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PRISM: Preventive Road Safety and Intelligent Sleep Monitoring System, a Low-Cost Solution for Driver Safety

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Abstract

Road accidents are often caused by either driver drowsiness resulting from prolonged driving hours and nighttime driving, or the inability to detect sudden obstacles. To address these challenges, the paper presents PRISM (Preventive Road Safety and Intelligent Sleep Monitoring System), which is a low-cost IoT-based device designed to reduce the risk of fatal road accidents. The project integrates an ATmega328P microcontroller, an eye blink sensor for drowsiness detection, and an ultrasonic sensor for obstacle identification, along with dedicated buzzers for generating real-time alerts. The eye blink sensor continuously monitors the movement of the driver□s eye and detects prolonged closure of the eyes; when detected, the buzzer generates audible alerts for the driver. Simultaneously, the ultrasonic obstacle sensor monitors the vehicle's surroundings, and if it detects an obstacle within its operating range, it immediately warns the driver. The system offers dual-layer safety mechanisms while keeping it affordable, accurate, and easy to install in existing vehicles, unlike the advanced safety systems, which operate through expensive technologies such as radar, camera vision, and integration of machine learning and artificial intelligence. Overall, PRISM offers us the best solution at an economical cost and with easy installation.

Keywords: *Obstacle detection, Eye Blink Sensor, Ultrasonic Sensor, Accident Prevention, Arduino Nano, Driver Drowsiness Detection*

1. Introduction

Road accidents contribute to quite a significant number of fatalities that occur worldwide, with the inability to detect sudden obstacles and driver drowsiness being the major contributing factors. As reported by the Ministry of Road Transport and Highways (MoRTH), in India, about 4.5 lakh road accidents and more than 1.5 lakh fatalities were reported in the year of 2024. The majority of these reported accidents were caused by sudden obstacles that were not timely detected and driver fatigue due to long-distance travelling and driving at night.

The proposed project is designed to provide an affordable solution for the challenges addressed above. PRISM (Preventive Road Safety and Intelligent Sleep Monitoring System) focuses on providing real-time alerts and warnings to the driver under risky situations, thereby preventing fatal accidents. PRISM integrates multiple systems, that is an obstacle detection system, a drowsiness monitoring system plus alert system into one single platform. This solution primarily aims to reduce road accidents by continuously monitoring and detecting driver fatigue and sudden obstacles. Apart from this, PRISM also focuses on easy and low-cost deployment of the device that can be retrofitted into already existing vehicles, making it accessible to a much wider population.

2. Literature Review

Several studies have been done in the area of intelligent transportation, which could help us avoid accidents occurring due to driver fatigue and the sudden appearance of obstacles. Various ideas have been proposed for the same (Table 1).

The studies and projects discussed in the table either only focus on obstacle detection or driver drowsiness detection as separate systems. Some of the solutions, which included advanced technology such as Radar vision and integration of artificial intelligence, indeed provide high accuracy and better results, but they are very costly and highly complex to implement or integrate in existing vehicles.

Therefore, to solve all these problems, we built PRISM, which combines both the systems of drowsiness and obstacle detection, ensuring it to be cost friendly and easy to deploy and retrofit in existing vehicles.

3. Methodology

3.1 Hardware Technology

The hardware architecture of the proposed system is shown in Figure 1. It illustrates the complete circuit configuration that

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Table 1: *Review of existing related works done in the field of Obstacle and Drowsiness Detection*

Author and Year	Title	Technology Used	Key findings	Limitations
R. Syed, Ali Fathima, P. Muhammadhu, Nazari Ali, Naveen.S Dhinesh, M. Ram, Kumar, 2025	A Low-Cost IoT Solution for Real-Time Driver Drowsiness Detection using Eye-Blink Sensor [1]	IoT, eye-blink sensor, and GSM module.	This project provides a cost-effective solution for driver drowsiness detection along with alert-generating ability.	Focusing only on driver drowsiness, the obstacle detection is neglected.
A. Ambikapathy, Ayush Kumar, J. Verma, Gajendra Singh, Reena Sharma, 2021	Arduino-Based Accident Prevention Technique Using Eye Blink Sensor [2]	Arduino, Eye Blink Sensing system (EBS), and heart rate sensor.	The idea focuses on detecting driver drowsiness by monitoring the eye blink pattern of the driver and generating timely alerts to avoid accidents.	Absence of an obstacle detection system.
Vishal Jadhav, Omkar Kachare, Mujahid Shaikh, 2023	Anti-Sleep Alarm System for Vehicles [5]	Arduino, face-detecting camera, alarm system	It uses face detection techniques for monitoring driver drowsiness and sends real-time alerts to the driver to reduce fatigue-based accidents.	Costly and does not address the problem of sudden obstacle detection.
Reetu Malhotra, Vanshika, Neha, 2019	Construction of a Device for Obstacle Detection [6]	Ultrasonic sensor, Arduino	Proposes an economical solution for real-time obstacle detection and alerting the driver about the danger.	Only limited to detecting obstacles.
Bhupendra Singh, M. Kapoor, 2021	A Framework for the Generation of Obstacle Data for the Study of Obstacle Detection by Ultrasonic Sensors [8]	Ultrasonic sensors	Demonstrated successful implementation of obstacle detection and distance estimation by using ultrasonic sensors.	Only monitored obstacle detection; did not detect driver drowsiness.
X. Zhang, Mo Zhou, Peng Qiu, Yi Huang, Jun Li, 2019	Radar and vision fusion for the real-time obstacle detection and identification [12]	Millimeter-wave radar, Camera vision.	The project gives us a highly accurate and improved obstacle identification and detection system by using radar and vision cameras.	High cost and complex installation in already existing automobiles.

includes the ATmega328P-based microcontroller board, IR eye blink sensor, ultrasonic sensor, piezo buzzers, and power supply connections.

3.1.1 ATmega328P-Based Microcontroller Board

An ATmega328P-based microcontroller board (Arduino NANO) was used as the main processing unit of the proposed system. The microcontroller acquires and processes data from the connected sensors and controls the operation of the system. It consists of 14 digital pins that can be used for connecting any external components, with 8 analog pins, 6 power pins, and a reset pin on the board. It operates at a voltage of 5 V, having a clock speed of 16MHz. It is programmed using Arduino IDE software. This can be used in place of Arduino UNO, being much lighter, costing less, and similar in terms of functionality.

It is broadly used in useful projects, for example, robotic arms, collecting environmental parameters like temperature, pressure, and humidity, and IoT devices.

3.1.2 Buzzer

This buzzer works on the principle that when the pressure variation is generated by the electrical devices across a piezoelectric material, mostly a metal disc with a ceramic layer. It consists of piezo crystals between two conductors. When the potential is applied across these crystals, they push on one conductor and pull on the other. This action produces sound. It can operate in the range of voltage from 3 to 5 Volts. For connection, it has two wires, one for input and the other is grounded.

There are two types of the buzzer, namely:

- *Active Buzzer:* It consists of an internal oscillator, hence does not require any external frequency.
- *Passive Buzzer:* It needs an external frequency from the microcontroller.

Piezoelectric buzzers are commonly used in timers, alarms, or alert systems, etc.

3.1.3 Eye Blinking sensor

This sensor is used to detect eye blinks. An IR sensor is placed on the glasses, which detects whether the person□s eye is closed or not and provides the data accordingly, which is further processed as per the requirement. When the eye is closed, it gives output as high, and when open, it gives output as low. It operates on 5 V of voltage. There are three connection Input voltage, ground, and digital output pins. They are commonly used in drowsiness detection and human-computer interaction.

3.1.4 Ultrasonic sensor

This sensor has a pair of infrared transmitting and receiving sensors. It is used to detect obstacles when infrared light is reflected back to the infrared receiver when it strikes an obstacle. If the sensor encounters any object, the receiver detects this signal and gives an output of high. The detection range can be adjusted with the help of a potentiometer. It can be operated at a voltage of 3-5 V. It can detect distances of 2-30 cm. This sensor can be used in obstacle-avoiding robots, line tracking robots, etc.

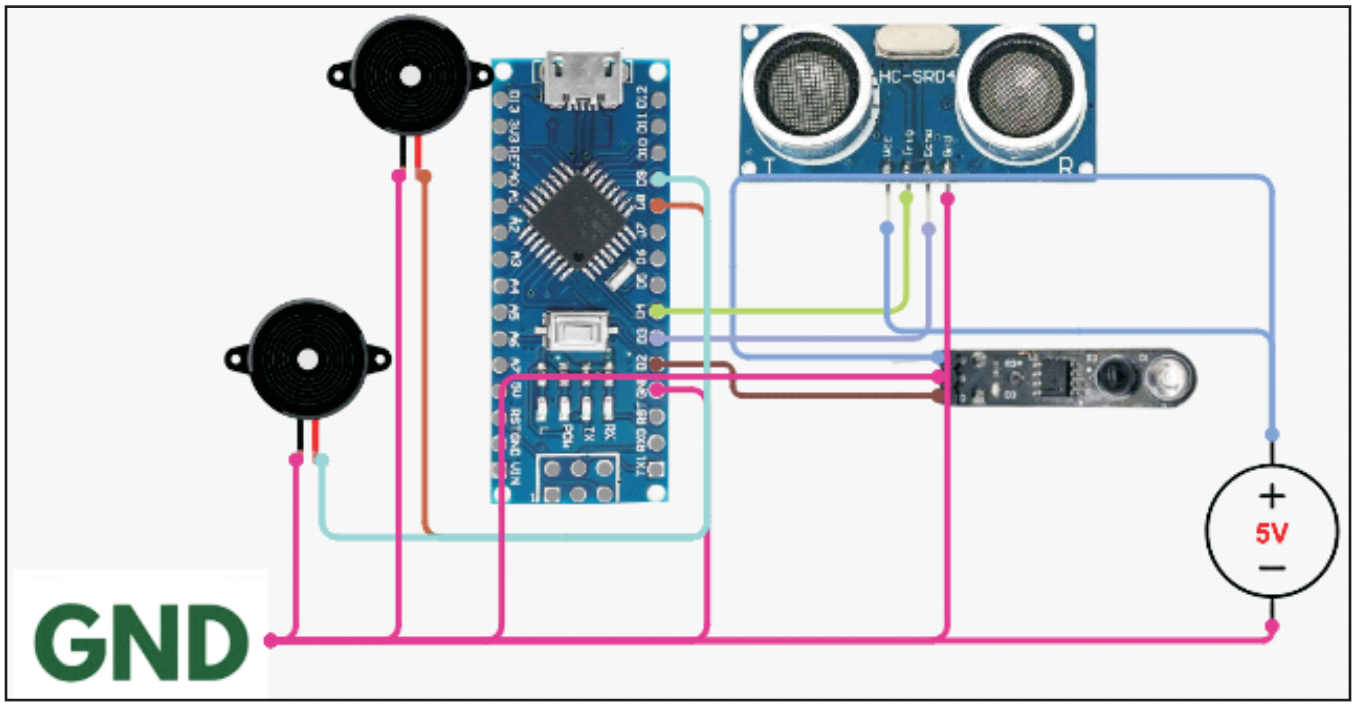


Figure 1: *Hardware Circuit Diagram of the Proposed System*

3.2 Software Technology

3.2.1 Arduino IDE

Figure 2 provides a systematic representation of the system architecture, which depicts how the system works from input to output through a microcontroller, which is programmed using the Arduino IDE. Arduino IDE provides a user-friendly platform for coding, which turns it into hardware projects. It consists of a library manager, compiler, serial monitor, and serial plotter in one application. Arduino IDE is a good choice for making any projects on Arduino or a microcontroller. It uses the concept of a sketchbook and provides a place to store your program, which can be accessed easily for future use.

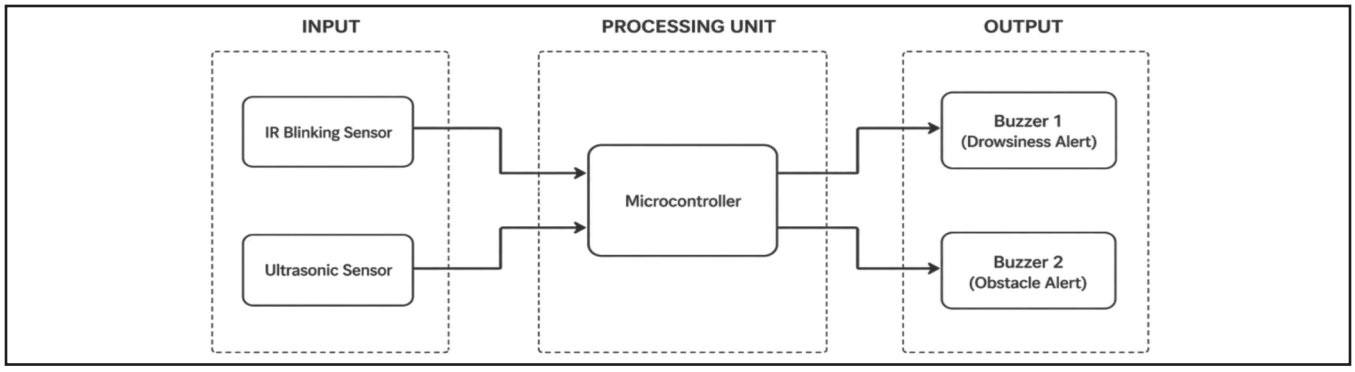


Figure 2: *Flowchart of the system architecture*

3.2.2 Procedure for Implementation

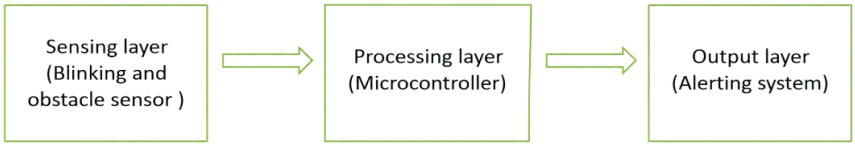


Figure 3: *Implementation of the prototype*

Figure 3 represents the procedure of implantation of how the workflow will be carried out from sensor initialization to data processing in the microcontroller, which will lead to the activation of the alerting system.

3.3 Sensing layer

3.3.1 IR blinking sensor

For sensing, the glasses on which the IR blinking sensor is placed are used by the user. Then the IR transmitter emits infrared light towards the eye. When the eye is open, it absorbs the light, and when the eyes remain closed, the infrared light is reflected back to the IR receiver then this signal is converted to an electrical signal.

3.3.2 Ultrasonic Sensor

When the sound waves come across the obstacle, the waves are reflected back. It is sensed by the transducer present in the sensor. Then it determines the distance to the target. Converting the result to the electrical signal, which can be read by the Arduino Nano.

3.3.3 Processing layer

- An ATmega328P microcontroller (Arduino Nano) was programmed using Arduino IDE software. The inputs of the obstacle IR sensor and IR blinking sensor are connected to the inputs. Signals are received by the Arduino Nano.
- For the IR blinking sensor, it detects the duration of eyes being closed. If eyes remain closed for a long time, Arduino generates alert signals.
- For the obstacle sensor, it checks the distance of the obstacle in the given range. If an obstacle is detected, it shows a warning signal.

3.3.4 Output layer

Table 2 provides a summary of the results of the buzzers when the output is set to HIGH during the detection through sensors. As the signals are sent to the processing unit, it generates the output according to the condition. Dual buzzers provide alerts whenever drowsiness or obstacles are detected

Table 2: *Output of the buzzer is taken when the output is set to HIGH*

Input	Results	Output
IR blinking sensor	Eye close - High (1) Eye open - Low (0)	Buzzer starts alerting at output high
IR obstacle sensor	Obstacle detected - High (1) Obstacle not detected - Low (0)	Buzzer starts alerting at output high

4. Result and Discussion

The PRISM prototype was successfully able to monitor and detect both driver drowsiness and obstacles present in the nearby range, up to 20 cm. The eye blink sensor detects the closing of the driver's eyes. If the closure of the eye is prolonged more than 3-5 seconds, then audible alerts are sent to the driver through a buzzer. Likewise, the obstacle detection sensor was effectively detecting obstacles in its operating range and was alerting the driver simultaneously. It has been shown in Figure 4 and Figure 5, which feature the implementation and testing of the prototype, which represents the successful working of the proposed system.

Table 3: *Experimental performance analysis of the PRISM Prototype*

Parameters	Test Condition	Observed Reading	System Response	Result
Driver's eye status	Eyes open	LOW (0)	No alert	Normal operation
Driver's eye status	Eyes closed for < 3 s	HIGH (1)	No alert	Normal blinking
Driver's eye status	Eyes closed for = 3-5 s	HIGH (1)	Buzzer activated	Drowsiness detected successfully
Obstacle distance	> 20 cm	No obstacle detected	No alert	Safe condition
Obstacle distance	15-20 cm	Obstacle detected	Buzzer activated	Warning generated
Obstacle distance	5-15 cm	Obstacle detected	Buzzer activated	Warning generated
Operating voltage	5V or 9V DC	Stable operation	All modules functional	Successful

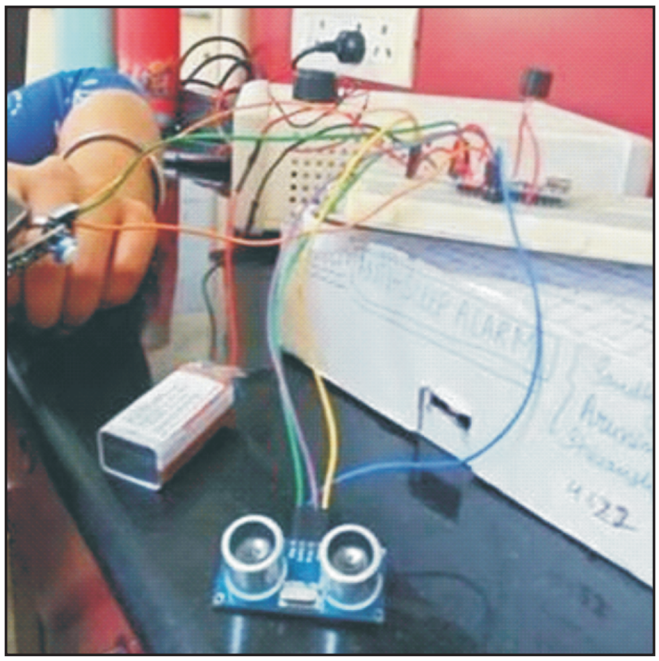


Figure 4: *Testing of circuit connections & components in the lab*



Figure 5: *Testing of the PRISM*

The experimental analysis in Table 3 highlights the performance of the PRISM prototype under various operating conditions as a dual safety mechanism, which is capable of sensing and addressing multiple accidents in real time.

Comparing PRISM to pre-existing premium vehicle safety models, it offers us a significantly lower cost solution, while maintaining the basic safety functionalities.

While PRISM successfully demonstrated real-time drowsiness and obstacle detection under laboratory conditions, certain limitations were identified and observed that could affect the performance of PRISM under a real-world environment.

Some of the limitations were as follows:

- The IR eye blink sensor can be influenced by the placement of the sensor and environmental lighting conditions, such as exposure to direct sunlight.
- The ultrasonic obstacle detecting sensor has a limited detection range of 2cm to 30 cm, and it may not be very reliable for the detection of very small obstacles or highly absorbent objects.
- Whether conditions such as heavy rainfall and dense fog can affect the sensing accuracy of the sensors.
- The current prototype of PRISM does not incorporate vehicle-to-vehicle communication and a live GPS tracking system.

Apart from this, PRISM showed strong potential to be deployed as a driver safety system in various automobiles.

5. Conclusion

The PRISM project has been successfully developed using a microcontroller-based embedded system and tested, showing effective and reliable performance. It continuously monitors the obstacles in the surroundings and the eye activity of the user and provides alert signals accordingly. This prototype can be installed in any vehicle, from a commercial fleet to a personal car. Being cost-effective, it can become an alternative for sophisticated, expensive alerting systems. This project aims to provide a safer environment, enhancing driver safety and reducing the number of accidents.

6. Future Work

- Further, developments of this project could include Vehicle-to-Vehicle (V2V) communication using advanced protocols, enabling nearby vehicles to receive alerts.
- Also, Vehicle-to-Infrastructure (V2I) communication can be integrated to communicate and notify the traffic management centre, which would further allow emergency response.
- Incorporating GPS, mobile applications, and cloud-based monitoring can enhance the effectiveness as well as the response of the system.
- This project can be enhanced by improving alert mechanisms using the SIM800L-GSM module and a high-intensity alarming system.
- By integrating advanced sensors with machine learning algorithms to avoid false alarms and simultaneously enhance the overall performance along with tracking, as well as making it effective in foggy climatic conditions.

- ESP 32 CAM board can be used for tracking eye action by facial recognition.
- LiDAR can be used for detecting small obstacles at a longer range.

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Conflict of Interest Statement

The authors declare that they have no competing financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

Ethical Declarations

The authors declare that this research does not involve human participants, animals, or any procedures requiring ethical approval. All data used in this study were obtained and processed in accordance with applicable ethical and legal guidelines.

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