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Automatic pothole detection while driving

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ABSTRACT

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 helps drivers to avoid accidents or vehicle damages, but also helps authorities to maintain roads. This paper discusses previous pothole detection methods that have been developed and proposes a cost-effective solution to identify the potholes and humps on roads and provide timely alerts to drivers to avoid accidents or vehicle damages. Ultrasonic sensors are used to identify the potholes and humps and also to measure their depth and height, respectively. The proposed system captures the geographical location coordinates of the potholes and humps using a global positioning system receiver. The sensed-data includes pothole depth, height of hump, and geographic location, which is stored in the database (cloud). This serves as a valuable source of information to the government authorities and vehicle drivers. An android application is used to alert drivers so that precautionary measures can be taken to evade accidents. Alerts are given in the form of a flash messages with an audio beep.

Index Terms: Android application, GSM SIM900, GPS, PIC16F877A, Ultrasonic sensors.

INTRODUCTION

NDIA, the second most 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 [1]. However, most of the roads in India are narrow and congested with poor surface quality and road maintenance needs are not satisfactorily met. No matter where you are in India, driving is a breath-holding, multi-mirror involving, potentially life threatening affair.

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 [2], an integral part of vehicular area networks, which is the need of the hour today.

Roads in India normally have speed breakers so that the vehicle's speed can be controlled to avoid accidents. However, these speed breakers are unevenly distributed with uneven and unscientific heights.

Potholes, formed due to heavy rains and movement of heavy vehicles, also become a major reason for traumatic accidents and loss of human lives. According to the survey report "Road Accidents in India, 2011", by the ministry of road transport and highways, a total of 1,42,485 people had lost their lives due to fatal road accidents. Of these, nearly 1.5 per cent or nearly 2,200 fatalities

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were due to poor condition of roads. Figure 1 portrays the condition of roads with killer potholes. To address the above mentioned problems, a cost effective solution is needed that collects the information about the severity of potholes and humps and also helps drivers to drive safely. With the proposed system an attempt has been made to endorse drivers to ward off the accidents caused due to potholes and raised humps.



Fig. 1. Condition of roads with potholes.

RELATED WORK

Pavement distress detection is an intriguing topic of research and researchers have been working on pothole detection techniques. This section gives a brief description about the existing solutions for detecting potholes and humps on roads.

Moazzam *et al.* [3] have proposed a low cost model for analysing 3D pavement distress images. It makes use of a low cost Kinect sensor, which gives the direct depth measurements, thereby reducing computing costs.

The Kinect sensor consists of a RGB camera and an IR camera, and these cameras capture RGB images and depth images. These images are analysed using MATLAB environment, by extracting metrological and characteristic features, to determine the depth of potholes. Youquan *et al.* [5] developed a model to detect the three-dimensional cross section of pavement pothole. The method makes use of LED linear light and two CCD (Charge Coupled Device) cameras to capture pavement image. It then employs various digital image processing technologies including image pre-processing, binarization, thinning, three

The remaining sections of the paper are as follows: section II emphasises on the related work that has been done and is going on in the field of detection of potholes and humps. Section III discusses the various components used in the proposed system. Section IV describes the architecture and implementation of the proposed system. Experimental results of the proposed work are presented in Section V. Section VI talks about conclusion and future scope.

dimensional reconstruction, error analysis and compensation to get the depth of potholes. However, results get affected by LED light intensity and environmental factors. Lin and Liu [6] have proposed a method for pothole detection based on SVM (Support Vector Machine). This method distinguishes potholes from other defects such as cracks. The images are segmented by using partial differential equations. In order to detect potholes, the method trains the SVM with a set of pavement images. However, the training model fails to detect the pavement defects if the images are not properly illuminated. Orhan and Eren [7], have proposed a work developed on android platform to detect road hazards. There are three components in this proposed work viz, Sensing component, Analysis component and Sharing component. The sensing component basically works by collecting raw data from accelerometer and synchronizes with interface, hence leading to ease of access. In analysis component, the values obtained from the sensors are used for developing analysis modules. The sharing component works as follows: the developed framework is connected

with the central application, where it can directly communicate with the social network. All the collected data is stored at central repository for further processing. Although this method communicates traffic events with other drivers, it increases the cost and complexity of implementation.

Mednis *et al.* [8] have proposed a real time pothole detection model using Android smartphones with accelerometers. Modern smart phones with android OS, have inbuilt accelerometers, which sense the movement and vibrations. The accelerometer data is used to detect potholes. Different algorithms such as Z-thresh, which measures the acceleration amplitude at Z-axis, Z-diff to measure the difference between the two amplitude values, STDEV (Z) to find the standard deviation of vertical axis acceleration and G-Zero are used to identify potholes. Zhang *et al.* [9] have made use of stereo camera images coupled with a disparity calculation algorithm to identify potholes. The location coordinates of the potholes are also captured and stored in the database. Strutu *et al.* [10] have proposed a method for detecting defects on the road surface using accelerometers. It also makes use of GPS system to identify the exact location of the defects. Pothole detection algorithm runs on a mobile platform (moving vehicles), which is installed with accelerometer, GPS, local computer and a wireless router. The sensed data is communicated to the central database using primary access points and secondary access points which can be used for future processing. However, installing wireless router and local computer on all mobile platforms and setting up access points turns out to be quite expensive. Murthy and Varaprasad *et al.* [11], have proposed a system that detects potholes based on a vision based approach. The pictures of the road surface are captured using a properly mounted camera. The images are then processed using MATLAB to detect the occurrence of potholes. It is a 2D vision based solution and works only under uniform lighting conditions and also the system does not involve any kind of warning system. The above solutions are limited only to the identification of a pothole. These solutions do not provide any aid to the driver to avoid accidents due to potholes and humps.

Rode *et al.* [4] have proposed a system in which, Wi-Fi equipped vehicles collect information

about the road surface and pass it to the Wi-Fi access point. The access point then broadcasts this information to other vehicles in the vicinity in the form of warnings. However, the system turns out to be an expensive one as all vehicles should be installed with Wi-Fi stations and more number of access points have to be set up. Venkatesh *et al.* [12] have proposed an intelligent system that has made use of laser line stripers and a camera to detect and avoid potholes. This system maintains a centralized database of the location of potholes. It also sends warning messages to the nearby vehicles about the occurrence of potholes using Dedicated Short Range Communication protocol. Hegde *et al.* [13], have proposed an intelligent transport system to detect potholes. It makes use of ultrasonic sensors to detect the presence of potholes. This system also sends warning messages to all the vehicles in the range of 100 meters using Zigbee module. However, the system provides warnings after detecting the potholes which does not effectively help drivers to avoid potential accidents.

More *et al.* [15], proposed a system where sensors are mounted on public vehicles. These sensors record vertical and horizontal accelerations experienced by vehicles on their route. The installed GPS device logs its corresponding coordinates to locate potholes and the collected data is processed to locate potholes along the path traversed earlier by the vehicle. A Fire Bird V robot is used for experimenting with constant speed. The moving robot is mounted with a servo motor which rotates 0-180 degrees along with IR Sharp sensors. IR Sharp sensors check for variance in constant speed. If variance is detected, it is an indication of a pothole; robot stops and camera moves to take pictures of the pothole while GPS device locates its coordinates. Although this is a cost effective solution, it is restricted to collecting information about potholes. Yu and Salari [16], implemented a system that uses laser imaging for detecting potholes. Pavement distress such as pothole is detected when the laser source deformation is observed in the captured images. Different techniques such as multi-window median filtering and tile partitioning are applied to detect the presence of potholes. These potholes are further classified based on their shapes and severity.

Although this is an accurate and efficient method for detecting potholes, the cameras capture shaky images due to uneven road surface, which reduces the efficiency of pothole detection.

Chen *et al.* [17] proposed a system for detecting potholes using GPS sensor and three-axis accelerometer. The outputs are taken from the GPS

sensor and three-axis accelerometer and fed into data cleaning algorithm. In the second part of the implementation the inputs to the algorithm are processed for power spectra density (PSD) to calculate the roughness of potholes. After analysing, roughness is classified into different levels.

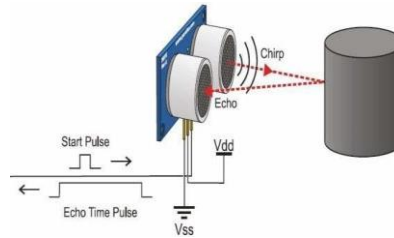


Fig. 2. Working principle of ultrasonic sensor.

COMPONENTS USED IN THE PROPOSED SYSTEM

The proposed system offers a cost effective solution for detecting potholes and humps on roads and notifying drivers about their presence. Components used in the proposed work are as follows:

PIC 16F877A Microcontroller: Peripheral Interface Control (PIC 16F887A) is a 40 pin microcontroller with 8k program memory. It is widely used due to its low cost, high application support and wide availability. Microcontroller is the heart of the proposed system and is responsible for performing various tasks starting from processing all the sensor inputs to alerting the driver.

Ultrasonic Sensors HC-SR04: The HC-SR04 is an active ultrasonic sensor and contains a transmitter and a receiver. It is used to measure distance at which, objects are placed in front of it. The ultrasonic sensor transmits high frequency sound waves and waits for the reflected wave to hit the receiver. The distance is calculated based on the time taken by the ultrasonic pulse to travel a particular distance [19]. The working principle of this device is shown in figure 2. There are different types of ultrasonic sensors with different transmission ranges and angles of detection. The HC-SR04 sensor work at frequency of 40 KHz and

can measure distances of the objects in the range 2 to 400 cm with a 15° angle of detection.

GPS Receiver: Global Positioning System (GPS) is a satellite navigation system and is used to capture geographic location and time, irrespective of the weather conditions. It is maintained by the U.S. Government and is freely available to anyone who has a GPS receiver. It obtains the GPS information from satellites in National Marine Electronics Association (NMEA) format. The NMEA has defined a standard format for the GPS information. This is followed by all the satellites. The standard defines various codes such as GLL-Latitude/Longitude data, GSV-Detailed satellite data and RMC-Minimum Recommended Data [14].

GSM SIM 900: Global Standards for Mobile Communication (GSM) is a set of standards for Second Generation (2G) cellular networks. The GSM SIM 900 module uses any network provider's SIM to communicate over the telecommunication network. This modem can be used to send and receive text messages and to make and receive voice calls. GSM SIM 900 is a quad-band GSM modem that functions at 850, 900, 1800 and 1900 MHz frequencies. This modem also supports features like transferring voice data, integrated support for GPRS and TCP/IP stack.

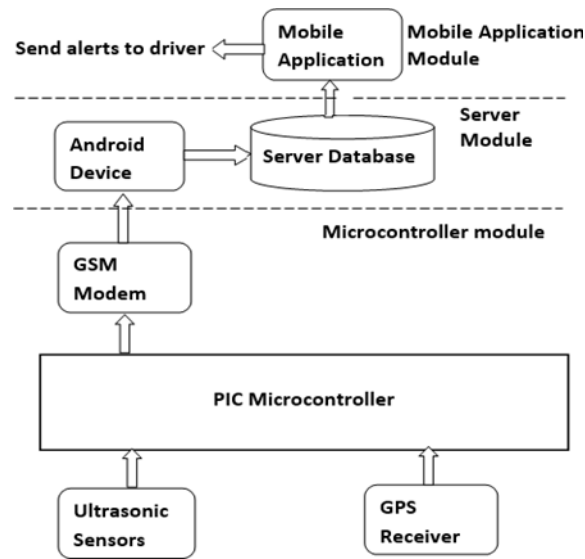


Fig. 3. Architecture of the proposed system.

ARCHITECTURE & IMPLEMENTATION

The architecture of the proposed system is shown in figure 3. It consists of 3 parts; microcontroller module, server module and the mobile application module. Microcontroller module is used to gather information about potholes and humps and their geographical locations and this information is sent to the server. Server module receives information from the microcontroller module, processes and stores in the database. Mobile application module uses information stored in the server database and provides timely alerts to the driver.

Microcontroller Module: This module consists of 4 components, namely, PIC 16F877A microcontroller, ultrasonic sensors, GPS receiver and GSM modem. Ultrasonic sensors are used to measure the distance between the car body and the road surface and this data is received by the microcontroller. The distance between car body and the ground, on a smooth road surface, is the threshold distance. Threshold value depends on the ground clearance of vehicles and can be configured accordingly. If the distance measured by ultrasonic sensor is greater than the threshold, it is a pothole, if it is smaller, it is a hump otherwise it is a smooth road.

The GPS receiver captures the location coordinates of the detected pothole or the hump and sends messages to the registered mobile SIM using GSM modem. This registered mobile SIM is present on the android device that acts as server. The messages sent include information about depth of the pothole or height of the hump and its location coordinates.

Server Module: This module consists of two parts; the android device and the database. It acts as an intermediary layer between the microcontroller module and the mobile application. The server module is implemented as an android application that runs on a device and is responsible for reading messages sent by the registered mobile SIM present in the microcontroller module. It processes the contents of this message and stores it in the database (cloud). Integrating sensor networks with cloud and Internet of Things [18], it is possible to allow broader access to sensor data.

Mobile Application Module: This module is implemented as an android application that is installed on the vehicle driver's mobile phone to provide timely alerts about the presence of potholes and humps. Figure 4 shows the workflow of this application. The application continuously runs in the phone background. It first captures the current geographic location of the vehicle and then accesses the locations of potholes and humps

stored in the server database. The distance between the vehicle location and the pothole location stored in database is computed. If the distance between the two is within 100 meters, an alert message

pops up on the mobile screen. This message is accompanied with an audio beep so that the driver can differentiate it from other flash messages.

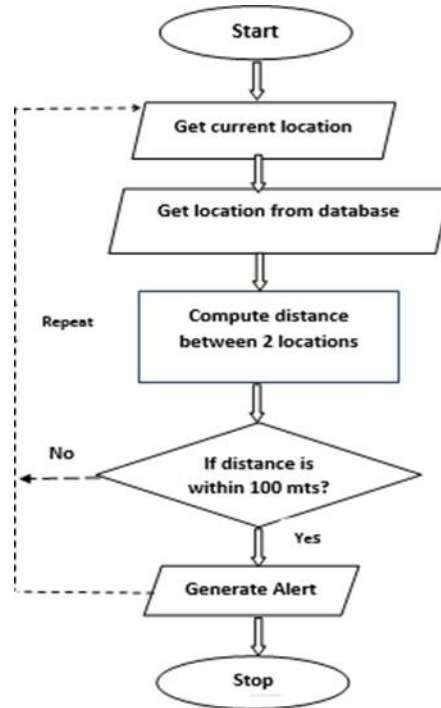


Fig. 4. Workflow of mobile application.

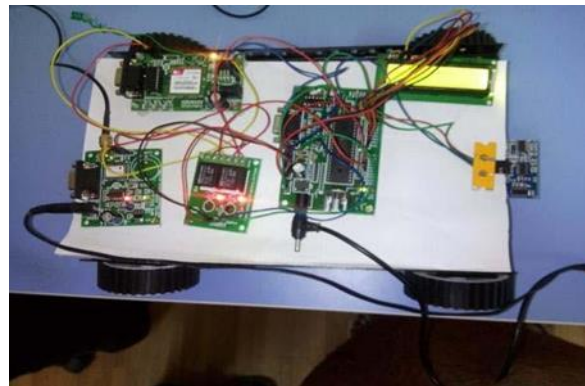
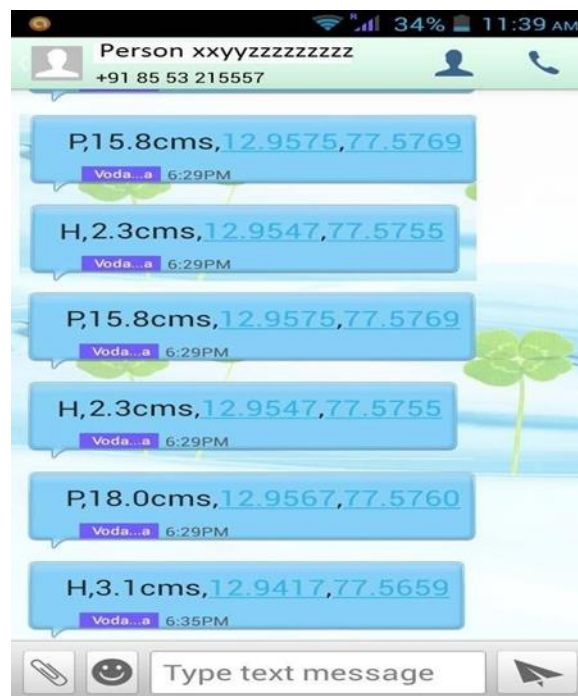


Fig. 5. Working model of the proposed system.

Table I: Information about potholes and humps collected in simulated test environment

Sl No	Obstacle Type	Height/Depth in cms	Latitude	Longitude
1	P	19.35	12.9563	77.5544
2	H	3.1	12.9406	77.5661
3	H	3.8	12.9421	77.5668
4	P	13.2	12.9434	77.5669
5	P	8.7	12.9411	77.5654
6	P	6.3	12.9423	77.5658
7	H	2.3	12.9547	77.5755
8	P	15.8	12.9575	77.5769
9	H	3.1	12.9417	77.5659
10	P	18.2	12.9567	77.5760

**Fig. 6. Message sent to android device about the pothole and hump locations.**

EXPERIMENTAL RESULTS

The working model of the proposed system is shown in figure 5. It was tested in a simulated environment with artificial potholes and humps. The mode was also tested in real time by fixing it on a motor bike (Honda Activa).

Tests were carried out in two phases. In the first phase, information about potholes and humps was recorded and stored in the server database. In second phase, alerts were generated based on pothole and hump information stored in database. While testing in the simulated environment, the

microcontroller module was fixed on a toy-car and the threshold value was configured to 5 cm. During the tests it was found that the microcontroller module worked as expected to identify potholes and humps. Table I shows a set of potholes and humps identified by the system in the simulated environment. Information about potholes and humps was successfully sent to the android device (server). The snapshot of these messages can be seen in figure 6. The server processed the messages received and stored in the database.

In the above table, obstacle type 'P' indicates a pothole and 'H' indicates a hump. In the second

phase of testing, the mobile application that generates alerts was successfully tested by moving the toy-car on routes containing potholes and humps and alerts were generated for potholes and humps recorded in the first phase. Figure 7 shows an alert generated by this application.

Figure 8 shows the real time testing of the proposed model. The microcontroller module was

fixed on Honda Activa and the threshold distance value was configured to 16 cm, which is the ground clearance for Honda Activa. The vehicle was moved on Bangalore roads for the purpose of recording information about potholes and humps, and the test results were as expected. Table II shows a set of potholes and humps detected during real-time tests.



Fig. 7. Pothole alert displayed on the mobile phone.

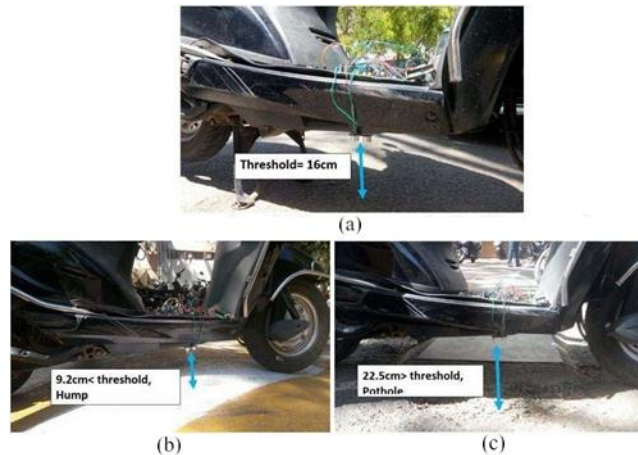


Fig. 8. (a) Proposed model fixed on two wheeler bike for testing. (b) Detection of lump. (c) Detection of pothole.

Table II: Information about potholes and humps collected during real-time testing

Sl No	Obstacle Type	Height/Depth in cms	Latitude	Longitude
1	P	22.5	12.94048	77.56598
2	H	9.2	12.94062	77.56583
3	H	7.5	12.94039	77.56569
4	P	24.3	12.94047	77.56692
5	P	23.7	12.94073	77.56480

CONCLUSION AND FUTURE RESEARCH WORK

The model proposed in this paper serves 2 important purposes; automatic detection of potholes and humps and alerting vehicle drivers to evade potential accidents. The proposed approach is an economic solution for detection of dreadful potholes and uneven humps, as it uses low cost ultrasonic sensors. The mobile application used in this system is an additional advantage as it provides timely alerts about potholes and humps. The solution also works in rainy season when potholes are filled with muddy water as alerts are

generated using the information stored in the database. We feel that the solution provided in this paper can save many lives and ailing patients who suffer from tragic accidents.

The proposed system considers the presence of potholes and humps. However, it does not consider the fact that potholes or humps get repaired by concerned authorities periodically. This system can be further improved to consider the above fact and update server database accordingly. Also, Google maps and SATNAV can be integrated in the proposed system to improve user experience.

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