overview of microcontrollers and microprocessors for ML (ARM Cortex, ESP32, Raspberry Pi, NVIDIA Jetson, Coral TPU), Sensors and actuators in robotics, Power constraints and deployment considerations, Introduction to TinyML.

Unit 3: Machine Learning Models for Edge Devices

Review of basic ML models: Linear regression, Decision Trees, KNN, Lightweight neural networks for edge: Quantization and Pruning, Model training pipelines and dataset preparation for robotics applications, Using TensorFlow Lite, Edge Impulse, and microTVM

Unit 4: Integrating ML with Robotics Control

Perception: Object detection, gesture recognition, and obstacle avoidance, Edge ML for SLAM and path planning, Case study: Line following using embedded ML, Real-time constraints and latency issues

Unit 5: Hands-on Implementation and Deployment

Building and deploying ML models on microcontrollers for robotics tasks, Data collection from robotic sensors for model updates, Tools: Arduino + TensorFlow Lite, ESP32 + Edge Impulse, Mini-project: Develop a simple robotic application (object tracking, anomaly detection in motors, etc.)

List of Textbooks:

1. Pete Warden, Daniel Situnayake, TinyML: Machine Learning with TensorFlowLite on Arduino and Ultra-Low-Power Microcontrollers, O'Reilly Media, 2019.
2. Joseph Howse, Prateek Joshi, Michael Beyeler, OpenCV 4 for Secret Agents, Packt Publishing, 2019.
3. Daniel Situnayake, Jan Jongboom, AI at the Edge: Solving Real World Problems with Embedded Machine Learning, O'Reilly Media, 2023.

List of Reference Books:

1. Donald Norris, Programming Machine Learning on the Edge, McGraw Hill, 2022.
2. BharathRamsundar, Reza BosaghZadeh, TensorFlow for Deep Learning, O'Reilly Media, 2018.
3. Adrian Kaehler, Gary Bradski, Learning OpenCV 4: Computer Vision with Python, O'Reilly Media, 2019.
4. M. Tim Jones, AI and Machine Learning for On-Device Development, Apress, 2020.
5. Sandeep R. Shukla, Machine Learning for Embedded System Security, Springer, 2021.

Different problems to be framed to enable students to understand the concept learnt and get hands-on on various tools and software related to the subjects. Such assignments are to be framed for ten to twelve lab sessions.

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Robotics and Artificial Intelligence, VII Semester

RA 702(A): Generative AI

Course Objectives:

1. To introduce the fundamentals and applications of Generative AI.
2. To understand various generative models including GANs and VAEs.
3. To explore GAN architectures, training challenges, and solutions.
4. To study practical applications of Generative AI in text, image, and audio generation.
5. To familiarize students with tools, frameworks, and ethical considerations in Generative AI.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Explain the principles, evolution, and applications of Generative AI.
- CO2: Differentiate between generative models and apply them to real-world problems.
- CO3: Analyze GAN architectures and address challenges in their training.
- CO4: Implement Generative AI techniques for tasks like image and text generation.
- CO5: Utilize frameworks such as TensorFlow and PyTorch for generative model development considering ethical issues.

Syllabus

Unit 1: Introduction to Generative AI
Definition and evolution of Generative AI, difference from Discriminative AI, major applications (image, text, audio generation), ethical concerns.

Unit 2: Generative Models
Overview of probabilistic models, introduction to GANs (Generative Adversarial Networks), VAEs (VariationalAutoencoders), comparison between models.

Unit 3: GAN Architectures and Training
Components of GANs (Generator and Discriminator), loss functions, training challenges (mode collapse, instability), conditional GANs.

Unit 4: Applications of Generative AI
Text generation and style transfer, image-to-image translation, deepfake technology, use cases in creative industries.

Unit 5: Tools and Frameworks Popular libraries (TensorFlow, PyTorch for GANs), datasets for training, ethical and regulatory aspects, future directions.

Text Books:

1. Ian Goodfellow, YoshuaBengio, Aaron Courville, *Deep Learning*, MIT Press.
2. David Foster, *Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play*, O'Reilly Media.

Reference Books:

1. Ajay Baranwal, *Hands-On Generative Adversarial Networks with Keras*, Packt Publishing.
2. Sebastian Raschka, VahidMirjalili, *Python Machine Learning*, Packt Publishing.
3. Sorelle A. Friedler, *Ethics of Generative AI*, MIT Press

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Robotics and Artificial Intelligence, VII Semester

702(B) Soft Computing

Course Objectives:

1. To introduce the concepts and scope of soft computing techniques.
2. To learn fuzzy logic systems and their applications.
3. To understand the fundamentals of neural networks and their practical uses.
4. To explore genetic algorithms for optimization tasks.
5. To study hybrid approaches combining fuzzy logic, neural networks, and genetic algorithms.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Explain the scope and characteristics of soft computing techniques.
- CO2: Apply fuzzy logic for modeling and control problems.
- CO3: Design and train neural networks for classification and prediction.
- CO4: Utilize genetic algorithms for optimization in engineering problems.
- CO5: Develop hybrid soft computing systems for practical applications.

Syllabus

Unit 1: Introduction to Soft Computing
Concept and scope, difference between soft and hard computing, characteristics of soft computing techniques, hybrid systems.

Unit 2: Fuzzy Logic Systems
Fuzzy sets and membership functions, fuzzification and defuzzification, fuzzy inference system, applications in control systems.

Unit 3: Neural Networks
Basic concepts of ANN, perceptron model, backpropagation algorithm, applications of neural networks in classification and prediction.

Unit 4: Genetic Algorithms
Introduction to GA, working principles, operators: selection, crossover, mutation, applications in optimization problems.

Unit 5: Hybrid Soft Computing
Integration of fuzzy logic, neural networks and GA, neuro-fuzzy systems, case studies and practical applications.

Text Books:

1. S. N. Sivanandam, S. N. Deepa, *Principles of Soft Computing*, Wiley India.
2. J. S. R. Jang, C. T. Sun, E. Mizutani, *Neuro-Fuzzy and Soft Computing*, Prentice Hall.

Reference Books:

1. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, Wiley.
2. Simon Haykin, *Neural Networks and Learning Machines*, Pearson.
3. David E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley.

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Robotics and Artificial Intelligence, VII Semester

RA 702(C) Robot Gripper Design

Course Objectives:

1. To understand the importance and types of grippers used in robotics.
2. To learn the mechanical design aspects of robot grippers.
3. To study actuation methods for gripper control.
4. To integrate sensors and control strategies in gripper design.
5. To explore recent trends and advanced gripper technologies.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Explain the types, roles, and selection criteria of robot grippers.
- CO2: Design mechanical structures for grippers considering force and friction.
- CO3: Select and implement appropriate actuation methods for grippers.
- CO4: Integrate sensors and control strategies in gripper systems.
- CO5: Analyze emerging trends and design application-specific grippers.

Syllabus

Unit 1: Introduction to Robot Grippers
Types of grippers, selection criteria, role of grippers in industrial robotics, gripper performance parameters.

Unit 2: Mechanical Design Considerations
Mechanical structure, linkages, materials for grippers, calculation of gripping force, friction considerations.

Unit 3: Actuation Methods
Pneumatic, hydraulic, electric actuation, drive mechanisms, control methods for actuators, compliance and adaptability.

Unit 4: Gripper Control and Sensors
Integration of sensors (force, tactile), feedback control, safety mechanisms, real-time control strategies.

Unit 5: Emerging Trends
Adaptive and intelligent grippers, soft robotic grippers, recent developments, application-specific gripper design examples.

Text Books:

1. Gareth J. Monkman, Stefan Hesse, Ralf Steinmann, Henrik Schunk, *Robot Grippers*, Wiley-VCH.
2. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson (selected chapters on grippers and end effectors).

Reference Books:

1. Saeed B. Niku, *Introduction to Robotics: Analysis, Control, Applications*, Wiley.
2. John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson.
3. Robert J. Schilling, *Fundamentals of Robotics: Analysis and Control*, Prentice Hall.

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Robotics and Artificial Intelligence, VII Semester

RA 703(A) Operations Research

Course Objectives:

1. To introduce the scope and application areas of Operations Research.
2. To learn linear programming methods for resource allocation.
3. To study transportation and assignment models for optimization.
4. To explore network models and project management tools.
5. To understand queuing theory and simulation methods.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Formulate and solve linear programming problems.
- CO2: Apply simplex and graphical methods for optimization tasks.
- CO3: Solve transportation and assignment problems efficiently.
- CO4: Utilize network models and project management techniques like PERT/CPM.
- CO5: Apply queuing models and simulation for system analysis.

Syllabus

Unit 1: Introduction to Operations Research
Definition, scope and applications, phases of OR study, formulation of linear programming problems.

Unit 2: Linear Programming Techniques
Graphical method, simplex method, duality, sensitivity analysis, applications in resource allocation.

Unit 3: Transportation and Assignment Models
Formulation and solution of transportation problems, methods (North-West Corner, Least Cost, Vogel's Approximation), assignment problem and Hungarian method.

Unit 4: Network Models
Network representation, shortest path, minimum spanning tree, maximum flow problem, project management: PERT and CPM.

Unit 5: Queuing Theory and Simulation
Basic queuing models (M/M/1, M/M/c), applications in service systems, introduction to simulation and Monte Carlo methods.

Text Books:

1. Hamdy A. Taha, *Operations Research: An Introduction*, Pearson.
2. KantiSwarup, P. K. Gupta, Man Mohan, *Operations Research*, Sultan Chand & Sons.

Reference Books:

1. Frederick S. Hillier, Gerald J. Lieberman, *Introduction to Operations Research*, McGraw-Hill.
2. P. K. Gupta, D. S. Hira, *Operations Research*, S. Chand Publishing.
3. Ravindran, Phillips, Solberg, *Operations Research: Principles and Practice*, Wiley.

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Robotics and Artificial Intelligence, VII Semester

RA 703(B) Agile Methodology for Project Development

Course Objectives:

1. To introduce Agile principles and their application in project development.
2. To understand the Scrum framework and its components.
3. To learn Extreme Programming (XP) practices in Agile.
4. To explore Agile project management tools and techniques.
5. To study best practices and challenges in adopting Agile methodologies.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Explain Agile principles and differences from traditional methodologies.
- CO2: Apply the Scrum framework for managing projects.
- CO3: Utilize Extreme Programming practices for software development.
- CO4: Use Agile project management tools like Jira and Trello.
- CO5: Analyze challenges and best practices in Agile implementation.

Syllabus

Unit 1: Fundamentals of Agile
Agile principles and manifesto, differences between Agile and traditional methodologies, benefits and limitations.

Unit 2: Scrum Framework
Scrum roles (Product Owner, Scrum Master, Team), Scrum events, Scrum artifacts, working with backlogs.

Unit 3: Extreme Programming (XP)
Key practices of XP, pair programming, test-driven development, continuous integration, refactoring.

Unit 4: Agile Project Management Tools
User stories, story points, sprint planning, burn-down charts, tools like Jira and Trello.

Unit 5: Agile Best Practices and Trends
Scaling Agile, Agile in distributed teams, challenges in Agile adoption, Agile certifications and career paths.

Text Books:

1. Ken Schwaber, Mike Beedle, *Agile Software Development with Scrum*, Prentice Hall.
2. Robert C. Martin, *Clean Agile: Back to Basics*, Prentice Hall.

Reference Books:

1. Mike Cohn, *Agile Estimating and Planning*, Prentice Hall.
2. Jeff Sutherland, *Scrum: The Art of Doing Twice the Work in Half the Time*, Crown Business.
3. Jim Highsmith, *Agile Project Management: Creating Innovative Products*, Addison-Wesley.

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RA 703(C) Hydraulics and Pneumatics

Course Objectives:

1. To introduce the fundamentals of hydraulics and pneumatics in automation.
2. To understand the components and design of hydraulic systems.
3. To learn pneumatic system components and basic circuits.
4. To design and control fluid power systems.
5. To explore advanced applications and trends in hydraulics and pneumatics.

Course Outcomes:

After completing this course, students will be able to:

- CO1: Explain the basics and applications of fluid power in automation.
- CO2: Design and analyze hydraulic systems and their components.
- CO3: Develop pneumatic circuits using appropriate components.
- CO4: Apply design and control strategies for fluid power systems.
- CO5: Analyze emerging trends and applications in fluid power systems for robotics and automation.

Syllabus

Unit 1: Introduction to Fluid Power
Basics of hydraulics and pneumatics, advantages and disadvantages, applications in industrial automation.

Unit 2: Hydraulic Systems
Hydraulic fluids, pumps, actuators, valves, circuit design, maintenance and safety.

Unit 3: Pneumatic Systems
Compressors, air treatment, pneumatic actuators and valves, control elements, basic pneumatic circuits.

Unit 4: System Design and Control
Design of fluid power systems, selection of components, control strategies, troubleshooting and fault diagnosis.

Unit 5: Emerging Applications
Electro-hydraulic and electro-pneumatic systems, automation trends, use in robotics and industrial machinery.

Text Books:

1. Anthony Esposito, *Fluid Power with Applications*, Pearson.
2. Majumdar S. R., *Oil Hydraulic Systems: Principles and Maintenance*, Tata McGraw-Hill.

Reference Books:

1. Andrew Parr, *Hydraulics and Pneumatics: A Technician's and Engineer's Guide*, Butterworth-Heinemann.
2. Majumdar S. R., *Pneumatic Systems: Principles and Maintenance*, Tata McGraw-Hill.
3. James A. Sullivan, *Fluid Power: Theory and Applications*, Prentice Hall.