IoT Based Humps and Pothole Detection on Roads and Information Sharing

Chellaswamy C
Professor, Department of ECE,
Rajalakshmi Institute of technology, Chennai, India
e-mail: chella_info@yahoo.co.in

Anusuya T
Student, Department of ECE,
Rajalakshmi Institute of technology, Chennai, India
e-mail: anusuya.t.2014@ ritchennai.edu.in

Famitha H
Student, Department of ECE,
Rajalakshmi Institute of technology, Chennai, India
e-mail: famitha.h.2014@ritchennai.edu.in

Amirthavarshini S B
Student, Department of ECE,
Rajalakshmi Institute of technology, Chennai, India
e-mail: amirthavarshni.s.b.2014@ ritchennai.edu.in

Abstract— **One of the ways to reduce road accident is to identify the humps and potholes present in the path. In this paper, an internet of things based road monitoring system (IoT-RMS) is proposed to identify the potholes and humps in the road. The pathway which is affected by the pothole is greatly influenced by the scattering signal of the ultrasonic sensor. So the magnitude of the reflected signal decreased due to the roughness of the surface and the signal amplitude is difficult to analyze. The Kirchoff''s theory basically applied for real-time analysis and it has certain limitations. To overcome this difficulty, an accelerometer has been included with the ultrasonic sensor to measure variation present in the signal and optimized using honey bee optimization (HBO) technique. The IoT-RMS automatically updates the status of the road with location information in the cloud. Each road vehicles can access the information from the server and estimate the speed according to the potholes and humps present on the road. The simulation has been done and the result shows that the IoT-RMS can be accommodated in road vehicles to reduce the accidents. The proposed system is implemented and tested using Arduino Uno with ESP 8266.**

Keywords— Internet of things (IoT), road monitoring, HBO optimization technique, pothole and hump detection

I. INTRODUCTION

Nowadays the infrastructure development plays an important role in the economic growth and success of a country. Development of infrastructure meets the great challenge and it creates a way to enter in to the outside world. A well-structured network is used for communication, trade, industry, and social mobility of a country. The road provides maximum safety when it is maintained properly and the surface discontinuity may cause an increasing number of accidents. The bad road condition is the main reason for all the truck accidents, according to the survey in [1]. The weakened road system increases the maintenance cost and the negative effects on the axle and suspension system of the vehicles. Various factors which affect the performance of the road are 1) Heavy traffic which causes the repetition of the load 2) low-quality materials and inappropriate moisture condition at construction. Road transportation is an important system that makes smooth and comfortable travel for passengers. The major cause for irregularities of the road such as cracks, potholes, and humps are led to damage the vehicles [2]. The potholes and roughness level in the roads were monitored by using the smart-phones accelerometer for capturing the vibration. The Gaussian model based mining algorithm is used to detect the abnormalities of the road [3]. The Haar wavelet transform based on multi-scale image segmentation is used to identify the changes in the damaged regions of Kullback Leibler. This method automatically detects the damages in the pathways. So, that there will be a smooth flow of transportation [4]. A track monitoring system using an accelerometer with global positioning system has been introduced by Chellaswamy et al. [5]. The system automatically identifies the abnormalities present in the track with location information.

To reduce the roadbed damages ground penetrating radar-based system is used in the driven head at the regular speed of 600 km/h. This will improve to maintain the road by eliminating errors and pavement from blind spots [6]. Infrared wave-based detection is used to detect the ice formation in the hilly regions and this system analyzes the temperature of the asphalt surface. Here the data are collected together and evaluated to determine whether the ice is formed or not [7]. In agricultural marketing, the transportation plays the vital role. Since the farmers transport the agricultural crops by means of transportation. So it is essential to transport the cultivated crops at the right time to the market. A new approach is used to detect the reliability of the road with less transportation time [8]. An IoT based track condition monitoring system is used for maintaining the quality of the track. The status of the track is updated in the cloud and share the information with the driver for safety measures [9].

The collision between vehicles on the road has been increased due to high speed, unawareness of the damaged road, cracks, and potholes in the roads. The condition road on a highway is shown in Fig. 1. The increasing number of accidents due to humps and potholes forced us to design a monitoring and information sharing system for reducing the accidents. The system automatically updates the information about the pothole and humps in the cloud and shares the same to the vehicle which is on the same road. This paper introduces both the accelerometer and ultrasonic sensor based pothole detection with a global positioning system (GPS). The system actively monitors the road and continuously updates the location of abnormality (latitude/longitude) to the cloud and processes the data which is received from the vehicles and send the alert information to the entire vehicles move towards the problematic area. If many vehicles cross the same location, the accident alert will be sent to the entire vehicle from the server. The proposed pothole detection and information sharing system has different advantages

- This system provides alert information in time to the driver to prevent accidents.
- it also provides information to the highway maintenance department for easy rectification.
- it is a cost-effective method for to detect the humps and potholes.

Fig. 1. Highway with pothole.

II. Proposed Road Monitoring System

The Proposed system to monitor the surface of road uses Ultrasonic sensors and accelerometer for sensing and detecting. Sensing and Pre-processing operations are performed on obtaining data and then given to honey bee optimization algorithms that perform monitoring the surface of the road. In this proposed road surface monitoring system consists of 1) Obtaining information of road condition. 2) Detection of potholes in the pavement and 3) Intimation about the abnormal location through the server to the other vehicles traveling to that area.

As we define the changes in the road reduces its capability to serve as smooth path and safe riding. There are many ways that cause damage and will intimate its maintenance. Some of the important causes of crashes, cracks, potholes, and rash driving cause lead to roughness. In India, 50% of the roads are damaged due to potholes. This will probably trigger to maintain the pavement. The survey has been done for Indian roads and focused mainly based on potholes and hardness for avoiding accidents. The block diagram of the proposed pothole detection system is shown in Fig. 2.

A. *Factors Affecting Pothole*

The major cause of potholes in the road is mainly due to heavy traffic and capacity to bear the load. Apart from the construction of road material quality the capability to adapt the changes and bear the influence made due to heavy load and different circumstances. This may be very low or high-temperature changes and traffic that affect the layers of the pavement. Some research says that mostly the potholes are caused due to the attributes of materials like an excess of asphalt content, sand particles, susceptible asphalt at low temperature cause less density to the surface.

B. *Depth Measurement of Pothole*

The measurement of roughness and depth of potholes has been detected by NPRA on the network of Norwegian national roads for so many numbers of years. That has been registered and possible measures have been developed. Many records are gathered annually. But, only a few years ago the ultrasonic device has been introduced to measure the changes. This will sense the object and also detect the movement of the vehicles. This technology has not boomed in those years due to improper updating of data and accuracy of measurements. Since the potholes depth varies from one to another in meters. So a new version of an ultrasonic sensor has been used to sense the surface of the road and detects the potholes. Both the accelerometer and ultrasonic sensor is fixed in a flat surface of every vehicle and the controller (Arduino Uno with ESP 8366) always monitors the signal and captures the location through the GPS if the pothole is detected. The controller always watches both the accelerometer and ultrasonic sensor signal and verifies both the signals. If both signal variations are exceeding the threshold level then the controller confirms the location of vibration and fetches the coordinates. Such that the information of a particular pavement will be updated in the cloud. This information is intimated to another vehicle that arrives by that way.

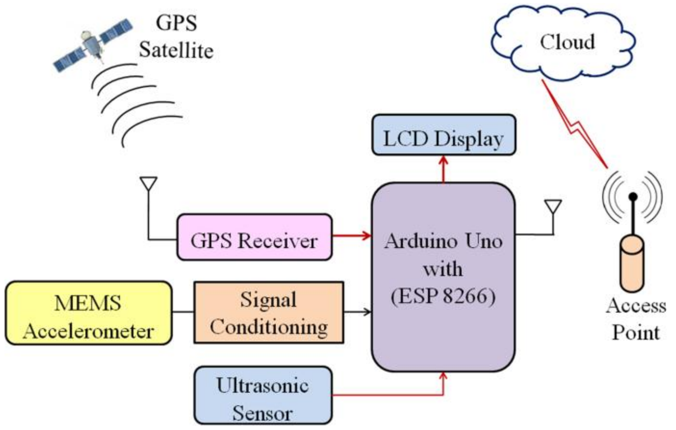

Fig. 2. Proposed hump and pothole detection and information sharing system

The Arduino Uno is used in IoT-RMS because it is flexible to code its instructions, inbuilt ADC and extra features are not required for detection. The architecture of the proposed pothole detection and information sharing system is shown in Fig. 3. The data is updated in the cloud through the wireless

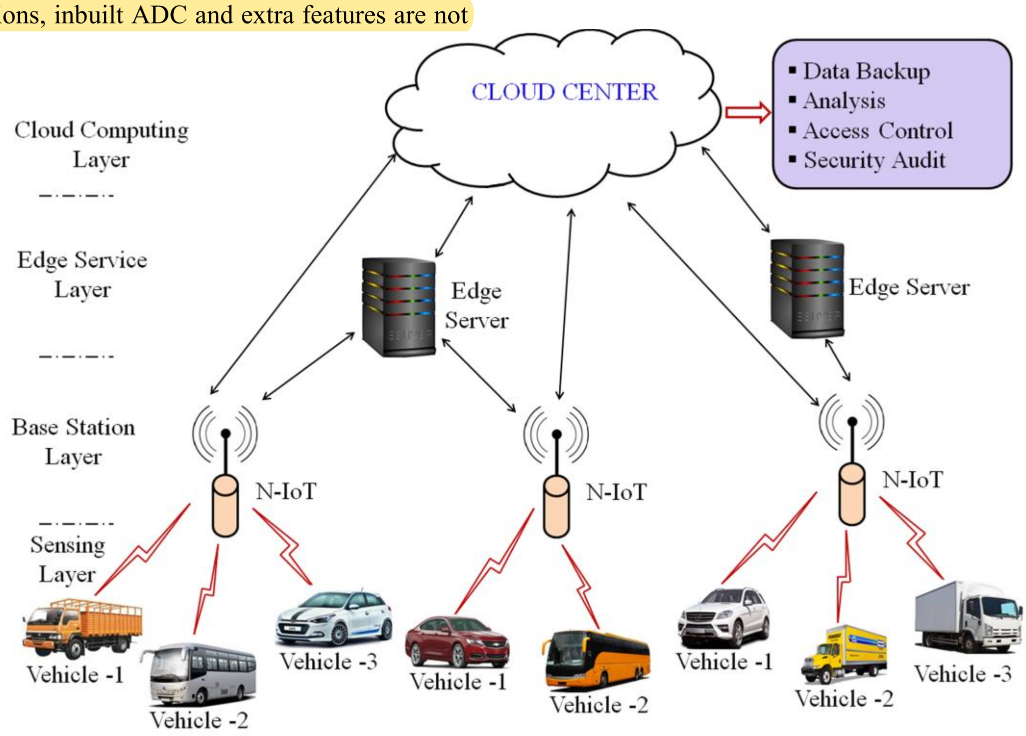

Fig. 3. Architecture of the proposed hump and pothole monitoring system

network, the system will navigate the location and gives alert to other vehicles. The data captured from the ultrasonic sensors is processed and estimated using custom computer software by embedded C language. This makes easy detection of potholes that present in the pavement and prevents form accident. Even there are different other ways to prevent an accident, the proposed method guide the vehicle in pothole area in an effective way. So that completely driving through damaged road path is prohibited during real-time implementation.

C. *IoT Platform*

The IoT platform is easily developed for monitoring road abnormalities. For easy access, one needs to understand the technology of the service provider. There are various international standard bodies such as IEEE Standards Association [10, 11], the Industrial Internet Consortium [12, 13], Internet Protocol for Smart Objects Alliance [14], is working on the proliferation of architecture and communication protocol. The proposed architecture for IoT-based road monitoring system consists of 4 layers: 1) first is the data gathering and translation layer 2) the railroad data management layer 3) the decision-making layer and 4) the application layer. Sensors are connected in the flat surface of the vehicle, and the signal state is continuously observed and stored in the memory based on the signal which is received from the accelerometer, these jobs are continuously performed by the data collection and conversion layer [15]. The unusual conditions are detected by the controller and the corresponding locations are detected concurrently by it. The information related to the road are received, stored, and transmitted to the cloud server, which is done by the data gathering and translation layer. The gathered data are translated into useful information by the conversions layer and

these are transferred to the next layer. The road data management layer forms an IoT-based cyber network by connecting the controller present in the vehicle. Using this cyber network, information about all other region is easily updated and monitored easily. There are two major advantages due to this, they are, and first, updating the road related information is easily done. The algorithm is framed in such a way that it adopts any changed situation, thus any information regarding the addition or deletion of the road is easily shared among the network. Secondly, the information regarding the road abnormalities is sent to the cloud server and maintenance department, for reducing their work to locate the problem.

The Arduino Uno with ESP 8266 can be connected to a cloud server, the RemoteXY allows us to manage the device from anywhere in the world. The ESP8266 module will be configured as a client to connect to a WiFi access point. The access point must have an Internet connection. The RemoteXY library will ensure registration of the device on the cloud server. The mobile application will connect to the cloud server and not to the device directly. Thus, the device will be available from anywhere on the Internet. There might be several reasons for the connection error. The main ones are: 1)

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The N-IoT and the vehicle are not connected correctly, the contacts are reversed, or not connected to the right contacts, or not connected at all. 2) there is no power supply to the ESP8266, when the power is supplied to the ESP8266, the red LED must be lit 3) there is not enough 3.3 V power supply for the ESP8266 4) the ESP8266 module is defective.

D. *HBO Algorithm*

HBO algorithm is used to optimize the received signal from the accelerometer (D_{ACC}), an ultrasonic sensor (D_{US}) and from the GPS receiver (D_{GPS}). Generally, a HBO algorithm consists of the queen bee, drone bees, and worker bees. The initialization process is done for the queen and drone and the queen has been selected from the individual which has best fitness value. The steps involved in the HBO algorithm for estimating the humps and potholes in the road are shown in Fig. 4.

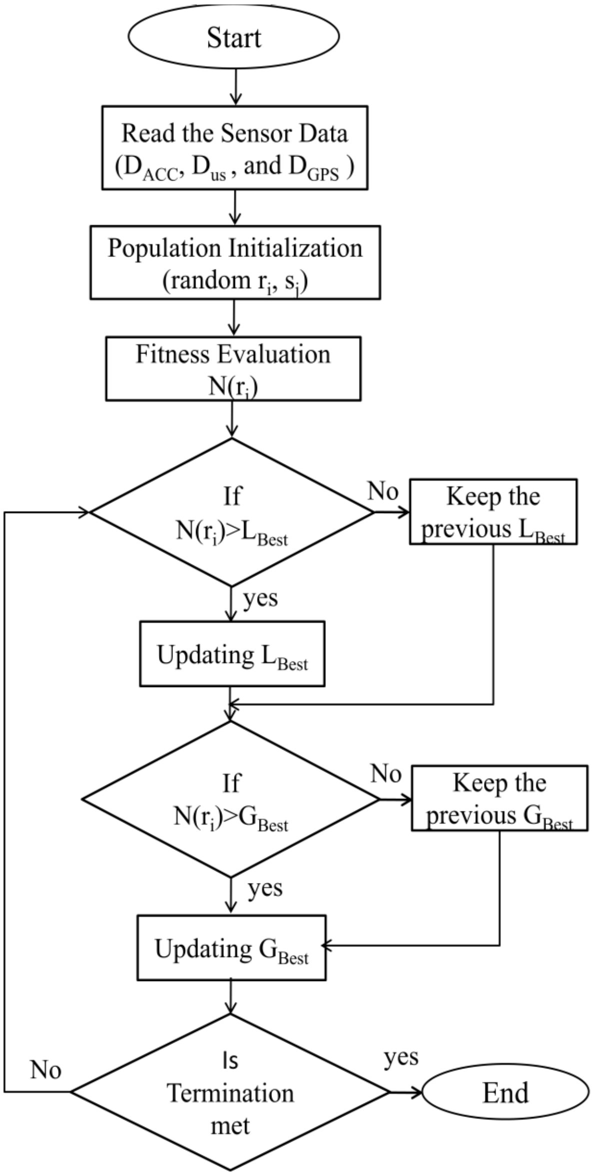

Fig. 4. Flow chart for HBO algorithm

III. SCATTERING SIGNAL FROIM THE SENSOR

A. *Current Signal Amplitude*

The coherent signal amplitude is observed from the ultrasonic of every realized defect present in the highway. This statistical state is placed above the roughness and governed as:

$$\beta_{co}^{\sigma} = \frac{\sum_{k=1}^{N} \beta_{co}^{\sigma}}{N} \tag{1}$$

Where, $\beta_{co}{}^{\sigma}$ represents the response of scattered signal from each realized surface k, σ represents the statistical state of defect of surface roughness, and N represents the total number of realized states of roughness. To cumulate these response made by statistical state, the effect leads to out-ofphase which is positioned above the surface and the incompatible effects around the surface is taken off. The remaining in-phase coherent signal from (1) is reduced for its roughness in order to the smooth surface which consists of

$$\frac{|\beta_{co}^{\sigma}|}{|\beta_{in}^{\sigma=0}|} = \frac{|\Sigma_{k=1}^{N}\beta_{co}^{\sigma}|/N}{|\beta_{in}^{\sigma}|} \quad (2)$$

Where $\beta^{\sigma=0}$ represents the response from smooth defect with σ=0. The level of the roughness surface is proposed within two techniques such as 1) FE technique and 2) Kirchhoff theory. The HBO method is used for high level scattering of signal whereas Kirchhoff theory is used for low level scattering of signal. There is some limitation in Kirchhoff theory since the shadowing of surface are not considered. The accurate solution of flat surface is obtained by comparing the signal from input waves. The property of surface has a function that is expressed as radius of curvature γ. According to the nature of Gaussian surface the parameter is defined by distribution function. The minimum value to spread the wave is important and defined by γ_{min}.

$$\gamma_{min} = \frac{0.1\mu_0^2}{\sigma} \quad (3)$$

where μ_0 is the length of the surface correlation. Roughness is inversely proportional to Υ_{min}, So, Kirchhoff theory is not valid for very high levels of roughness. The accuracy represented by this theory is quantitatively denoted by a rule based on [16]

$$M_{in}\gamma_{min}cos^3\theta_{in} \gg 1 \quad (4)$$

It is physically related to radius of surface, b_{min} incident wave number q_{inc} and incident angle $\theta_{inc.}$ By combining these expression the condition for Kirchhoff theory is

$$\frac{0.1\, M_{in}\,\mu_0^2\, cos^3\theta_{in}}{\sigma} \gg 1 \quad (5)$$

B. *Total Signal Amplitude*

The amplitude of signal which is scattered from the rough surface, humps and pothole will be decreased. The combination of coherent and diffusion signal amplitude forms total signal amplitude. It reflects multiple responses but, only the values from each iteration are considered for calculating the average amplitude. This will reduce the variation that occurs in-phases of reflected signal. In back side scattering of signal it contributes coherent field and diffusion field to obtain total field. This extension is numerically expressed as:

$$\beta_{total}^{\sigma} = \left|\beta_{co,k}^{\sigma}\right| \quad (6)$$

Increase in roughness will result in reduction of total signal amplitude

$$\frac{|\beta_{total}^{\sigma}|}{|\beta_{in}^{\sigma}|} = \frac{|\beta_{co,k}^{\sigma}|}{|\beta^{\sigma=0}|} \quad (7)$$

C. *Back Scattering*

Ultrasonic sensor is used to detect the potholes and the information will be updated in the server. If any vehicle travels in the same location again, the potholes wherever present in the road will be intimated to the corresponding vehicle from the serve. Mostly indirect incidence occurs in this case. When indirect incidence is being encountered the scattering from the rough surfaces contains both diffuse and coherent scattering signals. It is difficult to assess the signal quantitatively by using analytical methods. To overcome this difficulty, a numerical method is used to analyze the signal and it has the capability to deduce scattering from any direction with any angle. In this approach, the mean signal amplitude is obtained from the statistical distribution under normal incidence for the hump and potholes. To study the performance of defects such as potholes and humps different angular roughness has been considered (S=0.065Υ_{in} and S=0.201 Υ_{in}.). The comparison is performed between various surface roughnesses with the smooth surface. An accelerometer is placed in the flat surface of the vehicle and it will produce signal variations when the vehicle runs over humps and potholes. The controller checks both the signals from the accelerometer and the ultrasonic sensor and decides the abnormality and picks the location immediately.

IV. Simulation Results and Implementation

The measured signal which is received from the road monitoring unit is used to identify the humps and pothole present in the highway. The simulation is carried out using Matlab 2017 and the measured voltage from the sensing unit (both the ultrasonic and accelerometer). For simulation, different roughness has been considered and the received signal is processed by the proposed system; there are twenty states of roughness has been taken from s=0.017 Υ_{in} to s=0.35 Υ_{in}. The attenuation of mean signal required to the realization is provided according to the state of roughness. When the roughness is less, then the convergent solution is also decreased and the roughness is increased till the surface is considered during the presence of convergent solution. This study of convergence is compared with Kirchhoff theory simulation which is presented and discussed by Zhang et al [17].

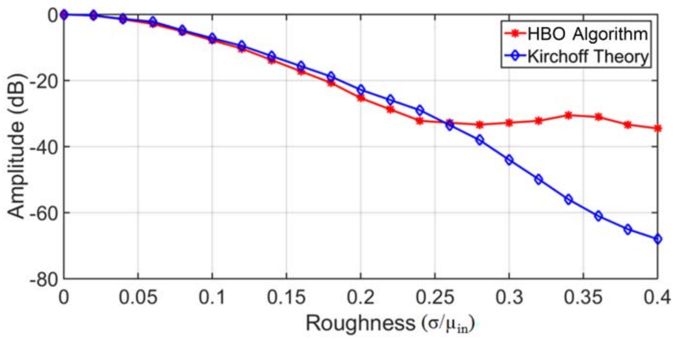

Fig. 5. Comparison of the amplitude of reflecting wave for Kirchoffs and HBO.

When there is an increase in roughness of surface then it produces the value of 1. It shows that the HBO provides accurate value than Kirchhoff theory at a high level is shown in Fig. 5. From Fig. 5 one can easily understand that the amplitude of the reflecting wave gets reduced in the rough surface compared to smooth one. Since statistical states observe coherent signal at multiple realizations and also it requires an exact count of the true coherent signal. Only a few scattered signals are considered due to an increase of computational expense and benefit in obtaining accuracy.

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To represent the variations in coherent signal amplitude three states of roughness is considered such as s=0.125μ_{in}, s=0.210μ_{in} and s=0.350μ_{in} (ie) lower, middle, higher levels are shown in Fig. 6. Fig. 6 illustrates that the amplitude variation is larger if the surface roughness increases. In case of the lower level, it requires only few realization around the order of hundred and it obtains little variation. In case of a very rough surface, the requirement is thousands of realization that leads to the expectation of more RMS values. When the length of crack is larger, then the surface realization is decreased to obtain a solution of convergent at the coherent field. This will also increase the computational expense of every unit cell. So, it is not a preferable trade-off.

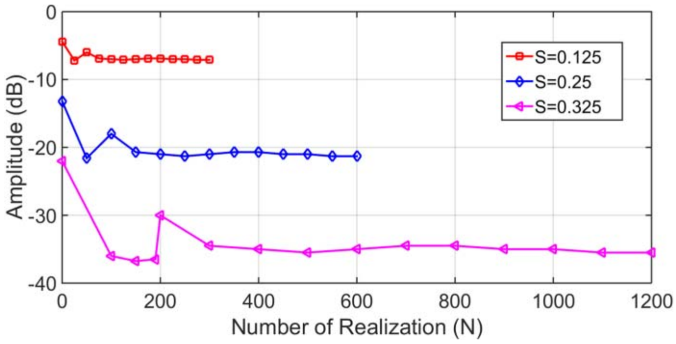

Fig. 6. Variation of the coherent signal for three different roughness surfaces.

The acceleration signal is measured by the MEMS accelerometers placed on the bottom surface of the vehicle. These measured accelerations are filtered and made to be effective using the HBO algorithm.

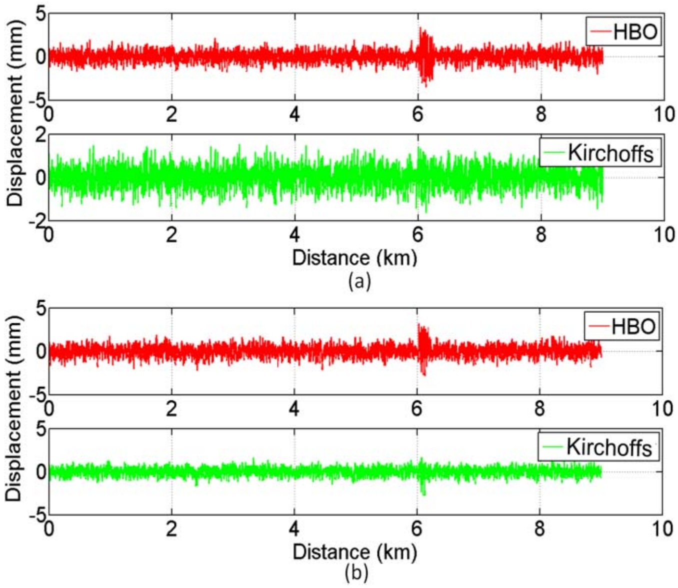

Fig. 7. Measured signal from the accelerometer for two different speeds: (a) 40 km (b) 60 km.

The measured acceleration is compared to the acceleration which is received during normal operation for both the MEMS accelerometer. Fig. 7 shows the output which is received from the accelerometer fewer than two different speeds such as 40 km and 60 km. The signal variation is present in 6.2 km distance for both speed scenarios and it is shown in Fig. 7(a) and (b) respectively. The comparison result shows that the proposed HBO method provides a better result than the geometry measurement and filtering methods. Fig. 8 shows the set up of the proposed hardware implementation.

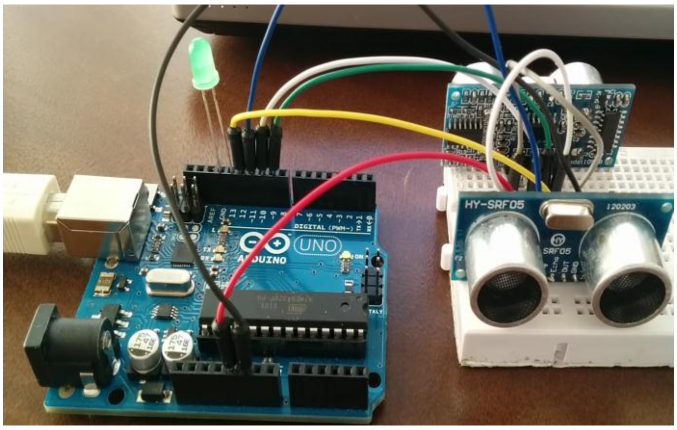

Fig. 8. Hardware implementation set up.

V. Conclusion

An IoT based road abnormality monitoring and the status sharing through the cloud is proposed in this paper. The ultrasonic sensor and the accelerometer are placed at the bottom surface of the vehicle to find the irregularity in the road. The simulation is carried out for two different speed scenarios such as 40 km and 60 km using MATLAB 2017. The location of abnormality is measured with the help of a GPS receiver which is linked with IoT-RMS. Here the HBO optimization algorithm is used to optimize the measured signal from the sensors. The performance of IoT-RMS is compared with the Kirchoffs method and the result shows that the proposed system with HBO provides better performance under all the speed scenarios. The comparison comes to a conclusion that the IoT-RMS is efficient for pothole detection at all levels. If the system detects humps or pothole, immediately it stores the coordinates in the server and alert information will be shared to the other vehicles which are passing in that location and hence the good percentage of accidents can be reduced.

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