21AD1703	AI AND ROBOTICS (LAB INTEGRATED)	L	T	P	C
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OBJECTIVES

- To study the Robot Locomotion and types of robots.
- To explore the kinematic models and constraints
- To learn sensors of robots and image processing for robotics.
- To understand the methods for mobile robot Localization
- To study the Path planning and Navigation of Robots.
- To understand the simulation for robot Localization.

UNIT I ROBOT LOCOMOTION 9

Introduction to AI and Robotics – robot locomotion – legged mobile robots – wheeled mobile robots – aerial mobile robots.

SUGGESTED ACTIVITIES:

- Define what a robot is.
- Describe the main components of a robot.
- Explain how the aerial mobile robots can be programmed to move.
- Explain that troubleshooting is an important part of engineering something new.

SUGGESTED EVALUATION METHODS:

- Quizzes on AI and Robotics
- Assignments on illustrative problems.
- Quizzes on simple AI programs.

UNIT II MOBILE ROBOT KINEMATICS 9

Kinematic models and constraints – mobile robot maneuverability (a mobile robot with a steerable wheel and two passive casters) – different types of kinematics in robotics - kinematics used in robotics - mobile robot workspace –advanced kinematics – motion control.

SUGGESTED ACTIVITIES:

- The course will feature several practical sessions with hands-on robot programming
- It also teaches algorithmic strategies that enable the coordination of multi-robot systems and robot Kinematics.
- Explain how the Mobile Robot Kinematics can be programmed to move forward and reverse.

SUGGESTED EVALUATION METHODS:

- Quizzes on Mobile Robot Kinematics
- Assignments on illustrative problems.
- Quizzes on simple Mobile Robot Kinematics programs.

UNIT III ROBOT PERCEPTION 9

Sensors for mobile robots – sensing and perception in robotics - 4 Characteristics of robots - computer vision for robots – image processing for robotics – place recognition – range data.

SUGGESTED ACTIVITIES:

- This course teaches the foundations of autonomous mobile robots, covering topics such as perception, motion control, and planning.
- It also teaches algorithmic strategies that enable the coordination of multi-robot systems and robot swarms.
- The course will feature several practical sessions with hands-on robot programming.

SUGGESTED EVALUATION METHODS:

- Quizzes on Robot Perception

- Assignments on illustrative problems.
- Quizzes on simple Robot Perception programs.

UNIT IV MOBILE ROBOT LOCALIZATION **9**

Introduction to localization – 4 basic parts of a mobile robot - localization in mobile robot - noise and aliasing – localization-based navigation – belief representation – map representation – probabilistic map-based localization – autonomous map building.

SUGGESTED ACTIVITIES:

- Understand the role of mobile robots in the improvement of industrial processes and
- be able to design and implement software that allows them to behave autonomously.
- Understand the structure of the Robot Operating System (ROS) and use it to build robotic software.
- Assemble all the basic modules that allow a mobile robot to behave autonomously.

SUGGESTED EVALUATION METHODS:

- Quizzes on Mobile Robot Localization
- Assignments on illustrative problems.
- Quizzes on simple Mobile Robot Localization programs.

UNIT V ROBOT PLANNING AND NAVIGATION **9**

Planning and navigation – 3 types of navigation - purpose of navigation - planning and reacting – path planning – obstacle avoidance – navigation architectures - The benefits of navigation.

SUGGESTED ACTIVITIES:

- The students will undertake mini-projects, which will be formally evaluated through a report and presentation
- Understand the structure of the Robot planning and navigation and use it to build robotic software.
- Assemble all the basic modules that allow a robot planning and navigation to behave autonomously.

SUGGESTED EVALUATION METHODS:

- Quizzes on Robot Planning And Navigation
- Assignments on illustrative problems.
- Quizzes on simple Robot Planning and Navigation programs.

TOTAL: 45 PERIODS

OUTCOMES

At the end of the course, the student will be able to

- Explain the types of Robots
- Narrate the kinematics of Robots
- Implement image processing algorithms
- Devise Localization algorithms
- Devise Path planning methods for navigation
- Implement the line tracing algorithms

TEXT BOOKS

1. R. Siegwart, I. R. Nourbaksh, and D. Scarramuzza, ―Introduction to Autonomous Mobile Robots‖, Second Edition, MIT Press, 2011.
2. Stuart Russel and Peter Norvig, ―Artificial Intelligence: A Modern Approach‖, Fourth Edition, Pearson Education, 2020.

UNIT – I

PART - A

1. Define Locomotion Mechanism?

   A mobile robot needs locomotion mechanisms that enable it to move unbounded throughout its environment. But there are a large variety of possible ways to move, and so the selection of a robot's approach to locomotion is an important aspect of mobile robot design. In the laboratory, there are research robots that can walk, jump, run, slide, skate, swim, fly and of course roll.

2. What are the Key issues for locomotion?

   Locomotion and manipulation thus share the same core issues of stability, contact characteristics and environmental types.

3. Define mobile robot localization?

   Perception- the robot must interpret its sensors to extract meaningful data; localization- the robot must determine its position in the environment; cognition- the robot must decide how to act to achieve its goals; and motion control- the robot must modulate its motor outputs to achieve the desired trajectory.

4. What is robot?

   Robots are the artificial agents acting in real world environment. Robots are aimed at manipulating the objects by perceiving, picking, moving, modifying the physical properties of object, destroying it, or to have an effect thereby freeing manpower from doing repetitive functions without getting bored, distracted, or exhausted.

5. Types of Robot Locomotion

   Locomotion is the mechanism that makes a robot capable of moving in its environment. There are various types of locomotion

   1. Legged

   2. Wheeled

   3. Combination of Legged and Wheeled Locomotion 4. Tracked slip/skid

6. What is the difference between narrow AI and general AI?

   Narrow AI, also known as weak AI, is designed to perform a specific task or set of tasks within a limited domain, such as playing chess or recommending movies. General AI, on the other hand, refers to artificial intelligence that exhibits human-like intelligence and can understand, learn, and apply knowledge across a wide range of tasks and domains.

7. Define reinforcement learning in the context of artificial intelligence.

   Reinforcement learning is a type of machine learning where an agent learns to make decisions by interacting with an environment. The agent receives feedback in the form of rewards or penalties based on its actions, and its goal is to maximize cumulative rewards over time by learning which actions lead to desirable outcomes.

8. Name one application of robotics in the healthcare industry.

   One application of robotics in the healthcare industry is robotic surgery. Robotic surgical systems, such as the da Vinci Surgical System, enable surgeons to perform minimally invasive procedures with enhanced precision and dexterity, resulting in shorter recovery times and reduced risk for patients.

9. What is the significance of computer vision in the field of robotics?

   Computer vision allows robots to perceive and interpret visual information from their environment, enabling tasks such as object recognition, navigation, and manipulation. By integrating computer vision capabilities, robots can interact more effectively with their surroundings and perform complex tasks autonomously.

10. Briefly explain the concept of swarm robotics.

    Swarm robotics involves coordinating multiple robots to work together in a decentralized manner to accomplish tasks. Inspired by collective behaviour observed in natural systems, such as swarms of insects or flocks of birds, swarm robotics emphasizes scalability, robustness, and adaptability in achieving collective goals.

PART B

1. Explain robot locomotion and its types?
2. Introduction to AI and Robotics?
3. Explain about legged mobile robots?
4. Classify the wheeled mobile robots and explain any two of them.
5. Design a hybrid locomotion robot for urban search and rescue. Justify your design with key components
6. Discuss how stability is achieved in legged locomotion, with examples.
7. Analyze the role of sensors and control algorithms in maintaining flight stability in aerial robots.
8. Compare and contrast the kinematic constraints of wheeled and legged robots. How do these constraints influence path planning?
9. Critically assess the current challenges in implementing AI for autonomous navigation in legged robots.
10. How an aerial mobile robot works?

UNIT – II

PART – A

1. How mobile robotics Kinematics works?
   Kinematics is the most basic study of how mechanical systems behave. In mobile robotics, we need to understand the mechanical behaviour of the robot both in order to design appropriate mobile robots for tasks and to understand how to create control software for an instance of mobile robot hardware.

2. How mobile robotics manoeuvrability functions?
   The kinematic mobility of a robot chassis is its ability to directly move in the environment. The basic constraint limiting mobility is the rule that every wheel must satisfy its sliding constraint.

3. Explain the concept of degrees of freedom in the context of robotic manipulators.
   Degrees of freedom (DOF) in robotics refer to the number of independent parameters or axes that define the motion of a robotic manipulator. Each degree of freedom represents a unique direction in which the manipulator can move or rotate. For example, a simple robotic arm with three revolute joints has three degrees of freedom, allowing it to move in three-dimensional
   Space by rotating each joint independently. DOF is a crucial factor in designing and controlling robotic systems, as it determines the flexibility and range of motion required to perform specific tasks effectively.

4. What is inverse kinematics in robotics?
   Inverse kinematics in robotics refers to the process of determining the joint angles or parameters required to achieve a desired position and orientation of the robot's end-effector. Unlike forward kinematics, which calculates the end-effector's position based on joint angles, inverse kinematics solves the problem in reverse, determining the joint configurations needed to reach a specific pose. It is essential for motion planning and control in robotics applications, allowing robots to perform tasks accurately and efficiently by translating desired end-effector positions into corresponding joint motions.

5. What is robotics Kinematics?
   Robotics kinematics is a branch of robotics that deals with the study of motion in robotic systems. Specifically, it focuses on the analysis of the movement and positioning of robot manipulators, such as robot arms or robotic mechanisms, without considering the forces that cause these movements. Kinematics describes the geometry of motion, including the relationships between different parts of the robot and how they move relative to each other.

6. What is Forward Kinematics?
   Forward kinematics involves determining the position and orientation of the end-effector (the tool or manipulator) of a robot given the joint angles or parameters of its individual robotic joints. It predicts the configuration of the robot's end-effector based on the kinematic structure of the robot. Forward kinematics is essential for motion planning, trajectory generation, and controlling the movement of robotic systems.

7. What is inverse kinematics?

Inverse kinematics, on the other hand, refers to the process of determining the joint angles or parameters required to achieve a desired position and orientation of the robot's end-effector. It involves solving the mathematical equations that relate the positions and orientations of the end-effector to the joint variables of the robot. Inverse kinematics is crucial for tasks such as path planning, motion control, and robot programming, allowing robots to perform complex motions and reach specific positions accurately.

8. Explain the Redundant Manipulator Kinematics?

Redundant manipulators have more degrees of freedom than necessary to accomplish a given task. Advanced kinematics techniques are used to exploit this redundancy to optimize task performance, improve workspace coverage, and avoid singular configurations.

9. Define the Non holonomic Kinematics?

Non holonomic robots are constrained in their motion, such as wheeled mobile robots or snake-like robots. Advanced kinematics methods are required to model and control their motion while accounting for these constraints, enabling them to navigate complex environments and perform specific tasks.

10. Define the Closed-loop Kinematics.

Closed-loop kinematics involves analysing robotic systems with closed kinematic chains, such as parallel manipulators or cable-driven mechanisms. Advanced techniques are needed to solve inverse kinematics problems in these systems and ensure stable and accurate control of the end-effector.

PART B

1. List out its types and constraints of kinematic models.
2. Explain about mobile robot workspace.
3. Several factors contribute to mobile robot maneuverability.
4. Compare forward kinematics and inverse kinematics.
5. Explain the kinematic constraints of a robot with a steerable wheel and two passive casters
6. Apply forward and inverse kinematics to determine wheel velocities for differential drive robot
7. Evaluate the maneuverability of a robot with steerable front wheel and passive casters vs. differential drive.
8. Given an Ackermann steering geometry, derive the steering angle to turning radius relation
9. Propose an advanced kinematic solution for a robot in a constrained 3D workspace.
10. Explain motion control in robotics.

UNIT – III

PART – A

1. What is robot perception?

Robot ability to interact with their surroundings is an essential capability, especially in unstructured human-inhabited environments. The knowledge of such an environment is usually obtained through sensors. The study of acquiring knowledge from sensor data is called robotic perception.

2. What are types of Sensors for mobile robots?

GPS and odometer sensors are some examples of this type of sensors. Distance sensors: devices to measure the movement range between different reference positions. LiDAR and camera point cloud provide this capability. Image sensors: devices used by the robot to capture images of the environment.

3. Define robot perception in the context of robotics.

Robot perception in robotics refers to the ability of a robot to sense and interpret information from its environment using various sensors and sensory modalities. It encompasses processes such as sensing, recognition, and understanding of the surrounding environment, including objects, obstacles, people, and other relevant features. Robot perception enables robots to gather data, make informed decisions, and interact effectively with their surroundings, contributing to their autonomy and adaptability in performing tasks.

4.Explain the purpose of LIDAR in robotics.

LIDAR, which stands for Light Detection and Ranging, is a remote sensing technology used in robotics to measure distances and create detailed maps of an environment. It works by emitting laser pulses and measuring the time it takes for the light to reflect off objects and return to the sensor. LIDAR provides high-resolution 3D point cloud data, allowing robots to accurately perceive their surroundings, navigate autonomously, and avoid obstacles in real-time.

5. Gesture and Expression Recognition

Computer vision allows robots to interpret human gestures and facial expressions, facilitating natural and intuitive human-robot interaction. Robots can understand and respond to gestures, expressions, or body language, enabling communication and collaboration with humans.

6. How Object Tracking and Following works?

Robots can track and follow objects or people in real-time using computer vision. By continuously analysing the video stream, the robot can keep track of the target's position and adjust its own motion to follow it, facilitating applications such as mobile robot assistants or surveillance systems.

7. Explain about GPS?

GPS (Global Positioning System): GPS sensors use signals from satellites to determine the robot's global position (latitude, longitude, and altitude). GPS is commonly used for outdoor localization and navigation in applications such as autonomous vehicles or drones.

8. Explain about Ultrasonic Sensors/

Ultrasonic sensors emit high-frequency sound waves and measure the time it takes for the sound waves to bounce back after hitting an object. They are commonly used for proximity sensing and obstacle detection in close-range applications

9. Explain Image Enhancement/

Image processing techniques are used to improve the quality of images captured by robots. This includes operations such as noise reduction, contrast adjustment, image de-noising, and image sharpening, which enhance the visual clarity and make images more suitable for subsequent analysis.

10. Explain Feature Extraction?

Image processing enables the extraction of relevant features from images. These features can include edges, corners, textures, or keypoints, which are important for object recognition, tracking, and mapping tasks. Feature extraction algorithms identify distinctive patterns or regions in images that can be used for subsequent processing and analysis

PART B

1. Describe about sensors for mobile robots.
2. Explain computer vision for robots.
3. Identify the techniques used in image processing for robotics.
4. List the some of the characteristics of robots.
5. Design a sensor fusion system combining LiDAR and stereo camera for environmental perception
6. Evaluate the performance of vision-based place recognition in dynamic outdoor environments
7. Compare the use of 2D image data and 3D range data for place recognition.
8. Analyze the impact of different sensor modalities on perception accuracy.
9. Propose a computer vision system for a warehouse robot with image processing and decision-making.
10. Explain the range data in robotics.

UNIT – IV

PART A

1. Describes Passive Localization to dealing with the challenge of robot localization?

Passive localization involves relying solely on external signals or landmarks already present in the environment to determine the robot's position. This approach assumes that the robot has prior knowledge of its environment or can detect features such as walls, corners, or distinctive objects to triangulate its position. Passive localization methods might include using visual cues, landmarks, or natural features for navigation without actively emitting signals or interacting with the environment.

2. Describes Active Localization with Beacons to dealing with the challenge of robot localization?

In contrast to passive localization, active localization involves equipping the robot with sensors or beacons that actively emit signals to aid in self-localization. This approach often relies on technologies such as GPS (Global Positioning System) or RFID (Radio-Frequency Identification) tags placed in the environment. The robot receives signals from these beacons and uses them to calculate its position relative to known reference points. Active localization methods provide more accurate and reliable position information but require infrastructure setup and may not be suitable for all environments.

3. Define path planning?

Even before the advent of affordable mobile robots, the field of path planning was heavily studied due to applications in the area of industrial manipulator robotics. Interestingly, the path planning problem for a manipulator with, for instance, 6 degrees of freedom (DOF) is far more complex than that of a differential drive robot operating in a flat environment.

4. Define configuration space?

Path planning for manipulator robots and, indeed, even for most mobile robots, is formally done in a representation called configuration space. Suppose that a robot arm (e.g. SCARA-robot) has k degrees of freedom (DOF). Every state or configuration of the robot can be described with k real values.

5. Explain Odometer-based Localization?

Odometer involves estimating a robot's position by measuring the changes in wheel rotations or other motion sensors. By tracking the distance and direction travelled, the robot can estimate its position relative to a known starting point. However, odometer is prone to cumulative errors and can drift over time, making it less reliable for long-term localization.

6. Define SLAM?

SLAM allows a robot to navigate in unknown or dynamic environments by continuously updating its position and map as it moves. It is particularly useful in scenarios where the robot needs to explore and build a map of its surroundings in real-time, such as in autonomous exploration or search and rescue missions.

7. Expand Probabilistic map-based localization (PMBL).

Probabilistic map-based localization (PMBL) is a localization technique used in robotics that combines probabilistic models and map information to estimate a robot's position within an environment. PMBL is often employed in scenarios where a robot has access to a pre-built map of the environment and utilizes sensor measurements to estimate its position on the map.

8. Explain Exploration and Localization?

The robot moves through the environment, often employing localization techniques such as simultaneous localization and mapping (SLAM) to estimate its position within the environment. The robot collects sensor data, such as range measurements from LIDAR or camera images, to understand its surroundings.

9. Explain the Sensor Data Processing**?**

The sensor data acquired by the robot is processed to extract relevant information. This may involve filtering, noise reduction, feature extraction, or image processing techniques depending on the type of sensors used.

10. Explain Map Update and Fusion

As the robot explores further, it continues to update and refine the map based on new sensor measurements and observations. Sensor fusion techniques may be employed to integrate data from multiple sensors, such as LIDAR and cameras, to improve the map's accuracy and completeness

PART B

1. Explain about Introduction to localization.
2. Explain the concept of localization and its importance in mobile robots
3. How probabilistic map-based localization in robotics works?

4. List of techniques used in map representation in robotics.
5. Analyze the impact of noise and aliasing on localization
6. Compare metric and topological map representations.
7. Apply autonomous map building in an unknown environment.
8. Discuss different map representation techniques such as occupancy grids and topological maps.
9. Propose a probabilistic map-based localization framework.
10. Explain autonomous map building in detail.

UNIT - V

PART A

1. What is NLP?

NLP (Natural Languages Processing) can be used to give voice commands to AI robots. It creates a strong human-robot interaction. NLP is a specific area of Artificial Intelligence that enables the communication between humans and robots. Through the NLP technique, the robot can understand and reproduce human language. Some robots are equipped with NLP so that we can't differentiate between humans and robots.

2. Explain Reinforcement learning?

Reinforcement learning is a feedback-based learning method in machine learning that enables an AI agent to learn and explore the environment, perform actions and learn automatically from experience or feedback for each action. Further, it is also having feature of autonomously learn to behave optimally through hit-and-trail action while interacting with the environment.

3. What are the Features of Prolong?

Supports basic mechanisms such as

1. Pattern Matching,
2. Tree-based data structuring, and
3. Automatic backtracking.
4. Prolong is a declarative language rather than imperative.

4. Explain Prolong?

Logic Programming Paradigm: Prolong is based on the logic programming paradigm, where programs are expressed as collections of logical rules and facts. It allows developers to define relationships and rules that describe the problem domain in terms of logical predicates, which represent statements about objects and their properties.

5. Explain about Path Planning**?**

Path planning involves finding a collision-free path from a starting point to a goal point in the robot's environment. This process takes into account the robot's kinematics, the layout of obstacles, and any constraints on the robot's movement, such as its size or maximum velocity. Various algorithms, such as A*, Dijkstra's algorithm, or Rapidly-exploring Random Trees (RRT), are commonly used for path planning.

6. Explain about Task Planning?

Task planning refers to determining a sequence of actions or behaviours required to accomplish a specific goal or task. It involves breaking down the high-level task into subtasks, considering preconditions, dependencies, and constraints, and generating a plan that satisfies the task requirements. Task planning can be achieved using approaches like classical planning, hierarchical task networks (HTNs), or behaviour trees.

7. How perception works?

Perception refers to the robot's ability to perceive and understand its surroundings using various sensors, such as cameras, LIDAR, or depth sensors. Perception techniques enable the robot to detect and recognize objects, estimate distances, identify obstacles, and build a representation of the environment.

8. Define Obstacle Avoidance?

Obstacle avoidance ensures that the robot can navigate safely by detecting and avoiding obstacles in its path. This can be achieved through sensor-based methods, such as reactive control, where the robot reacts to immediate sensor inputs, or through planning-based approaches, where the robot anticipates potential obstacles and plans paths accordingly.

9. Explain the concept of obstacle avoidance in robotics.

Obstacle avoidance in robotics refers to the ability of a robot to detect and navigate around obstacles in its environment to reach a desired goal safely. It involves using sensors such as cameras, LIDAR, ultrasonic sensors, or infrared sensors to perceive obstacles and determine their locations relative to the robot's position. Based on this information, the robot employs algorithms to plan collision-free paths and adjust its trajectory in real-time to avoid obstacles while pursuing its intended task or destination. Obstacle avoidance is essential for enabling robots to operate autonomously in unstructured environments and perform tasks effectively without human intervention.

10. Name two types of sensors commonly used for obstacle avoidance in robotics.

Two types of sensors commonly used for obstacle avoidance in robotics are ultrasonic sensors and LIDAR (Light Detection and Ranging) sensors.

PART B

1. Explain about Planning and navigation in robotics.
2. Define the path planning in robotics?
3. Define obstacle avoidance in robotics and explain it.
4. Explain about Planning and navigation in robotics.
5. Explain the purpose of navigation in mobile robots.
6. Define and describe the three types of robot navigation
7. Design a hybrid navigation architecture for an autonomous delivery robot.
8. Implement a real-time obstacle avoidance system using sensor input.
9. List and explain the benefits of robust navigation in mobile robots
10. Explain Environment Representation in path planning.