An IoT Based Driver Assistance System to Detect and Notify the Presence of Potholes and Humps on Roads

Ganga Holi[#1], Rachna Rao[*2]

[#1]*Professor, Information Science & Engineering, Global Academy of Technology Rajarajeshwari Nagar, Bengaluru, Karnataka, India.*

[*2]*Student, Information Science & Engineering, Global Academy of Technology Rajarajeshwari Nagar, Bengaluru, Karnataka, India.*

Abstract *— One of the prime reasons for vehicular accidents is due to undetected potholes and road humps. Potholes force vehicles to slow down in places where the speed of vehicles may be expected to be higher, drivers do not expect to slow down and end up crashing into other vehicles. Some potholes go unattended for several weeks and get deeper with time, so much so that vehicular damage increases by just passing over the pothole. Several lives are lost each year due to pavement distress, and it is high time for a cost-efficient solution to this problem so that it can be implemented immediately. This paper provides a prototype of an IoT based pothole and hump detection system that can be integrated with the vehicle and provide timely information to maintenance authorities so that necessary steps can be taken for safety of drivers.*

Keywords *— IoT, NodeMCU, ultrasonic sensor, FSR.*

I. INTRODUCTION

A pothole is defined as a bowl-shaped depression in the pavement with a minimum depth of 150mm. Potholes can be hazardous since they cause severe damage to vehicles and drivers. It is necessary to detect and repair potholes instantly to avoid punishing circumstances. When drivers try to avoid potholes that they spot on the road ahead of them, they drive in an unexpected manner, this also leads to accidents. On conducting a survey, it was found that 19 out of 42 drivers choose to avoid the depression rather than go over it. These results tell us a significant number of users care about the safety of their vehicle. With this information it becomes apparent that there are drivers that value knowing where there are potential road hazards.

Pothole detection is a regular task for road maintenance authorities, which is now done manually. It is a time-consuming task which requires workers to travel to several roads and look for potholes or other types of pavement distresses, assess the quality of the roads and properly maintain road quality. This is done through a yearly inspection, which is not nearly enough in regions where the weather plays a key role in the wear and tear of roads. Thus, a cost-efficient, time-efficient solution is required to inspect roads more frequently.

Road humps are made to curb vehicle speed, but many humps are made with uneven and unscientific heights and in unexpected intervals. Sometimes timely road signs are not provided to warn drivers to slow down for an upcoming road hump, which results in accidents or vehicle damage. The system is made to also detect road humps and provide timely alerts to drivers.

II. RELATED WORK

Maithili Naik et. al. [1] proposed a system using RaspberryPi and HC-SR04 sensors to detect potholes. The data was to be pushed to cloud storage and passed on to road maintenance authorities through an android application designed for this system.

The system described in this paper is based on the same concept applied using NodeMCU and can be used even by drivers to receive alerts through voice commands on road humps and potholes that are detected by the system, as well as alerts to check the tires of the vehicle.

Youquan et al. [2] have developed a model which employs optical imaging principle of three-dimensional projection transformation to obtain pictorial information of pothole's cross-section in pothole detection. Multiple digital image processing technologies, including: binarization, image processing, thinning, three-dimensional reconstruction, error analysis and compensation are conducted in the series of image analysis and processing.

Lin and Liu [3] have proposed a method for pothole detection based on SVM, where SVM stands for Support Vector Machine. Texture measure based on the Histogram is extracted as the features of the image region, and the non-linear support vector machine is built up to identify whether a target region is a pothole. Based on this, an algorithm for recognizing the potholes of the pavement is proposed. The experimental result shows that the algorithm can achieve a high recognition rate.

Moazzam et al. [4] have developed a model in which a low-cost Kinect sensor is used. Kinect gives the direct depth measurements, thereby reducing computing costs. Meshes are generated for better visualization of potholes. Area of pothole is analysed with respect to depth. The approximate volume of pothole is calculated using trapezoidal rule on area depth curves through pavement image analysis. In addition, pothole's area, length, and width are estimated. The paper also proposes methodology to characterize pothole.

Rode et al. [5] have designed a system in which novel Wi-Fi based architecture for pothole detection and warning system which assists the driver in avoiding pothole on the roads by prior warning. The system consists of access points placed on the roadsides for broadcasting data, which can be received by Wi-Fi enable vehicles as they enter the are covered by the influence of the access points. The application can be integrated in the vehicle to alert the driver in the form of a visual signal, audio signal or even trigger the braking system.

Samyak Kathane, et al. [7] have proposed a model which is Real time pothole detection and vehicle accident detection and reporting system and Antitheft. In this system the wireless access point collects the information about potholes, it distributes this information to BMC using wireless broadcast. This system is used for the accident detection too. Antitheft in car can help to save millions of dollars. Sensor boards that we used for collecting the environmental data also has an accelerometer that can measure both the vertical and the horizontal acceleration. for example, when a bus goes over the pothole there would be significant change in vertical component of the acceleration and for humps there would be a horizontal component.

Taehyeong Kim, et al. [8] proposed a paper in which classification of potholes are given. Potholes are classified according to the location, shape, length and depth. Many researchers have studied the methods to detect potholes and improve survey efficiency and pavement quality through prior investigation and immediate action. With these detecting methods, there is need for developing a classification guideline for supporting decision-making system of pothole repair. The purpose of this study is to develop a guideline of pothole classification for supporting a decision-making system of pothole repair.

Ajit Danti, et al. [9] have developed a model based on Image Processing approach. In this paper Haugh Transformation is given for lane detection. Clustering based algorithm is used for detection of potholes. In this, experimental results are tested with real time image database.

Analysing potholes based on their depth helps us classify them based on how dangerous they pose to be on road to drivers. Therefore, this concept is borrowed from Moazzam et. al. [4] and this system will detect pothole depth using ultrasonic sensors. Pothole classification can be used to implement a recommendation system that helps drivers choose safer routes. This prototype system will adopt the pothole classification concept from Taehyeong Kim, et al. [8] in the future to implement a recommendation system based on pothole density using the location and depth of potholes recorded.

III. COMPONENTS REQUIRED

The following are the components that are required to design a prototype of the proposed system

A. Arduino Compiler

Arduino IDE is a GUI based Software that supports all the Arduino based microcontrollers. It is a cross platform application written in the programming languages C, C++ and Java. It runs on various operating systems like Windows, Mac OS and Linux.

B. NodeMCU

The NodeMCU (Node Micro Controller Unit) is an open source software and hardware development environment that is built around a very inexpensive System-on-a-Chip (SoC) called the ESP8266. The ESP8266, designed and manufactured by Espressif Systems, contains all crucial elements of the modern computer: CPU, RAM, networking (Wi-Fi), and even a modern operating system and SDK. That makes it an excellent choice for IoT projects of all kinds.

However, as a chip, the ESP8266 is also hard to access and use. One must solder wires with the appropriate analog voltage to its PINs for the simplest tasks such as powering it on or sending a keystroke to the "computer" on the chip and you must program it in low level machine instructions that can be interpreted by the chip hardware. While this level of integration is not a problem when the ESP8266 is used as an embedded controller chip in mass-produced electronics, it is a huge burden for hobbyists, hackers, or students who want to experiment with it in their own IoT projects.

This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area.

C. Ultrasonic Sensor

HC-SR04 ultrasonic sensor is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. It has two projections, one to transmit the ultrasonic waves, and the other receives the echo

that is reflected back from an obstacle. The distance is calculated based on the time taken by the ultrasonic pulse to travel a particular distance as follows:

$$Distance = (Time \times 343m/s)/2$$

We power the Sensor using a regulated +5V through the Vcc and Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins. The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return to the sensor. The amount of time during which the Echo pin stays high is measured by the MCU as it gives the information about the time taken for the wave to return to the sensor.

D. Force Sensitive Resistor

FSRs are resistors that change their resistive value in ohms Ω depending on how much it's pressed. These sensors are fairly low cost, and easy to use but their accuracy is low. When FSRs are being used, one should only expect to get ranges of response. This FSR is model 402 by Interlink Electronics with the sensing region diameter 14.7mm. The FSR is a single-zone Force Sensing Resistor optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications. FSRs are two-wire devices. They are robust polymer thick film sensors that exhibit a decrease in resistance with increase in force applied to the surface of the sensor.

E. Bluetooth Module HC-05

The Bluetooth module HC-05 is a master/slave module. By default, the factory setting is slave. The role of the module can be configured only by AT COMMANDS. It typically has - 80dBm sensitivity and up to +4dBm RF transmit power. It has a voltage range of 3.3 to 5 V I/O. The module has PIO control and UART interface with programmable baud rate. HC-05 comes with an integrated antenna and edge connector.

IV. PROPOSED SYSTEM

The proposed system consists of an ultrasonic sensor that senses the distance between the vehicle and the pothole/hump. The sensor provides the distance values to the microcontroller. Based on the distance, an indication is provided to the driver through voice commands. Further, the system also captures the geographical location coordinates of potholes and humps using GPS receiver. The data is then pushed to ThingSpeak cloud for analysis and can be sent to maintenance authorities.

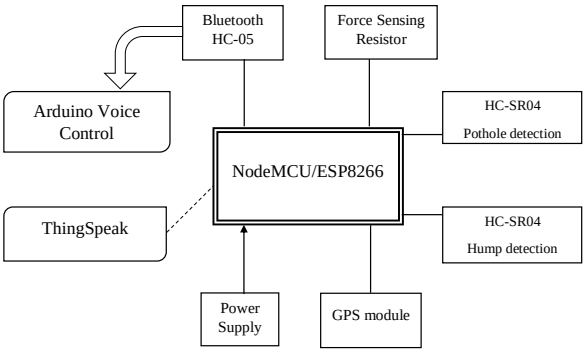

Figure 1: Fundamental block diagram of the proposed system

Fig. 1 shows the elemental block diagram of the system. NodeMCU is the microcontroller used to integrate all the components together. The microcontroller is powered through a USB cable connected to the computer. It can further be made wireless by use of alkaline batteries. HC-SR04 is the ultrasonic sensor used to measure distance to an obstacle.

To detect potholes, we programme the HC-SR04 unit to alert the user when the distance is greater than the distance between the sensor and the road. In our model, the distance between the vehicle and the road is 5cm so any distance greater than 5cm is programmed to send an alert.

Similarly, HC-SR04 unit can also be used to detect humps by programming it to detect obstacles at, say, 10cm. So, if a hump is detected by the sensor at 10cm distance, an alert will be sent to the user. This sensor is attached to the anterior end of the vehicle.

A Force Sensor Resistor (FSR) is used to check the amount of air in the tires of the vehicle. If there is less air in the tire it may result in tire puncture. Punctures that go unnoticed can cause road accidents due to loss of control over the vehicle. A threshold resistance is recorded for the tire before installation, and if the threshold is crossed, the driver is alerted to check the tires.

The values of pothole depth and height of the hump that are recorded by the ultrasonic sensors and the values recorded by the FSR are pushed to ThingSpeak which is an open IoT platform that enables us to visualize the data or perform analysis. We can also trigger reactions in our system using ThingSpeak. The data is constantly recorded in ThingSpeak database and can be retrieved in .json, .xml and .csv formats and used to perform survey.

Using the Bluetooth module HC-05 we can connect to Arduino Voice Control application which is an open source application that can be used to receive voice signals. So, the driver would have to connect to the Bluetooth module of the system before starting his/her journey and the system is programmed to send voice commands that alert him/her about humps to avoid and potholes that are detected. Even alerts to check the tires of the car will be received through this application.

V. EXPERIMENTAL RESULTS

The pothole and hump measurements detected by HC-SR04 can be viewed on the serial monitor tool of the Arduino IDE as shown in Figure 2 and 3. The pressure sensor's resistance values are also displayed on the serial monitor.

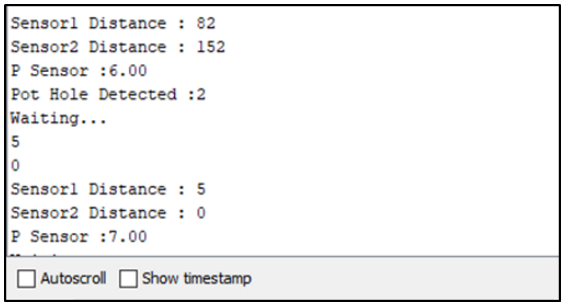

Figure 2: Sensor 1 detects pothole since the distance to road is greater than 7cm

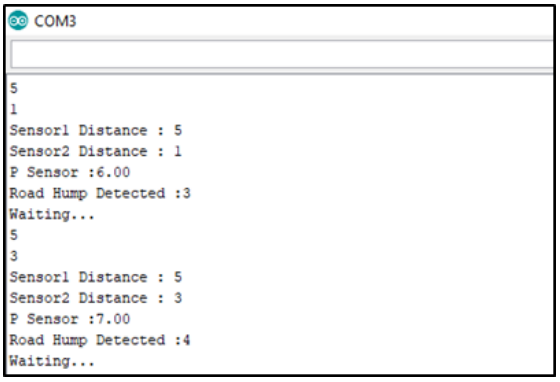

Figure 3: Sensor 2 detects road hump since the distance to obstacle is less than 6cm

Figure 4 and 5 are images of the prototype model. The microcontroller is mounted on the vehicle, two ultrasonic sensors are attached to the vehicle – one is attached on the anterior end of the vehicle that is used to detect humps, and another is attached below the vehicle facing the road to detect potholes. The FSR that is to be placed within the tire is attached to the side of the model for better demonstration.

Figure 4: Front view of the model

Figure 5: Side view of the prototype model

Figure 6 and 7 depict the ThingSpeak channels that record the data received from the sensors in the form of time-value plots.

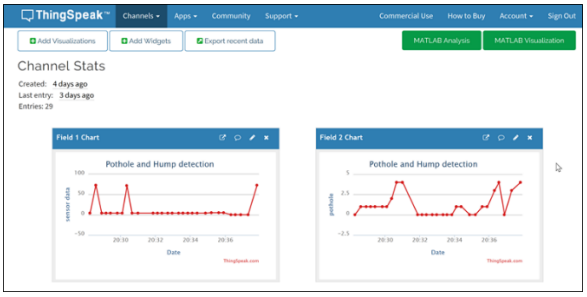

Figure 6: ThingSpeak channels to visualize data recorded by FSR and HC-SR04

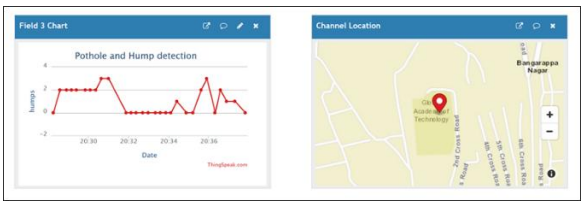

Figure 7: Road hump sensor values plotted against time, and the location of system

VI. CONCLUSION AND FUTURE WORK

The proposed system basically serves two purposes; it automatically detects the potholes and humps and sends the information regarding this to the vehicle drivers, so that they can avoid accidents. This is a cost-efficient solution for detection of humps and potholes. This system is effective even in rainy season when roads are flooded with rainwater as well as in winter during low visibility, as the alerts are sent from the stored information in the server/database. This system helps us to avoid dreadful humps and helps maintenance authorities track potholes more efficiently and hence avoid any tragic accidents due to bad road conditions. The information can be used by government authorities for regular maintenance of the roads.

The proposed system can be further improved to recommend safer routes based on the density of potholes on roads. Using concepts of machine learning, threshold values need not be set for each sensor. For all the variable threshold values in different vehicles, the system can be made to learn the threshold values automatically to make the system adapt to any vehicle easily. A mobile application made to collect all the data in one place and can be used to track the recorded values in one place and pass it on to road maintenance authorities for ease of use.

REFERENCES

[1] Maithili Naik, Nischita Jaiwant, Neha M, N.M. Anmol, Prof. R. Mattimani, Dr.R.M.Banakar, "Pothole Detection through IoT ", International Journal of Technology and Science, ISSN (Online) 2350-1111, (Print) 2350-1103 Volume 9, Issue 2, 2016 pp. 23 -26.

[2] H. Youquan, W. Jian, Q. Hanxing, Z. Wei, and X. Jianfang, "A research of pavement potholes detection based on three-dimensional projection transformation," in Proc. 4th Int. Congr. Image Signal Process (CISP), Oct. 2011, pp. 1805–1808.

[3] J. Lin and Y. Liu, "Potholes detection based on SVM in the pavement distress image," in Proc. 9th Int. Symp. Distrib. Comput. Appl. Bus. Eng. Sci., Aug. 2010, pp. 544– 547

[4] I. Moazzam, K. Kamal, S. Mathavan, S. Usman, and M. Rahman, "Metrology and visualization of potholes using the microsoft Kinect sensor," in Proc. 16th Int. IEEE Conf. Intell. Transp. Syst., Oct. 2013, pp. 1284–1291.

[5] S. S. Rode, S. Vijay, P. Goyal, P. Kulkarni, and K. Arya, "Pothole detection and warning system: Infrastructure support and system design," in Proc. Int. Conf. Electron. Comput. Technol., Feb. 2009, pp. 286–290.

[6] R. Sundar, S. Hebbar, and V. Golla, "Implementing intelligent traffic control system for congestion control, ambulance clearance, and stolen vehicle detection," IEEE Sensors J., vol. 15, no. 2, pp. 1109–1113, Feb. 2015.

[7] Samyak Kathane, Vaibhav Kambli, Tanil Patel and Rohan Kapadia, "Real Time Potholes Detection and Vehicle Accident Detection and Reporting System and Anti-theft (Wireless)", IJETT, Vol. 21, No. 4, March 2015.

[8] Taehyeong Kim, Seung-Ki Ryu, "A Guideline for Pothole Classification", International Journal of Enginering and Technology (IJET), Vol. 4, No. 10, October 2014.

[9] Gunjan Chugh, Divya Bansal and Sanjeev Sofat, "Road Condition Detection Using Smartphone Sensor: A Survey", International Journal of Electronic and Electrical Engineering, Vol. 7, No. 6, 2014.

[10] Ajit Danti, Jyoti Y. Kulkarni, and P. S. Hiremath, "An Image Processing Approach to Detect Lanes, Potholes and recognize road Signs in Indian Roads", International Journal of Modeling and Optimization, Vol. 2, No. 6, December 2012.