SEMESTER S6

MOBILE ROBOTICS

Course Code	PBRAT604	CIE Marks	60
Teaching Hours/Week (L: T:P: R)	3:0:0:1	ESE Marks	40
Credits	4	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	None	Course Type	Theory

Course Objectives:

1. To give students the ability to apply mathematical modelling to kinematics, localization and path planning of mobile robots
2. To give students the ability to apply various strategies to system level control of mobile robots

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SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Locomotion:** Introduction, Key issues for locomotion, **Legged Mobile Robots** - Leg configurations and stability, **Wheeled Mobile Robots** - Wheeled locomotion: the design space, Wheel design, Wheel geometry, Stability, Maneuverability, Controllability, **Aerial robots** – advantages of UAVs over conventional manned aircraft, Types of UAVs - Fixed-wing UAV or airplane – characteristics, Rotary-wing UAV - Multi-rotor, Tricopter, Quadcopter or quadrotor, Hexacopter, Y3/Y6, Octocopter **Mobile Robot Kinematics:** Introduction, Kinematic Models and Constraints - Representing robot position, Forward kinematic models, Wheel kinematic constraints for Fixed standard wheel, Steered standard wheel and Castor wheel only, Robot kinematic constraints Example of Robot kinematic models and constraints: Differential-drive robot only Mobile Robot Maneuverability - Degree of mobility, Degree of steerability,	11

	Robot maneuverability, Mobile Robot Workspace - Degrees of freedom, Holonomic robots	
2	**Mobile Robots Fundamental problems**: Path Planning, Localization, Sensing, Mapping, Simultaneous Localization and Mapping **Mobile Robot Localization:** Introduction, The Challenge of Localization - Noise and Aliasing, Localization-Based Navigation versus Programmed Solutions, Belief Representation - Single-hypothesis belief, Multiple-hypothesis belief, Differences between Markov and Kalman Localization (detailed explanation not required) **Representation and Reasoning about Space:** Representing Space - Spatial Decomposition, Geometric Representations, Topological Representations	**11**
3	**Path Planning for Mobile Robots:** Free-space path versus Semi-free-space path, Non-homotopic paths versus Homotopic paths **Constructing a discrete search space** - Visibility graph, Tangent graph, Retraction Methods **Searching a Discrete State Space** - Graph search - Depth-first Search, Breadth-first Search, Dijkstra's Algorithm, Best first search – A and A* Algorithm **Searching a Continuous State Space** – Potential Fields, Vector field histogram, Bug 1, 2 and Tangent Bug algorithms **Probabilistic path planning** – RPP, PRM, RRT	**11**
4	**System Control:** Horizontal Decomposition, Vertical Decomposition, Hybrid Control Architectures, Middleware, Alternative Control Formalisms, The Human Robot Interface **Off-Board Communication:** Tethered, Untethered – types of untethered communication	**11**

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Suggestion on Project Topics

Students may be given projects on modelling to kinematics, localization and path planning of mobile robots

Course Assessment Method
(CIE: 60 marks, ESE: 40 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Project	Internal Ex-1	Internal Ex-2	Total
5	30	12.5	12.5	60

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 2 marks **(8x2 =16 marks)**	• 2 questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 2 sub divisions. • Each question carries 6 marks. **(4x6 = 24 marks)**	**40**

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Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Derive kinematic constraints and models for mobile robots	**K2**
CO2	Describe the techniques used in mobile robot localization	**K2**
CO3	Apply various algorithms to path planning for mobile robots	**K3**
CO4	Apply various techniques for mobile robotic system control	**K3**
CO5	Implement a mobile robot that incorporates functionalities suitable for an application	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3		3							3
CO2	3	3	3		3							3
CO3	3	3	3		3							3
CO4	3	3	3		3							3
CO5	3	3	3	3	3				3	3	3	3

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to Autonomous Mobile Robots	R Siegwart, IR Nourbakhsh, D Scaramuzza	MIT Press	Second Edition 2012
2	Computational Principles of Mobile Robotics	Gregory Dudek, Michael Jenkin	Cambridge University Press	2nd edition, 2010
3	Chapman & Hall_CRC Artificial Intelligence and Robotics Series - A First Course in Aerial Robots and Drones-	Yasmina Bestaoui Sebbane	CRC Press	1st edition, 2022

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to Mobile Robot Control	Spyros G. Tzafestas	Elsevier Science Publishing Co Inc	1st edition, 2013
2	Autonomous Mobile Robots and Multi-Robot Systems - Motion-Planning, Communication, and Swarming	Kagan, Shvalb, Ben-Gal	Wiley	1st edition, 2019

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Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/112/106/112106298/
2	https://archive.nptel.ac.in/courses/112/106/112106298/
3	https://archive.nptel.ac.in/courses/112/106/112106298/
4	https://archive.nptel.ac.in/courses/112/107/112107289/

PBL Course Elements

L: Lecture (3 Hrs.)	**R: Project (1 Hr.), 2 Faculty Members**		
	Tutorial	**Practical**	**Presentation**
Lecture delivery	Project identification	Simulation/ Laboratory Work/ Workshops	Presentation (Progress and Final Presentations)
Group discussion	Project Analysis	Data Collection	Evaluation
Question answer Sessions/ Brainstorming Sessions	Analytical thinking and self-learning	Testing	Project Milestone Reviews, Feedback, Project reformation (If required)
Guest Speakers (Industry Experts)	Case Study/ Field Survey Report	Prototyping	Poster Presentation/ Video Presentation: Students present their results in a 2 to 5 minutes video

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Assessment and Evaluation for Project Activity

Sl. No	Evaluation for	Allotted Marks
1	Project Planning and Proposal	5
2	Contribution in Progress Presentations and Question Answer Sessions	4
3	Involvement in the project work and Team Work	3
4	Execution and Implementation	10
5	Final Presentations	5
6	Project Quality, Innovation and Creativity	3
Total		**30**

1. **Project Planning and Proposal (5 Marks)**
   - Clarity and feasibility of the project plan
   - Research and background understanding
   - Defined objectives and methodology

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2. **Contribution in Progress Presentation and Question Answer Sessions (4 Marks)**
   - Individual contribution to the presentation
   - Effectiveness in answering questions and handling feedback

3. **Involvement in the Project Work and Team Work (3 Marks)**
   - Active participation and individual contribution
   - Teamwork and collaboration

4. **Execution and Implementation (10 Marks)**
   - Adherence to the project timeline and milestones
   - Application of theoretical knowledge and problem-solving
   - Final Result

5. **Final Presentation (5 Marks)**

   - Quality and clarity of the overall presentation
   - Individual contribution to the presentation
   - Effectiveness in answering questions

6. **Project Quality, Innovation, and Creativity (3 Marks)**

   - Overall quality and technical excellence of the project
   - Innovation and originality in the project
   - Creativity in solutions and approaches

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