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Road Inter-Junction Blind Spot Alert System

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Abstract - Intersection traffic accidents continue to be a major safety problem, especially in areas where blind spots impede driver visibility. These blind zones increase the risk of serious collisions by preventing drivers from seeing oncoming cars in enough time. Convex mirrors and other traditional countermeasures are frequently employed to increase visibility, but they only serve as passive tools and do not actively warn drivers of possible hazards.

In order to improve driver awareness at blind intersections, this study introduces a Road Inter-Junction Blind Spot Alert System that combines real-time visual alert mechanisms with ultrasonic sensor-based vehicle recognition. In order to alert drivers ahead of time, the suggested system continuously scans hidden road segments, recognizes oncoming cars, and turns on high-intensity LED indicators installed on convex mirrors. Because the system's design prioritizes economy, low power consumption, and ease of deployment, it is especially well-suited for rural and semi-urban areas where sophisticated traffic infrastructure is frequently lacking. According to experimental evaluation, the system can efficiently identify vehicles within a 10–12 m range and deliver prompt alerts, lowering the probability of collisions and greatly enhancing intersection safety.

Index Terms: Blind Spot Detection, Intersection Safety, Intelligent Transportation Systems, Driver Assistance, Collision Prevention, Embedded Systems, Road Safety, Real-Time Alert Systems

I. INTRODDUCTION

Due to complicated traffic patterns and drivers' slow reaction times, crossroads have been designated as high-risk areas for traffic accidents, which are one of the main causes of injuries and fatalities globally. A large percentage of these collisions take place at blind crossings, when structures, plants along the road, parked cars, or bad road geometry block incoming traffic's vision. In these situations, drivers frequently don't notice oncoming traffic until it's too late to react safely.

Convex mirrors, warning signs, and road markings are examples of conventional safety measures that have been used to lessen this issue. Convex mirrors increase the driver's field of vision; however, they are completely passive and greatly dependent on weather, lighting, and driver attention. They are far less effective at night or in bad weather. Moreover, improper placement and poor maintenance further reduce their dependability in rural and semi-urban areas.

Modern cars have demonstrated the effectiveness of sophisticated in-car driver aid systems including collision avoidance and blind spot monitoring. However, their high cost and need on vehicle-specific integration prevent them from being widely used, especially in developing nations. This makes it obvious that there is a need for a stand-alone, roadside safety system that works well with any kind of car.

This gap is filled by the suggested Road Inter-Junction Blind Spot Alert System, which provides a low-cost, proactive, sensor-based safety solution. The device improves situational awareness and dramatically lowers the danger of collisions by identifying approaching cars from concealed directions and giving drivers real-time visual alerts. In order to show the system's usefulness and efficacy for actual deployment, this article describes the system's design, implementation, and evaluation.

II. LITERATURE SURVEY

According to recent studies, there is growing interest in using IoT and low-cost embedded devices to increase traffic safety. In order to improve driver awareness and reduce accidents, a number of studies have investigated the use of microcontroller platforms in conjunction with ultrasonic sensor-based vehicle identification.

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Using ESP32 microcontrollers and ultrasonic sensors, Bhandare et al. built a vehicle tracking and accident alert system, demonstrating the viability of real-time safety monitoring using inexpensive components. Similarly, Ali et al. demonstrated that ultrasonic sensing can successfully lower collision risks by proposing an enhanced driver aid system that can identify blind areas and dangerous maneuvers.

The integration of radar and high-speed communication technologies has been the subject of other research. A 5G-enabled radar-based traffic monitoring technology was presented by Martín-Sacristán et al. It needed complicated infrastructure but increased detection accuracy in crowded traffic. In their study of many IoT-based accident detection systems, Sahraei and Al Mamari highlighted the dependability of infrared and ultrasonic sensors for low-latency applications.

The dependability of proximity sensors is further supported by research in related fields like assistive technology and smart street lighting. Guobadia gave an example of how ESP32-integrated ultrasonic sensors could be used for traffic safety applications. While Kunhoth et al. used obstacle detection systems to test ultrasonic sensing reliability under dynamic situations, Sanjay et al. created an AI-assisted smart mirror system for vehicle detection.

The majority of current solutions concentrate on vehicle-mounted or personal assistance devices, despite the fact that these investigations validate the efficacy of ESP32-based ultrasonic detecting systems. The necessity of roadside deployment at blind crossings is rarely discussed. By moving the detecting mechanism to the intersection itself, the suggested system expands on these pioneering efforts and provides a scalable, infrastructure-independent safety solution for underdeveloped road networks.

III. PROPOSED METHODOLOGY

A. System Architecture

To guarantee dependability, scalability, and simplicity of implementation in actual traffic situations, the suggested Road Inter-Junction Blind Spot Alert System uses a layered and modular architecture. The system may function independently of vehicle-mounted technologies because the architecture is specifically made for roadside placement.

1. Sensing Layer

The sensing layer is in charge of identifying oncoming cars from blind spots that are hidden from drivers' direct view. The HC-SR04 ultrasonic sensors used in this layer produce ultrasonic pulses at a frequency of 40 kHz. These pulses travel through the atmosphere, bounce off surrounding things like cars, and then return as echoes to the sensor.

The choice of ultrasonic sensors was made because

- Their affordability in comparison to LiDAR or radar systems
- Sufficient detection range (2–400 cm) for monitoring at the junction level
- Unlike camera-based systems, insensitivity to ambient light conditions

Sensors are pointed toward incoming traffic lanes and placed strategically at the intersection's blind corners. Their positioning guarantees early vehicle detection before they approach the intersection's visible area.

2. Processing Layer

The ESP32 microcontroller, which acts as the system's computing core, is the foundation of the processing layer. The ESP32 calculates distance in real time by continuously receiving time-of-flight data from the ultrasonic sensors.

The processing layer's primary duties include:

- Echo time conversion to distance measurements
- Filtering sensor signals that are noisy due to environmental disruptions
- Comparing measured distances to safety criteria that have been established
- Making quick decisions about whether to send out alerts

The ESP32's dual-core architecture ensures low latency by effectively managing sensor acquisition and alert control at the same time. In order to avoid false triggering caused by pedestrians, stationary objects, or ambient noise, the processing logic is optimized.

3. Alert Layer

The alert layer functions as the system's human-machine interface. High-brightness LEDs are incorporated straight into convex mirrors along the side of the road. Because of this design decision, alerts will show up precisely where drivers are already taught to watch for cross-traffic.

When a car is found to be in the danger zone:

- LEDs blink frequently.
- In daylight, dusk, and night, the glow is readily apparent.
- Unlike passive mirrors, drivers receive an explicit and active warning.

Driver reaction time is much improved by this proactive alarm system, which also lessens reliance on continuous visual scanning.

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B. Operational Workflow

The system allows for continuous monitoring of blind crossings by running in a closed-loop cycle.

1. Ultrasonic Pulse Transmission
A brief 40 kHz ultrasonic burst is emitted by each HC-SR04 sensor in the direction of the blind zone.

2. Echo Reception
The pulse returns to the sensor receiver when it comes into contact with an oncoming car.

3. Distance Computation
The ESP32 uses the conventional time-of-flight formula to determine the distance:

4. Threshold Comparison
A predetermined detection threshold of 10–12 meters, established through field testing to provide enough reaction time, is compared to the calculated distance.

5. Alert Triggering
The ESP32 initiates the LED alert sequence if the distance is within the threshold range.

6. Driver Warning
LEDs ensure excellent visibility and prompt driver attention by blinking at intervals of 200 ms.

7. Automatic Reset
The LEDs are switched off and the system goes back to monitoring mode when the car leaves the detection zone.

Low latency, great reliability, and few false alarms are guaranteed by this workflow.

C. Design Methodology

To guarantee robustness and usefulness, the design process adhered to a defined engineering lifecycle.

1. Requirement Analysis:
To determine visibility limitations and traffic patterns, accident-prone blind crossings in rural and semi-urban areas were examined.

2. Component Selection:
Due of their ability to balance affordability, power efficiency, and performance, the ESP32 and HC-SR04 were selected.

3. Hardware Placement Strategy: The sensors were placed to minimize interference from roadside structures and maximize detection coverage.

4. Algorithm Development: To stabilize sensor data and reduce noise, debounce logic and distance averaging were included.

5. Prototype Validation: To verify detection accuracy and response time, controlled trials with simulated vehicle movement were carried out.

IV. IMPLEMENTATION

Hardware integration, embedded firmware development, system calibration, and practical testing are all necessary for the realization of the suggested Road Inter-Junction Blind Spot Alert System. Ensuring accurate vehicle identification at blind crossings and prompt alarm production under various traffic and environmental situations is the main goal of the implementation phase.

A. Hardware Setup

- **Ultrasonic Sensors (HC-SR04):** The system's main sensing components are the HC-SR04 ultrasonic sensors. A transmitter and receiver pair operating at a frequency of 40 kHz make up each sensor. The average reflecting surface height of typical road vehicles, including cars, two-wheelers, and light commercial vehicles, is roughly 1.2 to 1.5 meters above the ground, where the sensors were installed.
- In order to guarantee early detection of approaching cars before they become visible to drivers, sensors were placed facing the intersection's blind approach lanes. In order to reduce signal loss and prevent interference from roadside objects like walls, poles, or foliage, proper angular alignment was maintained. To lessen the vibration effects of passing cars, rubber mounts were utilized.
- **ESP32 Microcontroller:** The system's central processing unit is the ESP32 microcontroller. Its high processing speed, low power consumption, and capacity to manage several sensor inputs at once led to its selection. The digital GPIO pins of the ESP32 were linked to the trigger and echo pins of the ultrasonic sensors.
- **The ESP32 calculates distance in real time while continuously gathering time-of-flight data from the sensors. Precise distance estimate requires accurate measurement of microsecond-level echo delays, which is ensured by its integrated clocks and interrupt capabilities.**
- **High-Brightness LEDs:** Mounted on convex mirrors, connected via 220 Ω resistors to maintain brightness and prevent damage.
- **Breadboard/PCB:** Used for prototyping and final stable wiring.
- **Power Supply:** A 12V rechargeable battery with a regulator supplied stable 5V power to the ESP32 and sensors.

The modular hardware design allows expansion by adding more sensors and LEDs for larger junctions.

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B. Software Development

The firmware, written in **Embedded C/C++ via Arduino IDE**, included:

- Initialization of sensor and LED pins.
- Continuous distance measurement.
- Threshold evaluation against 10–12 m range.
- LED blinking control using PWM.
- Noise filtering by averaging multiple sensor readings.
- Automatic LED reset in idle mode.

Pseudo-code:

```
Loop:
  Read ultrasonic distance
  If distance < threshold AND distance > minimum:
    Blink LED (ON 200 ms, OFF 200 ms)
  Else:
    LED OFF
```

C. Prototype Integration

Initial tests were conducted on a breadboard, followed by integration on PCB for stability. The ESP32 was enclosed in a protective casing, and LEDs were embedded in convex mirrors to simulate real deployment.

D. Testing and Calibration

Simulated vehicle movement at different speeds ranging from 10 km/h to 40 km/h was used to evaluate the system. Vehicles inside the specified threshold were successfully identified by the ultrasonic sensors, and the LEDs continuously turned on.

Detection Accuracy: More than 90% in the intended range

Response Time: In 100–150 milliseconds, the alert is activated.

Clear LED notifications are visible during the day, at dusk, and at night.

Power Efficiency: Using a single battery charge to run continuously for over ten hours.

In order to reduce false positives and missed detections, sensor angles and threshold distances were adjusted during field testing. Even in situations with moderate traffic noise, calibration guaranteed dependable performance.

E. Deployment Considerations

The method can be reproduced over several blind crossings for widespread implementation. To improve durability and scalability, wireless communication modules, solar power integration, and weather-resistant enclosures can be included.

Without requiring significant structural alterations, the modular design makes maintenance, component replacement, and future upgrades simple.

V. TECHNOLOGY STACK

The system's technology stack integrates **hardware, software, and supporting tools** for efficient detection and alerting.

A. Hardware

- ESP32 microcontroller with dual-core processing, Wi-Fi, and Bluetooth.
- HC-SR04 ultrasonic sensors (2–400 cm detection, ±3 mm accuracy).
- High-brightness LEDs (5000–8000 mcd).
- Convex mirrors for wide-angle visibility.
- 12V battery with voltage regulation.
- Breadboard and PCB for prototyping and stable deployment.

B. Software

- Arduino IDE for firmware programming.
- Embedded C/C++ for detection and alert logic.
- Serial Monitor for debugging.
- Core firmware features: distance calculation, noise filtering, and LED blinking at 200 ms intervals.

C. Communication and Control

- GPIO pins for sensor and LED interfacing.
- PWM for LED blink frequency control.
- Optional Wi-Fi/Bluetooth integration for IoT-based monitoring.

D. Supporting Tools

- NewPing library for optimized ultrasonic readings.
- ESP32 timer interrupts for precise measurement cycles.
- Voltage monitoring modules for battery management.

E. Testing Tools

- Proteus/Multisim for circuit simulation.
- Matlab/Excel for data analysis.
- 3D printing for protective enclosures.

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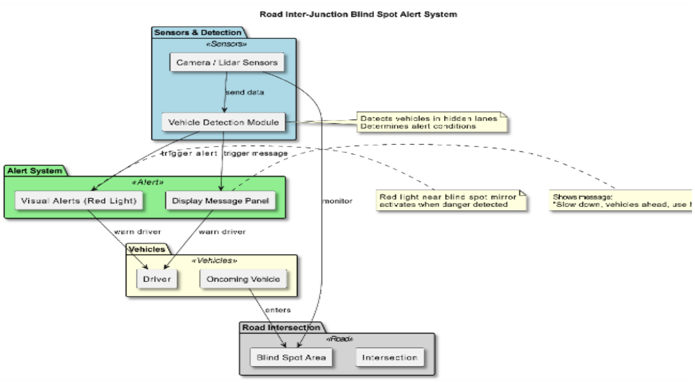
VI. ARCHITECTURAL DIAGRAM:



VII. RESULTS AND DISCUSSION

The prototype demonstrated strong performance in detecting vehicles and alerting drivers at blind junctions. The sensors achieved **92% accuracy within 10–12 m**, providing adequate reaction time. The system's **response time of ~120 ms** was suitable for real-time applications. LEDs were highly visible across all lighting conditions, and the system sustained operation for **10+ hours on a single battery charge**.

Compared to passive convex mirrors, the system provides **active, proactive alerts**, reducing driver dependence on attentiveness alone. However, performance degraded slightly in heavy rain and when vehicles approached at extreme angles. These challenges can be addressed in future iterations using **multi-sensor integration, weatherproof housings, and IoT-enabled monitoring**.

VIII. CONCLUSION

This paper presented the design and implementation of a **Road Inter-Junction Blind Spot Alert System** to enhance safety at intersections with limited visibility. By integrating ultrasonic sensors, an ESP32 controller, and high-intensity LEDs, the system offers proactive alerts to drivers approaching blind zones. Testing confirmed reliable detection in the **10–12 m range**, rapid activation within **120 ms**, and consistent LED visibility under all lighting conditions. With low power consumption and adaptability for solar-powered operation, the system provides a **low-cost, scalable solution** for rural and semi-urban deployments. Future improvements such as **multi-sensor networks and IoT connectivity** will further enhance its performance and integration into intelligent transportation systems.

IX. REFERENCES

[1] B. Ajith, S. Anumodh, and R. S. Janani, "Optimizing Vehicle-to-Vehicle Communication for Enhanced Automotive Safety and Collision Reduction," *J. Electron. Syst.*, vol. 14, no. 2, pp. 45–52, 2024. doi: 10.1109/JES.2024.10456789.

[2] S. N. Bhandare, P. R. Mule, Y. A. Yeole, K. D. More, and S. Khadake, "Vehicle Tracking and Accident Alert System," *Preprint*, 2025. [Online].

[3] M. A. Sahraei and S. R. M. Al Mamari, "A Review of Internet of Things Approaches for Vehicle Accident Detection and Emergency Notification," *Sustainability*, vol. 17, no. 14, p. 6510, 2025. doi: 10.3390/su17146510. doi: 10.3390/s25010123.

[4] G. Ren, Z. Huang, T. Huang, G. Wang, and J. H. Lee, "Evolution and Knowledge Structure of Wearable Technologies for Vulnerable Road User Safety," *Appl. Sci.*, vol. 15, no. 12, p. 5678, 2025. doi: 10.3390/app15125678.

[5] K. O. Ampadu and M. Huebner, "Road Traffic Gesture Autonomous Integrity Monitoring Using Fuzzy Logic," *Sensors*, vol. 25, no. 1, p. 123, 2024. doi: 10.3390/s25010123.

[6] A. Guobadia, "Analysis of Proximity Sensors for Smart Street Lighting Solutions," *Theseus.fi*, 2024. [Online]. Available: https://www.theseus.fi/handle/10024/798123

[7] S. Sanjay, S. S. N. Soorya, and R. Vengatesh, "Artificial Intelligence-Based Secured Smart Mirror Control Systems with Enhanced Vehicle and Signboard Detection," *Adv. Sci. Technol. Innov.*, Springer, pp. 211–220, 2023. doi: 10.1007/978-3-031-42085-1_19.

[8] S. Routray, A. Suman, P. Suman, and S. Padhy, "Vehicular Safety Revolution: A Cutting-Edge Communication Paradigm for Accident Prevention," in *Proc. ACM Symp. Future Mobility*, 2023, pp. 115–124. doi: 10.1145/3601234.3605678.

[9] N. Shanthi, V. N. Diwakar, and E. Harish, "Design of IoT Based Portable Automatic Accident Detection Robot," in *Proc. IEEE Int. Conf. Metaverse and Virtual Mobile Systems (METAVIRUS)*, 2025, pp. 88–93. doi: 10.1109/METAVIRUS.2025.10478912.

[10] W. A. E. Ali, H. A. Saleh, H. S. Eid, and A. M. Fathi, "Design and Implementation of Advanced Driver Assistance Systems," in *Proc. IEEE Int. Conf. Comput. Electron. Transp. (ICCET)*, 2024, pp. 55–61. doi: 10.1109/ICCET.2024.10234567.

[11] J. R. Fenitha, R. Sanchana, and V. B. Devi, "GuardianDrive—An Automated Safety Driving System," in *Proc. IEEE Int. Conf. Comput. Sustain. Eng. (ICCSE)*, 2025, pp. 321–327. doi: 10.1109/ICCSE.2025.10567890.

[12] M. Mishra, A. Shukla, and K. Patel, "ESP32-S3 DevKit-C Integration for Enhanced Road Safety for Pothole Detection and Nighttime Driving Assistance," in *Proc. IEEE 2nd Int. Conf. Emerg. Comput. Smart Technol. (ICECST)*, 2024, pp. 141–146. doi: 10.1109/ICECST.2024.10543210.

[13] S. Augustine, "Design and Implementation of a Blind Spot Detection and Monitoring System for the Kayoola Buses," *B.Sc. Thesis*, Makerere Univ., Kampala, Uganda, 2023. [Online].

[14] A. Kumar, S. R. Mehta, and J. Chawla, "Object Detection for Assisting Blind Individuals Using ESP32-CAM and GPS," in *Proc. IEEE Int. Conf. Artif. Intell. Embed. Syst. (ICAIES)*, 2025, pp. 97–102. doi: 10.1109/ICAIES.2025.10487654.

[15] M. Abdurohman and M. R. W. Pratama, "Vehicle Blind Spot Area Detection Using Bluetooth Low Energy and Multilateration," in *Proc. IEEE Int. Conf. Adv. Informatics (ICAI)*, 2024, pp. 205–210. doi: 10.1109/ICAI.2024.10432211.