Total No. of Questions: 23 **Enrollment No :** ____________________

MEDICAPS UNIVERSITY

Faculty of Engineering

End Semester Examination May 2025

RA3CO33 Robot System Design & SLAM

Programme	:	B.Tech.	**Branch/Specialisation**	:	RA
Duration	:	3 hours	**Maximum Marks**	:	60

Note: *All questions are compulsory. Internal choices, if any, are indicated. Assume suitable data if necessary. Notations and symbols have their usual meaning.*

Section 1 (Answer all question(s)) — **Marks CO BL**

Q1. Which of the following is a key factor influencing the industrial applications of robots? — **1 1 1**
- ○ Availability of free open-source software
- ● Type of industrial environments and constraints
- ○ Color of the robot
- ○ Number of robot arms

Q2. Which software is widely used for robot simulation and is available as free open-source software? — **1 1 1**
- ○ SolidWorks
- ○ AutoCAD
- ● Gazebo
- ○ MATLAB

Q3. Which of the following is NOT a fundamental concept of ROS? — **1 2 1**
- ○ Nodes
- ○ Topics
- ● URDF
- ○ Messages

Q4. What does URDF stand for in the context of robotics? — **1 2 1**
- ○ Universal Robot Development Framework
- ○ Unified Robotic Design Format
- ● Unified Robot Description Format
- ○ Unique Robot Deployment Foundation

Q5. Which of the following best describes SLAM? — **1 3 1**
- ○ Sequential Localization and Mapping
- ○ Simultaneous Localization and Management
- ● Simultaneous Localization and Mapping
- ○ Simple Localization and Mapping

Q6. What is the purpose of Occupancy Grid Mapping? — **1 3 1**
- ○ To create a topological map of the environment
- ○ To estimate the position of the robot relative to landmarks
- ● To represent the probability of occupancy of grid cells in a map
- ○ To detect obstacles using LiDAR sensors

Q7. Which of the following is a common method used for object manipulation? — **1 4 1**
- ○ Voice recognition
- ● Teleoperation
- ○ LIDAR scanning
- ○ GPS navigation

Q8. Which of the following is an example of prehension? — **1 4 1**
- ○ Identifying the color of an object
- ● Grasping an object with a robotic gripper
- ○ Detecting obstacles in the robot's path
- ○ Calculating the shortest route to a destination

Q9. What is the purpose of the Logical Camera in ROS? — **1 5 1**
- ○ To physically capture images from the environment
- ● To simulate camera inputs in a virtual environment
- ○ To process images for object detection
- ○ To calibrate real cameras for better accuracy

Q10. Which algorithm is commonly used for object detection tasks? **1 5 1**

- ○ Support Vector Machines (SVM)
- ● Convolutional Neural Networks (CNN)
- ○ K-Means Clustering
- ○ Principal Component Analysis (PCA)

Section 2 (Answer all question(s))

Marks CO BL

Q11. Define Industrial Robots. Name two industrial environments where robots are commonly used. **2 1 1**

Rubric	Marks
clear definition	1
2 correct environment name	1

Q12. Describe how Ubuntu is useful for robot simulation and development. **3 1 2**

Rubric	Marks
Mentions Ubuntu as a popular operating system for robotics	1
Lists relevant features	1
(e.g., compatibility with ROS)	1

Q13. (a) Compare and contrast ROS and Gazebo in the context of robotic development. **5 1 2**

Rubric	Marks
Defines ROS and Gazebo (1 mark)	1
Explains the functionality of ROS	1
Explains the functionality of Gazebo	1
Compares (e.g., ROS for communication, Gazebo for simulation)	1
contrasts their usage	1

(OR)

(b) Describe step-by-step guide to installing and configuring a robot simulation software like Gazebo and MoveIt.

Rubric	Marks
Lists the steps in logical order	1
Lists the steps in logical order	1
Provides details of required dependencies	1
Mentions troubleshooting or	1
common errors	1

Section 3 (Answer all question(s))

Marks CO BL

Q14. Explain Robotic Operating System (ROS) in brief. **2 2 2**

Rubric	Marks
Define ROS	1
Mention its primary Purpose.	1

Q15. Differentiate ROS topics and ROS services. 3 2 2

Rubric	Marks
Define ROS topics and ROS services	1
first difference	1
second difference	1

Q16. (a) How does ROS support the development of robot simulation environments? Discuss the integration of ROS with simulation tools like Gazebo and how it benefits roboticists in testing and validating their algorithms. 5 2 2

Rubric	Marks
Explanation of ROS Support for Robot Simulation **1 mark**: Mentions that ROS provides the middleware and infrastructure to create robot simulations.	1
1 mark: Discusses ROS components like topics, services, and actions that facilitate communication between simulated robots and their environment.	1
Integration of ROS with Gazebo	1
Benefits to Roboticists (2 marks) **1 mark**: Describes how simulation tools like Gazebo, integrated with ROS, allow roboticists to test algorithms in realistic environments without hardware (e.g., simulating sensor data, robot movement, and interactions).	1
1 mark: Explains how this integration helps with debugging, algorithm validation, and performance testing before deployment on physical robots, thereby reducing development time and cost.	1

(OR)

(b) Explain the role of URDF in robot modeling and simulation within ROS. Discuss its advantages in representing robot kinematics, dynamics, and sensor configurations.

Rubric	Marks
Provides a clear, comprehensive explanation of URDF, its purpose, and its role in robot modeling and simulation within ROS.	1
Thoroughly explains how URDF represents robot kinematics (e.g., joints, links, transformations) with relevant examples.	1
Provides a detailed explanation of how URDF captures robot dynamics (e.g., mass, inertia, friction) and its importance.	1
Clearly explains how URDF supports sensor configuration (e.g., sensors placement, types, transformations) and how this contributes to simulation.	1
Fully discusses the advantages of using URDF for representing kinematics, dynamics, and sensors in simulation, providing clear insights.	1

Section 4 (Answer all question(s))

Marks CO BL

Q17. Explain in brief the role of visualization tools like Rviz in robot navigation. **2** **3** **2**

Rubric	Marks
Provides a clear and concise explanation of how RViz helps visualize robot states, sensor data, and environment,	1
supporting navigation by displaying real-time data like maps, trajectories, and sensor readings.	1

Q18. (a) Explain the concept of Simultaneous Localization and Mapping (SLAM) in robotics. How does SLAM enable robots to autonomously navigate and map unknown environments? Discuss the challenges associated with SLAM implementation and potential strategies to overcome these challenges. **8 3 2**

Rubric	Marks
Concept of SLAM	1
Role in Autonomous Navigation	1
Mapping Process	1
Localization Process	1
Challenges in SLAM Implementation	1
Strategies to Overcome Challenges	1
Clarity	1
and Coherence	1

(OR)

(b) Explain the role of Occupancy Grid Mapping in robotics. How does Occupancy Grid Mapping represent the probability of occupancy of grid cells in a map? Discuss the sensor data commonly used in Occupancy Grid Mapping and the techniques employed to generate accurate occupancy maps.

Rubric	Marks
Provides a comprehensive explanation of the role of Occupancy Grid Mapping (OGM) in robotics,	1
describing its importance for environment representation and autonomous navigation.	1
Thoroughly explains how Occupancy Grid Mapping represents the probability of occupancy for each grid cell,	1
including a detailed explanation of the probabilistic model (e.g., log-odds	1
provides a detailed explanation of the types of sensor data commonly used in OGM (e.g., LIDAR, sonar, RGB-D cameras)	1
and how this data is incorporated into the grid map.	1
provides a comprehensive discussion of the techniques used to generate accurate occupancy maps, such as filtering, sensor fusion (e.g., Kalman filters), and mapping algorithms (e.g., FastSLAM).	1
Thoroughly explains how OGM handles uncertainty and inaccuracies in sensor data, including the role of probabilistic models and uncertainty propagation in grid maps.	1

Section 5 (Answer all question(s))

Marks CO BL

Q19. Define object manipulation in robotics and explain in brief its importance in various applications. **2 4 2**

Rubric	Marks
Define object manipulation in robotics	1
explain its importance in various applications.	1

Q20. (a) Derive the Jacobian matrix for a robotic manipulator arm with multiple degrees of freedom, explaining its significance in manipulation planning and control. **8** **4** **2**

Rubric	Marks
Clear introduction to the task, explaining the role of the Jacobian matrix in robotic manipulation and control. A brief context on the manipulator's degrees of freedom (DOF).	1
Correctly deriving the Jacobian matrix, considering multiple DOFs. This includes: 1. Kinematic equations.	1
Correctly deriving the Jacobian matrix, considering multiple DOFs. This includes: 2. Appropriate use of position and orientation of the end effector in terms of joint variables.	1
Correctly deriving the Jacobian matrix, considering multiple DOFs. This includes: 3. Correct application of partial derivatives to form the Jacobian.	1
Explanation of the Jacobian Matrix	1
Significance in Manipulation Planning	1
Significance in Control	1
Clarity and Structure, Mathematical Rigor and Accuracy	1

(OR)

(b) What factors are considered in gripper selection for object manipulation tasks? How do different gripper designs impact manipulation capabilities?

Rubric	Marks
Introduction to Gripper Selection	1
identification and discussion of key factors in gripper selection: 1. Object type (size, shape, weight). 2. Material and texture of objects.	1
3. Required precision and force. 4. Environmental conditions (e.g., temperature, humidity). 5. Gripper versatility (adaptability to different tasks).	1
Clear explanation of different types of grippers (e.g., parallel, suction, pneumatic, adaptive, etc.), their features, and applications.	1
Explanation of how different gripper designs impact manipulation capabilities, considering: 1. Dexterity and flexibility. 2. Force control and feedback.	1
Explanation of how different gripper designs impact manipulation capabilities, considering: 3. Object handling precision. 4. Speed and efficiency of manipulation.	1
Trade-offs in Gripper Selection	1
Clarity and Structure	1

Section 6 (Answer any 2 question(s))

		Marks	CO	BL
Q21.	Explain how object detection is implemented in robot vision systems. What are the key challenges faced in object detection, and how can they be overcome?	5	5	2

Rubric	Marks
Provides a clear, detailed explanation of object detection, covering how algorithms (e.g., image processing, machine learning) identify and locate objects in images or video streams.	1
Identifies and explains multiple key challenges, such as occlusion, lighting conditions, scale variance, and real-time processing. Provides specific examples.	1
Provides well-thought-out solutions to each challenge, such as the use of deep learning, data augmentation, multi-view cameras, or sensor fusion, with specific strategies discussed.	1
Uses appropriate technical terms related to object detection and robot vision (e.g., convolutional neural networks, feature extraction, classification).	1
The response is well-organized, logical, and easy to follow, with a clear introduction, body, and conclusion.	1

		Marks	CO	BL
Q22.	What is a logical camera in the context of robot vision? How does it differ from a physical camera? Discuss its importance in a robot's perception system within ROS.	5	5	2

Rubric	Marks
Provides a clear and detailed explanation of a logical camera in robot vision, emphasizing its role as a virtual camera used in simulation or for visualizing data in a logical space. Explains how it differs from a physical camera.	1
Clearly distinguishes between a logical camera and a physical camera, highlighting differences in their use, functionality, and how they are implemented in robot vision.	1
Provides a thorough explanation of how a logical camera integrates into the robot's perception system in ROS, explaining its role in simulating environments, creating sensor models, and testing algorithms without needing physical hardware.	1
Uses appropriate technical terms related to robot vision and ROS (e.g., sensor models, simulation, tf, RViz) accurately and in context.	1
The response is well-organized and logically structured, making it easy to understand and follow. The explanation flows smoothly from one point to the next.	1

Q23. What are some of the key ROS tools and packages used for vision processing? Describe their roles and how they contribute to a robot vision system in ROS. **5** **5** **2**

Rubric	Marks
Provides a comprehensive list of key ROS tools and packages (e.g., OpenCV, image_pipeline, sensor_msgs, cv_bridge, vision_opencv, etc.), explaining each one in detail.	1
Clearly and thoroughly explains the role of each tool/package in robot vision, including their specific functions (e.g., image processing, camera calibration, image conversion) within ROS.	1
Explains how each tool/package integrates with ROS, including communication methods (e.g., topics, messages) and how they fit into the ROS ecosystem for vision tasks.	1
Provides clear examples or use cases for each tool/package, showing how they are used in real-world robot vision applications within ROS.	1
The response is well-organized, logical, and easy to follow, with each tool/package and its role clearly explained in a structured manner.	1

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