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Design and Development of an Intelligent System for Pothole and Hump Identification on Roads

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Abstract—Country's economy depend on well-maintained roads as they are major means of transportation. It becomes essential to identify pothole and humps in order to avoid accidents and damages to the vehicles that is caused because of distress to drivers and also to save fuel consumption. In this regard, this work presents a simple solution to detect potholes and humps and hence avoid accidents and help drivers. Potholes are detected using Image Processing Technique and Ultrasonic Sensors are used to detect humps. Controlling device used is Raspberry Pi. The system acquires the geographical position of potholes using Wi-Fi and transmits it to authorities to take corrective measures.

Keywords : Maintenance of roads, Pothole, Hump, Image Processing, Ultrasonic sensor, Raspberry Pi, Wi-Fi.

I. INTRODUCTION

The major challenges faced in the road transportation sector are: The roads are narrow, not of good quality and the road maintenance is low funded. The road vehicle handling capacity is also low, but the vehicle density on road is increasing. As a result, the roads deteriorate and increase the users cost of transportation. This had led to road accidents. The other reason for traffic jams and accidents is the poor condition of roads [1].

Potholes are formed due to heavy rains and dense movement of vehicles on the poorly constructed roads. Pothole formation has given rise to accidents and loss of human lives.

Various methods like image and video analysis, and laser based techniques have been proposed to detect pothole and also to provide information in terms of their shape, size, depth and volume, so that an appropriate maintenance measure can be taken.

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Fig. 1 Potholes and Humps on Roads

Indian roads have speed breakers to control the vehicle's speed. The speed breakers are not distributed uniformly and are of incorrect heights. If regular maintenance of the road is neglected, it results in huge portholes and results in accidents, fuel consumption of vehicle increases and deteriorates the economic growth of the country. So, it becomes important to get information of these bad road conditions, gather and dispense them to the vehicles, to warn the drivers. Potholes and humps are detected using ultrasonic sensors and their information like location is provided to the authorities with the help of GPS and GSM and alerts the driver regarding the bumpy roads and potholes on its path.

This project aims at identifying the potholes using image processing technology with the help of a camera. The system sends the location of these potholes to authorities using GPS, so that they can take action of maintaining the roads and help the drivers in avoiding the accidents. The humps are detected using the ultrasonic sensors and the electronics system alerts the driver about the humps and the driver can accordingly slow down the vehicle and hence avoid the accidents. The alert is provided in the form of voice through speakers and displayed on the LCD and using GSM, SMS is sent to the driver.

II. EXISTING PROBLEM AND SOLUTION

The paper [2] describes and implements a real-time pothole detection and traffic monitoring system, and has been able to harness Smartphone sensors to solve a global challenge, apply Machine learning to a real world problem and develop a scalable, reliable system driven by the power of crowd sourcing.

The paper [3] Uses a Kinect sensor, to obtain images from concrete and asphalt roads and exported to the MATLAB environment for processing. An extensive data processing algorithm analyses the image and the parameters like, pothole area, length, and width are estimated.

The paper [4] proposes a Wi-Fi based architecture for Pothole Detection and Warning System which assists the driver in avoiding potholes on the roads by giving prior warnings.

The pothole detection presented in this paper helps the driver to receive information of the potholes on the roads.

The reference paper [5] proposes a method which employs optical imaging principle of three-dimensional projection transformation to obtain pictorial information of pothole's cross-section in pothole detection.

The paper [6] explains the use of ultrasonic and accelerometer sensors to detect the potholes ahead the vehicles and alert the vehicle user about the potholes via GSM SIM900A so the user can take precautionary measure to avoid the accident.

The reference paper [7] uses Raspberry-Pi microcomputer to detect and report potholes from a moving car, all detection were uploaded to the web server.

Multiple digital image processing technologies, including: image preprocessing, binarization, thinning, three-dimensional reconstruction, error analysis and compensation are used in the series of image analysis and processing [8].

The reference paper [9], the features of the image region are extracted based on the histogram and the non-linear support vector machine is built to identify whether a target region is a pothole.

In the paper [10], the potholes and obstacles on the road are identified using Ultrasonic sensors, and the detected pothole's depth is displayed on the LCD.

In the paper [11], depth of the pothole was detected by ultrasonic sensor and GPS receiver for recording its location in the terms of latitude and longitude. Wi-Fi module was used for sending the data to the server.

The paper [12] presented android application to recognize defects on the roads, which is composed of three core ingredients: Sensing, Analysis and Sharing. The information gathered is stored and maintained at the central repository.

III. PROBLEM STATEMENT

The goal of this proposal is to design and develop a prototype of an intelligent data gathering system that can be fitted in any transportation vehicle or car to detect the road or highway conditions. The prototype develops an information gathering system that informs the authorities about the road conditions. With this information the authorities could take measures to repair the roads which in turn help to avoid accidents caused due to nontechnical humps and hence lower the percentage of damaged roads and avoid road accidents.

IV. OBJECTIVE

The objectives of the proposed work are:

- Design and Development of the Pothole and hump detection System.
- Help Road maintenance, aiding economic growth.
- Avoidance of accidents via real time alerts through GSM.
- To display the pothole location with latitude and longitude, the link that takes to Google map is also displayed in TCP/UDP test tool.

The Design and Development of the pothole and hump detection system involves the use of the following components and their description as below:

A. *Raspberry Pi 3 model B:*

The Raspberry Pi 3(Fig. 2) [7] is a single-board computers developed in the United Kingdom by the Raspberry Pi Foundation. Raspberry Pi Debian GNU/Linux operating system exist for this SBC. A ceramic chip antenna is used by Wi-Fi and Bluetooth 4.1 SoC BCM43438.

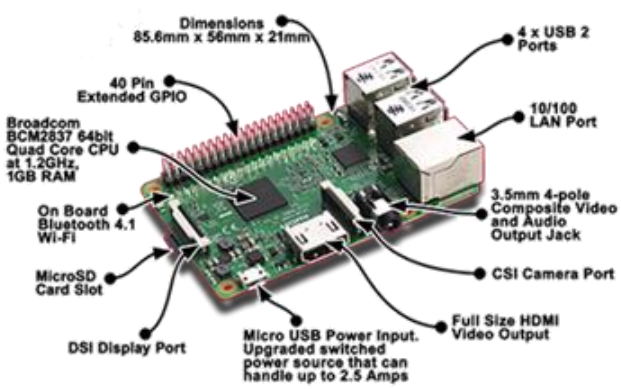
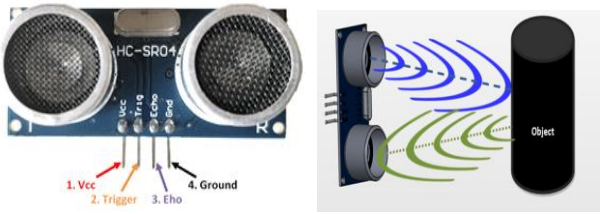


Fig. 2 Raspberry Pi 3 model B[Source: ResearchGate]

B. *Ultrasonic Sensor HC-SR04:*

HC-SR04 sensor is a 4-pin module as shown in Fig. 3a, whose pin names are Vcc, trigger, echo and ground respectively. The sensor uses a regulated +5V through the Vcc and ground pins of the sensor. To measure, the trigger pin is to be made high for 190µs and then turned off [6]. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. The wave returns after getting 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 back 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 back to the Sensor. This sensor measures the distance of the hump which is present in front of it. The sensor works with the formula: **Distance=Speed×Time.**

To use the above equation we should know the speed and time. Speed of Ultra Sonic (US) wave is 330m/sec.



(a) (b)

Fig. 3a Ultrasonic Sensor [Source: Internet]
Fig. 3b Receive and Transmit operation

The Ultrasonic transmitter transmits an ultrasonic wave. This wave travels in air and when it gets objected by any material it gets reflected back toward the sensor. This reflected wave is observed by the Ultrasonic receiver module as shown in Fig. 3b.

C. *LCD 16×2 (1602a):*

LCD (Liquid Crystal Display) screen (Fig. 4) is an electronic display module.

A 16×2 LCD can display 16 characters per line and there are 2 such lines. In this project it is used to provide display of hump and porthole to car driver.

Fig. 4 LCD 1602a[Source: Internet]

D. *DC Motor:*

A DC motor converts direct current electrical energy into mechanical energy. In the prototype the wheels are coupled to motor for providing motion for the prototype robot car.

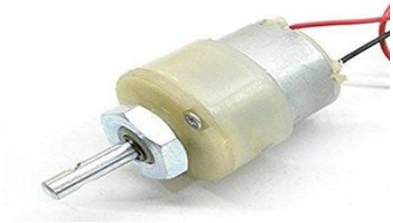


Fig. 5 DC Motor [Source: Internet]

E. *Camera:*

A webcam is a video camera that feeds or streams image in real time to or through a computer to a network. The term "webcam" may also be used in its original sense of a video camera connected to the Web continuously for an indefinite time, rather than for a particular session, generally supplying a view for anyone who visits its web page over the Internet. In this project the pothole images are taken by the web camera and sent to Raspberry Pi for processing, the picture of the pothole along with its location is sent to the authorities using the Wi Fi feature in Raspberry Pi.

Fig. 6 Logi Cam [Source: Internet]

F. *Relay (JQC-3FC (T73) DC12V):*

A relay is an electrically operated switch. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal.

G. *TCP/UDP Test Tool:*

TCP/UDP test tool is ideal for the microcontroller and the communication test, such as Raspberry Pi. Connection confirmation to the designation address in PING. In IP CONFIG, the status of Wi-Fi can be checked. In addition to the share of the communication content file storage and other applications-repeat transmission of the same data, there are also features such as sending and receiving in hexadecimal as shown in Fig. 7

Fig. 7 TCP/UDP Test Tool

VI. SYSTEM DESIGN AND DEVELOPMENT

The pothole and hump detection system development is as shown in Fig. 8. It makes use of Raspberry Pi as the central processing unit, receives the data inputs through sensors and processes it and takes action of sending alerts, display and messaging to the Municipal officials and vehicle drivers.

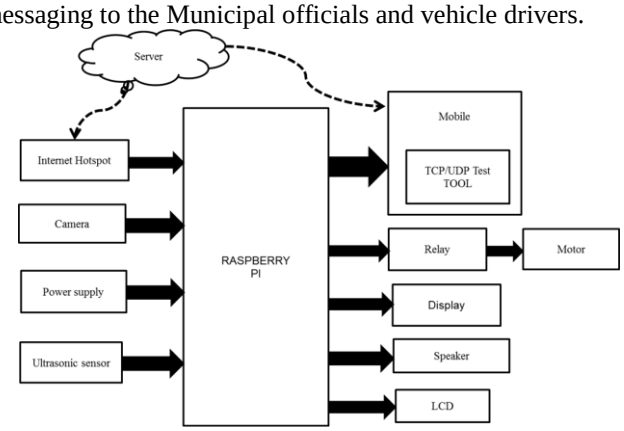


Fig. 8 Block diagram of the Pothole and Hump detection System

LCD, Sensor, Relay are interfaced to Raspberry Pi. TCP/UDP test tool is connected to the same IP address as Raspberry Pi. Raspberry Pi gathers data about potholes and humps and geographical position of potholes and this data is transmitted to the server. The data of geographical position received by server from Raspberry PI via Wi-Fi is processed and stored. Mobile application module uses information stored in the server database and provides timely alerts to the driver about potholes along with geographical position.

VII. METHODOLOGY

A. *Pothole Detection:*

The location of the vehicle is tracked using Wi-Fi. The camera captures the image of the road continuously through Open C V in RGB form. Then it converts the image from RGB form to HSV by image processing technique. It is then dilated for image enhancement of the concentrated region.

The obtained image is then compared with the stored pothole reference image in the database. If, the captured image matches with stored image, then the Raspberry Pi sends the location of the pothole to the municipal officials through E-mail along with the captured image. The same will be displayed on the TCP/UDP test Tool. The location can also be saved and shared in the test tool. It also generates alert to the driver through LCD display and speaker that a pothole is detected. This process is repeated. The above mentioned process can be understood as shown in the flow chart as shown in Fig. 9.

Fig. 9 Flow Chart of Pothole Detection

RGB to HSV Conversion
[source: Internet open source]
def rgb_to_hsv(r, g, b):

```
# R, G, B values are divided by 255
# to change the range from 0..255 to 0..1:
   r, g, b = r / 255.0, g / 255.0, b / 255.0

   # h, s, v = hue, saturation, value
   cmax = max(r, g, b)    # maximum of r, g, b
   cmin = min(r, g, b)    # minimum of r, g, b
   diff = cmax-cmin       # diff of cmax and cmin.

   # if cmax and cmin are equal then h = 0
   if cmax == cmin:
      h = 0

   # if cmax equal r then compute h
   elseif cmax == r:
      h = (60 * ((g - b) / diff) + 360) % 360

   # if cmax equal g then compute h
   elif cmax == g:
      h = (60 * ((b - r) / diff) + 120) % 360

   # if cmax equal b then compute h
   elif cmax == b:
      h = (60 * ((r - g) / diff) + 240) % 360

   # if cmax equal zero
   if cmax == 0:
      s = 0
   else:
      s = (diff / cmax) * 100

   # compute v
   v = cmax * 100
   return h, s, v
```

B. Hump Detection:

The ultrasonic sensor regularly measure the distance between the vehicle and the road. The distance is compared with the set threshold. When the distance is lesser than the set threshold it generates an alert to the driver through LCD and speaker. This process is repeated and is as shown in the flow chart as shown in Fig. 10.

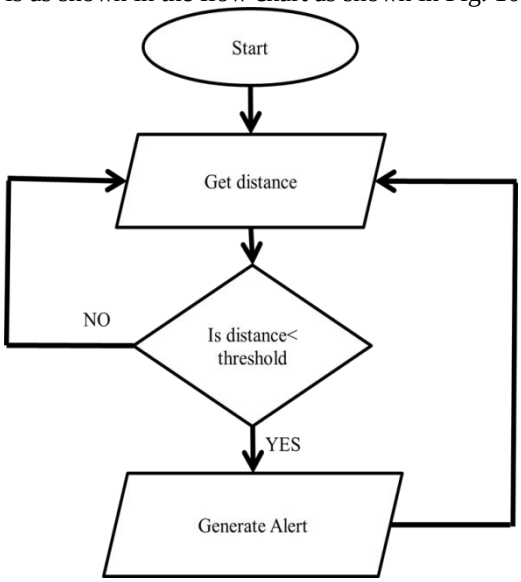


Fig.10 Flow Chart of Hump Detection

Working of the Ultrasonic sensor interfaced with Raspberry Pi is shown in Fig. 11

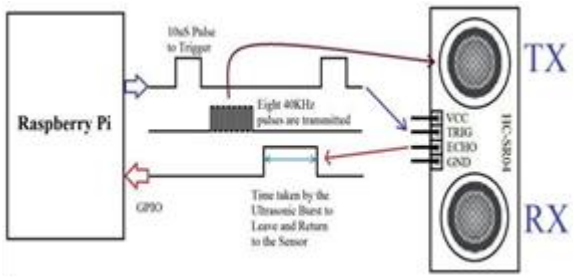


Fig. 11 Working of HC-SRO4 Sensor[Source: Internet]

VIII. EXPERIMENTAL IMPLEMENTATION RESULTS

The schematic diagram of the development of the pothole and hump detection system is shown in Fig. 12. The prototype working model of the pothole and hump detection system is shown in Fig. 13.

The prototype was tested with artificial potholes and humps. Firstly information about potholes was gathered and stored in the server database. Secondly, alerts were generated based on pothole data stored in database. For testing, the Raspberry Pi module was fixed on a Prototype car as shown in Fig. 13 and the threshold value was set for hump detection. During the tests, the Raspberry Pi module worked as expected in identifying potholes and humps. The messages received were processed by server and saved in the database.

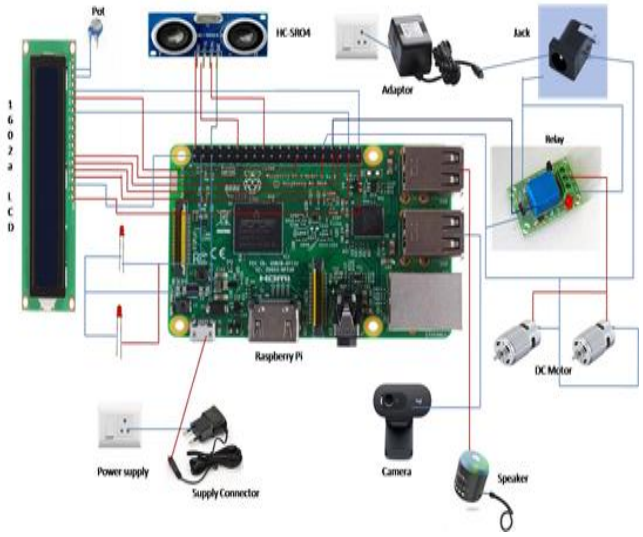


Fig. 12 Schematic of the system

The prototype developed, made use of the following hardware components: Raspberry Pi, Ultrasonic sensor, Camera, LCD, Motor and Relay integrated together to perform as pothole and hump detection system. When a pothole is detected its location is sent to the authorities along with image through mail. The TCP/UDP test tool also displays the location of pothole. The pothole detected will be displayed on the display screen (Fig. 14) along with latitude and longitude. The image of pothole along with its location is sent to authorities through mail (Fig. 15). The message "POTHOLE DETECTED" will be displayed on the LCD (Fig. 16) and can be heard through speaker.

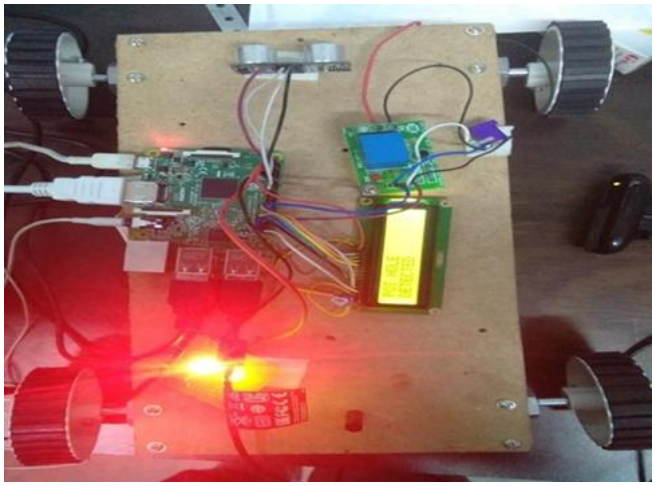


Fig. 13 Prototype of the Pothole and Hump Detection System

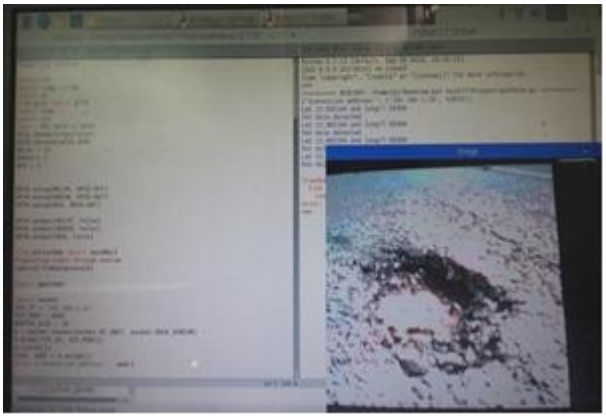


Fig. 14 Pothole detected output on display screen

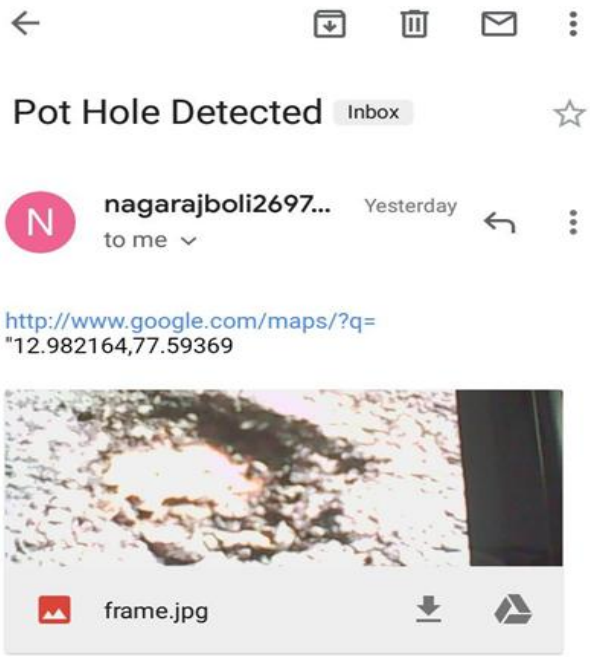


Fig. 15 Pothole detected and sent to BMC through e-mail

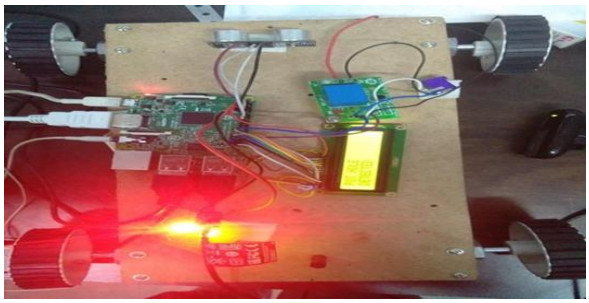


Fig. 16 LCD display when pothole is detected

Second testing was carried by moving the toy-car on routes containing potholes and humps and the mobile application generated alerts for potholes and humps using the information in database that were saved the first phase. The pothole location in terms of latitude and longitude, the link that takes to Google map is also displayed in TCP/UDP test tool (Fig. 17). The link takes to the Google map and indicates the location of pothole (Fig. 18).The display of pothole location in Google map is shown in Fig. 18 .

Fig. 17 TCP/UDP Test Tool display

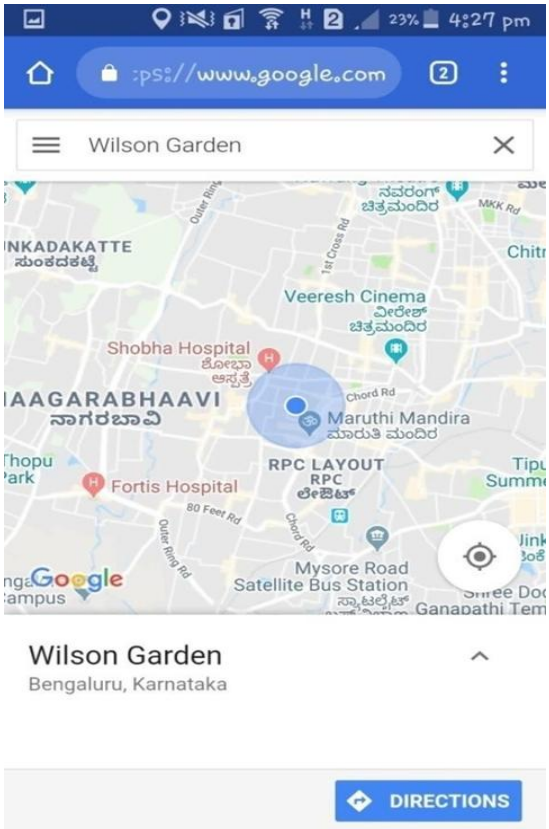


Fig. 18 Google map showing location of Pothole

The hump once detected will be displayed on the display screen along with its distance from the vehicle (Fig. 19). The LCD displays the message "HUMP DETECTED" (Fig. 20). The same message is heard through speakers to aid drivers.

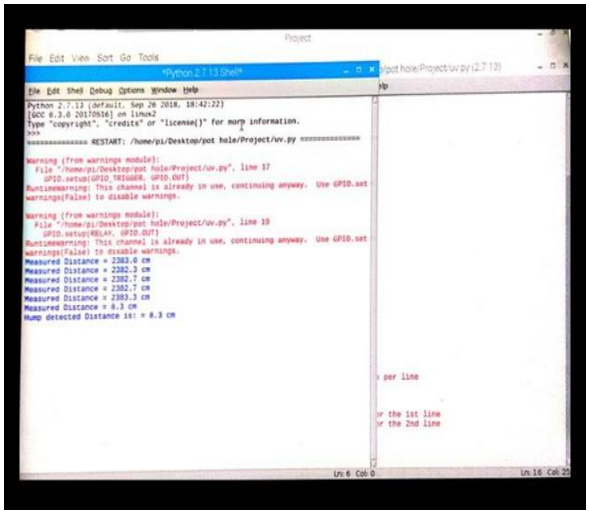


Fig. 19 Hump detected output on display screen

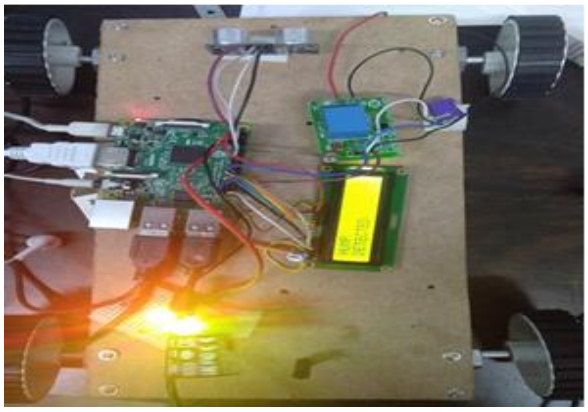


Fig. 20 LCD display when Hump is detected

IX. CONCLUSION

The system presented in this paper provides solution for intelligent detection of potholes and humps to aid transport vehicle or car drivers in avoiding accidents and provide information to the municipal officials to take action of maintenance of such roads. The system uses camera and ultrasonic sensor to detect potholes and humps. It makes use of the GPS for sending the location of potholes and GSM for sending the SMS alerts to registered mobile numbers. The hump detection is also displayed on the LCD panel to aid the drivers in the car, thus providing alerts to drivers.

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