

PulseGuard: A Biometric-Assisted V2V Safety System For Real-Time Accident Prevention Using Iot

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Abstract— Traffic crashes resulting from sleepy drivers, medical emergencies, and poor communication between vehicles continue to pose significant problems in today's transportation networks. PulseGuard emerges as a comprehensive safety technology that tracks driver health metrics constantly while facilitating instant vehicle-to-vehicle (V2V) messaging. Through the MAX30102 sensor, the platform monitors pulse rate and blood oxygen levels, whereas an eye-blink detector identifies signs of drowsiness. A vibration/impact detector recognizes sudden crashes. Once irregular conditions are identified, the system promptly activates local warnings and sends emergency notifications to nearby vehicles using ESP32-powered V2V communication using IoT and Python Simulation. This shortens response times and helps avoid multi-vehicle pile-ups. Testing outcomes reveal enhanced precision in biological monitoring and swift alert distribution, highlighting PulseGuard's promise as a cost-effective, expandable, and reliable crash-prevention solution for intelligent transportation systems.

Keywords — PulseGuard system, pulse rate monitoring, SpO₂ detection, drowsiness detection, V2V communication, IoT safety system, accident prevention, ESP32 wireless alerts.

I. INTRODUCTION

Road accidents caused by driver fatigue, health issues, and delayed response remain a major challenge in modern transportation systems. Existing vehicle safety technologies mainly focus on environmental sensing and often ignore the driver's physical condition, which plays a critical role in safe driving. To address this gap, PulseGuard integrates real-time biometric monitoring with intelligent vehicle-to-vehicle (V2V) communication. The system continuously tracks heart rate, oxygen saturation, and eye-blink patterns using the MAX30102 and IR-based sensors, while a vibration module detects sudden impacts. When an abnormal vital sign or accident risk is detected, the system immediately triggers alerts inside the vehicle and transmits warning signals to nearby vehicles through ESP32-based wireless communication. This unified approach enhances situational awareness, reduces reaction time, and provides a cost-effective solution for improving road safety and preventing collision-related injuries.

II. PROBLEM STATEMENT

- (1) Process based: Traditional vehicle safety systems rely mainly on external sensors such as ultrasonic, radar, and camera modules, which monitor only the surrounding environment and not the driver's internal condition. These systems often fail to detect health-related issues like abnormal pulse rate, reduced oxygen saturation, or drowsiness. The PulseGuard system improves this process by integrating biometric sensing (MAX30102, eye-blink IR sensor) with intelligent V2V communication, enabling early detection of physiological abnormalities and providing immediate safety alerts.
- (2) Operator based: Most existing driver monitoring systems require manual intervention or depend heavily on constant camera-based monitoring, which consumes continuous power and may not perform reliably in low-light or high-vibration scenarios. To overcome these limitations, PulseGuard uses low-power biometric sensors and ESP32-based wireless communication to autonomously detect driver fatigue, pulse irregularities, and emergency conditions. This reduces operator

dependency and ensures automatic warning transmission to nearby vehicles without requiring driver input.

III. DESIGN AND CALCULATIONS

Graph-Theoretic Models for VANETs

Graph theory provides a powerful formal framework for modeling Vehicular Ad-Hoc Networks (VANETs). In this representation, each vehicle is treated as a node within a dynamic network, while communication links between vehicles are expressed as edges.

- Nodes (Φ)
- Each vehicle in the network is represented as a node. Edges (Ψ)
- A direct communication link between two vehicles i and j is modeled as an edge denoted by the pair (i,j) . Edge Weights (Θ)

Numerical weights may be assigned to edges to represent different interaction characteristics, such as: Distance-based weight:

$$\omega_{ij} = d_{ij}$$

Binary connectivity weight:

$$\omega_{ij} = \delta_{ij}$$

These weights help capture communication capability, proximity, and network topology dynamics.

Extended Car-Following Model with V2V Communication

Traditional car-following models describe how a following vehicle adjusts its acceleration based on the relative speed and distance of the lead vehicle. In VANET-enabled systems, these models are extended to incorporate real-time information received through Vehicle-to-Vehicle (V2V) communication.

The acceleration of a following vehicle

n is influenced not only by speed differences but also by acceleration data received from the lead vehicle $n+1$.

Model Equation

$$a_n(t + \tau) = \lambda [v_{n+1}(t) - v_n(t)] + \mu [a_{n+1}(t) - a_n(t)]$$

Where:

- $A_n(t)$: Acceleration of vehicle n at time t .
- τ : Driver reaction time.
- λ, μ : Sensitivity parameters capturing the influence of speed differences and acceleration differences, respectively.

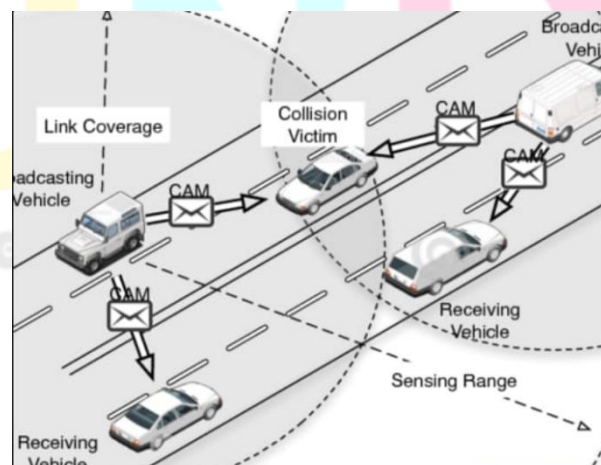


Figure 1 System Model of Vehicle-to-Vehicle (V2V) Communication and Cooperative Awareness Messaging (CAM) Exchange

Heart Rate Calculation (MAX30102 Sensor): The MAX30102 provides peak intervals of detected pulses. The heart rate is calculated using:

$$HR = \frac{60}{T}$$

Where T is the time between two pulse peaks.

SpO₂ Calculation

$$SpO_2 = A - (B \times R)$$

Where R is the ratio of red and IR absorption.

Communication Delay Calculation

Equation:

$$T_{total} = T_{tx} + T_{proc} + T_{rx}$$

This is the total V2V alert time.

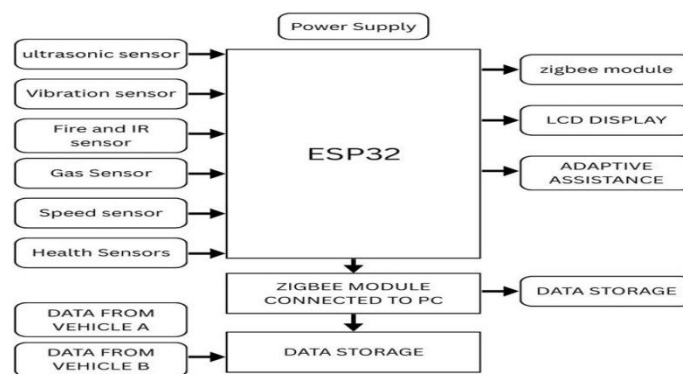


Figure 2: Block Diagram of the System

IV. ADVANCEMENT

- Implementation of real-time V2V communication using ESP32 to transmit alerts to surrounding vehicles, reducing reaction time and preventing chain-reaction accidents.
- Integration of MAX30102 sensor to continuously monitor heart rate and oxygen saturation, enabling early detection of driver health issues.
- Use of an eye-blink sensor to detect drowsiness, providing timely alerts to prevent accidents caused by driver fatigue.
- Incorporation of vibration/impact sensor to identify sudden collisions, triggering immediate local alarms for the driver.
- Development of an integrated system combining physiological monitoring and V2V communication, improving overall safety, scalability, and efficiency for smart mobility applications.

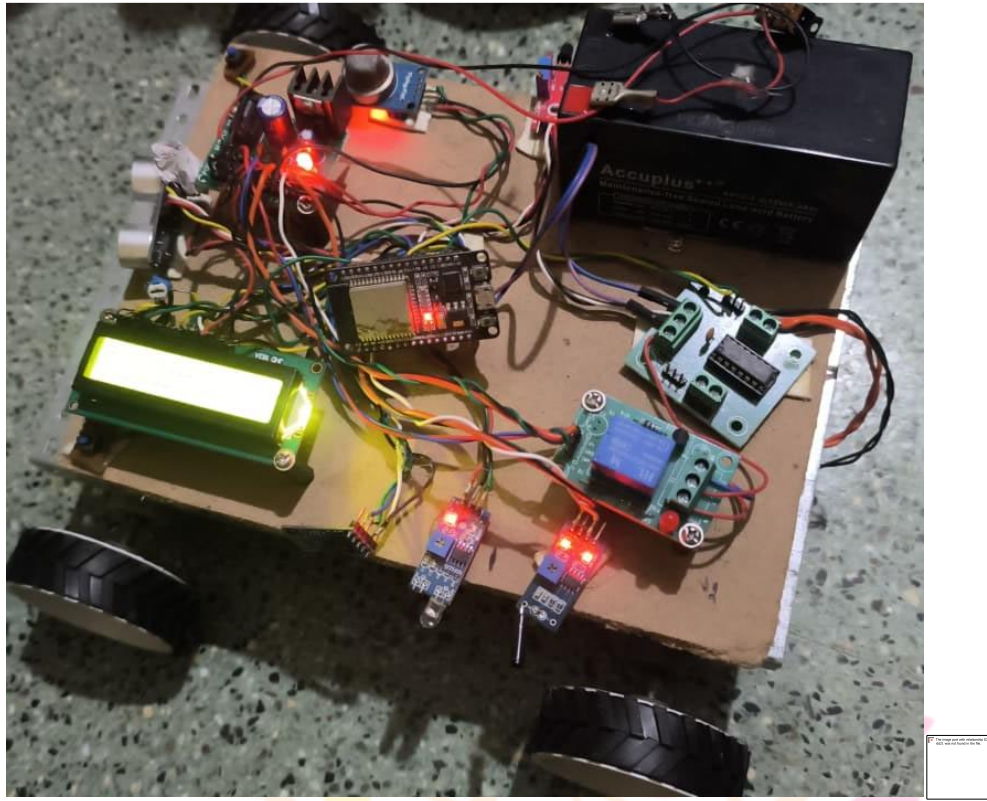


Figure 3: Final Automation system

V. RESULT AND GRAPHS

1) Graph for Visualization of System Behaviour

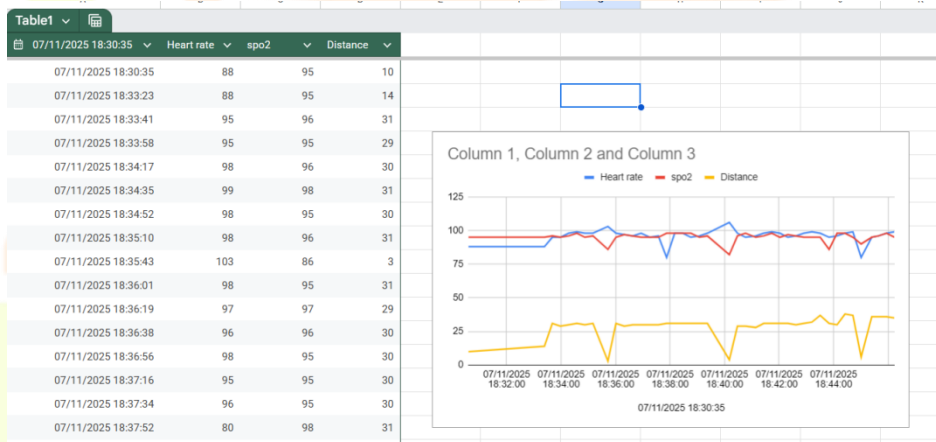


Figure 4: Graph of Distance, Heart Rate and SpO2

Research Through Innovation

2) Machine Learning Model for Heart Disease Prediction

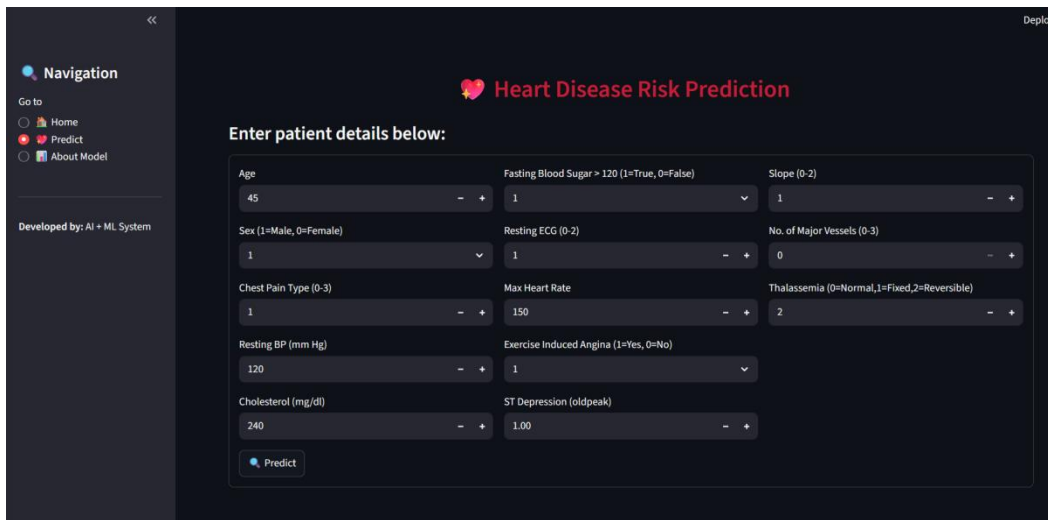


Figure 4: Website for Heart Disease Prediction using Machine Learning

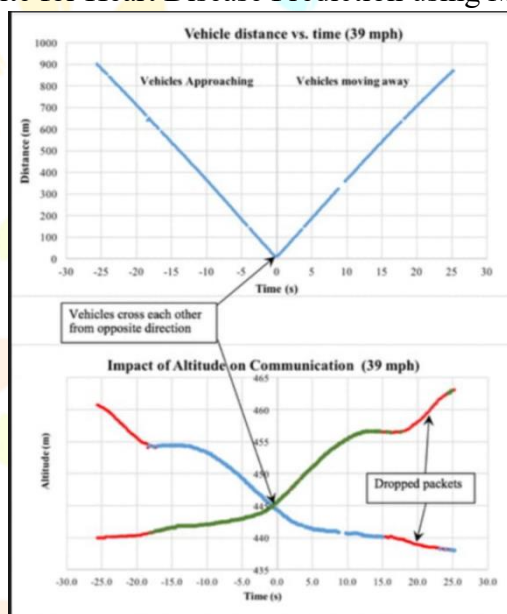


Figure 5: Variation of Inter-Vehicle Distance and Altitude Effects on V2V Communication Reliability During Opposite-Direction Crossing

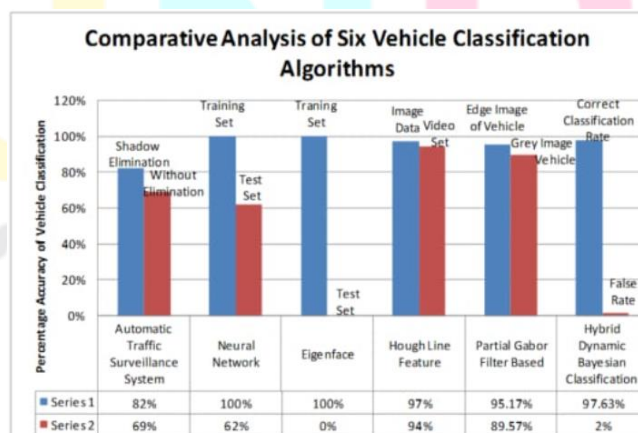


Figure 6: Comparative Analysis of Six Vehicles Classification Algorithms

VI. CONCLUSION

PulseGuard-V2X effectively enhances road safety by enabling real-time, cooperative communication between vehicles for early hazard detection. Its integration of sensor fusion, AI-based prediction, and low-latency V2V messaging significantly reduces collision risks. Overall, the system demonstrates a scalable and reliable approach toward achieving safer, smarter, and fully connected transportation networks.

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