

Curveyard -A Hairpin Bend Accident Prevention System in Realtime

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Abstract— This project shows a real-time accident prevention system that uses artificial intelligence, GPS, sensors, and cloud connectivity to make curvy roads and hairpin bends safer. Due to poor visibility, fast-moving cars, and turns that are hard to predict, curvy roads and sharp hairpin bends are known to cause a lot of accidents. To fix this, the system uses a camera on the car to constantly record the road around it. Image processing techniques and AI models then look at the live feed to find curves, sharp turns, and other dangerous situations. The central processing unit is a Raspberry Pi that runs light AI algorithms that check the road's curvature and the vehicle's speed in real time. The GPS module gives you the exact location and speed data, which lets the system know when the car is getting close to a dangerous turn. The system tells the driver right away to slow down or do what needs to be done if it sees a risk. Also, all relevant data is sent to a cloud database so it can be monitored, analyzed, and improved in the future. This method is a smart, low-cost way to make roads safer and cut down on accidents on difficult terrain.

Keywords— *AI Detection, Cloud Monitoring, Road Safety, Sensor Integration, and Vehicle Classification are some of the keywords.*

INTRODUCTION

Road accidents in hilly areas are still a major threat to traffic safety in India, especially on roads with sharp turns and hairpin bends. Even though these road features are necessary for going up and down steep

hills, they make it hard for drivers to see and require them to be very careful with their speed and handling. Because of this, they are now well-known places where big car accidents happen. The Ministry of Road Transport and Highways (MORTH) of the Government of India released official statistics that show how serious the problem is. They said that in 2023 alone, almost 1.68 lakh people died and about 4.43 lakh were injured in road accidents across the country. A considerable portion of these tragedies occurred on hilly roads, especially at sections with sharp turns and blind hairpin bends, which show how dangerous it is for drivers and passengers to be in the mountains. These numbers not only show how big the problem is, but they also show how important it is to figure out what causes these accidents to happen over and over again. Mountain roads are very important for connecting remote villages and making it easier for tourists to get around hill stations like Himachal Pradesh, Uttarakhand, Sikkim, and the Nilgiris. Tamil Nadu and the Western Ghats in Kerala. However, even though highway engineering is getting better all the time and hill roads are getting wider, hairpin bends are still one of the hardest things for road users to deal with. Drivers often have trouble judging how much space they need to turn safely because of how sharply they curve. The challenge is made worse by steep slopes that put extra stress on braking systems, especially when going downhill. Fog, heavy rain, landslides, and low light are all examples of weather that can make these areas even harder to see. Many tourists who drive don't have much experience driving in the mountains, and they often don't know how to handle steep slopes and sudden turns, which leads to accidents. All of these things together add up to high

accident rates during vacation seasons when there are a lot more tourist cars on the road, making the beautiful hill roads more dangerous.

I. LITERATURE SURVEY

This literature review concentrates on recent developments in accident prevention systems for hairpin bend roads. M. Poongothai and Gokulkathirvel [1] found that bad visibility and not being able to talk to other cars were two of the main reasons why accidents happen in hilly areas. They suggested an IoT-based system that uses ultrasonic sensors and NodeMCU with ESP-NOW to find cars and send alerts in real time, even when there is no internet connection. Their results showed that the system does a good job of warning drivers about cars coming up behind them, which gives them more time to react and lowers the risk of accidents. This study shows how important low-cost IoT solutions are for making roads safer, especially in remote areas where traditional safety measures don't work as well. The research in [2] elucidates that inadequate visibility on curved and mountainous roads heightens the likelihood of vehicular collisions. The authors suggest a real-time warning system that uses CCTV and electronic displays on the side of the road to warn drivers about cars that are coming up behind them. This makes drivers more aware and helps stop head-on collisions. But the system is expensive and hard to set up in hilly areas that are far away because it needs maintenance and power. [3] Srikanth et al. (2024) say that blind curves and bad visibility are two of the most important Reasons for accidents at hairpin bends. They suggest an alert system based on a microcontroller that uses IR sensors and LED lights to find and warn drivers of cars coming up behind them. The system is cheap and helps drivers be more aware and react faster, especially in hilly areas. But things like dust and bad weather can make it work worse. [4] Amit Kumar Goel et al. (2024) found that bad visibility at hairpin turns is a big reason why head-on collisions happen in hilly areas. The authors suggest a vehicle detection system that uses the Internet of Things (IoT) and a Raspberry Pi with ultrasonic sensors to find cars that are coming toward it. The system lets drivers know through LED and LCD lights, which helps them take the right steps at the right time. The

system works well in real time to warn drivers and make them more aware of their surroundings, which makes it a cost-effective way to avoid accidents. But the performance might be affected by things like rain, fog, and dust, which can make the sensors less accurate and less reliable overall [5] The study says that bad visibility and high speed are the main causes of accidents at hairpin turns. It suggests a simple warning system based on Arduino that lets drivers know about curves ahead and cars coming toward them. This makes it easier for drivers to slow down and be more careful, especially on dark and rural roads. The paper says that inexpensive sensor systems can cut down on accidents, but bad weather and hardware problems may make them less effective. [6]. Rushikesh Gapat and Ritu Rakesh Dubey (2023) suggest using the Internet of Things (IoT) to control traffic in hilly areas to cut down on accidents at narrow hairpin bends. The study shows that head-on crashes happen a lot when cars don't move in a coordinated way. Their system sees cars on one side of the curve and uses signals to control traffic from the other side, making it safe for cars to pass in a single lane. This makes blind turns safer and lessens the need for drivers to make decisions. But for it to work, drivers must follow the rules and sensors and signals must work correctly. [7] The paper says that blind hairpin turns in hilly and wooded areas are dangerous not only because of oncoming cars but also because animals can cross the road at any time. It suggests an IoT-based alert system that can find both cars and animals and warn drivers ahead of time, making them more aware and safe. The study shows that adding environmental hazards to real-time monitoring can help make travel safer on narrow roads and cut down on accidents. But things like fog, rain, plants, and low light can make the system work worse. [8] E. Karthik et al.'s (2023) study shows that hairpin bends are dangerous because cars coming from opposite directions often enter the curve at the same time, which makes it hard to see. To fix this, the authors made a simple IoT-based system with sensors, LEDs, and buzzers that can see when a car is moving and warn drivers. When another car is on the bend, the system turns red; when the road is clear, it turns green. This method helps drivers pay more attention and make safer choices, like slowing down or waiting. It shows that a cheap solution can really cut down on

accidents. The field is changing quickly, with new ways to integrate IoT and new ways to fix things. There is a clear trend toward solutions that are more automated, accurate, and cost-effective increasing emphasis on real-time monitoring, data analytics, and integrated systems for comprehensive road infrastructure management.

II. PROPOSED METHODOLOGY

Sensors and camera modules are carefully placed on both sides of the hairpin bend to make sure that the whole road is covered. These devices keep an eye on how vehicles move by recording important information like speed, distance, and direction. The system can effectively understand traffic conditions and find potential risks early on by gathering this information in real time, especially in places where visibility is poor. The obtained data are then processed and sent through reliable communication technologies such as Wi-Fi or IoT modules. This allows the fast and efficient transfer of information to the central alert unit. In this system, quick communication is critical as it ensures that warnings can be generated and delivered to drivers without delay thus improving response time and safety. Once data is received and analyzed, the system activates appropriate warning mechanisms to alert drivers approaching the hairpin bend. Such alerts can be LED signal lights, OLED display boards with caution messages or audible buzzers. These alerts are meant to quickly grab the driver's attention and get them to slow down or proceed carefully.

The system operates 24/7, monitoring traffic and road conditions day and night. By constantly analysing vehicle movement it is able to predict possible collision risks and give timely warnings. This continuous monitoring is essential to improve safety at dangerous curves, particularly in areas where drivers have limited visibility.

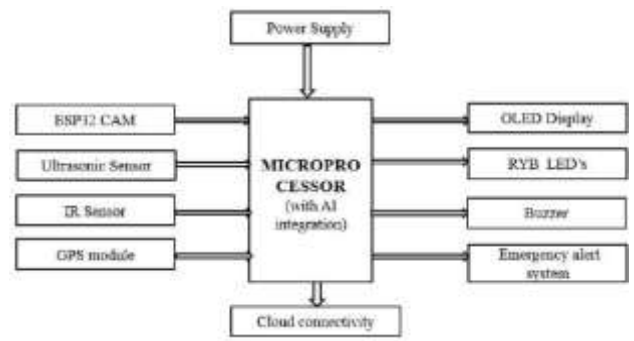


Figure .1 General block diagram of proposed system.

The suggested system combines cameras, sensors, and communication modules to make hairpin turns safer.

An ESP32-CAM captures real-time video for AI-based vehicle detection, while IR and ultrasonic sensors pick up cars that are getting closer. The proposed system uses cameras, sensors, and communication modules to make hairpin turns safer. An ESP32-CAM records video in real time for AI-based vehicle detection, and IR and ultrasonic sensors pick up cars that are getting closer.

A. Hardware Components

Raspberry Pi 4 Model B is the system's main processing unit. It handles data from sensors and cameras quickly and easily. It runs on Raspberry Pi OS and supports Python programming, so it can be used for AI and image processing tasks. It has built-in Wi-Fi, USB ports, and support for cameras, which makes it easy to talk to each other and analyze things in real time. Because it is small, it is perfect for safety applications that are built in.

ESP32-S3 Sense Camera Module is used to see the road in real time at blind curves. It takes pictures and uses its built-in AI to process them and find cars and other obstacles. It has less lag and faster response time because it can run lightweight machine learning models. This helps send out quick alerts to stop accidents from happening.

Battery gives all the parts of the system a reliable and portable power source. It keeps things running even in places where there isn't direct access to power. A voltage regulator keeps the power output steady and protects devices. Because it can be charged again, the system is energy-efficient and good for long-term use.

Ultrasonic sensor uses sound waves to figure out how far away things are. It constantly looks for obstacles and sends the controller real-time information. This helps find possible collision risks even when visibility is poor. It is very good for safety systems because it is accurate and uses very little power.

IR sensor detects things by bouncing infrared light off of them. It is especially helpful when it's dark or there isn't much light, when you can't see well. When something comes into the sensor's range, it quickly sends signals to the controller. This makes it easier for the system to find obstacles and make things safer.

B. Software Implementation

Raspberry Pi OS (Raspbian)

Raspberry Pi OS, which used to be called Raspbian, is a Debian-based operating system that works best on Raspberry Pi devices. It makes it easy for hardware to talk to each other and run apps in a stable way. It has both a lightweight and a full version, so it can be used on systems with or without a GUI.

Using measurements of depth and width, this formula gives an estimate of the size of the pothole.

Python Programming Environment

Python is the main programming language used to write the logic for the system, connect sensors, and process data. Built-in tools like Thonny IDE and package managers like pip make it easy to install libraries. Virtual environments also help with managing dependencies in a more effective way.

AI and Image Processing Libraries

Libraries like TensorFlow Lite and OpenCV let you analyze images in real time and make smart choices. They can help with things like finding objects, following movement, and recognizing patterns. These tools make the system better at finding unusual situations and sending out alerts quickly.

Cloud Database

The cloud database serves as a central platform for storing and accessing system data including GPS location and sensor readings. It allows for live updates, remote access and data integrity. This allows for efficient monitoring and swift action during emergency situations.

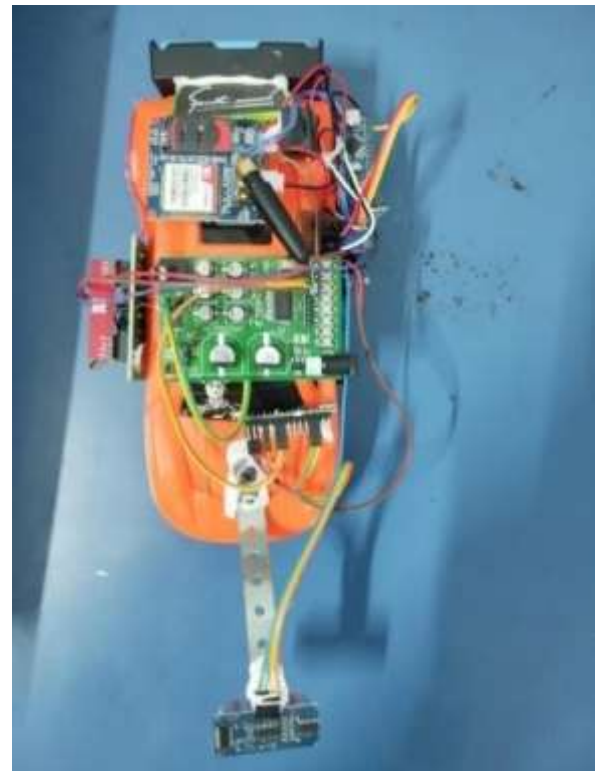


Fig. 1. Robot detects and estimates repair cost for a pothole.

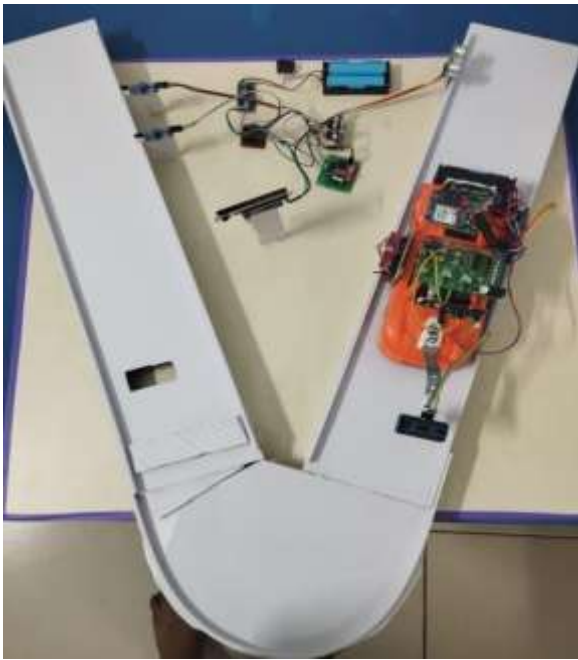


Fig.2. The digital interface. shows the data being transmitted by the Blynk IoT platform. It shows the GPS coordinates (latitude and longitude) of a detected pothole, a total cost of 702.00 (presumably for repair) and a green indicator saying "Path hole is detected". It shows the ability of the system to transmit real-time data and monitor remotely.

III. CONCLUSION

The project proposes an AI-enabled safety and monitoring system to reduce accidents at hairpin bends through enhanced vehicle awareness and real-time communication. The system combines sensors, camera modules, GPS, cloudbased connectivity, and a central processing unit to provide an intelligent and responsive traffic safety solution. The proposed model combines IoT and artificial intelligence to address the critical issue of limited visibility and uncoordinated vehicle movement on curved roads.

The developed system can detect the approaching vehicle by ultrasonic and IR sensors and also can support the AI-based classification and monitoring through the camera module. The processed data is transferred via wireless communication to facilitate real-time alerts using display units and signal indicators to ensure that drivers receive timely warnings. This greatly improves road safety by

reducing the likelihood of head-on collisions and bettering the decisions drivers make.

The implementation shows that the integration of smart technologies in traffic systems can offer an efficient, lowcost and scalable solution for accident prevention in challenging terrains. The system is robust, flexible and can be extended to include features such as cloud analytics, remote monitoring and advanced predictive models.

Finally, the proposed solution has been successfully able to accomplish the goal of improving safety at hairpin bends through intelligent detection and alert systems. Further developments could include more sophisticated machine learning algorithms, integration with smart city infrastructure and large scale deployment to augment its effectiveness and real-world impact.

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