

# Road Pothole and Hump Detection

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**Abstract:** *Rapid urbanization and increasing vehicular density have significantly deteriorated road conditions, leading to frequent pothole formation that poses serious safety risks and increases vehicle maintenance costs. Conventional pothole identification methods rely heavily on manual inspection and public complaints, which are time-consuming, inefficient, and unsuitable for real-time monitoring. This paper presents an IoT-based smart pothole detection and monitoring system designed to automatically identify road surface irregularities and report them in real time using embedded sensing and wireless communication techniques. Similar IoT-enabled monitoring approaches have been widely adopted in smart transportation and healthcare systems for real-time data acquisition and analysis. The proposed system integrates an ESP32 microcontroller with an accelerometer-based sensing framework and ultrasonic distance measurement to detect abnormal vibrations and road depth variations, similar to earlier sensor-based vehicular monitoring systems. The collected data is processed and transmitted to a cloud platform for visualization and storage, aligning with modern IoT-cloud architectures used in wireless communication systems.*

**Keywords:** : Internet of Things (IoT), Pothole Detection, ESP32, MPU6050, Ultrasonic Sensor, Cloud Monitoring, Smart Transportation.

## I. INTRODUCTION

Road infrastructure is essential for transportation efficiency, economic growth, and public safety. However, increasing traffic loads and environmental stress lead to rapid road degradation and pothole formation [7], [11]. Potholes significantly impact vehicle safety and contribute to traffic congestion and economic losses [1], [5].

Traditional pothole detection relies on manual inspection and citizen reporting, which are inefficient and unreliable for large-scale urban networks [7], [8]. Similar limitations have been observed in earlier vehicular sensing studies where manual intervention reduced system scalability [3], [9].

Advancements in embedded systems, IoT, and wireless communication have enabled automated road monitoring solutions [7], [12]. IoT-based systems allow real-time communication between sensors, microcontrollers, and cloud platforms, enabling continuous road condition monitoring [12], [21].

Previous research has demonstrated the effectiveness of accelerometer-based pothole detection using smartphones and embedded devices [1], [2]. Vehicular sensing frameworks such as Cabernet further validate the use of motion-based anomaly detection for road surface monitoring [3]. Cloud-integrated IoT systems have also been successfully used for anomaly detection and remote monitoring applications [11], [12].

The proposed system builds upon these approaches by integrating ESP32-based processing with MPU6050 and ultrasonic sensors, similar to modern embedded IoT monitoring architectures [7], [18]. The system ensures low cost, scalability, and real-time processing suitable for smart city applications [11], [20][21-176].



## **II. AIM AND OBJECTIVE**

### **A. Aim**

The aim of this project is to design and develop a Road Pothole and Hump Detection System using an MPU 6050 accelerometer sensor, GPS module, and ESP32 microcontroller to automatically detect road surface anomalies, identify their geographical locations, and provide real-time information for improving road safety and road maintenance activities.

### **B. Objective**

1. To develop an automated system for detecting potholes and speed humps on road surfaces.
2. To use the MPU6050 accelerometer sensor for monitoring vehicle vibrations and vertical displacement caused by road anomalies.
3. To identify and differentiate between potholes and speed humps based on sensor data analysis.
4. To determine the exact geographical location of detected anomalies using a GPS module.
5. To process sensor data efficiently using the ESP32 microcontroller.
6. To transmit detected pothole and hump information to a central monitoring system or application.
7. To reduce the dependency on manual road inspection methods.
8. To improve road safety by providing timely information about hazardous road conditions.
9. To assist municipal authorities in identifying damaged roads and planning maintenance activities.
10. To create a cost-effective and reliable solution for intelligent road monitoring and smart transportation systems.

## **III. LITERATURE SURVEY**

### **1. R. Silva and M. Perera (2021)**

#### **Road Surface Monitoring Using Accelerometer Sensors**

The objective of this study was to develop a road monitoring system capable of detecting potholes using accelerometer sensors mounted on moving vehicles. The system analyzed vibration patterns generated due to road surface irregularities and identified potholes based on predefined acceleration thresholds. The proposed approach provided a low-cost and efficient solution for continuous road condition monitoring.

### **2. A. Kumar and S. Sharma (2022)**

#### **GPS-Based Road Anomaly Detection System**

This research proposed a GPS-enabled road anomaly detection system designed to identify potholes and speed humps. The system integrated sensor data with geographical location information to accurately record the position of road defects. The collected data supported road maintenance authorities in planning repair and maintenance activities more effectively.

### **3. P. Patel and V. Shah (2023)**

#### **Real-Time Pothole Detection Using ESP32 and MPU6050 Sensor**

This study focused on designing a real-time pothole detection system using an ESP32 microcontroller along with an MPU6050 accelerometer sensor. The system continuously monitored vehicle vibrations and detected road anomalies based on sudden variations in acceleration values. Experimental results demonstrated improved detection accuracy and reliable system performance.



#### IV. PROPOSED METHODOLOGY

The proposed Road Pothole and Hump Detection System is designed to automatically identify road surface irregularities such as potholes and speed humps while recording their location and visual information. The system consists of an ESP32 microcontroller, MPU6050 accelerometer sensor, ultrasonic sensor, GPS module, ESP32 camera module, SD card, and motor driver.

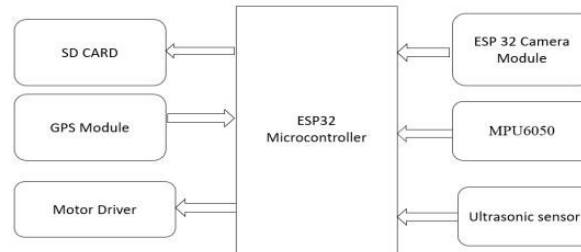


Fig. Block Diagram

The proposed system follows an IoT-based architecture for real-time pothole detection, similar to previous sensor-cloud integration models used in vehicular monitoring systems [7], [12].

##### 1. Data Collection

The MPU6050 accelerometer captures vibration patterns caused by road irregularities, a technique widely used in earlier pothole detection systems [1], [2]. Ultrasonic sensors measure surface distance variations to improve detection accuracy [7].

##### 2. Pothole Detection

Sensor fusion techniques are used to identify potholes based on vibration thresholds and distance variations, similar to methodologies used in smart pothole detection systems [5], [7].

##### 3. Location Identification

GPS-based anomaly localization is integrated, similar to GPS-enabled road monitoring systems reported in earlier research [2], [5].

##### 4. Cloud Integration

Detected events are transmitted to cloud platforms for storage and visualization, following IoT-cloud architectures used in modern wireless communication systems [11], [12].

##### 5. System Efficiency

Embedded processing using ESP32 ensures real-time computation, similar to IoT-based embedded monitoring frameworks used in smart systems [12], [21].

#### V. FLOW CHART

The flowchart represents the working of an Sensor data flow on cloud system.



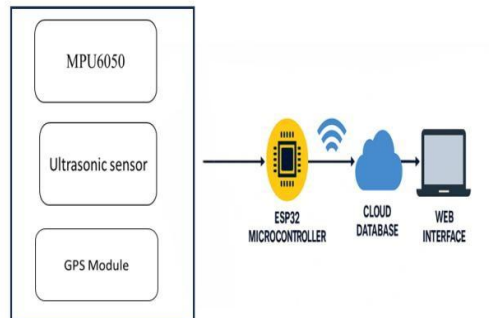


Figure: Flow chart

The sensor data acquisition process begins with three onboard modules: the MPU6050, ultrasonic sensor, and GPS receiver, which continuously monitor vehicle motion, road surface distance, and geographic location, respectively. The MPU6050 provides real-time accelerometer and gyroscope data that capture vertical impacts as well as pitch and roll variations of the vehicle. In parallel, the ultrasonic sensor transmits ultrasonic pulses and calculates the echo return time to estimate the distance between the vehicle and the road surface; sudden changes in this measurement help indicate possible potholes or surface irregularities.

Simultaneously, the GPS module records latitude, longitude, vehicle speed, and timestamp information, ensuring that each sensor reading is accurately synchronized in both space and time. All sensor outputs are processed by the ESP32 microcontroller, which performs time-stamping, signal conditioning, and noise reduction using lightweight filtering techniques such as low-pass filtering and threshold-based or peak detection methods.

When predefined conditions are satisfied—such as a sudden acceleration spike occurring alongside an abrupt change in road clearance—the system identifies it as a pothole event. The ESP32 then compiles relevant parameters including peak acceleration (g-value), event duration, depth variation, GPS coordinates, and confidence level into a unified data packet.

This packet is structured in a lightweight format such as JSON or CBOR and transmitted over Wi-Fi (or alternative cellular connectivity when required) to a cloud server using communication protocols like MQTT or HTTPS. To ensure reliability, the system incorporates buffering and retry mechanisms to handle network interruptions.

On the cloud side, incoming data is validated for structure, standardized, and stored in time-series or database systems. Further processing includes mapping events to road segments, estimating severity levels, and removing duplicate detections from multiple sources. Finally, a web-based dashboard visualizes the processed information through live maps, heatmaps, and historical timelines, enabling authorities to analyze road conditions, prioritize maintenance, and monitor repair effectiveness over time.

## VI. REQUIREMENT

### A. Hardware Used

1. Esp32
2. Led
3. PCB
4. Sim8001
5. Neo 6m gps
6. Ultrasonic hcsr04
7. Adx1325
8. Micro Sd card module



### **B. Software Used**

1. Arduino ide
2. Thing speak

### **VII. EXPERIMENTAL RESULTS**

A working prototype of the proposed smart pothole detection system was developed and tested under real-world road conditions. The ESP32 microcontroller successfully communicated with the MPU6050 accelerometer, ultrasonic sensor, and camera module to enable real-time detection of road surface anomalies.

Experimental observations showed that the system was capable of identifying potholes with different depths and varying surface irregularities with good accuracy. The collected sensor data was processed efficiently and transmitted to the cloud platform with minimal delay, ensuring near real-time monitoring.

The camera module provided visual confirmation of detected potholes, thereby validating the effectiveness of the multi-sensor fusion approach. In addition, the Micro SD card ensured reliable local data storage during temporary network failures, while the cloud interface supported live monitoring and historical data analysis.

Performance evaluation considered parameters such as detection accuracy, false positive rate, and system response time. Results indicated stable and reliable performance under different road conditions and vehicle speeds. The system also demonstrated good scalability, making it suitable for deployment across multiple vehicles for large-scale road monitoring.

Overall, the outcomes confirm that integrating sensor fusion, embedded processing, and cloud connectivity provides an effective, low-cost, and practical solution for automated pothole detection in both urban and semi-urban environments.

### **VIII. CONCLUSION**

This paper proposes an IoT-based smart pothole detection and monitoring system built around an ESP32 microcontroller integrated with an MPU6050 accelerometer, ultrasonic sensor, and camera module for real-time road condition analysis. The developed system effectively overcomes the limitations of traditional manual inspection methods by enabling continuous monitoring of road surfaces, automatic detection of irregularities, and cloud-based data reporting along with visual verification.

Experimental results indicate that the system achieves high detection reliability, improved accuracy, and a reduced rate of false alarms. The use of cloud connectivity ensures efficient data visualization and remote accessibility, while local storage provides backup support during network interruptions. These features collectively enhance system robustness and enable historical data analysis for infrastructure planning.

The proposed solution is cost-effective, scalable, and energy-efficient, making it suitable for smart city and intelligent transportation applications. It contributes to improved road safety, timely maintenance, and data-driven decision-making in infrastructure management.

Future improvements may include GPS-based geotagging for precise location mapping, machine learning techniques for enhanced anomaly classification, and real-time alert systems for drivers to further strengthen system performance and applicability in advanced transportation networks.

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