An Intelligent Real Time Pothole Detection and Warning System for Automobile Applications Based on IoT Technology

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One of the major causes for road accidents in Indian roads is due to the potholes and humps. There is currently no system for detecting and identifying such potholes; thus, human intervention checks are performed manually, resulting in poor road maintenance, particularly in villages. In this digital era, it becomes essential to identify and report these potholes to the corresponding authorities in an automated version. This paper proposes a simple IoT based low-cost portable and economically affordable device to detect the potholes and intimate the damaged scenario to the corresponding authorities. This methodology avoids road accidents and ensures the proper maintenance. This proposed system can be installed on the moving vehicle and images are captured and mailed to the respective authority along with the GPS coordinates, which further alert the authorities to take corrective measures. This paper mainly focuses on implementing the above technology to motorbikes in a customized version as per the user requirements. The coordinates of the Global Positioning System (GPS) location will be stored in the ThingsBoard server and hosted in the Amazon Web Service. The entire system was successfully implemented using Raspberry Pi3 Single Board Computer (SBC) to capture, analyze the images and for email communication protocol. Amazon Web Service (AWS) is used as a backend to store the GPS location of the damaged rods with 100 % reporting success rate.

Keywords: Raspberry Pi3, Amazon Web Service, Things Board, Pothole detection, IoT system

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1. Introduction

The key problems and difficulties the road transport network faces are small roads, low road quality. Road transportation has expanded exponentially over the last two decades with a huge boom in highway transportation, city transportation and even in villages, linking all corners of the world. Based on a recent study conducted by "financial express" dated on September – 2019, 55 % of the highway roads received only 3-star rating (just a passing grade) and 39 % of the village roads doesn't makeup to the level even to receive a star, which is marked as unsafe for the users. Despite this the people are travelling in the road; around 87 % of the Indian population using roads daily. As a result, road condition depreciates and leads to an increase in road damages and potholes. Pothole formation has given rise to accidents and loss of human lives. Various techniques [1–7] like image and videography analysis [8] along with laser spectroscopy-based techniques have been implemented earlier in the literature to find the pothole and to provide information about the road depth, size, volume of the pothole, and pothole shape as well. This will provide a suitable maintenance measure which can be retrieved periodically. Image processing techniques are used in [9] to sense the exact pothole location. But capturing and processing the image at the rapid time requires a fast processor, which increase the component cost. Mobile sensors are used in [10] to detect the potholes and share the information through the GSM network. The obtained location information is shared using the Global System for Mobile Communication (GSM) and General Packet Radio Service (GPRS) modules to the corresponding authorities [11, 12]. However, the availability of high-speed network coverage in village and hilly areas are feeble. Ultrasonic based pothole detection system suffers from the problem of frequent device failure [5]. High-resolution cameras used in spectral space analysis and in telescopes are used in [4], in which, the cameras are combined with fast video frame analysis algorithm to detect the potholes [2].

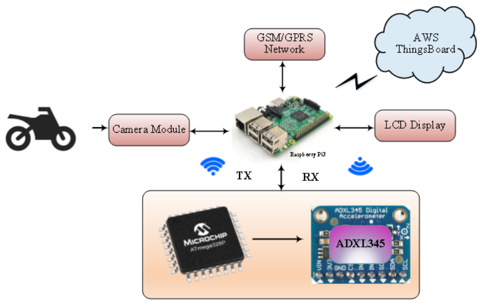


Fig. 1. Schematic Block diagram of Pothole detection system.

This project aims to develop and introduce a portable system that uses an accelerometer to locate the potholes and use a camera mounted in the motorbike suspension strut. The system sends the location of the pothole to authorities using GSM as a text message. This paper mainly emphasizes on the compactness of the portable device which can be fitted in any type of motorbikes. The location data are stored in the cloud for future analysis. The main objectives of this paper are as follows:

- To design a low-cost pothole detection system that can be fitted in any types of vehicles.
- To model an email notification system to the authorities and users as well.
- To store the data of potholes in the cloud for future references and analysis.

The Design and Development of the pothole and hump detection system are implemented using a Raspberry Pi3 as SBC, which controls the peripherals of GSM, camera, and sensor module. The sensor module is made of an ADXL345 accelerometer and Atmega328p microcontroller as the sensor controlling unit. AWS ThingsBoard server is an open-source platform which is used for data storage and future reference management in the server.

2. System Design

Raspberry Pi3 is the main control unit of the detection system [11–14]. It synchronizes the process of SIM808 module for sensing, capturing the pothole image, fetching GPS location, network connection establishment respectively. The SIM808 module is responsible for data transmission to the AWS ThingsBoard cloud [3]. Fig. 1 represents the architecture diagram of the pothole detection device. LCD is used as a dashboard for the driver, delivering the system status, pothole information, and real-time navigation. Sensing unit is designed with an ADXL345 accelerometer sensor and Atmega328P microcontroller. ADXL345 is used to sense the pothole with the help of a change in XYZ axis gravity, literally similar to the gyroscopic sensor. The microcontroller fetches the data from the sensor to the Raspberry Pi through the Serial communication.

3. Methodology of Implementation

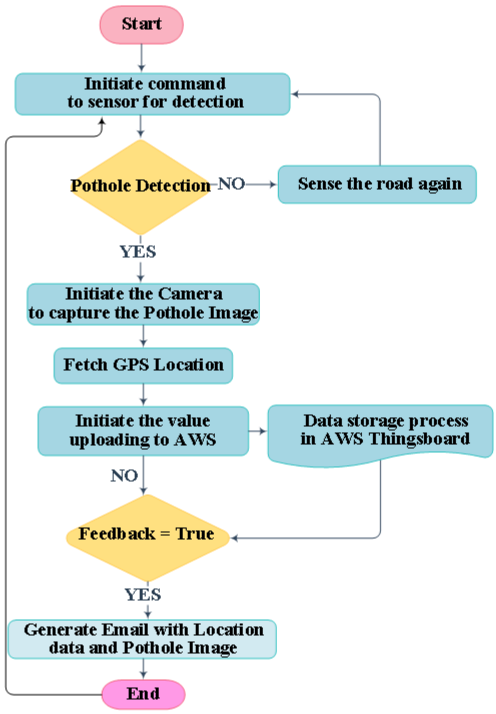
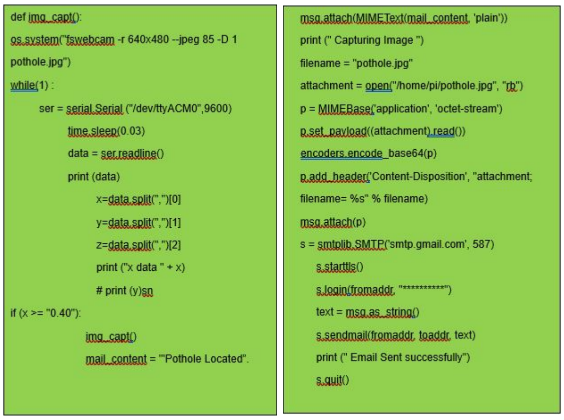


Fig. 2. Flowchart of proposed work.

The proposed concept is executed in six steps as mentioned in Fig. 2. A prototypical model has been designed and developed in the laboratory as shown in Fig. 6a and Fig. 6b. Sensor module is calibrated for higher accuracy. From sufficient field trials and with abundant iterations it is observed that the appropriate location in the motorbike for fixing the sensor is at the front wheel shock absorber as shown in Fig. 6c. The camera is fixed in such a way that the image will be captured without any disturbance in pixels, as represented in Fig. 6d. The sensor evaluates the pothole by having the changes in coordinates of the XYZ axis. In the same way, when the XYZ acceleration value changes concerning gravity acceleration 9.8 m/s, the ADXL345 sensor internal capacitor value changes concerning the change in XYZ value [6]. This change in value is captured by the internal registers present in the sensor. The stored values are transmitted to the Atmega328p over Inter-Integrated Circuit (I2C) protocol. The microcontroller analyzes the data consistency and sends it to the Raspberry Pi3 via serial communication by using the Serial Peripheral Interface (SPI) protocol. The source code used in python platform for XYZ axis detection is given in Fig. 3a. The serial communication is established with 9600 Baud rate. The data transmitted over the serial communication used to trigger the system for capturing the pothole image along with the GPS coordinates.



(a) **(b)**

Fig. 3. (a)-Source codes for XYZ coordinate detection (b)-Source codes for uploading in the server

SIM808 module is used for both GPS location and GPRS communication network for transmitting the data to the cloud. The source code for uploading in the cloud server is given in Fig. 3b. The sensor continuously checks for the pothole presence, once it detects it, the data will be transmitted to the Raspberry pi for further process as mentioned above. If the received data matches with the threshold value fed in the program, it initiates an activation command to the camera and SIM808 module. After fetching the GPS location from SIM808 it initiates the AWS value update. The data is sent to the Things board server through the Message Queuing Telemetry Transport (MQTT) protocol. The data from Raspberry Pi3 to AWS is transmitted in the following format,

Var text = '{"Lat":"11.2743666", "Lon": "77.6075372", "Time": "16.30"}';

The AWS Things Board server logs the individual data based on the rule chain implemented in the server as shown in Fig. 4. Once the data logging is completed in the server, it generates **TRUE** feedback. Based on this feedback the system decides whether the data updating needs iteration or to proceed further with the already retained data. When the received feedback is **FALSE**, Raspberry Pi3 initiates a command to update the data again. Once the feedback received is **TRUE** it generates an email containing pothole location and pothole image to the respective authority and users as well and it is shown in Fig. 6f.

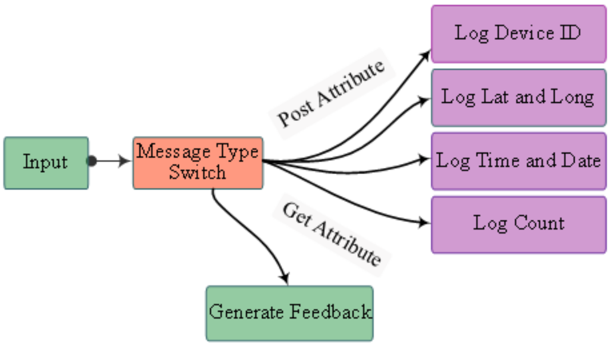


Fig. 4. Schematic of data logging and uploading to AWS cloud.

4. Result and Discussion

The developed prototypical model is tested in a real-time platform by connecting the system in a two-wheeler/motorbike. It is to be noted that, under testing condition, the vehicle speed is limited to 30 Km/Hr. When the vehicle passes over the pothole, with the change in the value of the sensor, the Raspberry Pi3 executes the process as mentioned in Fig. 2. The vehicle has been tested under various road conditions and the results were tabulated in Table 1. Time stamping helps the controller to retrieve the previous time-wise data.

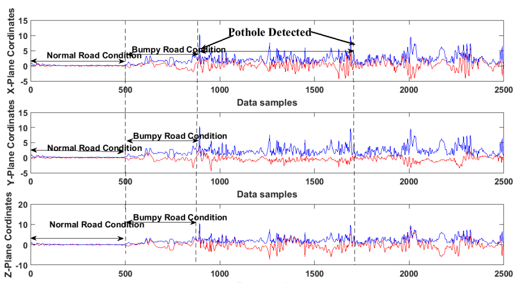


Fig. 5. XYZ coordinates value on pothole detection.

Table 1. Potholes GPS location stored in ThingsBoard server.

S.No	X-Coordinates	Y-Coordinates	Z-Coordinates	Latitude	Longitude	Time stamp
1.	0.1144	-0.0875	-0.3276	11.2743666	77.6075372	16.54
2.	0.1283	-0.1104	-0.2811	11.2643366	77.6075372	16.42
3.	0.0701	-0.1206	-0.2444	11.2852360	77.6075372	16.30
4.	-0.0097	-0.1899	-0.2054	11.2945861	77.6075372	16.25
5.	-0.0445	-0.1419	-0.107	11.2768463	77.6075372	16.08
6.	-0.0629	-0.137	-0.0257	11.1271224	78.6568942	17.05
7.	-0.0581	-0.0895	0.0386	11.3261224	78.6568942	17.18
8.	-0.0014	0.0148	0.1241	11.2751224	78.6568942	17.37
9.	0.0597	0.0702	0.1855	11.5981224	78.6568942	17.49
10.	0.1734	0.0747	0.1942	11.1251224	78.6568942	18.02

In the testing condition, the vehicle is passed in a normal flat road followed by a bumpy road with a pothole on it. By sensing the coordinates of XYZ and comparing with the reference value, the pothole is detected as shown in Fig. 5. That is, the controller will sense for the highest peak and retain the value and wait for the next highest peak. The coordinate values are compared based on the highest peak value, the pothole is detected and it follows the procedures shown in flowchart Fig. 2.

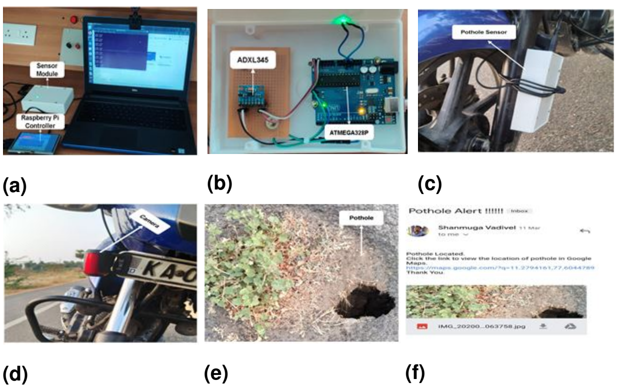


Fig. 6. (a) – Laboratory Setup – Controller programming, (b) – Laboratory Setup – Sensor Programming, (c) – Vehicle Setup - Equipment installation, (d) – Vehicle Setup – Camera position, (e) – Pothole detection in the road, (f) – Mail to the with its location coordinates.

5. Conclusions

This paper contributes economically affordable equipment to motorbike users and the government authorities as well. This equipment is suitable for all types of motorbike variants, which helps to have a safe ride and an accident-free nation. This portable product consumes a total power of 7.8 watts from the vehicle battery (12 V / 15 Ah), which is easily affordable and does not affect the normal operation of the vehicle. The over-all unit cost incurred for the fabrication and installation is around 80 $, which will be consistently reduced for bulk production. A real-time solution has been proposed and implemented the same by designing a portable device that can be fitted in any vehicle and used for locating the potholes, intimating the driver on the dashboard, and the respective public work departments about the location of potholes as well as data storing for future reference and analysis of the road conditions.

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