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IoT FRAMEWORK FOR MONITORING THE CONDITION OF THE ROADS

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Abstract

Today it is still a major problem that road fatalities exceed the number of accidents. So determining the factors of risk which includes determining the condition of the roads is crucial in developing strategies to decrease road fatalities. An important role in providing smooth and safe road infrastructure is road surface monitoring. Detecting irregularities on the road surface, cracks is the heart of the road surface condition monitoring which interfere with driving comfort and safety. So the project is aimed to construct a system that detects uneven roads and alert the respective government authorities. With an IoT model we will be able to detect the roughness of the road which could transform how roads maintenance is planned and monitored. Whenever a vehicle passes over any irregular road surface, there is more vibration and motion than when it passes over a smooth one. With this approach, road surface irregularities can be detected and informed to the respective authorities. This paper also gives the analysis of surface-micromachined accelerometer. COMSOL Multiphysics is the software that is used for the analysis which describes about the displacement with respect to acceleration of the sensor. The method used for the analysis of this 3D model is Finite Element Method (FEM).

Keywords: COMSOL, Detection, IoT, Monitoring, Road safety, Surface-micro-machined accelerometer.

1. Introduction

It is the roads that are superior mode of transportation as of today. Accidents takes place every day, but the probability of accidents that takes place in the road transportation mode is very much greater when compared to the other modes of transportation [1]. According to WHO 1.3 million people are facing road accidents and due to unsafe road infrastructures. This work concentrated on rural areas where it is helpful in improving road conditions with timely warning message [2]. Majority of the accidents that are occurring are due to the unmaintained condition of the roads and many are losing lives due to those accidents. In order to avoid accidents it is required to monitor the roads regularly. It is very difficult to monitor the roads by using manpower in each and every place. Cameras are used to monitor the roads and their condition on the national highways. So that it will be easy to monitor the roads, but it requires manpower to verify the captured condition of road and also it is very difficult to find the exact location where the road needs to repair [1, 2]. This process requires heavy manpower. This process will be done only on national highways, but it is impossible to monitor roads in such a way on local roads or small areas and small streets. In such areas the government will not monitor and will not take any action to repair the roads.

A device can be designed to monitor the road condition to avoid road accidents by using Internet of things (IoT). Main factor to provide solution to this problem is by communicating with the respective authority. IoT is used because it is a huge network of connected devices [3-5]. By using IoT (Google cloud platform) we can gather the required information which is the primary step in IoT and then the collected information will be sensed and processed to the next level by transferring the information. Using an appropriate sensor will be helpful in detecting the abnormalities on the road. Global system for Mobile (GSM) module sends the location of the uneven road detected by the sensors using Global positioning System (GPS) module to the respective authorities.

Monitoring the condition of the roads [1] discussed about the detection of the road condition by using LABVIEW and by using motion sensor and the path is showed graphically by using statistically calculated values. The road condition is also tracked by using MATLAB based Graphical user interface (GUI) with push buttons for data collection [2]. Intelligent assessment methods are also used like collecting data from sensors and some other methods are done by using machine learning by using supervised and unsupervised learnings to classify paved and unpaved roads [3]. The affected pathway and humps and potholes can be detected by using ultrasonic sensor by using some optimization techniques like honeybee technique and updates that location into the cloud [4]. For designing of surface-micromachined accelerometer COMSOL Multiphysics software has been used and designed a comb structure accelerometer and studied the mechanical properties for different types of materials [5]. The importance of IoT in monitoring road conditions is discussed. Road traffic management is important in reducing the accidents. The better solution in rural areas is still a question mark. Now a day’s android and IoT is supporting the researchers to work in the area of developing a device for monitoring road conditions [6-9].

Traffic management solutions are discussed using AI and IoT [7-9]. In our work also IoT is used for developing the system [7] . Here the IoT framework utilizes the internet and provides the location of uneven roads. Gundala et al. [8] discussed the road industry digitalization. The real time inspection and monitoring ICs are discussed. In our work GPS and GSM are used to provide position through SMS which is discussed in [9].

2. System Architecture

This section gives about the devices that are used in designing our device and are described in Fig. 1. It gives about the block diagram of system architecture. Let's see about the devices that are used in our design for monitoring the condition of the roads. IoT framework is selected here for giving prompt information through internet. The main component in identifying uneven roads is MEMS accelerometer. The acceleration and amplitude based on depth gives the relevant information of road condition. Also the Global position system (GPS) is used in this work to send the exact location of road deformity. Experiments were conducted and based on results of accelerometer the threshold levels are identified and used in this work.

The main component to track the motion of the vehicle in which both 3-axis gyroscope and 3-axis accelerometer are present and also consists of a digital motion processor is MPU6050. This sensor will work in the range of temperature from -40° C to +85°C and the required voltage for the sensor is 3.6V to 5V. A microcontroller that is Arduino UNO is used to hook with other components that are used in designing the device.

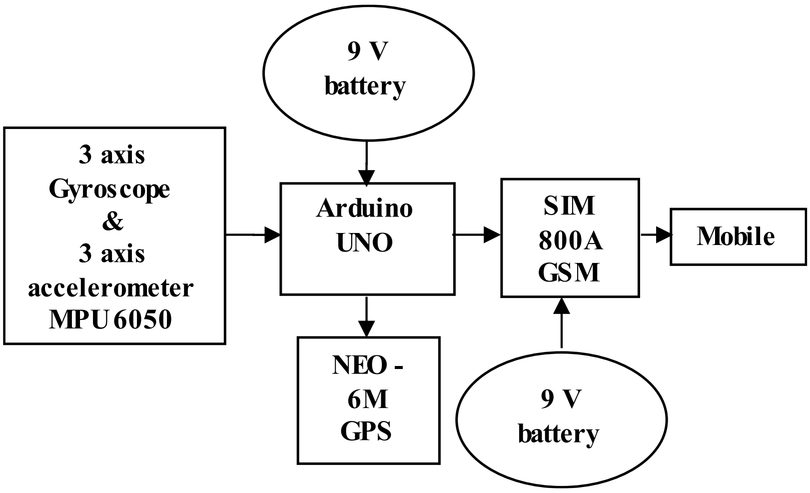

Fig. 1. Block diagram of road monitoring system architecture.

NEO-6M is the GPS module which is used to track the location. This module contains an LED which will glow for every one second if the satellites are found to track the location. For sending message to the respective authority SIM800A GSM module is used and it contains LED's which gives about the network status. If the signal is established, then the LED will glow for every three seconds. A 9V battery is used to supply the power for every component that is used.

3. Implementation and Working

The solution for the uneven roads problem uses the following sub-systems:-

- Measuring MPU6050 values
- Tracking the location
- Sending the location to the road safety authority.

So when there is an uneven road then the device will send the message to the road safety authority. Let us see the working of the device.

When a vehicle is moving on an uneven road then the device will sense and will send a message that contains the location of the uneven road to the road safety authority. When there are no uneven roads that is plain roads or even roads then it will not send any message. This uneven road detection is completely based on the MPU6050 sensor. The MPU6050 is fixed in such a way that the x-axis direction in the sensor is facing the ground. First a test drive has been conducted on the roads to note the cut-off values for the sensor. After noting the cut-off values these values are used to detect the condition of the roads by giving them as reference values to the microcontroller that is used.

Arduino UNO a microcontroller is used as a main control unit for the solution of road condition detection. A code was written and dumped into the Arduino UNO by using Arduino IDE software to easily interface with the other components that are used. Arduino UNO is programmed in C++ language.

There are two plates in the MPU6050 sensor. One is fixed and the other is polysilicon movable spring. Whenever a vehicle moves on an uneven road then vibrations generated due to the condition of the road will be affected on the movable spring present in the sensor. Now the acceleration will be created due to the vibrations. Due to this acceleration the movable spring will move in between the fixed plates. This movement of the movable plates will create a capacitance in between the movable and fixed plates. This generated capacitance will be directly proportional to the acceleration that is applied on the movable spring. Now the sensor will sense the capacitance and it will be converted into analog voltage by the sensor.

The analog voltage will again be converted to the digital values by the sensor automatically. The voltage values generated from the sensor are now compared with the values that are given in the code for the microcontroller. The values are in the specified range then only the location will be tracked by the GPS device. Now this location will be processed by the GPS by using the microcontroller and will be updated to the GSM that is used. This location will be sent as a message to the road safety authorities. The message indicates that the road needs to be repaired in that particular location that is given in the message. When the link is opened a map will be opened indicating the location of the place by using latitudes and longitudes. And the road safety authorities can easily go that location and can take action to repair the road in order to avoid deaths due to accidents that are caused due to the condition of the roads without any manpower [7, 8].

When there are no uneven roads or when the roads are plain then the values of MPU6050 will be different from the given range and GPS will not track the location and GSM will not send any message to the road safety authorities [9-17].

In order to design the device a step wise procedure has been followed where the components required are aligned in an order where the device will work properly. The step wise procedure has been given in the flowchart. It represents the conditions where the device will work, and under which conditions the device will not work. By following the order of steps given in the flowchart we can easily construct a device.

4. Results

Figure 2 shows the device setup which is designed to monitor the road condition to avoid accidents on the roads. In Fig. 3 the message shows that the road needs to be repaired in the given location. The location will be sent in the form of link in the message which will be indicating the latitude and longitude numbers. When the link is clicked it will redirect to the google maps and the location will be indicated in the red mark. This will happen only in the case of uneven roads, or any humps are present on the road whereas in the case of plain roads message will not be sent. Figure 3 shows the SMS that is sent to the road safety authorities.

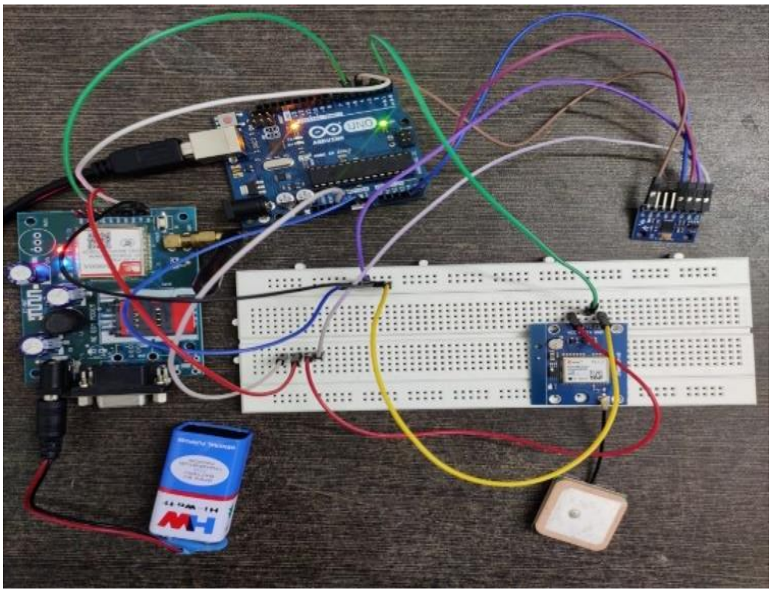

Fig. 2. Connections for device setup.

Fig. 3. Location is sent as message when there is uneven road.

Figures 4 and 5 show the results for two different cases that is when a bike is moving on even roads and bike moving on uneven roads.

Figure 6 shows the location where the road needs to be monitored and it needs to be repaired. The red mark represents the exact spot of the damaged road.

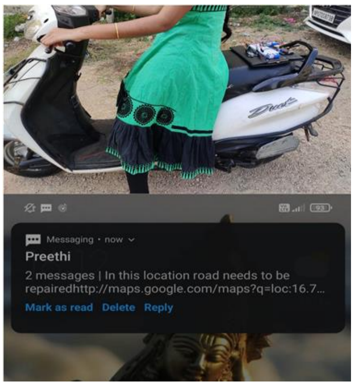

Fig. 4. Message sent when there is uneven road.

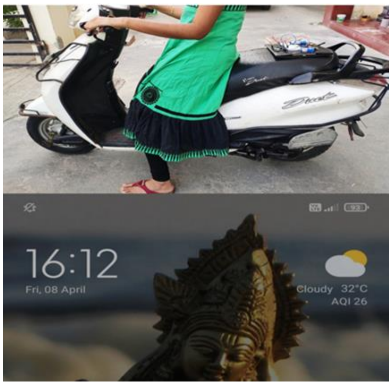

Fig. 5. No message is sent when there is plain road.

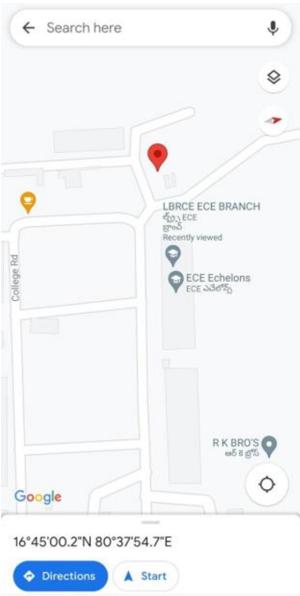

Fig. 6. Map that shows the location.

5. 3D Model of an Accelerometer

There are many types of accelerometers which will be in different shapes like construction of the sensor by using piezoresistive material, by using capacitive change measurement method, etc. Figure 7 gives the three dimensional model of an accelerometer which is designed in the shape of comb.

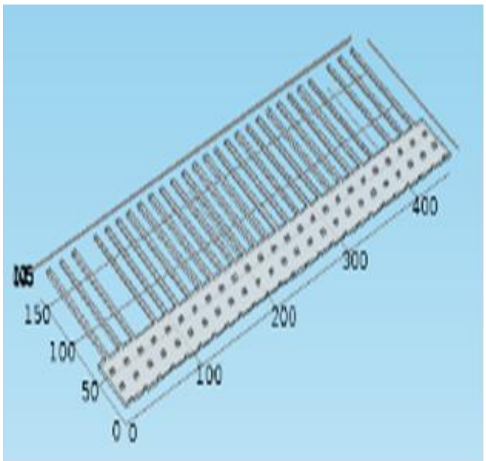

Fig.7. Model of comb-shaped accelerometer.

Here the main focus is on the analysis of change in displacement with respect to acceleration and also change in voltage with respect to acceleration for the comb-shaped accelerometer. For the analysis the accelerometer sensor has been designed as shown in Fig. 7.

Table 1. Parameters of the sensor.

Parameter	Value
Length	448μm
Width	100μm
Thickness	2μm
Length of finger	114μm
Width of finger	4μm
No. of self-test fingers	3
No. of sense fingers	21

The above table shows the parameters that are used to design the sensor. The sensor's dimensions are given in the table and the sensor's structure consists of three self-test fingers and twenty one sense fingers.

The sensor has been designed by following the required procedures [5, 6, 9, 10]. The suitable components and the suitable materials are chosen for designing the accelerometer. As shown in Fig. 8, we have designed the sensor by using two different types of materials. The materials that are used for the design of the sensor are polysilicon and germanium. These materials are chosen because of their excellent properties and these materials show good changes in displacement and voltage with respect to change in acceleration.

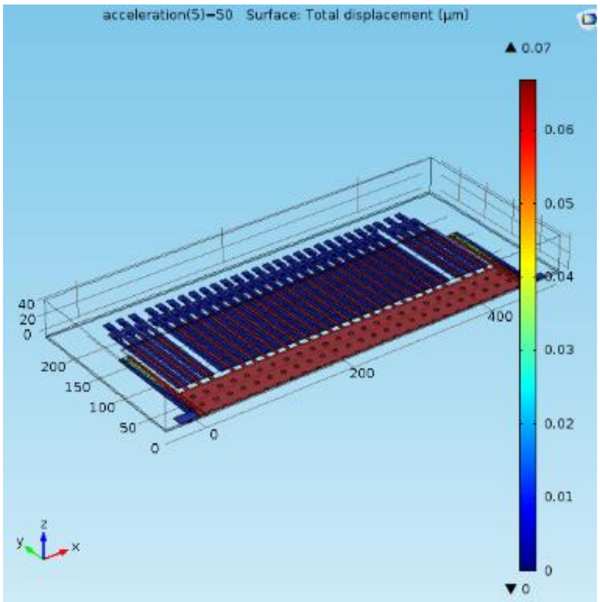

Fig. 8. Design of surface-micromachined accelerometer.

6. Simulation Results

The total displacement of the sensor has been observed as a function of acceleration. Figure 9 shows the graph for polysilicon material. From the above graphical representation it shows there is linearity in between displacement and acceleration of the sensor. According to this, we can know that the designed sensor will accurately for the above values of acceleration [10].

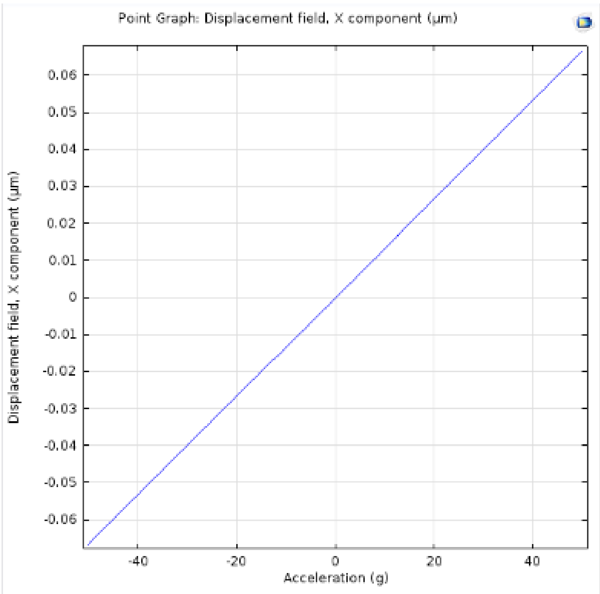

Fig. 9. Displacement versus acceleration graph for polysilicon

Similarly the displacement values in accordance with acceleration have been studied by changing the material of the accelerometer to germanium [11, 12]. This material also shows a linear graph between displacement and acceleration. Figure 10 shows the graphical representation for germanium material and the sensor will work properly.

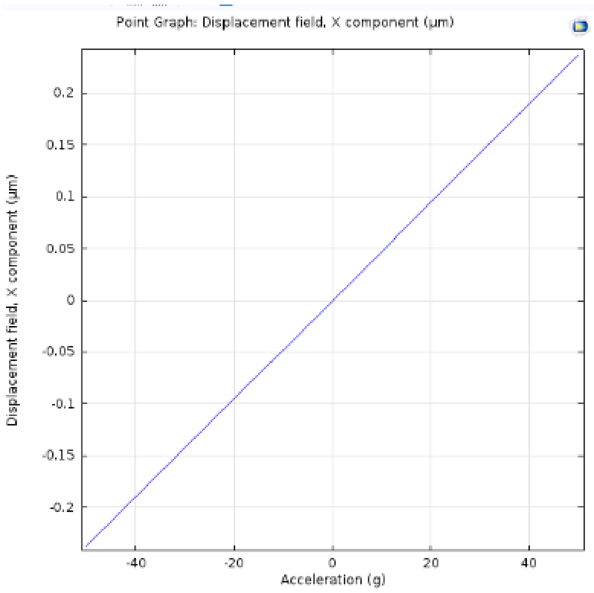

Fig. 10. Displacement versus Acceleration graph for germanium.

We also have observed the change in voltage of the sensor for germanium material with respect to the change in acceleration values for the sensor.

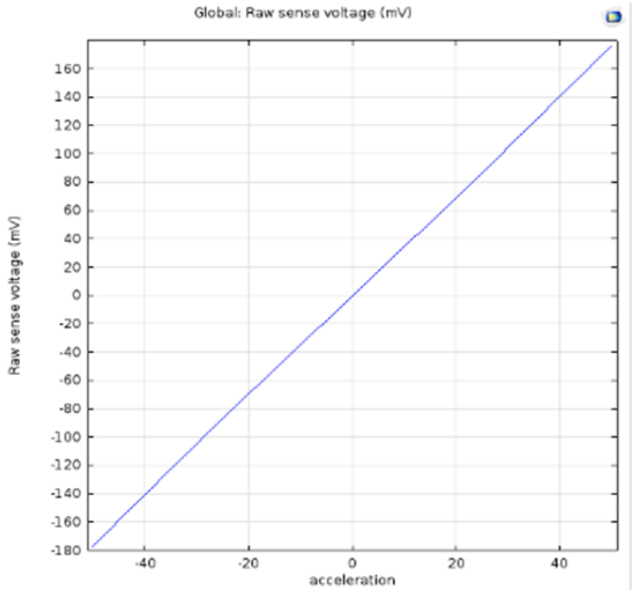

Fig. 11. Voltage versus acceleration graph for germanium.

7. Conclusions

The work dealt with the design and use of digital motion processor sensor for monitoring the condition of the roads. When the uneven roads are detected by the device then a message will be sent to the road safety authorities to repair the road in that particular location. When there are no uneven roads detected by the device then it will not send any message to the road safety authorities. We also designed a comb-shaped surface-micromachined accelerometer and checked the displacement and voltage values in accordance with acceleration for surface-micromachined accelerometer for two different types of materials polysilicon and germanium.

8. Future Scope

The device can be developed further by implementing the GPS and GSM module directly into the smart motion unit. The surface-micromachined accelerometer can also be designed in different shapes and by giving different dimensions for the sensor.

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Appendix A

Computer Programme

A.1. Programme Structure and Description of Subroutines

The programming language that is used in the prediction methods is C++ language.. The flowchart for the programme is shown in Fig. A-1.

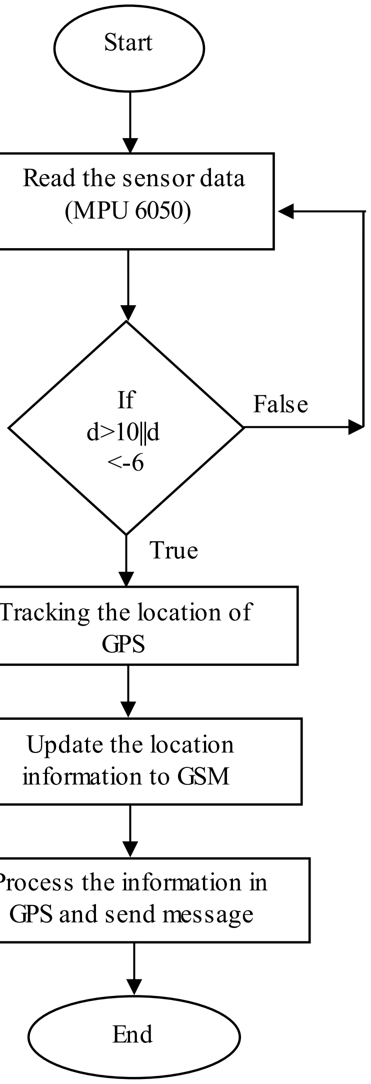

Fig. A-1. Flowchart.