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VANET-Based Blind Curve and Landslide Risk Warning System

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Abstract

Blind curves and landslide-prone roads present significant safety risks because drivers may have limited visibility of approaching vehicles and road hazards. This paper proposes a low-cost VANET-based blind curve and landslide risk warning system using two On-Board Units (OBUs) and one Roadside Unit (RSU). One OBU is the functional vehicle unit while the second is used for demonstration. The functional OBU usesESP32, BO DC geared motors, motor driver, GPS and an ultrasonic sensor to obtain vehicle information. The RSU monitors environmental conditions using rain, soil-moisture, and MPU6050 sensors. ESP-NOW is used as the wireless communication mechanism between the ESP32 nodes. The RSU analyses vehicle and environmental information to identify potential blind-curve collision and landslide-risk conditions. When a hazardous condition is detected, a warning is transmitted to the OBUs and presented through an Organic Light-Emitting Diode (OLED) display and buzzer. The proposed system provides a low-cost physical prototype for demonstrating real-time vehicle-to-roadside hazard communication and driver warning.

1. Introduction

Road transportation plays an important role in everyday life, but blind curves, sharp turns, hilly roads, and narrow road sections can create safety risks due to limited visibility. At blind curves, drivers may not identify approaching vehicles or obstacles in advance. In hilly areas, heavy rainfall, soil instability, and ground vibration can also increase landslide risks. To address these challenges, the proposed system uses a Vehicular Ad Hoc Network (VANET) concept for early warning. An ESP32-based vehicle node consists of an ultrasonic sensor, BO DC geared motors, OLED display, buzzer, and Bluetooth control. The ultrasonic sensor detects obstacles and measures the distance, while the motors control vehicle movement. The vehicle communicates with the Roadside Unit (RSU) using ESP-NOW. The RSU monitors vibration, soil condition, and rainfall status and sends a warning to the vehicle when a critical condition is detected. The vehicle controller processes both obstacle and environmental alert information. When an obstacle reaches the critical distance or a critical environmental alert is received, the system blocks forward movement and activates the buzzer and OLED display. Thus, the proposed system provides a low-cost physical prototype for

blind-curve vehicle safety and landslide-risk warning, with scope for future enhancement using GPS and additional sensors.

2. Literature Survey

"Toward an Effective Risk-Conscious and Collaborative Vehicular Collision Avoidance System. "Provides the foundation for risk-based collision warning using vehicle speed, relative distance, and movement information, which are useful for detecting collision risk at blind curves [1]. "Decision Making Module for Cooperative Collision Warning Systems Using Vehicular Ad-Hoc Networks". Supports the decision-making and warning mechanism of the proposed system, where received vehicle information is processed to determine whether a warning is required [2]. "Internet of Things: Vehicle Collision Detection and Avoidance in a VANET Environment". Supports the use of IoT sensors and wireless VANET communication for vehicle collision detection, similar to the ESP32-based hardware in the proposed project [3]. "Collision Avoidance in V2X Communication Networks". Supports reliable V2V/V2X communication, which is essential for transmitting collision-warning information between vehicles before they reach a blind curve[4]."Multiple Channel Access using Deep Reinforcement Learning for Congested Vehicular Networks" Addresses communication congestion and packet collisions in VANETs, supporting reliable transmission of safety messages when multiple vehicles are present[5]."A Forward Collision Warning System Using Driving Intention Recognition of the Front Vehicle and V2V Communication" use V2V communication to exchange vehicle information and provide early collision warnings[6]."2CAP: A Novel Curve Crash Avoidance Protocol to Handle Curve Crashes in Vehicular Ad-Hoc Network". The system uses vehicle and road information to identify dangerous conditions on curved roads and provide early warnings to approaching vehicles. This work is closely related to the proposed project because it focuses on preventing collisions at blind/curved roads through vehicle communication and risk detection [7].

3. Proposed System

The proposed system is a VANET-based Blind Curve and Landslide Risk Warning System for improving vehicle safety on blind curves and hilly roads. It consists of one Roadside Unit (RSU) and two On-Board Units (OBUs). One OBU is the functional vehicle unit, while the second OBU is used for demonstration. The functional OBU uses an ESP32, ultrasonic sensor, BO DC geared motors, motor driver, OLED, buzzer, and Bluetooth. The ultrasonic sensor measures obstacle distance and classifies it as NORMAL, MEDIUM, or CRITICAL. The motors control vehicle movement, while the OLED and buzzer provide warnings. The RSU monitors vibration, soil condition, and rainfall and sends environmental alerts to the functional OBU through ESP-NOW. If an obstacle or environmental condition becomes critical, the vehicle blocks forward movement and activates the warning system. Thus, the proposed system provides a low-cost physical prototype for blind-curve safety, wireless hazard communication, and landslide-risk warning.

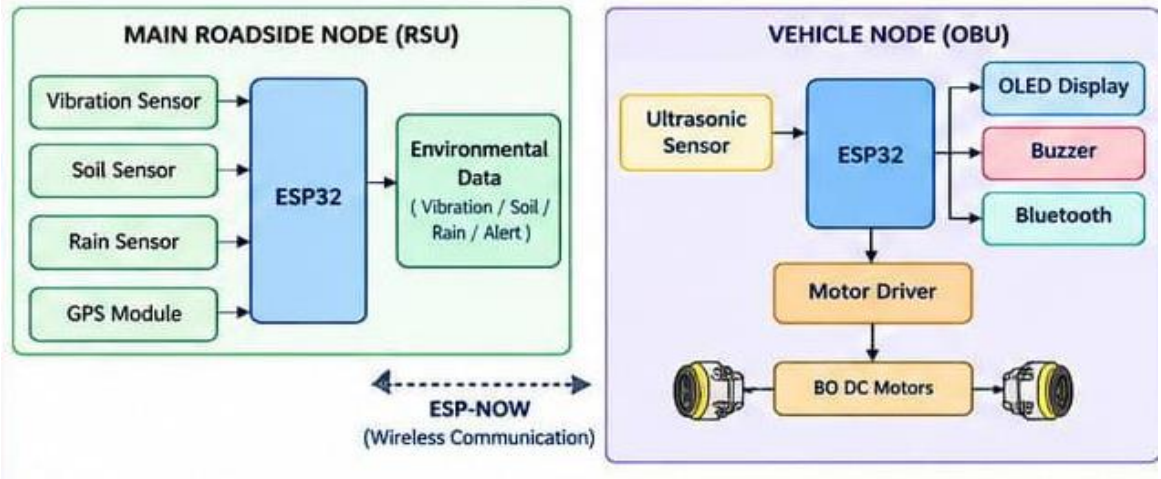


Figure 1 Overall Proposed System

4. Key Features

- Real-time blind-curve collision warning.
- Vehicle speed monitoring.
- GPS-based vehicle location.
- OBU–RSU wireless communication.
- ESP-NOW communication without internet.
- Environmental hazard monitoring.
- Landslide risk warning.
- Audible and visual driver alerts.
- Low-cost ESP32-based implementation.
- Suitable for accident-prone and hilly road sections

5. Methodology

5.1. Circuit Diagram

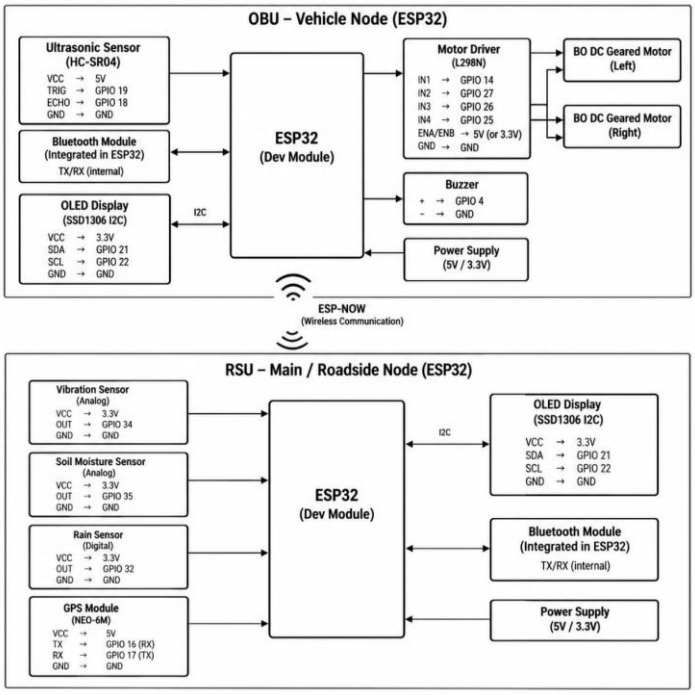


Figure 2 Circuit Diagram

5.2. Vehicle Distance Detection

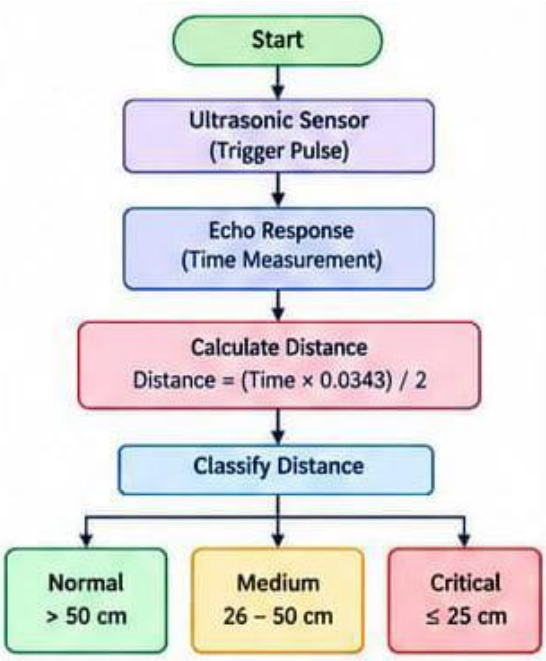


Figure 3 Vehicle Distance Detection

An ultrasonic sensor is used to measure the distance between the vehicle and an obstacle. The ESP32 generates a trigger pulse and measures the echo response from the ultrasonic sensor. The distance is calculated using:

Distance = (Time × 0.0343) / 2

5.3. Obstacle Detection

The ultrasonic sensor detects obstacles in front of the vehicle. When the measured distance is less than or equal to 25 cm, the system identifies the condition as critical. If the vehicle is moving forward during a critical obstacle condition, the ESP32 immediately stops the motor. Forward movement is also blocked until the obstacle condition becomes safe. The system therefore prevents the vehicle from continuing forward when an obstacle is detected within the critical distance.

5.4. Environmental Risk Detection

The main roadside node monitors environmental parameters such as vibration, soil condition, and rainfall. The processed environmental information is transmitted to the vehicle node through ESP-NOW. The vehicle receives the overall environmental alert status. The alert can be classified as NORMAL, MEDIUM, or CRITICAL. When the received overall alert becomes CRITICAL, the vehicle blocks forward movement. Figure 4 shows Environmental Risk Warning and Alert Flow

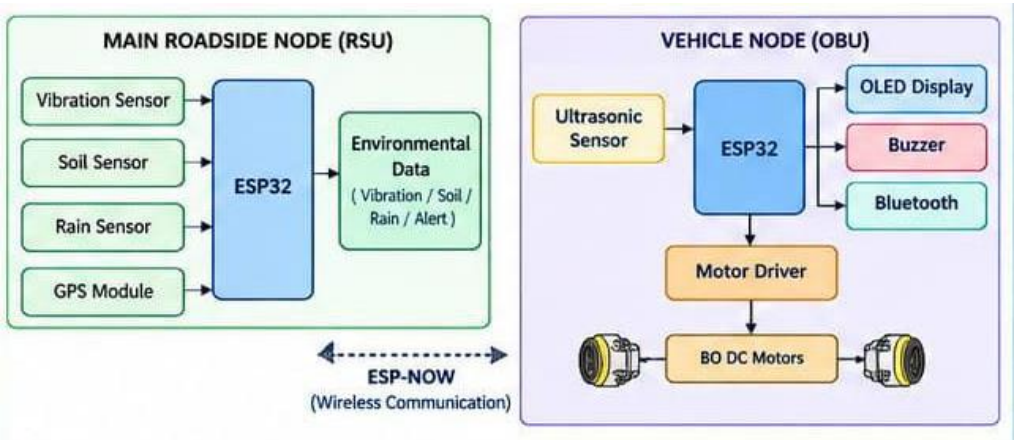


Figure 4 Environmental Risk Warning and Alert Flow

5.5. OBU–RSU Communication

ESP-NOW is used for communication between the vehicle node and the main roadside node. The ESP32 operates in Wi-Fi station mode for ESP-NOW communication. The vehicle transmits its data approximately once every one second. Figure 5 shows ESP_NOW Communication

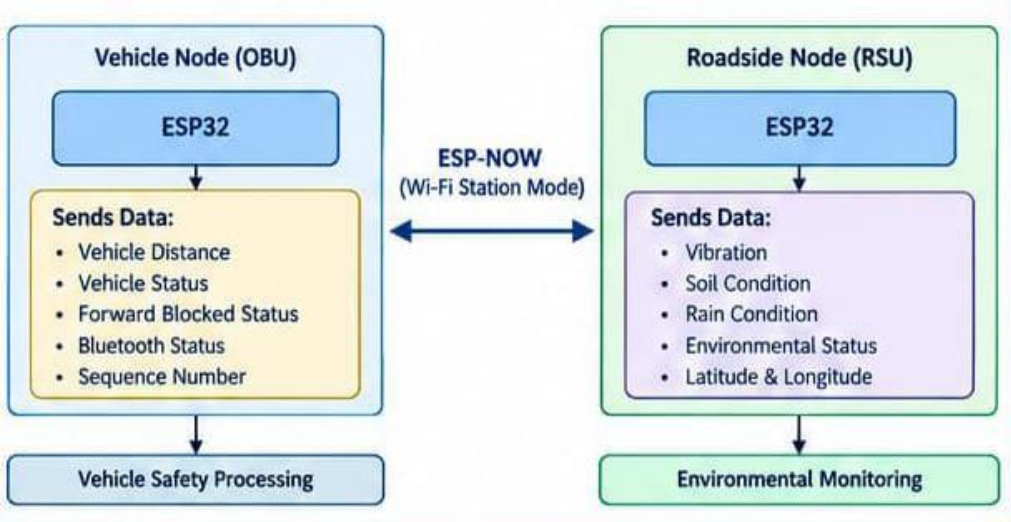


Figure 5 ESP_NOW Communication

5.6. Safety Alert and Motor Control

The vehicle can be controlled using Bluetooth commands. The available commands are Forward, Backward, Left, Right, and Stop.Before forward movement, the ESP32 checks the obstacle distance and environmental alert status.If the obstacle distance is critical or the environmental alert is critical, forward movement is blocked. The motor control is performed using four control pins connected to the motor driver. The system supports forward, backward, left, right, and stop operations.

6. Implementation

6.1. Hardware



Figure 6 Hardware

6.2. ESP32 Vehicle Node

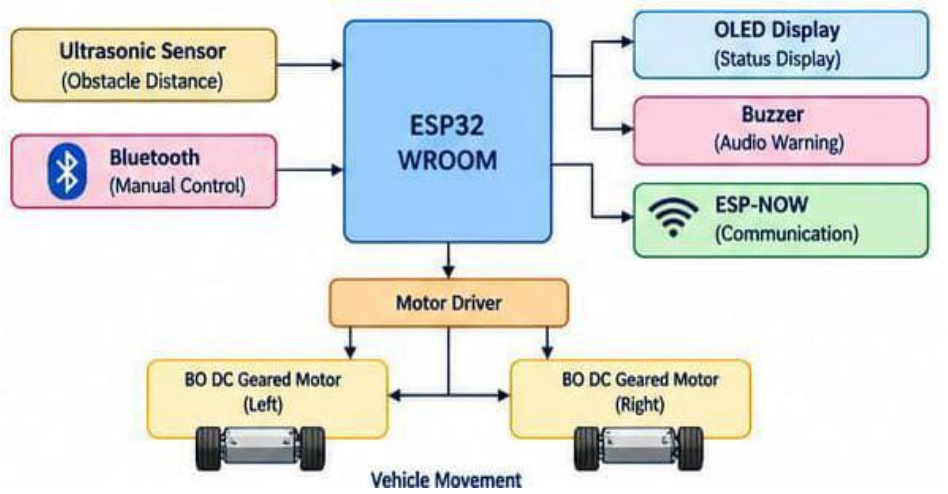


Figure 7 Vehicle Node

The ESP32 acts as the main controller of the vehicle node. It receives data from the ultrasonic sensor, controls the vehicle motors through the motor driver, updates the OLED display, and manages communication with the main roadside node using ESP-NOW. It provides the central processing and communication functions required for the prototype.

6.3. RSU

The Roadside Unit is installed near the blind curve. It receives data from multiple OBUs and processes the information to identify collision risks. The RSU also receives data from environmental sensors and generates appropriate warning messages. The RSU acts as the central monitoring and warning unit for the selected road section.

6.4. GPS

The GPS module provides latitude and longitude information for each vehicle. This information is used to identify the vehicle's position relative to the blind curve and other approaching vehicles.

6.5. Ultrasonic Sensor

The ultrasonic sensor is used to measure the distance between the vehicle and nearby obstacles. It sends ultrasonic waves and calculates the distance based on the returning echo. When an obstacle is detected within the predefined threshold distance, the ESP32 can provide a warning through the buzzer and OLED display.

6.6. BO DC Geared Motor

BO DC geared motors are used to provide movement to the prototype vehicle. The gear mechanism provides suitable speed and torque for the robot car. The motors allow the vehicle to move forward, backward, left, and right according to the control commands.

6.7. Motor Driver

The motor driver is used to control the direction and operation of the BO DC geared motors. Since the ESP32 cannot directly supply the required current to the motors, the motor driver acts as an interface between the ESP32 and motors. It receives control

signals from the ESP32 and drives the motors accordingly.

6.8. OLED Display

The OLED display provides visual information to the vehicle operator. It can display the measured obstacle distance, warning messages, vehicle status, and environmental or risk information received from the main node. This helps the user understand the current condition of the vehicle and road.

6.9. ESP-NOW

ESP-NOW is used for wireless communication between the vehicle node and the main roadside node.allows warning information and status data to be exchanged without requiring a Wi-Fi router or internet connection. In the prototype, ESP-NOW provides the communication link required for the VANET-based warning system.

7. Results

The prototype successfully demonstrates ESP32-based vehicle safety and environmental warning using ESP-NOW. The ultrasonic sensor detects obstacles and classifies them as NORMAL, MEDIUM, or CRITICAL. At ≤25 cm,the vehicle stops. Critical environmental alerts also block forward movement, while the OLED and buzzer provide warnings. Bluetooth enables manual vehicle control

Table 1 System Response Under Different Conditions

Parameters	Condition/ Threshold	System Response
Obstacle distance	>50 cm	Normal Movement
Obstacle distance	25-50 cm	Buzzer warning
Obstacle distance	<= 25 cm	Vehicle stop
Environment Alert	Normal	Vehicle movement allowed
Environment Alert	Critical	Forward Movement blocked
ESP-NOW comm	Alert received	Warning Displayed on OLED

7.1. Vehicle Node(OBU)& Road Side Unit(RSU)

7.1.1. Earth Vehicle (Normal)



Figure 8 Earth Vehicle (Normal)

7.1.2. Earth Alert (Normal)



Figure 9 Earth Alert (Normal)

7.1.3. Earth Vehicle (Medium)



Figure 10 Earth Vehicle (Medium)

7.1.4. Earth Alert (Medium)



Figure 11 Earth Alert (Medium)

7.1.5. Earth Vehicle (Critical)

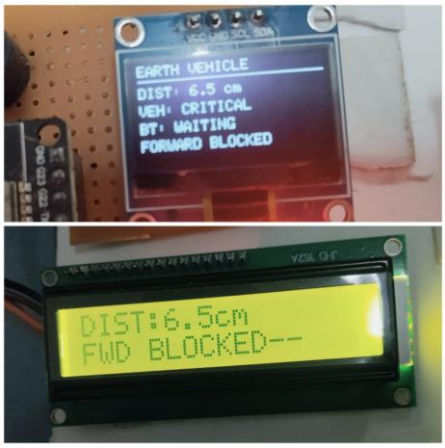


Figure 12 Earth Vehicle (Critical)

7.1.6. Earth Alert (Critical)

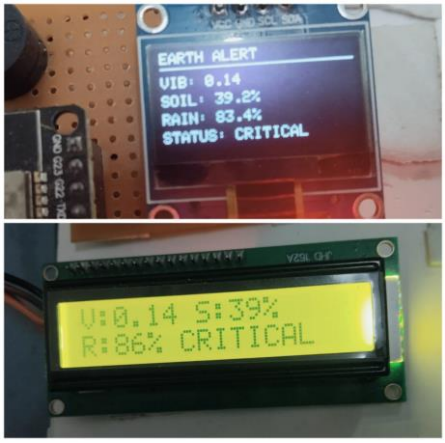


Figure 13 Earth Alert (Critical)

7.2. GPS Location

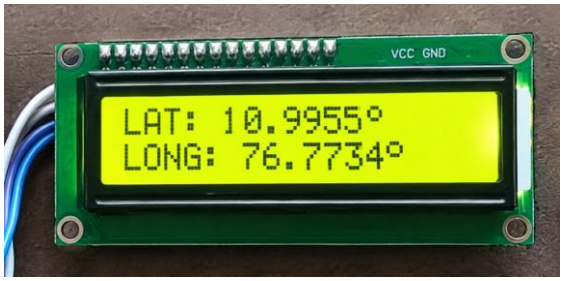


Figure 14 GPS Location

Conclusion

The proposed VANET-based Blind Curve and Landslide Risk Warning System successfully demonstrates a low-cost ESP32-based vehicle safety prototype. The system uses an ultrasonic sensor for obstacle distance detection and ESP-NOW for communication between the vehicle node and the main roadside node.The vehicle responds to predefined distance thresholds and environmental alert conditions. Critical conditions block forward movement and activate the warning mechanism using a buzzer and OLEDdisplay.Bluetooth communication also provides manual control of the vehicle. The prototype demonstrates how vehicle-side obstacle detection and roadside environmental monitoring can be integrated to provide an additional safety mechanism for blind curves and landslide-prone areas.

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