ISSN 2277-2685
IJESR/June. 2025/ Vol-15/Issue-3s/264-272
S.Mayuri *et. al.*, / International Journal of Engineering & Science Research

Road Condition Monitoring And Automatic Reporting System

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ABSTRACT

Road conditions play a crucial role in ensuring the safety and comfort of commuters. Potholes, humps, and uneven road surfaces pose significant risks, leading to accidents, vehicle damage, and increased maintenance costs. This project aims to develop an automated road condition monitoring system using Arduino UNO as the main controller. The system incorporates ultrasonic and IR sensors to detect potholes and humps, while an ESP32 CAM module captures images of detected irregularities.

A GPS module determines the exact location of these hazards, and a GSM module sends alerts with location details to a registered mobile number. Additionally, the system features a pothole-filling mechanism that activates when a pothole is detected. All detected data, including images and locations, are stored on an SD card for future reference. The project status is displayed on an LCD screen, providing real-time updates. The entire system is programmed using embedded C language, ensuring efficient and automated operation. This smart road monitoring and maintenance system can significantly improve road safety, assist in timely maintenance, and reduce accident risks caused by poor road condition.

Future improvements include integrating pothole detection with smart vehicles, enhancing AI accuracy, and enabling real-time navigation alerts. Collaboration with authorities can ensure quicker road repairs, improving overall safety.

1- INTRODUCTION

INDIA, the populous Country in the World and a fast-growing economy, is known to have a gigantic network of roads. Roads are the dominant means of transportation in India today. They carry almost 90 percent of country's passenger traffic and 65 percent of its freight. However, most of the roads in India are narrow and congested with poor surface quality and road maintenance needs are not satisfactorily met.

Over the last two decades, there has been a tremendous increase in the vehicle population. This proliferation of vehicles has led to problems such as traffic congestion and increase in the number of road accidents. Pathetic condition of roads is a boosting factor for traffic congestion and accidents. Researchers are working in the area of traffic congestion control, an integral part of vehicular area networks, which is the need of the hour today.

Potholes, formed due to heavy rains and movement of heavy vehicles, also become a major reason for traumatic accidents and loss of human lives. One of the major problems in developing countries is maintenance of roads. Well maintained roads contribute a major portion to the country's economy. Identification of pavement distress such as potholes and humps not only help drivers to avoid accidents, helps to avoid any vehicle damages, but also helps government authorities to maintain roads. Pothole detection methods that have been developed and also proposes a cost-effective solution to identify and locate the potholes or humps on roads and provide alerts to drivers to avoid accidents or vehicle damages. The proposed system captures the geographical location coordinates of the potholes or humps using a global positioning system receiver. Where the ultrasonic sensors are used to identify the potholes or humps and it also measures their depth or height. An android application is used to alert drivers so that precautionary measures can be taken to avoid any misfortune. Alerts are pinned on the google map in the application location of the pothole.

Sensor data includes pothole depth and height, as well as geographic location, which is stored in a cloud database. Governing authorities and drivers can benefit from this valuable information.

2- LITERATURE SURVEY

In the paper "IoT Based Highway Potholes and Humps Detection" by Liladhar Bhamare, Gauri Varade, Hrishikesh Mehta, and Nikita Mitra, the literature review highlights that traditional methods like manual inspection are slow, inaccurate, and inefficient, while smartphone-based detection methods relying on accelerometers are inconsistent and depend heavily on user participation.

Earlier systems also lacked real-time data sharing and automatic notifications to drivers. The authors emphasize that IoT-based systems enable real-time, automatic detection using sensors like ultrasonic and vibration sensors, ensuring greater accuracy and reliability. With the integration of GPS, their system provides precise location tracking of potholes and humps, helping in timely driver alerts and supporting authorities in better road maintenance planning.[1]

The paper "Automatic Detection and Notification of Potholes and Humps on Road to Aid Drivers" by Rajeshwari Madli, Santosh Hebbar, Praveen Raj Pattar, and Varaprasad Golla presents a system aimed at enhancing road safety by automatically detecting potholes and speed breakers (humps) and notifying drivers in real-time. The authors propose the use of ultrasonic sensors and GPS technology integrated with a microcontroller to identify irregularities on the road surface and mark their locations.

The system detects potholes and humps based on the variation in the distance between the vehicle and the road surface, with ultrasonic sensors placed at the front of the vehicle for continuous monitoring. Once an irregularity is detected, the GPS module captures the exact location, which can be stored in a centralized database and shared with other drivers through a mobile application or display unit, alerting them in advance. By leveraging sensor data and location tracking, the system aims to reduce accidents, vehicle damage, and driver inconvenience caused by unexpected road hazards.[2]

3-FUNCTIONAL DESCRIPTION

The functional description of the project work is explained in this chapter. For better understanding, the total module is divided into various blocks and each block explanation is provided here. The diagrams (block diagram and circuit diagram) of this project work are provided in the next chapter. The following is the description of the overall function or operation of the project work.

DETECTION OF POTHOLES

Potholes are typically detected using ultrasonic sensors that measure the distance between the vehicle and the road surface. These sensors emit high-frequency sound waves and record the time it takes for the waves to bounce back from the road. On a smooth, even road, the distance remains constant. However, when the vehicle passes over a pothole, the road surface dips, causing a sudden decrease in the distance between the sensor and the road. This change in measurement is detected by the ultrasonic sensors and sent to the system's microcontroller for processing. The microcontroller compares the measured distance against a set threshold, and if the deviation exceeds the threshold, it identifies the anomaly as a pothole.

In addition to ultrasonic sensors, the system can also use accelerometers or vibration sensors to detect the vehicle's response to the pothole. When the system detects a significant vibration or an abnormal change in distance from the ultrasonic sensors, it triggers an alert mechanism to notify the driver of the pothole. The GPS module then records the location of the detected pothole, providing valuable data for road authorities to schedule repairs. This integrated system ensures early detection and accurate location tracking of potholes, improving road safety for drivers.

DETECTION OF HUMPS

The detection of humps using Infrared (IR) sensors works by measuring the distance between the sensor and the road surface. IR sensors emit infrared light beams, and when these beams encounter an object, they are reflected back to the sensor. On a flat, even road surface, the sensor continuously detects the same distance, but when the vehicle moves over a hump, the road height increases, causing the distance measurement to decrease. The IR sensor detects this change, indicating the presence of a raised section of the road. The microcontroller processes this information by comparing the variation in distance to a predefined threshold value for road height changes. If the distance decreases significantly, the system identifies it as a hump

IR sensors provide a quick and reliable method for detecting humps, as they work in real-time and can detect small variations in road height. The system can also incorporate additional sensors like accelerometers to detect vehicle vibrations caused by driving over the hump. When the IR sensor detects a change in road height and the accelerometer registers a corresponding vibration, the system can confirm the presence of a hump with higher accuracy. Once confirmed, the system sends an alert to the driver and logs the location of the hump using the GPS module, providing both immediate warning and data for road maintenance authorities.

WORKING PRINCIPLE

The working principle of the system is based on continuously monitoring the road surface using sensors installed on a moving vehicle. The core components include ultrasonic sensors, which measure the distance between the vehicle and the road surface. When the vehicle moves over a pothole or hump, the elevation of the road surface changes, and this variation is detected by the ultrasonic sensors.

The sensors emit ultrasonic waves that bounce back after hitting the road, and based on the time it takes for the waves to return, the system calculates the distance to the road. If the distance varies significantly from the normal road height, the system registers the anomaly as either a pothole or hump. This data is sent to a microcontroller, which processes the readings, compares them with predefined threshold values, and determines whether a pothole or hump is present.

Once the anomaly is detected, the system activates the GPS module to capture the precise location of the pothole or hump. The GPS records the latitude and longitude of the vehicle's position at the time of detection, which is crucial for pinpointing the exact location of the road anomaly. This geographic information, combined with the type of anomaly detected, is used to trigger a real-time alert to the driver. The alert can be in the form of an audible alert (like a buzzer), or a mobile app notification, all designed to warn the driver about the road hazard. These notifications allow the driver to take immediate action, such as slowing down or steering away from the anomaly, to avoid damage or accidents.

In addition to providing alerts to the driver, the system also logs the anomaly data, including location and type of road defect. This information can be stored locally in a memory device, such as an SD card, and uploaded to a centralized server or cloud-based platform. The logged data helps municipal authorities to identify problematic areas and schedule road repairs accordingly. By compiling and analyzing this data over time, the system can build a comprehensive road condition map, allowing local governments to proactively address issues before they become major safety hazards. In essence, the combination of real-time alerts and data logging not only improves driver safety but also contributes to long-term road maintenance and management.

4-REQUIREMENTS

HARDWARE COMPONENTS

ARDUINO UNO

The Arduino UNO is widely used open-source microcontroller board based on the ATmega328P microcontroller chip. It operates at 5V with a clock speed of 16 MHz, making it ideal for real-time applications like pothole and hump detection systems. The UNO has 14 digital input/output pins (out of which 6 can be used as PWM outputs) and 6 analog input pins, allowing it to interface easily with sensors like ultrasonic sensors, IR sensors, and modules like GPS. Its USB interface makes it very easy to program using the Arduino IDE, and it supports C/C++ based coding, which is simple and efficient even for beginners. In the context of this project, Arduino UNO acts as the central controller that collects sensor data, processes it, and triggers notifications based on the road condition detected.One of the main reasons the Arduino UNO is used in this project is its versatility and ease of use. It can simultaneously process multiple sensor inputs - for example, it reads distance data from ultrasonic and IR sensors and vibration data from accelerometers. The Arduino board can be programmed to compare the collected data with predefined threshold values to differentiate between potholes, humps, and uneven surfaces. Furthermore, it can control alert systems such as buzzers or LEDs to notify the driver and communicate with a GPS module to capture the real-time location of detected road anomalies. Its ability to handle both analog and digital signals makes it an excellent choice for projects that require interaction with various types of sensors and devices.

In terms of connectivity and expansion, the Arduino UNO supports various shields and modules that can be stacked to add extra functionalities without complicated wiring. It is powered either through a USB connection or an external power supply, providing flexibility for in-vehicle use. Its reliability, widespread support community, and abundant documentation make troubleshooting and enhancements easy during the project development. Overall, the Arduino UNO plays a crucial role as the brain of the pothole and hump detection system, efficiently managing the real-time data collection, processing, and communication tasks necessary for ensuring driver safety.

MICROCONTROLLER

A Microcontroller (or MCU) is a computer-on-a-chip used to control electronic devices. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC). A typical microcontroller contains all the memory and interfaces needed for a simple application, whereas a general-purpose microprocessor requires additional chips to provide these functions.

ATMEGA 328P MICROCONTROLLER

The ATMEGA328P is a versatile 8-bit microcontroller developed by Atmel, now a part of micro -chip Technology. Featuring 32KB of flash memory, it is a part of the AVR family and operates at a maximum clock speed of 20 MHz.

Its architecture includes 32 general-purpose 1/0 pins, enabling connections to various peripherals and sensors. Equipped with 2KB of SRAM and IKB of EEPROM, it provides volatile and non-volatile memory for data storage. The ATmega328P integrates multiple communication Interfaces like UART, SPL and 12C, facilitating seamless connectivity. This microcontroller supports in-System programming through the SPI interface allowing firmware updates without removing from the circuit. It is compatible with Arduino boards, serving as the brain for nom DIY projects and prototypes due to its ease of use. The ATmega328P operates at low power, making it suitable for hattery-powered applications, extending device longevity. Its 8-channel 10-bit Analog-to-Digital Converter (ADC) enables the reading of analog sensors and inputs accurately. To program the ATmega328P, developers commonly use the Arduino IDE, which simplifies the coding process with its user-friendly interface. The microcontroller supports C and assembly languages, providing flexibility for software development.

Its affordability, and extensive community support make it a preferred choice among hobbyists and professionals alike. When designing circuits with the ATmega328P, attention to the power supply, clock frequency, and proper grounding is crucial. Peripheral interfacing and interrupt handling are key skills for maximizing the microcontroller's capabilities. Optimizing code and utilizing hardware features efficiently are vital for achieving optimal performance in ATmega328P-based projects. Careful consideration of memory limitations and the utilization of optimization techniques can enhance the application's efficiency.

LM2596

The LM2596 is a DC-DC step-down (buck) voltage regulator module. It is designed to efficiently reduce a higher input voltage to a lower, stable output voltage. The LM2596 can accept input voltages up to around 40V and can provide a stable, adjustable output voltage in the range of 1.25V to 35V at currents up to 3A. It is highly efficient (up to 90%), which makes it perfect for projects where we need to reduce voltage without wasting too much energy as heat. It also includes important features like thermal shutdown, current limit protection, and a simple design for easy integration into circuits. The module version usually comes with an adjusting screw to fine-tune the output voltage.

SOFTWARE REQUIREMENTS

ARDUINO IDE

Arduino IDE (Integrated Development Environment) is an open-source software platform used for programming and developing applications for Arduino microcontroller boards. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino devices, making it accessible to both beginners and experienced developers. The IDE supports the Arduino programming language, which is based on C/C++, and offers a range of libraries and example codes to simplify the development process. It allows users to interact with various sensors, actuators, and hardware components, enabling the creation of a wide array of projects, from simple LED blinkers to complex robotics and IoT applications. Arduino IDE is cross-platform, compatible with Windows, Mac, and Linux, making it widely 27 adopted in the maker and electronics enthusiast communities. Its simplicity and extensive community support make it a popular choice for prototyping and experimenting with hardware projects.

EMBEDDED C LANGUAGE

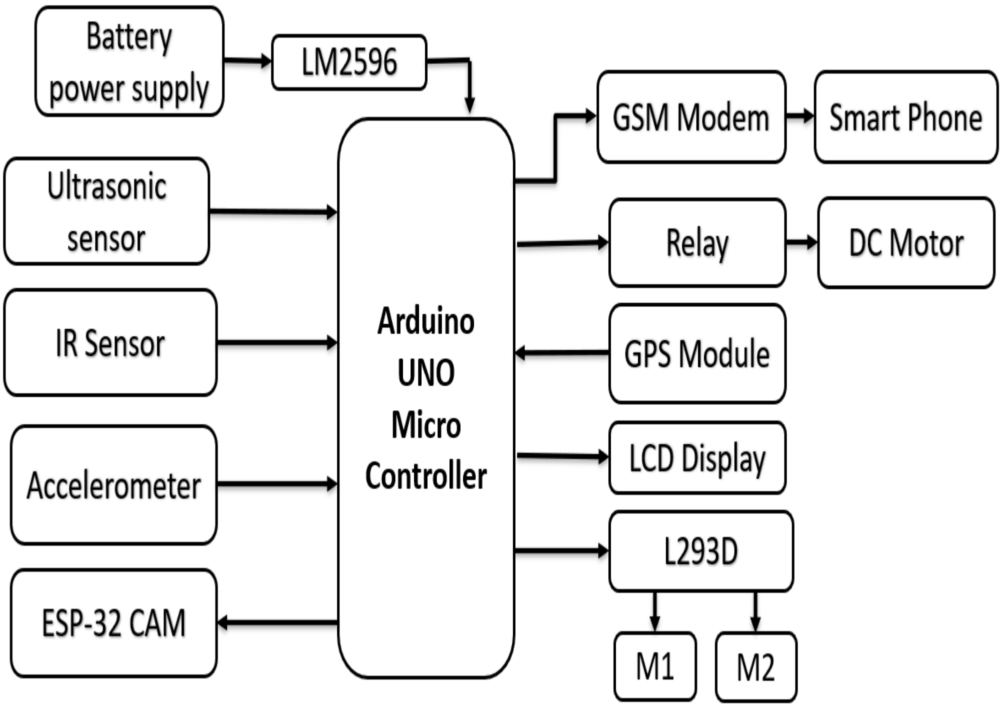
Embedded C is a crucial programming language in the field of embedded systems. These systems are at the heart of numerous modern devices, from smartphones and home appliances to automotive control systems and industrial machinery. Embedded C is specifically designed for embedded systems, and its importance lies in its efficiency, portability, and close-to-the-hardware capabilities. Embedded systems often have limited processing power and memory, making efficiency paramount. Embedded C allows developers to write compact and optimized code, ensuring these systems operate smoothly while conserving resources. Portability is another key aspect. Embedded C code can be written to be platform-independent, enabling the same code to run on various microcontrollers and processors, enhancing reusability and minimizing development time. Moreover, Embedded C provides low-level access to hardware components, making it ideal for tasks like controlling sensors, motors, and communication interfaces. Its ability to work at a hardware level ensures precise control and real-time responsiveness, crucial for safety-critical applications. In safety-critical industries like healthcare and automotive, Embedded C's reliability and determinism are invaluable. It allows for the development of robust and predictable systems, reducing the risk of failures.

PROGRAM

This program is written for an Arduino-based smart road condition monitoring and alert system. It detects road anomalies like potholes, speed bumps (humps), and uneven surfaces using various sensors, and notifies a predefined mobile number via SMS along with the GPS location.

5-DESIGN

BLOCK DIAGRAM



This block diagram represents a smart road safety system for automatic detection and notification of potholes and humps using Arduino UNO as the main controller.

ISSN 2277-2685
IJESR/June. 2025/ Vol-15/Issue-3s/264-272
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6- TESTING AND RESULTS

HARDWARE MODULE

The below figure shows the hardware module used for road condition monitoring and automatic reporting system. It includes various components such as Arduino UNO, GPS module, GSM modem, sensors, and motor driver, all integrated on a mobile platform. These components work together to detect road anomalies and transmit real-time alerts to aid drivers

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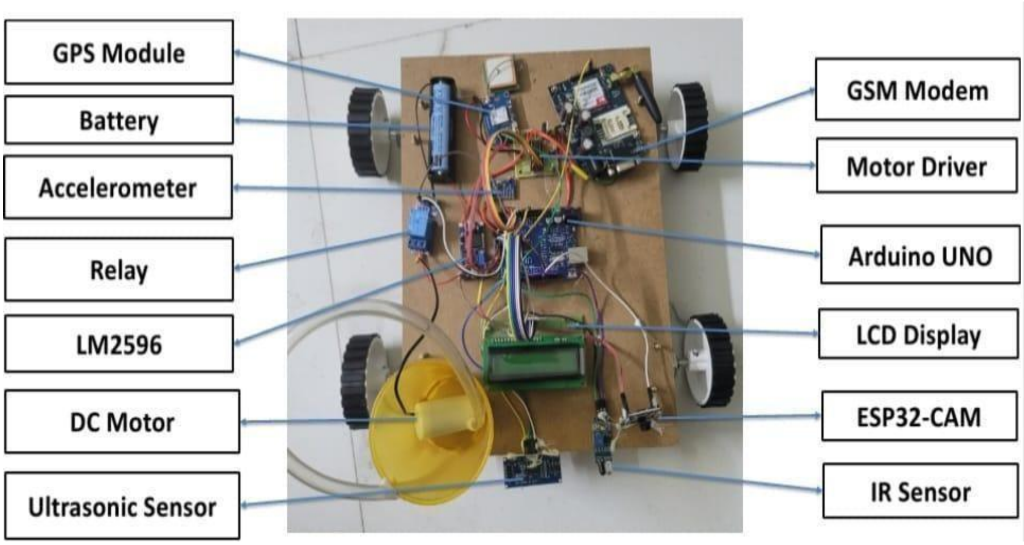

Fig 6.1 Hardware Module

Case 1: Pothole Detection

On flat roads, the sensor consistently reported distances within normal range (e.g., 8–10 cm). When passing over artificial potholes (dips of 4 cm or more), the measured distance increased sharply (e.g., 12–16 cm). The Arduino successfully recognized this variation and triggered a pothole detection event. On detection, the GPS module captured the location, and the GSM module sent an alert message.

The ultrasonic sensor is effective in detecting deep or medium-sized potholes by measuring sudden increases in road distance. It adds strong reliability when combined with an accelerometer, making it ideal for real-time pothole monitoring in smart road systems.

Fig 6.2 Pothole detected

Case 2: Hump Detection

The IR sensor emits infrared light and detects the reflected signal from the ground. When a hump is encountered, the distance between the sensor and surface decreases. This results in a stronger and quicker reflection, which is interpreted as a raised surface. When the system passed over a hump, there was a sharp increase in signal strength due to the closer proximity. The Arduino processed this sudden spike as a hump and triggers a detection alert. The event was logged, and a GSM alert was sent with GPS coordinates.

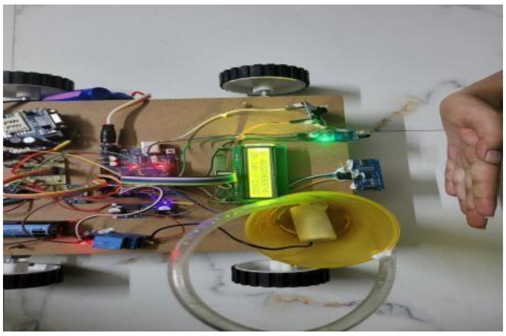

Fig 6.3 Hump detected

Case 3: GPS Location

Testing of the GPS module was done in both open and semi-urban environments. In open areas, the GPS module provided accurate coordinates with a margin of error under 3 meters. In urban environments with buildings around, the error margin increased slightly to 5–7 meters. Still, the results were sufficient to log road anomalies on a map precisely. The GPS results were verified against smartphone GPS readings and Google Maps data

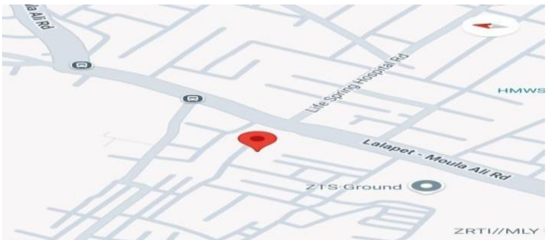

Fig 6.4 GPS located

Case 4: Real-Time Alert Transmission via GSM

The real-time alert notification feature was tested by simulating various road conditions such as potholes, humps, and uneven surfaces using appropriate sensors. The GSM module (SIM900A) was integrated with the Arduino to send SMS alerts to a predefined mobile number. During testing, when a pothole was detected by the ultrasonic sensor, an SMS stating "Alert: Pothole detected" was successfully delivered within 5–10 seconds. Similarly, detection of a hump using the IR sensor triggered a warning message like "Hump detected". The accelerometer (MPU6050) sensed abrupt vertical vibrations indicating uneven roads and sent notifications accordingly. All alerts were received in real-time without significant delay, confirming the system's effectiveness in promptly notifying users. The SMS delivery was reliable, and the system consistently responded to road anomalies, demonstrating its potential to enhance driver awareness and improve road safety through immediate mobile alert

7- CONCLUSION

The project titled "Automatic Detection and Notification of Potholes and Humps on Roads to Aid Drivers" successfully demonstrates how embedded systems and sensor technology can be used to enhance road safety. By integrating ultrasonic and IR sensors with a GPS and GSM module, the system is able to detect anomalies in the road surface and immediately send notifications with accurate location data. This helps drivers avoid potential accidents and allows authorities to take corrective action promptly.

The real-time alert system, including buzzer or LED indications, ensures that the driver is instantly informed about dangerous road conditions ahead. The overall setup is cost-effective, easy to install on vehicles, and scalable for larger networks. This smart solution not only prevents vehicle damage and personal injury but also contributes to better traffic management and road maintenance.

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