IoT Based Pothole Detection and Alert System

Dinesh Bhoyar
Electronics and Telecommunication Department, Yeshwantrao Chavan College of Engineering,
Nagpur, India
dinesh.bhoyar23@gmail.com

Rajesh H.Khobragade
Department of Electronics and Computer Science
Shri Ramdeobaba College of Engineering and Management,Nagpur,India
khobragaderh@rknec.edu

Swati K. Mohod
Electronics Department Yeshwantrao Chavan College of Engineering
Nagpur, India
swatimohod6882@gmail.com

Punit Fulzele
Datta Meghe Institute of Higher Education and Reaerch, Wardha , India
punittr007@gmail.com

2023 1st DMIHER International Conference on Artificial Intelligence in Education and Industry 4.0 (IDICAIEI) | 979-8-3503-3842-3/23/$31.00 ©2023 IEEE | DOI: 10.1109/IDICAIEI58380.2023.10406520

***Abstract*—The maintenance of roads is crucial for transportation and the economy. Potholes and humps on roads can lead to accidents, vehicle damage, and increased fuel consumption. Therefore, it is important to detect and identify potholes and humps to prevent accidents and reduce damage to vehicles. A simple and effective solution can be implemented to address this problem. Detection of potholes will be done by ultrasonic sensor and the width of the pothole can be determined by the picture taken by the ESP32 Camera Module. This photo along with the exact coordinates will be pushed on the map with the help of GPS module, the whole system will be controlled by Arduino Nano microcontroller, so that the other drivers get an alerted in advance.**

Keywords—Pothole, vehicle damage, ultrasonic sensor, GPS, Camera Module, Microcontroller

I. Introduction

In India, efforts have been made to reduce road accidents as part of the Brazil Declaration, with the goal of reducing accidents by 50% by 2022. The Motor Vehicles Act is aimed at improving road safety and reducing accidents. Despite the significant growth in the country's road network and number of vehicles, the condition of these roads continues to pose a risk for accidents. The proposal introduces the use of Ultrasonic sensors mounted on a robot to tackle the issue of poor road conditions and minimize accidents caused by potholes. By deploying such a system, the sensors would actively detect irregularities on the road surface, like potholes, by analysing the return time of sound waves. This technology enables proactive identification of potholes, allowing timely repairs and preventing accidents. Additionally, the system can aid in prioritizing road maintenance efforts by pinpointing areas with severe pothole problems. However, challenges including potential limitations of Ultrasonic sensors, such as multi-layered road surfaces, and the need for substantial investments in sensor technology, bot development, and data analysis infrastructure should be taken into account. Thorough testing, evaluation, and maintenance are essential to assess the practicality and effectiveness of this approach in real-world scenarios. The sensors collect data on the depth, width, height, and GPS coordinates of potholes, which are then stored locally in the device itself. The system consists of three subsystems: Sensing, Communication, and Localization, each with its own function but cantered around data. The Sensing system generates data, Communication coordinates and distributes data, and Localization uses data to provide information to drivers. The proposed system also employs an IoT-based track condition monitoring system to share information on road conditions with drivers for safety measures. The ultrasonic sensors along with GPS are used to detect potholes and share information on their location to vehicles on the same road. If multiple vehicles pass through the same location, the server sends a warning to all vehicles to avoid accidents. The proposed system using Ultrasonic sensors mounted on a bot offers advantages such as providing early warning to drivers, assisting highway maintenance departments, and being cost-effective for pothole detection.

II. Problem Statement

Road transportation faces major challenges due to poor road quality, inadequate maintenance, and the presence of potholes and humps. These issues lead to accidents, which can be fatal, especially when road damage goes unnoticed. Potholes are formed due to heavy rainfall and the continuous traffic on poorly constructed roads. They pose a significant threat to motorists, and their formation has caused many accidents resulting in the loss of human life. Indian speed breakers, designed to control vehicle speed, can also contribute to accidents. In some cases, drivers are unable to identify speed breakers due to heavy rainfall or other factors, resulting in vehicle imbalance and accidents.

Poor maintenance and incorrect road construction are the primary reasons for road accidents. Reporting potholes and road issues to the municipal corporation is crucial for improving road conditions and preventing accidents.

III. Literature Survey

A pothole detection system based on computer vision and machine learning techniques [1], in this paper authors utilize image processing algorithms and deep learning methods to detect and classify potholes in road images. They train a convolutional neural

network (CNN) on a large dataset of road images with labeled potholes. The system achieves promising results in terms of accuracy and can assist in proactive road maintenance.

In paper [2], the authors propose a pothole detection system based on the YOLO-V7 (You Only Look Once) object detection algorithm. They employ a convolutional neural network to detect potholes in real-time using video footage. The system demonstrates efficient and accurate pothole detection capabilities, which can contribute to timely repairs and safer roads.

Paper [3] presents a pothole detection system that combines a 2D LiDAR (Light Detection and Ranging) sensor and a camera. The LiDAR sensor measures the depth of the road surface, while the camera captures images for further analysis. By analyzing the sensor and image data, the system identifies potholes and provides accurate information about their location and severity. The proposed system offers a reliable solution for pothole detection using a combination of different sensing technologies.

Paper [4] his research paper introduces a stereo vision system that can detect potholes while driving, aiming to provide drivers with advance warning of potholes on the road. The aim of this system is to help drivers react to potholes before they encounter them. The system consists of two USB cameras that capture images simultaneously.

The proposed system utilizes camera calibration with a checkerboard and calculates a disparity map from the images. By projecting 2D image points onto 3D world points using the disparity map, the system can fit a road surface model using bi-square weighted robust least-squares approximation. This allows for the identification of points below the road surface model as the pothole region. Additionally, the system can determine the size and depth of each pothole. The experiments conducted demonstrate the system's robustness in detecting potholes in different road and light conditions. The experiments conducted on various road and lighting conditions demonstrate the system's robustness in detecting potholes [5].

A propose an IoT-based road monitoring system (IoT-RMS) to detect potholes and humps on roads, aiming to reduce road accidents. In this system, ultrasonic sensors are used to measure the scattering signal, which is affected by the presence of potholes. However, the decrease in the magnitude of the reflected signal poses challenges for signal amplitude analysis. To address this issue, the authors incorporate an accelerometer with the ultrasonic sensor. The accelerometer measures the variation in the signal, which is optimized using the honey bee optimization (HBO) technique. This optimization process enhances the accuracy and reliability of the system in detecting and identifying potholes and humps on the road. The IoT-RMS automatically updates the status of the road with location information in the cloud. Road vehicles c*a*n access the information from the server and estimate the speed according to the potholes and humps present on the road. The authors performed simulations and tests using Arduino Uno with ESP 8266 and showed that the IoT-RMS can be integrated into road vehicles to reduce accidents. The data from the server can be accessed by all road vehicles, which can estimate their speed based on the presence of potholes and speed bumps on the road. The simulation of the system shows that it can be integrated into road vehicles to reduce accidents [6].

Vinay Rishiwal suggests a vibration-based method for automatically detecting potholes and speed b along with their coordinates in his article from 2016 titled "Automatic Pothole and Speed breaker detection using Android system." The suggested method keeps a database for each route and makes it accessible to the public through a global database or a portal. The built-in accelerometer of Android smartphones is used to assess the severity of potholes and speed bumps. On a 4 km flat road, the suggested method is tried, and the outcomes are contrasted with those of manual inspection of potholes and speed bumps on the same road. The suggested method is found to be 93.75% accurate at spotting potholes and speed bumps.

A Virtual Road Network Inspector (VRNI) was introduced in 2019 by Ali Anaissi as extension of his "Smart Pothole detection system using vehicle mounted sensor and machine learning," which was capable of continuous monitoring of road conditions and made decision to support the managers and engineers. The VRNI evaluated road conditions with the help of acceleration data from vehicle-mounted sensors and suggested a novel method for detection of road damage constructed on two adaptive one-class SVM models that were applied to the vertical and lateral acceleration data. Using the information gathered from a real system deployed on Australian school buses, the suggested method was evaluated. The experimental results demonstrated that, with only 4% false alarm rate relating to benign anomalies like expansion joints, the proposed technique consistently detected 97.5% of the road damage accurately [7].

In 2019, Gayathri proposed a prototype for an "Automatic Pothole Detection System" which detected potholes on the road while driving and updated their location on the cloud. The feature in the prototype also enabled the system to provide a voice notification to the driver of potholes ahead. In addition, a website was deployed which allowed the concerned authorities to get access to the data collected by the prototype and take relevant measures to repair the potholes and restore optimal driving conditions . This feature in the system helped in maintaining the quality of roads [8].

B. G. Shivaleelavathi gave a suggestion in 2019 for a system to recognize and analyze potholes and speed bumps to avoid mishaps. Raspberry Pi was the main device used for the system's control and monitoring, and it utilized image processing techniques to pick out potholes and used ultrasonic sensors to locate and descry humps. Furthermore, the system incorporated Wi-Fi module techniques to distinguish potholes and send the data collected to the associated officials for corrective action and preventive measures [9].

This paper [10] introduces a novel imaging system and methodology for pothole 3D reconstruction using Structure from Motion (SfM) techniques. The authors combine a camera, laser range finder, and IMU to capture data while driving on roads. They use SfM algorithms to process the data and generate a 3D model of the road surface, including potholes. The system demonstrates accuracy in capturing pothole geometries and has potential applications in automated pothole detection and road maintenance planning.

These studies aim to improve the accuracy and efficiency of pothole detection, as well as enable real-time monitoring and proactive maintenance for road safety. The reviewed papers introduce innovative approaches such as computer vision and machine learning techniques, convolutional neural networks, LiDAR and camera integration, stereo vision, and IoT-based systems. These technologies enable accurate detection and classification of potholes, precise localization, and severity assessment. Additionally, some studies focus on sharing information with relevant stakeholders, such as drivers and road maintenance authorities. The use of mobile devices, sensors, and advanced algorithms facilitates the development of automatic pothole detection systems. The integration of 3D reconstruction techniques further enhances the understanding and visualization of potholes for effective road maintenance planning. Overall, these advancements contribute to the development of intelligent and proactive solutions for pothole detection and road safety.

IV. Methodology

Potholes on the roads are a significant problem for drivers, causing damage to vehicles and posing a danger to road users. To address this issue, an IoT-based pothole detection system has been developed that uses an ultrasonic sensor, GPS, GSM, and a camera module to detect and report potholes on the road in real-time. This system can help reduce the number of accidents caused by potholes and facilitate timely repairs.

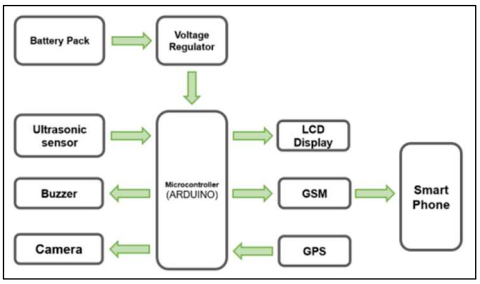

Fig. 1. Control System Block diagram

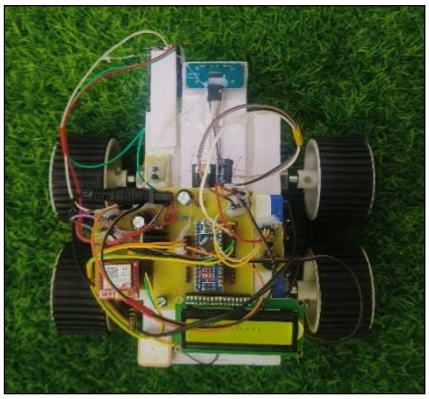
Fig. 2. Proposed system Image

The pothole detection system utilizes an ultrasonic sensor mounted on a vehicle to measure the depth of potholes. The sensor is designed to determine the distance between the vehicle and the road surface. When the measured distance exceeds a predetermined threshold, it indicates the presence of a pothole. This threshold is set to identify deviations in the road surface that are characteristic of potholes. By continuously monitoring the distance between the vehicle and the road surface, the system can detect and alert drivers to the presence of potholes, enabling them to take appropriate precautions and potentially avoid accidents or damage to their vehicles. The threshold value can be adjusted based on the depth of the potholes that are to be detected. The system uses an Arduino Nano microcontroller to interface the ultrasonic sensor with the other components of the system.

Once the system detects a pothole, it sends the location details to the concerned authorities using GPS and GSM technology. The GPS module records the latitude and longitude of the vehicle's location, while the GSM module sends an SMS alert to the concerned authorities. The SMS alert contains the message "pothole detection" and the location coordinates of the pothole. The authorities can use the information to plan and prioritize road repairs based on the severity and location of the potholes. The link to the Google Map location can be opened on the smartphone, providing a visual representation of the pothole location. In addition to sending location details, the system also captures an image of the pothole using a camera module. The camera module is mounted on the vehicle and captures an image of the road surface when a pothole is detected. The images

are stored locally in the ESP32 Camera module. The stored images can be used as evidence to verify the existence and severity of the potholes. The proposed system works in two stages, namely pothole detection and reporting.

During the pothole detection stage, the system employs an ultrasonic sensor to measure the distance between the vehicle and the road surface. When the measured distance surpasses a predetermined threshold, the system identifies the presence of a pothole. In the reporting stage, the system utilizes GPS and GSM technology to transmit the location details of the pothole to the relevant authorities. It also captures an image of the pothole, storing it locally within the module. To inform the driver, the system sends an SMS alert to their smartphone, including the location coordinates of the pothole and a link to the Google Map location for easy navigation and reference. This comprehensive reporting process ensures that both authorities and drivers are promptly notified about the pothole, facilitating swift action and enhancing overall road safety.

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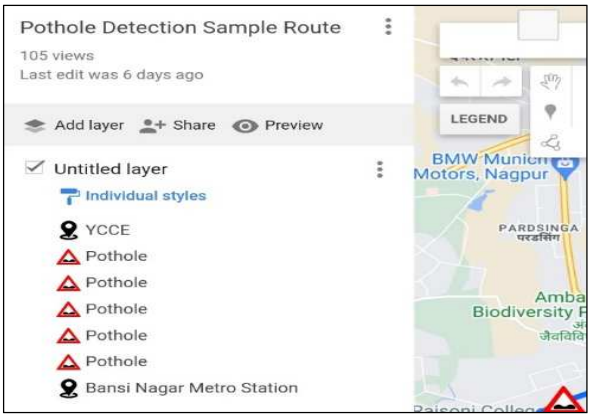

Fig. 3. Potholes Detected on a given route

Fig. 4. Potholes Detected on a given route

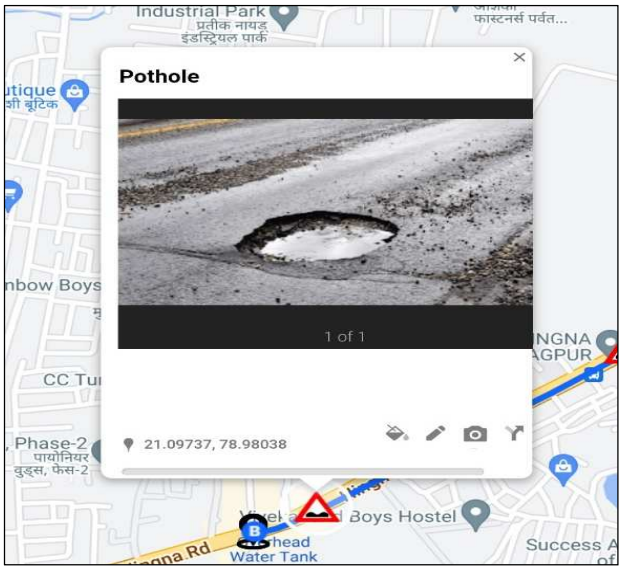

Fig. 5. Captured image of a Pothole

V. Sensor Testing

- Ultrasonic Sensor Testing:

Ultrasonic sensor also called as HC-SR04 module consists of ultrasonic transmitter, ultrasonic receiver and control circuitry. It is designed to measure distance between two objects by measuring time taken by the ultrasonic waves to travel a particular distance. This module transmits ultrasonic waves at 40KHz. The distance between two objects is calculated based on the time taken by the transmitted wave to return at receiver end.

TABLE I SENSOR TESTING RESULTS [11]

Condition	Ultrasonic Sensor (Cm)	State
Flat Road	= 8Cm	Unchanged
Pothole	< 8Cm	Detection
Humps	> 8Cm	Unchanged

VI. Result

The developed IoT-based pothole detection system has been designed, implemented, and field tested with successful results.

The system features:

- Ability to detect and monitor pothole parameters such as depth and size.
- Additionally, the system is capable of providing the precise GPS coordinates of the pothole by sending real-time SMS notifications from the sensor to the user.
- Furthermore, users can access the current road conditions on the website, providing a comprehensive overview of the road network.

VII. Conclusion

The IoT-based pothole detection system has the potential to revolutionize the way potholes are detected and repaired, ensuring the safety of road users and reducing the economic burden of vehicle damage caused by potholes. Additionally, the system's user-friendly interface, which sends alerts to both authorities and drivers, can help reduce the risk of accidents and damage to vehicles. Overall, this system has the potential to make our roads safer and more efficient for everyone who uses them.

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