

Research Report

Autonomous Vehicles and Drones

Submitted by: Guggilapu Sampath

Course: Robotics & Automation Internship

Institution: CodeAlpha

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Abstract

The development of Autonomous Vehicles (AVs) and Unmanned Aerial Vehicles (UAVs) has brought about a new level of robotics through automation and smart mobility with very limited involvement from humans. Combining AI, sensor fusion, control algorithms, and real-time communication, AVs and UAVs are able to perform complicated navigational and decision making processes. This report is an extensive look at the various types of robotics used in the design and operation of both AVs and UAVs. The report discusses the System Architecture, Core Technologies, Real World Applications, and Major Challenges associated with using AVs and UAVs. In addition, the report will discuss the major safety, ethical, and regulatory issues that will limit or impede the successful launch of AVs and UAVs throughout the world. Additionally, this report will provide information on emerging trends and research activities related to the use of autonomous systems in many industries, including but not limited to Transportation, Logistics, Healthcare and Emergency Response Operations.

Keywords: Autonomous Vehicles, Drones, Robotics, Artificial Intelligence, Sensor Fusion, UAV Navigation, ROS

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1 Introduction

The 21st century encompasses many strongly transformational areas of Technology. Robotics is one of the more increasingly transformational technologies. The areas of HealthCare, Manufacturing, Transportation, Security and Defense are all beginning to feel their impact.

Autonomous Vehicles and Unmanned Aerial Systems ("Drones") represent two of the most significant advances in Robotics. They are revolutionizing how people think about Mobility, Logistics, Surveillance and Safety. However, many complex Engineering and Research challenges prevail at various levels in the Engineering and Research community.

Autonomous Vehicles are capable of navigating themselves without the requirement for continuous human input, utilizing sophisticated sensors, Automation Algorithms, and Artificial Intelligence. Similarly, Unmanned Aerial Vehicles and Drones are extending the range of what Robots can do by being able to access Large, Remote, Hazardous and Inaccessible locations in the Aerial realm. Together, Autonomous Vehicles and Unmanned Aerial Systems (Drones) form the foundation of Intelligent Transportation Systems and Automated Mobility Ecosystems.

In this report, we will cover the Architecture, Core Technologies, Applications, Limitations and Future of Autonomous Vehicles and Drones, Supported by Significant Relevant Academic Research.

2 System Architecture of Autonomous Vehicles and Drones

Drones and autonomous vehicles utilize a layered system architecture for perception, decision-making and actuation. The perception layer is made up of sensors such as LiDAR, radar, cameras, GPS, and inertial measurement units (IMUs) which provide the autonomous vehicle with the real-time environment information which is necessary to operate safely and effectively. To improve reliability and accuracy of the information being collected from these sensors, the sensors are combined through use of sensor fusion techniques.

At the decision layer, the vehicle will localize itself, map its environment, create a path to reach its destination, and make decisions using various algorithms such as Simultaneous Localization and Mapping (SLAM) and Kalman filter.

The control layer takes a planned trajectory and converts it into commands sent to an autonomous vehicle's actuators (e.g., steering wheel, throttle) based on various control strategies, including proportional-integral-derivative (PID) controllers and model predictive control (MPC).

Communication systems provide the means for vehicles to communicate with each other (vehicle-to-vehicle or V2V) and the road infrastructure (vehicle-to-infrastructure or V2I), as well as enabling telemetry so that a vehicle's performance can be monitored remotely and coordinated with other vehicles.

3 Core Technologies in Autonomous Vehicles and Drones

The key technologies used for developing autonomous vehicles are sensor-fusion techniques. Sensor-fusion integrates the data collected by various types of sensors to create a robust perception for the vehicle.

Localization and mapping techniques, such as SLAM, allow the vehicle to move through unfamiliar or dynamic areas.

Path-planning techniques include the use of algorithms such as A*, Dijkstra's, and Rapidly-exploring Random Trees (RRT) which compute a path that avoids collisions.

Control systems help to maintain a smooth and stable motion throughout the various conditions that may occur during a vehicle's operation.

Thanks to the widespread use of artificial-intelligence techniques, including deep learning techniques, in autonomous vehicles, they are able to detect objects, avoid obstacles, and make decisions autonomously.

Many software platforms have been developed to support robotic development and testing. The main platforms used today for building robotic systems are the Robot Operating System (ROS) and ROS2. These platforms provide middleware support for modular communication, simulation, and hardware abstraction, thereby accelerating the speed of development and testing.

4 Autonomous Vehicles

The functioning of Autonomous Vehicles (AVs) depends upon Artificial Intelligence (AI), on-board sensors, and Computer-Controlled driving systems. Increased precision in perception, enhanced safety mechanisms, and predictive decision making have been the focus of research in this emerging field. Faisal et al. (2019) has highlighted the contribution of Autonomous Vehicles to the development of smart cities and the creation of environmentally sustainable forms of transportation.[1].

Modern autonomous vehicles integrate LiDAR, cameras, radar, GPS, and deep neural networks to achieve high-resolution environmental perception. Safety remains a critical concern, requiring predictive risk assessment and robust system validation [2]. Communication frameworks further enhance navigation reliability and coordination [3, 4].

5 Drones (Unmanned Aerial Vehicles)

Drones represent a rapidly growing domain in robotics research. They are widely used in surveillance, environmental monitoring, agriculture, infrastructure inspection, and logistics. Floreano and Wood (2015) describe drones as a disruptive innovation due to their ability to operate in hazardous environments [5].

Advanced embedded systems enhance flight stability and autonomous navigation [6]. However, drones face challenges such as limited battery life, weather sensitivity, and cybersecurity risks [7]. Research continues to improve autonomy, safety, and mission efficiency [8].

6 Applications of Autonomous Vehicles and Drones

6.1 Applications of Autonomous Vehicles

Applications include self-driving cars, autonomous public transportation, freight logistics, and emergency response systems. These vehicles reduce human error, improve traffic efficiency, and enhance accessibility.

6.2 Applications of Drones

Drones are used for disaster management, medical supply delivery, agriculture monitoring, military surveillance, and infrastructure inspection. Multi-drone swarm systems enable cooperative operations and large-area coverage[9].

7 Limitations and Research Gaps

Although there is much progress made with autonomous systems, there still exist several limitations associated with their usage. These limitations include:

- Sensor performance degradation under adverse weather conditions;
- Bias in artificial intelligence (AI) decision-making models;
- Limited battery capacity and energy constraints; and
- Cybersecurity threats affecting system integrity.

There are also several legal and ethical issues, including privacy, liability, and regulation, that prevent autonomous systems from being used in the general population.

8 Future Scope and Emerging Trends

Future studies intend to develop vehicles capable of full autonomy at Level 5, large-scale drone swarm deployment, as well as AI tools and procedures for decision-making. The seamless merging of future technologies—such as smart cities, 5G and macroscale telecommunication—along with cutting-edge technologies (such as battery technology), will allow for increased safety and coordination across systems. In addition, new regulatory frameworks around these technologies will provide for a more robust environment in which to integrate them.

9 Conclusion

Autonomous vehicles and drones represent transformative advancements in robotics, reshaping transportation and mobility systems worldwide. These technologies offer improved safety, efficiency, and accessibility across multiple sectors. Continued advancements in artificial intelligence, sensing technologies, and regulatory support will play a crucial role in realizing the full potential of autonomous mobility systems.

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