RV College of Engineering®

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Academic Year 2024-25 (ODD Semester)

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Department of Artificial Intelligence and Machine Learning

ARTIFICIAL INTELLIGENCE IN AUTONOMOUS VEHICLES (CIE III)

Course Code	:	21AI73G1	Date	:	18/02/2025
Semester	:	VII	Time	:	09:30:11:30
Max Marks	:	50	Duration	:	120 Mins

S. No	Quiz	M	BT	CO
1.a	How does reinforcement learning improve planning and control in real-world autonomous driving scenarios?	2	L3	4
b.	How would you assess the impact of computing platform challenges on an autonomous driving system's overall performance and safety?	2	L3	3
c.	How can an autonomous vehicle ensure safe and efficient operation without continuous learning if cloud connectivity is lost? Propose an alternative approach.	2	L3	3
d.	Write any two challenges faced by	2	L2	2

	autonomous delivery vehicles in urban environments compared to those in rural areas.			
e.	Mention any two factors that influence the production deployment of autonomous delivery vehicles.	2	L1	2

S. No	Part-B CIE	M	BT	CO
1	How would you implement Deep Q Reinforcement Learning to enhance decision-making in autonomous vehicle control? Can you provide a real-world example?	10	L3	4
2	Explain the key components of a Robot Operating System designed for autonomous driving and their functions.	10	L2	3
3	Evaluate the impact of edge computing versus cloud computing in real-time autonomous vehicle operations.	10	L4	3
4	With a neat sketch, explain the architecture of an autonomous driving system.	10	L2	3
5	Evaluate the importance of safety and security strategies in autonomous last-mile delivery.	10	L4	2

M-Marks, BT-Blooms Taxonomy Levels, CO-Course Outcomes

Marks Distribution	Particulars	CO1	CO2	CO3	CO4	L1	L2	L3	L4	L5	L6
	Max Marks	-	14	34	12	-	24	16	20	-	-

Course Outcomes: After completing the course, the students will be able to	
CO1:	Analyze the various driving conditions for autonomous cars and apply AI techniques.
CO2:	Identify various problems involved in developing Autonomous Driving cars and suggest the appropriate Solutions.
CO3:	Integration of advanced driver assistance system with cloud infrastructure for training and modeling.
CO4:	Development of Deep learning techniques to analyze the data for decision-making.
CO5:	Demonstrate the use of modern tools by exhibiting teamwork and effective communication skills.

Q.No	Scheme and Solutions	Marks
1a.	Reinforcement Learning (RL) improves planning and control in autonomous driving by: 1. Enabling adaptive decision-making in dynamic environments. 2. It helps vehicles learn optimal navigation policies, handle unpredictable traffic, and improve safety through real-time adjustments. 3. It enhances multi-agent coordination and optimizes trajectory planning for efficiency and safety.	2

b.	- Computing platform challenges, such as **processing power limitations, latency**, and **hardware reliability**, impact an autonomous driving system's performance and safety by affecting real-time decision-making and sensor fusion efficiency. - Assessing their impact involves evaluating **system responsiveness, failure recovery mechanisms,** and **robustness** in dynamic driving conditions.	2
c.	- An autonomous vehicle can ensure safe and efficient operation without continuous learning by using **pre-trained models** and **edge computing** for real-time decision-making. - Additionally, **rule-based fallback systems** and **local sensor fusion** can help maintain safety by relying on onboard data rather than cloud connectivity.	2
d.	**Traffic Complexity** – Urban environments have dense traffic, frequent stops, and unpredictable pedestrian behavior, making navigation and decision-making more challenging than in rural areas with lower traffic density. **Infrastructure Limitations** – Urban areas have complex road networks, narrow streets, and limited parking, which create obstacles for path planning and delivery execution, whereas rural areas often have more open space and simpler road layouts.	2
e.	**Regulatory Compliance** – Autonomous delivery vehicles must meet local laws and safety standards, which vary by region and can impact deployment timelines. **Infrastructure Readiness** – The availability of smart traffic systems, high-definition mapping, and reliable connectivity influences the efficiency and scalability of autonomous vehicle deployment.	2
1	**Introduction to Deep Q-Learning (2 Marks)** Deep Q-Learning (DQL) is a model-free reinforcement learning algorithm where an agent learns an optimal policy by interacting with the environment and maximizing a reward function. It is useful for autonomous vehicle control as it enables decision-making in real-time traffic conditions. - Uses a neural network to approximate the Q-value function. - Learns through experience using a replay buffer to store past experiences. - Utilizes an epsilon-greedy strategy for exploration and exploitation. **Steps for Implementing Deep Q-Learning in Autonomous Vehicles (7 Marks)** **Step 1: Define the Environment and State Representation** - The environment is modeled using a simulator (e.g., CARLA or SUMO). - The state includes sensor inputs (LIDAR, cameras, radar), velocity, lane position, and surrounding vehicles' locations. **Step 2: Define Actions and Reward Function** **Actions**: Steering angle, acceleration, braking, lane changes. **Rewards**: - Positive rewards for staying in the lane, maintaining safe distances, and smooth driving. - Negative rewards for collisions, abrupt braking, or violating traffic rules. **Step 3: Train the Deep Q-Network (DQN)** - Use a Convolutional Neural Network (CNN) to process visual and sensor data. - Train using a replay buffer and experience replay to improve learning stability. - Use a target network to avoid instability in Q-value updates. **Step 4: Policy Optimization and Deployment** - Fine-tune the model using transfer learning from simulation to real-world scenarios. - Deploy the trained model in real-world environments with additional safety constraints. **Real-World Example (1 Mark)** A real-world example is **Autonomous Highway Merging**:	10

	• The DQL agent learns to merge into highway traffic efficiently. • The state includes vehicle speed, traffic density, and gap between cars. • Actions include adjusting acceleration and steering for a safe merge. • The system is trained in a simulated environment and later tested on real highways. • Companies like Waymo and Tesla use similar RL-based approaches to improve decision-making in self-driving cars.	
2	**Introduction to ROS in Autonomous Driving (2 Marks)** • ROS is an open-source framework used for robotic applications, including self-driving vehicles. • It provides tools for sensor integration, real-time data processing, and modular software development. • It enables collaboration between different software modules, ensuring a scalable and reusable architecture. **Key Components and Their Functions (6 Marks)** **A. Perception (2 Marks)** • **Function**: Detects and interprets the environment using multiple sensors. • **Key Modules**: o **LIDAR & Camera Processing**: Identifies obstacles, lanes, and traffic signs. o **Radar & Ultrasonic Sensors**: Measures distances and detects moving objects. o **Sensor Fusion**: Combines multiple sensor inputs to improve accuracy. **B. Localization & Mapping (1 Mark)** • **Function**: Determines the vehicle's exact position on a map. • **Key Modules**: o **Simultaneous Localization and Mapping** (SLAM): Creates and updates maps. o **GPS & IMU Integration:** Enhances accuracy using global positioning. o **Kalman & Particle Filters:** Filters noisy sensor data for precise localization. **C. Path Planning & Decision-Making (1 Mark)** • **Function**: Computes the best possible route considering road conditions and traffic. • **Key Modules**: o **Global Path Planner**: Determines long-term navigation routes. o **Local Path Planner**: Adjusts routes based on real-time sensor data. o **Behavior Planning**: Decides when to accelerate, brake, or change lanes. **D. Control System (1 Mark)** • **Function**: Converts planned actions into vehicle movements. • **Key Modules**: o **PID & Model Predictive Control (MPC)**: Ensures smooth acceleration, braking, and steering. o **Drive-by-Wire System**: Interfaces with vehicle actuators to execute commands. **E. Communication & Middleware (1 Mark)** • **Function**: Enables interaction between different software modules. • **Key Modules**: o **ROS Nodes & Topics**: Exchange data between sensors, planners, and controllers. o **ROS Middleware (DDS/ROS 2)**: Ensures real-time communication and reliability. **3. Challenges and Future Directions (2 Marks)** • **Challenges**: o **Real-time Performance**: Managing high-frequency sensor data in real-time. o **Scalability**: Handling large-scale deployments in different environments.	10
3	**Introduction to Edge and Cloud Computing in AVs (4 Marks)** **Edge Computing (2)**: • Processes data **locally** on the vehicle using onboard computers. • Ensures **low latency** and fast decision-making.	10

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- Suitable for **safety-critical tasks** like collision avoidance and lane keeping.

Cloud Computing (2):

- Processes data in **remote servers** via internet connectivity.
- Used for **non-time-critical** tasks like fleet management and HD map updates.
- Supports **deep learning model training and data storage**.

Key Comparisons and Impact on Real-Time Autonomous Driving (6 Marks)

- **Latency & Real-Time Processing (2 Marks)**
  Edge Computing: Ensures **low latency (~1-10 ms)** by processing data on the vehicle. Essential for tasks like **collision avoidance, emergency braking, and object detection**.
  Cloud Computing: Introduces **higher latency (~100-500 ms)** due to network delays. Unsuitable for real-time safety decisions but useful for long-term AI learning.

- **Reliability & Connectivity (1 Mark)**
  Edge Computing: Works **independently** of network availability, ensuring continuous vehicle operation.
  Cloud Computing: **Depends on internet connectivity**, which can be unreliable in remote or congested areas.

- **Computational Power & Scalability (1 Mark)**
  Edge Computing: Limited by onboard **GPU/CPU capabilities**, restricting deep learning model complexity.
  Cloud Computing: Offers **virtually unlimited computational power**, enabling large-scale AI training.

- **Security & Data Privacy (1 Mark)**
  Edge Computing: **Improves security** by processing sensitive data locally, reducing exposure to cyber threats.
  Cloud Computing: **Higher risk of data breaches**, as data is transmitted to remote servers.

- **Cost & Infrastructure (1 Mark)**
  Edge Computing: Higher initial cost due to expensive onboard hardware but low recurring costs.
  Cloud Computing: Lower upfront cost but higher operational costs due to data transmission and storage fees.

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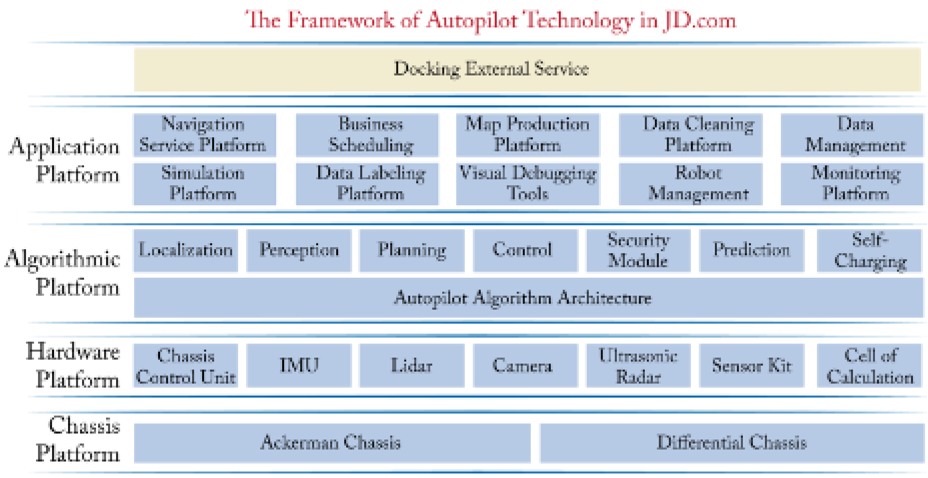

The architecture of our autonomous driving system.

Diagram: 4 Marks
Explanation of each module: 1.5*4 = 6 Marks

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1. **Collision Avoidance & Pedestrian Safety (1 M)**
   - Autonomous delivery vehicles must detect and avoid **pedestrians, cyclists, and obstacles** using sensors (LIDAR, cameras, radar).

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	o Implementing **real-time path correction** prevents accidents in dynamic environments. 2. **Reliable Navigation & Localization (1 M)** o Accurate **GPS, SLAM (Simultaneous Localization and Mapping), and IMU** help maintain precise positioning. o Reduces risk of getting stuck or deviating from designated paths, ensuring successful deliveries. 3. **Obstacle Handling & Traffic Compliance (1 M)** o Vehicles must adhere to **traffic rules, speed limits, and pedestrian crossings**. o AI-based perception helps in handling **sudden roadblocks or parked vehicles** on delivery routes. 4. **Cybersecurity Protection (1 M)** o Autonomous delivery systems are vulnerable to **hacking, GPS spoofing, and data breaches**. o Implementing **end-to-end encryption, authentication protocols, and intrusion detection** enhances cybersecurity. 5. **Data Privacy & Consumer Security (1 M)** o Protecting user information (addresses, package details) from unauthorized access is critical. o Compliance with **GDPR and data protection regulations** ensures trust and legal compliance. 6. **Weather Adaptability & Environmental Safety (1 M)** o Vehicles should operate safely in **rain, snow, fog, and extreme temperatures**. o Advanced **sensor fusion and AI models** help maintain functionality in adverse weather conditions. 7. **Remote Monitoring & Emergency Handling (1 M)** o Autonomous vehicles should have **human-in-the-loop capabilities** for remote intervention in case of failures. o Real-time alerts and **emergency stop mechanisms** improve system reliability. 8. **Anti-Theft & Vandalism Prevention (1 M)** o Delivery robots and vehicles are at risk of **theft, physical attacks, or sabotage**. o Strategies like **geofencing, tamper-proof locks, and video surveillance** deter criminal activity. 9. **Energy Efficiency & Battery Safety (1 M)** o Ensuring efficient **battery management, thermal control, and emergency power backup** prevents breakdowns. o Optimized **route planning** minimizes energy consumption and delivery delays. 10. **Regulatory Compliance & Ethical Considerations (1 M)** o Autonomous delivery solutions must adhere to **transportation laws, pedestrian safety standards, and local regulations**. o Ethical considerations include **responsible AI decision-making**, ensuring fairness in urban mobility.	