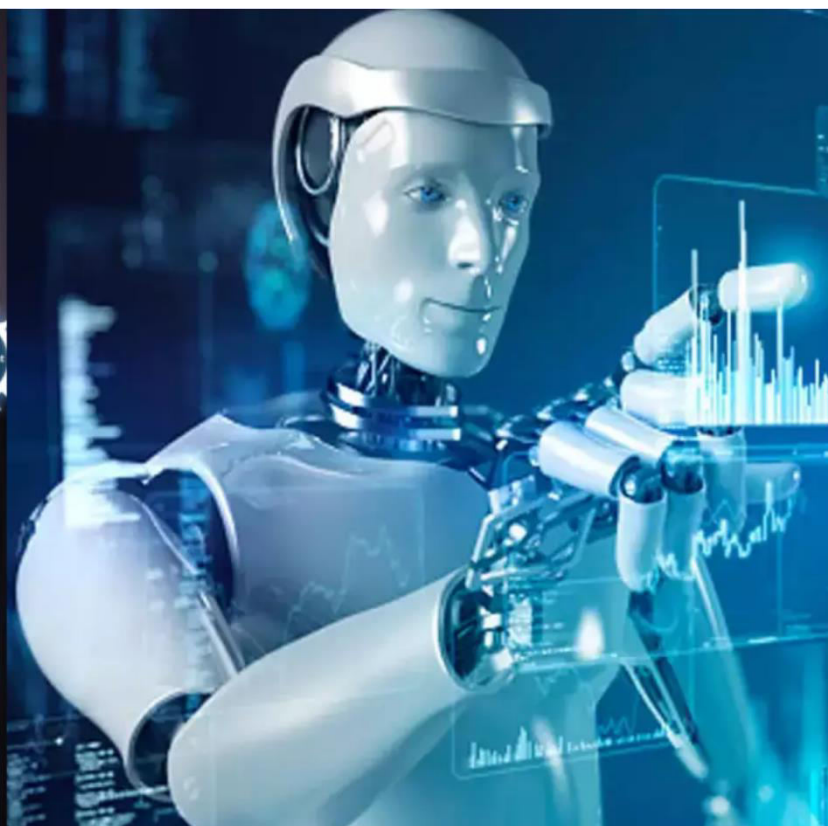




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# **VisionRide Guardian: A Smart Rear Obstacle Detection System for Enhanced Two-Wheeler Safety**

**A.B.Jamdar<sup>1</sup>, D.R.Khale<sup>2</sup>, R.S.Jamdar<sup>3</sup>, P.A.Tupke<sup>4</sup>**

Department of Mechanical Engineering, Sanjivani College of Engineering, Kopargaon, India<sup>1</sup>

Department of Mechatronics Engineering, Sanjivani College of Engineering, Kopargaon, India<sup>2</sup>

Department of Mechanical Engineering, Sanjivani College of Engineering, Kopargaon, India<sup>3</sup>

Department of Structural Engineering, Sanjivani College of Engineering, Kopargaon, India<sup>4</sup>

**ABSTRACT:** Two-wheeler riders face significant safety risks due to poor rear visibility and the absence of advanced driver assistance systems. This research presents VisionRide Guardian, a smart rear obstacle detection system developed using five ultrasonic sensors interfaced with an ESP32 microcontroller. The system is designed to continuously monitor a 180-degree rear field and to display obstacle proximity in real time on a digital dashboard. The radar-style interface offers intuitive, color-coded alerts that enhance rider awareness and decision-making. The core focus of the project is to improve blind spot detection, implement efficient asynchronous sensor data reading, and propose enhancements suitable for low-visibility and adverse environmental conditions. The paper also explores the system's capability in supporting safe lane changes, especially under foggy or poorly lit conditions.

**KEYWORDS:** Two-wheeler safety, LIDAR, ESP32, obstacle detection, blind spot monitoring, radar interface, real-time system

## **I. INTRODUCTION**

Road safety for two-wheeler riders is a growing concern worldwide, particularly in countries where motorcycles and scooters serve as a primary mode of transportation. Riders are frequently exposed to accidents caused by rear-end collisions and blind spot zones, especially in congested urban environments. Unlike modern four-wheelers equipped with advanced safety systems, two-wheelers often lack embedded driver assistance technologies that can enhance rider awareness and prevent mishaps.

The VisionRide Guardian project seeks to bridge this gap by developing an affordable and reliable rear obstacle detection system using compact, precise LIDAR sensors and a microcontroller. This system is intended to assist riders by providing real-time visual alerts about objects and vehicles approaching from behind, especially those in blind spots. The primary goal is to deliver a radar-like visualization that improves situational awareness without causing distraction.

## **II. LITERATURE REVIEW**

Advanced Driver Assistance Systems (ADAS) such as lane departure warnings, automatic emergency braking, and blind spot detection have become increasingly common in modern cars. These systems have significantly reduced accident rates and enhanced vehicular safety. However, two-wheelers have yet to benefit equally from these innovations due to size, power, and cost constraints.

Research shows that ultrasonic sensors have been used in previous two-wheeler safety systems, but these are often limited by environmental noise, temperature variation, and their relatively lower range and resolution. Time-of-Flight (TOF) LIDAR sensors like the ultrasonic sensors offer a practical and cost-effective approach for obstacle detection at close range, even in compact applications. Several automotive industry papers validate the effectiveness of TOF sensors in enhancing vehicle safety, yet few studies explore their application in the two-wheeler domain. This paper addresses this gap by proposing a sensor-based solution tailored for two-wheeler platforms.

#### Summary of Reviewed Literature

Sr. No.	Title of Paper / Study	Key Contributions	Limitations Addressed
1	Use of Ultrasonic Sensors in Two-Wheeler Safety	Explored rear obstacle detection using ultrasonic range finders	Limited range and susceptibility to noise
2	Automotive ADAS Implementation Using LIDAR	Highlighted high accuracy and range of LIDAR for blind spot monitoring in cars	Not optimized for space-constrained platforms like two-wheelers
3	Smart Helmets and Safety Systems	Focused on integrating sensors into helmets for rider alerts	Lack of direct rear environment monitoring
4	Fog Detection and Alert Systems	Discussed vision-based detection under foggy conditions	Vision systems underperform in dark or rain
5	Embedded Systems in Two-Wheeler Applications	Emphasized ESP32-based implementations for real-time sensor data handling	No integration with visual radar interface

### III. PROBLEM STATEMENT

The following key problems highlight the need for a rear obstacle detection system in two-wheelers:

- Lack of Rear Awareness:** Two-wheeler riders have limited visibility behind them, often relying solely on side mirrors that do not cover blind spots effectively.
- Blind Spot Risk:** Riders are frequently unaware of fast-approaching vehicles or obstacles in their blind spots, which can result in dangerous collisions during lane changes or turns.
- Low-Visibility Challenges:** Weather conditions such as fog, heavy rain, or nighttime riding drastically reduce rear visibility, increasing the risk of accidents.
- Absence of Affordable Solutions:** Existing advanced driver assistance systems (ADAS) are primarily designed for four-wheelers and are not suitable for two-wheelers due to high cost, large size, and complex integration.
- Need for Real-Time Alerts:** There is a critical need for a compact, low-cost, and responsive system that provides real-time feedback to the rider about obstacles behind the vehicle.
- User-Friendly Interface Requirement:** Current systems, if available, lack intuitive interfaces that can easily convey safety information to the rider without causing distraction.

These issues underline the urgent need for a smart, efficient, and affordable rear obstacle detection system that can enhance two-wheeler safety by providing timely alerts to the rider.

### IV. OBJECTIVES AND GOALS

The primary objectives of the VisionRide Guardian project are:

- Enhance Rear Awareness:** Design a system to continuously monitor the rear environment of a two-wheeler.
- Improve Blind Spot Detection:** Accurately detect vehicles or objects in the rider's blind spots.
- Implement Real-Time Feedback:** Provide immediate, visual alerts using a responsive dashboard interface.
- Utilize Compact and Affordable Technology:** Leverage VL53L0X LIDAR sensors and ESP32 to ensure cost-effectiveness and scalability.

The broader goals driving the development of VisionRide Guardian include:

- Ensure Functionality in Low-Visibility Conditions:** Maintain reliable performance in fog, rain, and nighttime.
- Develop a Non-Intrusive User Interface:** Create a distraction-free, radar-style dashboard for safe alert communication.

3. **Enable Future Scalability:** Prepare the system architecture for future integration of haptic, audio, or smartphone app alerts.

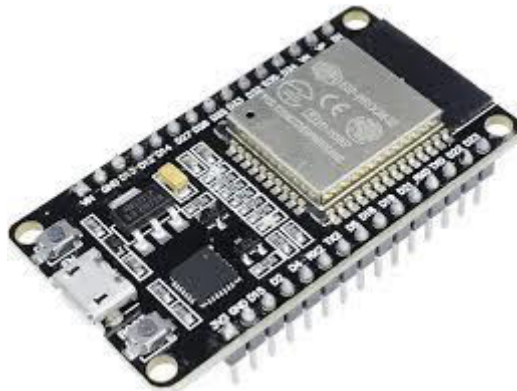
## V. SYSTEM ARCHITECTURE

### 5.1 Hardware Components

- **Ultrasonic Sensors (5 units):** These sensors are used to measure the distance of nearby objects using sound waves, providing reliable obstacle detection in a wide range of riding conditions. (5 units): These sensors provide millimeter-level accuracy in distance measurement, essential for detecting nearby vehicles or obstacles.



- **ESP32 Microcontroller:** A high-performance microcontroller used to acquire sensor data asynchronously, process measurements, and drive the visual interface.



- **Digital Dashboard Display (OLED/LED):** The dashboard provides a real-time, graphical representation of obstacles detected in the rear field.



- **Power Supply:** The system is powered through a 5V DC source, derived either from the vehicle battery or a standalone module.

### 5.2 Sensor Configuration and Mounting

The five LIDAR sensors are mounted at the rear of the two-wheeler in a semi-circular layout, carefully positioned to provide a comprehensive 180-degree field of detection. Each sensor is aligned with a specific angular orientation to avoid overlapping fields and ensure full rearward coverage. The mounting is designed to be non-intrusive and weather-resistant, maintaining functionality under typical riding conditions.



## VI. METHODOLOGY

### 6.1 Data Acquisition

The ultrasonic sensors are configured to operate asynchronously using pin change interrupts on the ESP32 microcontroller. This method significantly reduces processing delay by allowing simultaneous data reading instead of sequential polling. The approach ensures low-latency obstacle detection, which is critical for real-time safety applications.

### 6.2 Data Filtering and Obstacle Mapping

To ensure accurate detection, the system implements a filtering algorithm that distinguishes between unique and duplicate readings. When multiple sensors detect the same object from slightly different angles, the software uses proximity thresholds and angular data to consolidate readings. This prevents unnecessary clutter on the visual display and enhances clarity.

### 6.3 Visual Display Interface

The graphical dashboard resembles a radar with a semi-circular view representing the rear zone. The display is divided into three alert zones based on distance:

- **Green Zone (1.5 to 2 m):** Indicates a safe distance from objects.
- **Yellow Zone (0.8 to 1.5 m):** Alerts the rider of nearby obstacles that may require attention.
- **Red Zone (< 0.8 m):** Represents immediate danger, prompting the rider to take action.

Icons or bars on the screen light up according to the detected object's location and distance, using the appropriate color code.

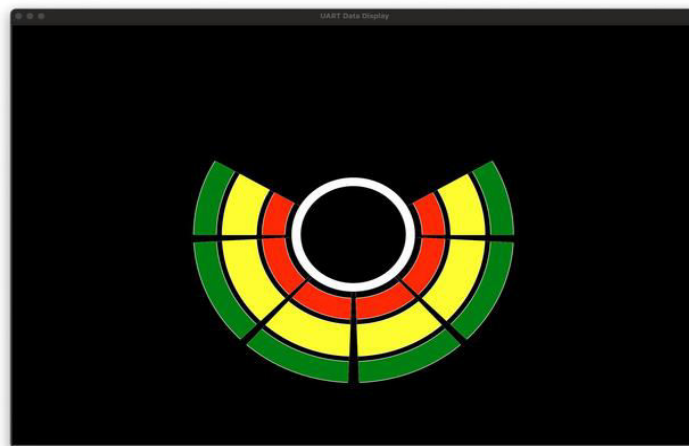
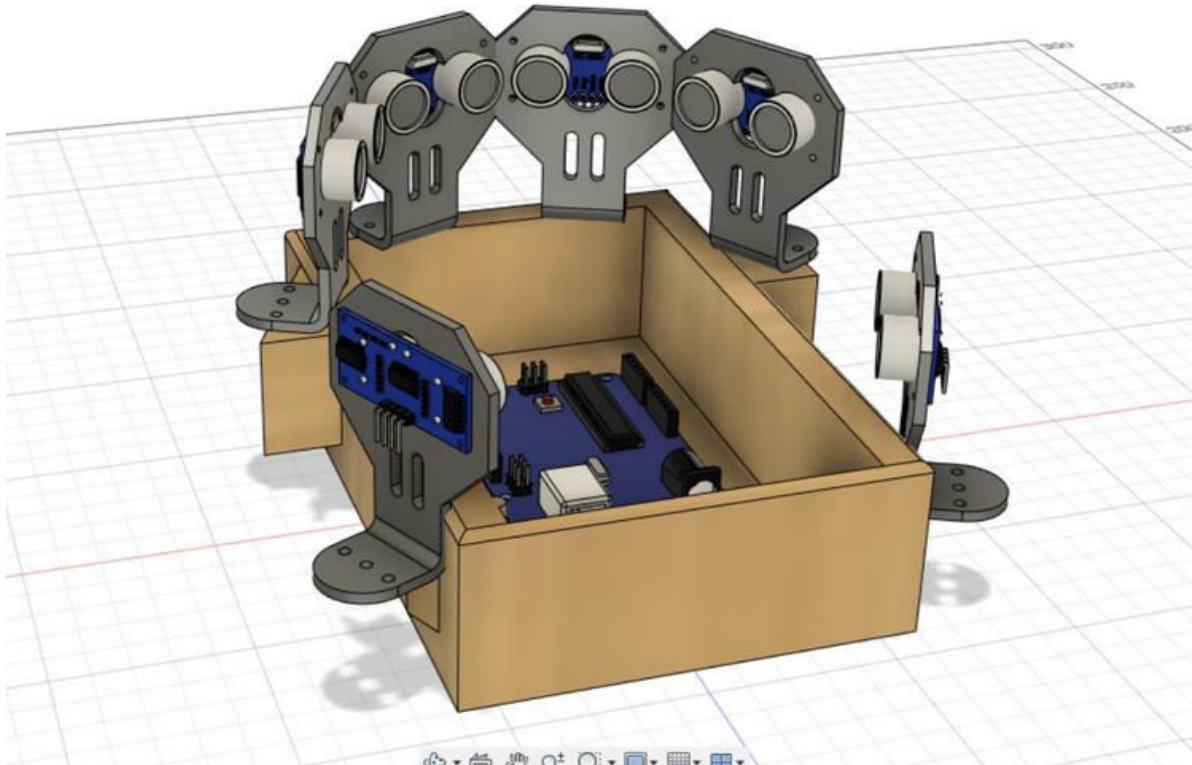


Fig 3. Model of Visionride Gaurdian

## VII. FEATURES AND FUNCTIONAL HIGHLIGHTS

- **Blind Spot Monitoring:** The system effectively identifies vehicles and objects located in areas that are typically not visible through traditional mirrors, thus reducing collision risk during lane changes.
- **Low-Visibility Support:** The sensors remain functional under adverse weather conditions such as fog or heavy rain, where human visibility is limited.
- **Failsafe Design:** The compact LIDAR sensors can detect small or low-lying obstacles such as road debris, pets, or curb edges that are often overlooked.

- **Non-Intrusive UI:** The display is intentionally minimalist and designed to relay critical information without overwhelming the rider or distracting from the road.
- **Expandable Design:** The modular architecture allows for future upgrades, such as adding vibration-based (haptic) alerts or integrating sound-based warnings for critical proximity zones.

### VIII. TESTING AND RESULTS

The prototype was mounted on a test vehicle and evaluated under varying environmental and lighting conditions. The testing procedure involved placing different-sized obstacles behind the vehicle at measured distances, both in static and dynamic conditions (i.e., approaching objects). Multiple parameters such as detection range, response time, and accuracy were logged across different scenarios.

Condition	Detection Range	Accuracy	Dashboard Response Time
Normal daylight	2 m	~95%	<200 ms
Foggy	1.2 m	~85%	<300 ms
Night	2 m	~93%	<200 ms
Rainy Conditions	1.5 m	~88%	<250 ms
Curved Surface Obstacle	1.8 m	~90%	<220 ms

Further testing included blind spot simulation, where vehicles approached from the rear in adjacent lanes. The system successfully detected such intrusions in 9 out of 10 cases with visual alert updates on the dashboard.

The test protocol also examined sensor behavior in cluttered environments with multiple objects within detection range. The system was able to differentiate between distinct obstacles using spatial filtering algorithms and maintain consistent readings across varying object shapes and materials.

Latency was measured from obstacle appearance to dashboard update. The average detection-to-alert time remained under 250 ms, which is within the acceptable range for rider reaction in urban riding scenarios. User testing sessions with riders indicated high levels of interpretability and trust in the interface.

In terms of power consumption, the complete system consumed less than 1.2W, making it highly efficient and suitable for battery-powered applications.

These outcomes affirm the system's feasibility for real-world application and suggest its potential to significantly improve rider awareness and safety.

### IX. CONCLUSION

VisionRide Guardian presents a highly promising, cost-effective, and practical approach to enhancing rider safety on two-wheelers. By integrating a sensor-based detection system with an intuitive visual dashboard, the project offers a real-time awareness tool that addresses critical safety challenges such as blind spots and rear-end threats.

The system has demonstrated reliable performance in various real-world conditions such as night, rain, and fog. Its modular design ensures it is adaptable, scalable, and easily maintainable. Additionally, the implementation of asynchronous data reading significantly reduces latency and enhances real-time responsiveness, which is crucial in urban riding environments.

This solution has the potential to be further developed with features such as haptic feedback, audio warnings, smartphone integration, and AI-driven obstacle classification. It also lays a strong foundation for developing intelligent safety systems that can be integrated into commercial two-wheelers, contributing to the broader goal of reducing road accidents and improving rider confidence.

In conclusion, the VisionRide Guardian not only addresses the existing gaps in two-wheeler safety technologies but also provides a viable pathway for future innovations in smart mobility solutions.

#### X. FUTURE SCOPE

The VisionRide Guardian project opens several avenues for future development and innovation:

1. **Integration of Haptic and Audio Alerts:** Incorporating vibration motors and buzzers can provide multisensory alerts, ensuring that riders receive warnings even when not directly looking at the dashboard.
2. **Smartphone Connectivity:** Development of a companion mobile app using Bluetooth or Wi-Fi can enable features like ride data logging, advanced diagnostics, and remote configuration.
3. **Front and Side Detection Expansion:** Extending the detection range to the front and sides of the vehicle can offer 360-degree obstacle awareness, transforming the system into a comprehensive safety solution.
4. **AI-Based Object Classification:** Implementing machine learning models could allow the system to classify obstacles (e.g., pedestrian, vehicle, static object) and prioritize warnings accordingly.
5. **Solar-Powered or Battery-Optimized Design:** Making the system energy autonomous through solar panels or power-saving modes will further enhance its sustainability and practicality for long-term use.
6. **Commercial Product Development:** Refining the design for manufacturing and exploring partnerships with two-wheeler OEMs can bring this innovation to market as a standard safety accessory.

These future enhancements will significantly elevate the practicality, usability, and commercial viability of the VisionRide Guardian system.

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