Robotics and Artificial Intelligence

Honors/Minor Degree program of Electronics and Computer Engineering / Electronics and Computer Science

Name of the Programme: Electronics and Computer Engineering / Electronics and Computer Science

Branch: Minor/ Honours (Specialization) Subject: Robotics and Artificial Intelligence

Course Code: RAI 601 **Title of the Course:** Robot Programming

Number of Credits: 04 (3L+1P)

Effective from AY: 2022-23

Pre-requisites for the Course:	Introduction to Robotics and Programming Skills	
Course Objectives:	The subject aims to equip the student with: 1. Understanding of the fundamentals of robotics, sensor and motor technologies 2. Knowledge of integration of Arduino with Robotics 3. Introduction to Python programming languageand Linux for accessing and controlling simulated robots. 4. Comprehension and analysis of the robot Operating System.	
Content:	**UNIT- I**	**No. of Hrs.**
	Arduino for Robotics: Basics of Arduino Uno: Features, samples sketches on Reading and Writing data, Interfacing Arduino: Relays, Transistors, Interfacing a Motor-Controller, Contact Sensing, Distance and Reflection Sensing, Orientation (Positioning), Non-Autonomous Sensors **Let's Get Moving**: Electric Motors: Brushed DC Motor (Permanent Magnet Type), Brushless Motors, Stepper Motors, Servo Motors, H-Bridge IC, Interfacing of motors (dc, stepper and servo)	12 Hrs.
	UNIT-2	
	Introduction to Python: Python variables, Python basic Operators, Python blocks, Data Types, Declaring and using Numeric data types, Python Program Flow Control Conditional blocks: if, else and else if; For loops in python (using ranges, string, list and dictionaries); While loops in python, Loop manipulation using pass, continue, break and else; Programming using Python conditional and loop blocks. Python File Operations: Reading and writing files in python **Introduction to Linux:** Linux File System Directories, Linux File Permissions, Basic Linux Commands, Introduction to Linux Shell and Shell Scripting	11 Hrs.

	UNIT-3	
	Robot Programming using ROS: Why Robot Programming Is Different? Capabilities of ROS frameworkNeed for Robot Software Platform, ROS as a Meta-Operating System, Objectives of ROS, Components of ROS, ROS Architecture and Concepts, Three levels of ROS: File system Level, Computation Graph Level, Community Level. ROS Ecosystem, History of ROS.ROS development environment, ROS Terminology, Message Communication, Message, Name, Coordinate Transformation (TF), Client Library, Communication between Heterogeneous devices, File System and Build System.	11 Hrs..
	UNIT-4	
	ROS Shell Commands, ROS Execution Commands, ROS Information Commands **Basic ROS Programming:** Things to know before Programming ROS, Creating and Running Publisher and Subscriber nodes, Creating and Service Server and Client nodes, Writing and Running the Action Server and Client Node **Working with 3D Robot Modelling in ROS:** Understanding robot modelling using URDF **Robot-Sensor-Motor:** Robot Packages, Sensor Packages, Camera, Laser Distance Sensor	11 Hrs.
Pedagogy:	Learner centric teaching	
References/ Readings:	**Textbooks:** 1. John-David Warren, Josh Adams, Harald Molle Arduino Robotics, Apress, illustrated edition, 2011. 2. YoonSeokPyo, HanCheol Cho, RyuWoon Jung, TaeHoon Lim , ROS Robot Programming, ROBOTIS Co.,Ltd. 2017 3. Jason M. O'Kane, A Gentle Introduction to ROS, CreateSpace, 2014 4. Wesley J. Chun, Core Python Applications Programming, Pearson Education India; 3rd edition (1 January 2015). **Refrences** 1. Charles Dierbach, Introduction to Computer Science using Python: A Computational Problem-solving Focus , Wiley, 2015. 2. Jeeva Jose &P. Sojan Lal, Introduction to Computing and Problem Solving with PYTHON, Khanna Publishers, New Delhi,2016.	
Contents for the Practical	**List of Experiments:** (Minimum 10 Experiments to be performed from the following list) 1. Interfacing Arduino Uno with Analog and Digital Sensors (any 3) 2. Interfacing Arduino Uno with motors 3. Handling data types in Python 4. Conditional blocks in Python 5. Installing and Configuring Your ROS Environment 6. Navigating the ROS File system	30 Hrs

	7. Creating and Building ROS Package 8. Understanding ROS Nodes 9. Understanding ROS Topics and ROS messages 10. Understanding ROS Services and Parameters 11. Writing a Simple Publisher and Subscriber 12. Creating and Running Service Servers and Client Nodes 13. Writing and Running the Action Server and Client Node 14. Simulating Robots Using ROS and Gazebo 15. Using the ROS Move It!	
Term work Rubrics	Students have to be evaluated based on assignments / class tests / mini-projects/ seminars / quiz / viva / presentations / circuit simulations, etc.	
Course Outcomes:	Upon completion of the course, students will be able to	
	RAI 601.1	Explain the fundamentals of Arduino for Robotics
	RAI 601.2	Interface Arduino with relays, sensors and motors
	RAI 601.3	Apply and analyse the Python Programming for Robotics
	RAI 601.4	Explain the basic concepts and components of ROS
	RAI 601.5	Apply ROS for Robot Programming

Name of the Programme: Electronics and Computer Engineering / Electronics and Computer Science

Branch: Minor/ Honours (Specialization) Subject: Robotics and Artificial Intelligence

Course Code: RAI 701 **Title of the Course:** Robotics Vision and Control

Number of Credits: 04 (3L+1P)

Effective from AY: 2024-25

Pre-requisites for the Course:	Introduction to Robotics and Image Processing Fundamentals	
Course Objectives:	The subject aims to equip the student with: 1. To apply Robotics to solve day-to-day problems using vision algorithms. 2. To learn and understand motion and path planning. 3. To analyse the kinematics parameters of robotic manipulator and Design a task plan. 4. To plan and execute tasks during robot locomotion. 5. To describe the kinematics and dynamics of moving robots.	
Content:	**UNIT- I**	**No. of Hrs.**
	Machine Vision: Introduction, Low Level Vision, Sensing and Digitizing function, Imaging Devices, Lighting techniques, Image storage, Image Preprocessing: Noise reduction and Enhancement, Higher level vision: Segmentation, Thresholding, Region growing, Edge detection, Object Description, Object Recognition, Training the vision system, Applications of Vision System**.**	12 Hrs.
	UNIT-2	
	Find path problems using: Visibility Maps: The Visibility Graph definition and construction, Deformation Retracts: Generalised Voronoi diagram- GVD definition, Roadmap Properties, Deformation Retract Definition, GVD Dimension, Construction of GVD, Cell Decomposition- Trapezoidal decomposition, Morse cell decompositions, Visibility based decompositions for pursuit/evasion. Motion Planning: Optimal Control, Steering Chained-Form systems using sinusoids, nonlinear optimization, Gradient methods for driftless systems, Differentially flat systems, cars and cars pulling trailers, Kinematic reductions of mechanical systems.	11 Hrs.
	UNIT-3	
	Control System Analysis: Basics of Feedback Control, Stability analysis, Frequency Domain Analysis; Control System Design – State space representation, Internal Model Control, PID control. Control of Robot Manipulators –Introduction, Control of Puma Robot Arm, Computed Torque Technique, Near-minimum-time control, Variable structure control, Nonlinear decoupled feedback control, Resolved Motion control, Adaptive control.	11 Hrs.

	UNIT-4	
	Robot Locomotion – Legged Robots and Wheeled Robots, Mobile Robot Kinematics, Perception and Mobile Robot Localization, Planning and Navigation. Robot Intelligence and Task Planning- State space search, Problem Reduction, Use of predicate logic, Means-ends analysis, Problem Solving, Robot learning, Robot task planning, Basic problems in Task Planning.	11 Hrs.
Pedagogy:	Learner centric teaching	
References/ Readings:	**Textbooks:** 1. Deb, S.R. and Deb, S.,. Robotics technology and flexible automation. McGraw-Hill Education, 2nd Edition, 2010 . 2. Choset, H., Lynch, K.M., Hutchinson, S., Kantor, G.A. and Burgard, W., 2005. Principles of robot motion: theory, algorithms, and implementations. MIT press,2007. 3. C. S. George Lee, King-Sun Fu, Rafael C. GONZALES, Robotics: Control, Sensing, Vision and Intelligence, McGraw-Hill Education, Edition 1987. 4. Nagoor Kani, Control System, 3rd edition, RBA Publication. 5. Siegwart R. and Nourbakhsh I.R., Introduction to Autonomous Mobile Robots, MIT Press, Cambridge, MA, USA, 2004. **References** 1. John J Craig; Introduction to Robotics, Mechanics and Control, Pearson Education Inc Horn B.K.P., Robot Vision, MIT Press, 1986. 2. Peter C., Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011. 3. Lewis F.L., Dawson D.M. and Abdallah C.T., Robot Manipulator Control: Theory and Practice, Marcel Dekker Inc., NY, USA, 2004. 4. Siegwart R. and Nourbakhsh I.R., Introduction to Autonomous Mobile Robots, MIT Press, Cambridge, MA, USA, 2004.Godfrey O., Mechatronics: Principles and Applications, Elsevier, 2005. 5. Murray R.M., Li Z. and Sastry S.S., A Mathematical Introduction to Robotic Manipulation, CRC Press, 1994. 6. Correll N., Introduction to Autonomous Robots, v1.7, Magellan Scientific, 2016. ISBN-13: 978-0692700877. 7. Berthold Klaus, Paul Horn “Robot vision” The MIT Press, 1987. 8. Godfrey O., Mechatronics: Principles and Applications, Elsevier, 2005.	
Contents for the Practical	List of Practicals **:** (Minimum 8 Experiments to be performed from the following list) 1. Introduction to Open CV platform and its use in image processing. 2. Detection of hand gestures and controlling the wheeled robot. 3. Identifying colours and controlling the wheeled robot. 4. Identifying shapes and picking up the square cubes and rejecting the round ones. 5. Pick and place robot with stacking of similar shape blocks together. 6. Text recognition and controlling robot movement.	30 Hrs

<table>
<tr><td></td><td colspan="2">7. Line/road lane follower using image processing.
8. Face recognition and control of stepper motor to point to a particular face.
9. Human pose detection</td><td></td></tr>
<tr><td rowspan="6">Course Outcomes:</td><td colspan="3">Upon completion of the course, students will be able to</td></tr>
<tr><td>RAI701.1</td><td colspan="2">Students will apply robotics and vision algorithms to solve practical day-to-day problems effectively.</td></tr>
<tr><td>RAI701.2</td><td colspan="2">Students will demonstrate a strong grasp of motion and path planning principles in robotics.</td></tr>
<tr><td>RAI701.3</td><td colspan="2">Students will master control system analysis and design, enabling them to effectively control robot manipulators, including the Puma Robot Arm, using advanced techniques like PID control and adaptive control.</td></tr>
<tr><td>RAI701.4</td><td colspan="2">Students will describe the kinematics and dynamics of moving robots, understanding their underlying mathematical and physical principles.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Name of the Programme: Electronics and Computer Engineering / Electronics and Computer Science

Branch: Minor/ Honours (Specialization) Subject: Robotics and Artificial Intelligence

Course Code: RAI 801 **Title of the Course:** Special Topics in Artificial Intelligence.

Number of Credits: 4 (4L+0P)

Effective from AY: 2024-25

Pre-requisites for the Course:	Introduction to Fundamentals of Artificial Intelligence.	
Course Objectives:	The subject aims to equip the student with: 1. Model autonomous systems as AI agents, 2. Formulate/solve relevant planning/ and tasks. 3. Insights in the computational challenges arising from uncertainty 4. Fundamentals of Markov decision process. 5. How to incorporate recent learning-based methods decision-making algorithms. 6. Concept of Reinforcement Learning and their application in the domain of Robotics, 7. Concepts of Imitation Learning and applications in Robotics..	
Content:	**UNIT- I**	**No. of Hrs.**
	AI Agents: Agents and Environments, Good behaviour, concept of rationality, Nature of Environments, Concepts of rationality, Structure of Agents, Problem solving agents. Motion Planning: Geometric representation and transformations, Configuration space, sampling based motion planning, combinatorial motion planning, feedback motion planning.	15 Hrs.
	UNIT-2	
	State Estimation: Uncertainty in Robotics, Probabilistic Robotics, implications, Robot environment interaction, Baye's Filter. Time and uncertainity, inference in temporal models, Hidden Markov models, uncertainty. Task Planning: Classical Planning, Algorithms for Planning as State Space approach, Planning Graphs, Other classical planning approaches, analysis of planning approaches. Finite Markov decision process: The Agent – Environment interface, Goals and rewards, returns and episodes, unified notation for episodic and continuing tasks, policies and value functions, optimality and approximation.	15 Hrs.
	UNIT-3	
	Reinforcement Learning for Robotics: Reinforcement Learning, Examples, Elements of Reinforcement Learning, Limitations and scope, Tic-tac-toe example.	15 Hrs.

	Multiarmed Bandits: A k-armed bandit problem, action value methods, The 10 armed testbed, incremental implementation, tracking a nonstationary problem, gradient bandit problems, associative search. Temporal difference Learning: TD prediction, Advantage of TD prediction methods, Optimality of TD(0), Sarsa: On policy TD control, Q Learning: Off policy TD control, Expected Sarsa, Minimization bias and double learning, Games, after states and other special cases.	
	UNIT-4	
	Imitation Learning: Key successes in imitation learning, imitation learning from the point of view of Robotics, Difference between imitation learning and supervised learning, statistical machine learning fundamentals, formulation of imitation learning problem. Design of Imitation learning algorithms: Design choices for imitation learning algorithm, behaviour cloning and inverse reinforcement learning, Model-Free and Model-Based Imitation Learning Methods, Observability, Policy Representation in Imitation Learning, Behaviour Descriptors.	15 Hrs.
Pedagogy:	Learner centric teaching	
References/ Readings:	**Textbooks:** 1. Russell, Stuart J., and Peter Norvig, Artificial intelligence: A modern approach. (3rd Edition) Prentice Hall. 2. LaValle, S.M.,Planning Algorithms 2006. Cambridge University Press. 3. Richard Sutton and Andrew Barto. Reinforcement Learning (Second Edition). MIT Press. 2018. 4. Takayuki Osa, Joni Pajarinen, Gerhard Neumann, J. Andrew Bagnell, Pieter Abbeel, Jan Peters , An Algorithmic Perspective on Imitation Learning ISBN-13 : 978-1680834109, Now Publishers Inc. **References :** 1. Thrun, Sebastian, Wolfram Burgard, and Dieter Fox, Probabilistic robotics. (1st Edition), MIT Press. 2. Decision Making Under Uncertainty, Mykel Kochenderfer, (1st Edition), The MIT Press. 3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning.MIT Press. ISBN-13 : 978-0262035613	
	TERM WORK: Assessment can be in terms of assignments, simulation-based exercises, mini project, case studies, etc.	
Course Outcomes:	Upon completion of the course, students will be able to RAI 801.1 — Model autonomous systems as AI agents and perform mo planning RAI 801.2 — Formulate/solve relevant planning/estimation tasks RAI 801.3 — How to incorporate recent learning-based methods decisi	

		making algorithms such as Reinforcement Learning in Robotics.
	RAI 801.4	How to incorporate recent learning-based methods decision-making algorithms such as Imitation Learning in Robotics..