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Vibration detection instrument based on Internet of Things

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ABSTRACT

This project is based on Vibration Detection using the Internet of Things. Vibration monitoring is the measurement of passing movements in a structure. This project involves developing an SMS alert when unusual vibrations are detected. It includes a lab-based experiment of detecting vibrations when the different magnitude of the force is applied. This force causes the change in values of the sensor from its initial values. Values of acceleration can be seen on the webpage and analysis can be done when required. Considering the maximum magnitude at which destruction is high, the alert signal would be generated. This alert would be sent to different mobile phones using GSM Technology. With the help of this, we can be aware of the vibrations. Properly done, vibration monitoring can be extremely helpful in preventing damage to structures understanding the nature of the damage and ascertaining its cause. Currently, we are using Arduino microcontroller, accelerometer sensor, and GSM Module as our main components. The code of the Arduino Uno microcontroller is written in C++.

Keywords—*Computerization, Arduino Uno, IoT, GSM module 900A, Thing speak, sensors, ADXL, Rain sensor, Landslide, Earthquake*

1. INTRODUCTION

Vibration is a mechanical phenomenon whereby oscillations obtain about an equilibrium point. Vibration detection emphasizes the need for incorporating multi-functional, multi-disciplinary and sectored approach involving engineering, social and financial processes. This can be useful in many sectors to easily detect the effect of vibrations.

Vibration monitoring is the measurement of passing movements in a structure. We are using IoT instruments to detect and record the movement. This project is about "A Vibration Detection Instrument based on IoT" where electromechanical devices are used to measure acceleration forces. Such forces may be static like the continuous force of gravity or, dynamic to sense movement and vibrations. Acceleration is the measurement of the change in velocity or speed divided by time.

This project includes lab-experimental setup to detect vibrations. When a certain amount of force is applied, change in the values of sensor takes place. This change is due to vibrations caused by the force that is applied. When the vibrations are detected, its values can be easily noted. It is possible through the webpage which is user-friendly. The webpage includes the initial set of values and difference between the values when the operation is performed from initial values. When the value exceeds a limit, an alert signal would be generated and SMS would be sent to mobile phones.

The objective of this project is to create a vibration detector using Arduino Uno and accelerometer sensor that is used to detect the vibrations. Whenever it would detect unusual vibrations, then alert signals would be generated using buzzer and LED glow and also a message would be sent on a particular mobile number.

When an emergency occurs, the first priority is always the safety of life whether ours or others. There are many actions that can be taken to stabilize an incident and minimize potential damage. Actions taken immediately in the first minutes following an emergency situation will significantly affect what happens afterward. So, sending an alert SMS to all the concerned authorities in an emergency situation can help in safeguarding lives. This prototype device will help us to note the vibrations created and if the reading exceeds the particular limit, then it will generate an alert signal.

2. LITERATURE REVIEW

In [4], A. Kaushik et al. (2016) mentioned in future IoT is going to become a reality. It will change our lifestyle. But there are many challenges to face related to the deployment, growth, implementation, and use of this technology. The Internet of Things involves a complex and evolving set of technological, social, and policy considerations across a diverse set of stakeholders.

In [5], Article about the module to connect Arduino with the external world. GSM Module SIM900A is basically used to connect Arduino Uno board with GPRS. It is connected with R_x and T_x pin of the Arduino. This is a small chip in which SIM card is inserted and AT commands are used to perform actions like calling, sending a text message or to send data to a website using HTTP connection. It acts as an interface between electrical devices and the internet.

In [14], The NEC Group has developed a piezoelectric vibration sensor that features sensitivity at about 20 times that of previous models. A vibration sensor is a device that corresponds to the auditory and tactile organs of the human body. The real world is flooded with vibration information generated by humans, goods, and environments. Our recently developed vibration sensor can collect minute waveform data that has been hitherto undetectable and has therefore not been utilized. The vibration waveform data collected from the sensors is analyzed in real time by the hub terminals, and the extracted significant information is transmitted to the cloud system.

In [15], The ADXL335 output is ratiometric, therefore, the output sensitivity (or scale factor) varies proportionally to the supply voltage. At VS = 3.6 V, the output sensitivity is typically 360 mV/g. At VS = 2 V, the output sensitivity is typically 195 mV/g. The zero g bias output is also ratiometric, thus the zero g output is nominally equal to VS/2 at all supply voltages. The output noise is not ratiometric but is absolute in volts; therefore, the noise density decreases as the supply voltage increases. This is because the scale factor (mV/g) increases while the noise voltage remains constant. At VS = 3.6 V, the X-axis and Y-axis noise density are typically 120 µg/√Hz, whereas, at VS = 2 V, the X-axis and Y-axis noise density are typically 270 µg/√Hz. The ADXL335 is a small, thin, low power, a complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

In [16], Kevin Ashton, co-founder and executive director of the Auto-ID Center at MIT, first mentioned the Internet of Things in a presentation he made to Procter & Gamble in 1999. Here's how Ashton explains the potential of the Internet of Things: The problem is, people have limited time, attention and accuracy- all of which means they are not very good at capturing data about things in the real world. If we had computers that knew everything there was to know about things- using data they gathered without any help from us -- we would be able to track and count everything and greatly reduce waste, loss, and cost. We would know when things needed replacing, repairing or recalling and whether they were fresh or past their best."

In [17], IoT is one of the transformational patterns that will shape the eventual fate of organizations in 2017 and past. Numerous organizations see a huge open door in IoT uses and endeavors begin to trust that IoT holds the guarantee to upgrade client connections and drive business development by enhancing quality, profitability, and dependability on one side, and on the opposite side diminishing costs, hazard, and robbery. By having the privilege IoT show organizations will be remunerated with new clients.

In [18], Earthquake is one of the dangerous and life-threatening natural disasters that can occur anytime anywhere on the earth which has the potential to dismantle lives and properties. In this paper, a simple earthquake indicator using Arduino board and a highly sensitive accelerometer is presented that can sense even minute vibrations. Earthquake indicator using Arduino has proved to be an economical and user-friendly product. The product is affordable for common people in terms of product cost and installation cost. Frequent monitoring of the system is also not necessary. The product can be easily installed in the home and industries. Power requirements of the system are also kept low.

3. DESIGN AND CONFIGURATION

The circuit uses Arduino Uno board wired to ADXL335 accelerometer module (connected across CON2) with its ADC inputs, namely, X-axis to A0, Y-axis to A1 and Z-axis to A2. Two pushbuttons through the supply of 5V are wired to Arduino Uno interrupt pins 2 and 3 that are pulled down to ground via resistors R2 and R1. These buttons are used for incrementing and decrementing the threshold of vibration detection. A 16×2 LCD (LCD1) is wired in a 4-wire mode with Arduino pins contrast control and backlight enabled.

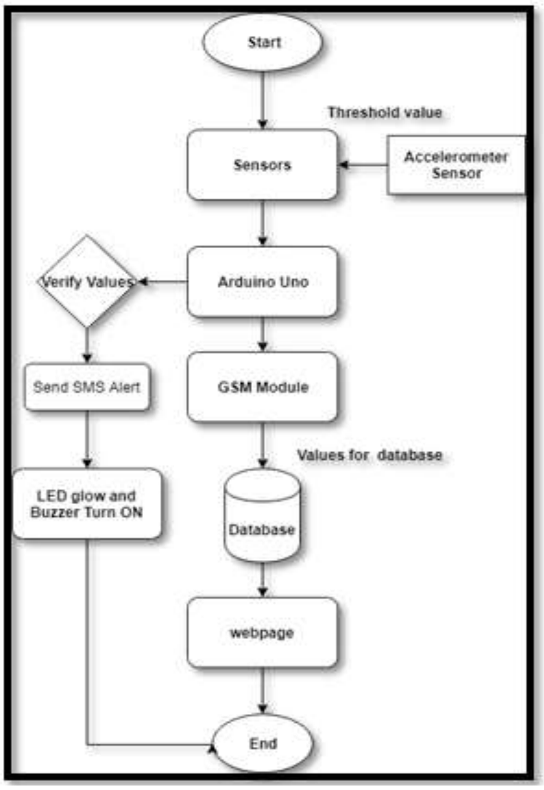


Fig. 1: Overview design of system

BC548 transistor (T2) is connected to pin 5 of Arduino for switching on the local alarm LED (LED1) and a buzzer connected across CON4. Another BC548 (T1) is connected to pin 10 for de-energizing a relay (RL1) in case the alarm is triggered for industrial PLC interfacing for safety interlocks. Pins 11, 12, 9, 8, 7 and 6 are used for LCD control and data lines. When the setup is powered, and while it is still, it reads and stores current accelerometer values in Arduino internal EEPROM regardless of its orientation.

Since the ADC is 10-bit, special header file has been provided with the code. A five-second delay has been provided for all voltages and for the system to be stable before any initial value is read. Arduino microcontroller reads all three axes data from the accelerometer and stores in the EEPROM. It also stores the default threshold value of 25 in the EEPROM.

Pushbuttons connected to pins 2 and 3 of Arduino serve as interrupts for incrementing and decrementing threshold values for sensitivity adjustments. The sensor can also be used to detect knocks and vibrations if the threshold is set to 5 to 8.

The entire setup can be wired and enclosed in a hard enclosure and mounted anywhere in industry or home. Users can also calculate resultant acceleration by using formulae of the square root of X2+Y2+Z2, where X, Y, and Z output from ADXL335, and then compare the result with the threshold to raise an alarm. Modifications can be done by the user on the same platform if required.

In this project, we have used Arduino that reads accelerometer's analog voltage and convert them into the digital values. Arduino also drives the buzzer, LED, 16x2 LCD and calculate and compare values and take appropriate action. Next part is Accelerometer which detects vibration of the earth and generates analog voltages in 3 axes (X, Y, and Z). LCD is used for showing X, Y and Z axis's change in values and also showing alert message over it. This LCD is attached to Arduino in 4-bit mode. RS, GND, and EN pins are directly connected to 9, GND and 8 pins of Arduino and rest of 4 data pins of LCD namely D4, D5, D6, and D7 are directly connected to digital pin 7, 6, 5 and 4 of Arduino. The buzzer is connected to pin 12 of Arduino through an NPN BC547 transistor.

As we mentioned earlier that we have used Accelerometer for detecting vibrations along any of the three axes so that whenever vibrations occur accelerometer senses that vibrations and convert them into equivalent ADC value. Then these ADC values are read by Arduino and shown over the 16x2 LCD. After finding real readings, Arduino compares these values with predefined max and min values. If Arduino finds any changes values are more then or less then the predefined values of any axis in both direction (negative and positive) then Arduino trigger the buzzer and shows the status of alert over the 16x2 LCD and a LED also turned on as well.GSM module sends the alert on the registered mobile number.

The readings of sensors can be seen and checked on the webpage which makes use of an API:

Fig. 2: Android app display

4. INSTRUMENT SET UP AND DATA USED

This chapter discusses the equipment setup, data acquisition, and basic data display. The vibration sensor was a setup to monitor the vibrations when it is placed inside soil particles. The soil is placed inside a container and force is provided to the container to create vibrations.

The recorded data is sent to the Arduino and parsed for further processing. The frequencies were plotted on a graph and based upon the graph, its threshold value is calculated above which the alert signals would be generated.

A plastic container is used to perform the experiment, the loose soil is placed inside the container in such a way that it is slanted in the form of slope depicting the real world situation. The sensor is placed inside the soil and the direction of x, y, z-axis are noted. Operations are performed with respect to each axis.

There are two separate setups used in this project. One is for vibration detection and other is used to send the alert signals. The accelerometer is chosen for detecting vibrations. This was chosen for several reasons. It has a wide amplitude range and it is small enough to be placed anywhere.

This sensor is placed inside the container which contains soil particles and stones. Initially, values are calculated at static state. After that force is applied using hammer by hitting the container and values are calculated. The change in values are recorded and then the analysis is done using a graph.

The equipment set-up is kept in horizontal condition, but the soil is placed in such a way that it is slanted in a form of a slope.

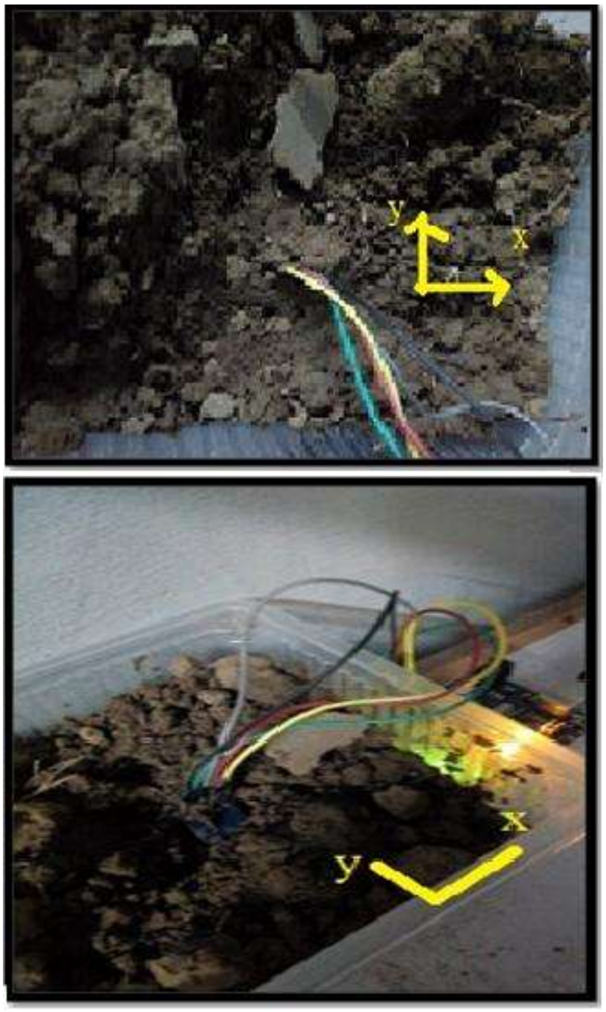


Fig. 3: Equipment setup

5. DATA ACQUISITION

5.1 Procedure

1. After placing the soil in a tilted position, the initial set of reading is noted and its average is calculated.

2. For T1 operation, the box is hit with respect to x-axis and values are noted and the graph is drawn.
3. For T2 operation, the box is hit with respect to the y-axis and the values are noted.
4. For T3 operation, the box is hit two times with respect to the x-axis.
5. For T4 operation, the box is hit two times with respect to the y-axis.
6. The difference between all the values can be seen with the help of the graph.
7. For calculation of threshold value, the maximum displacement is measured.
8. Length and width and depth of the container are 16.4cm and 12.7cm and 5.5 cm respectively.

Experiment 1: Initial set of reading (Everything is static)
These values are obtained from the sensor when there are no vibrations that mean the static condition. Here our setup is completely normal.

Table 1: Initial set of readings

S. no	X-axis (mm/s^2)	Y-axis(mm/s^2)	z-axis(mm/s^2)
1	240	243	240
2	240	243	239
3	240	244	240
4	241	244	239
5	240	244	239
6	241	244	240
7	241	244	241
8	241	242	241
9	241	243	240
10	241	244	240
11	239	244	240
12	240	243	239
13	240	242	238
14	240	243	238
15	241	244	239
16	242	244	239
17	241	245	239
18	241	244	239
19	242	244	239
20	241	245	239
21	241	244	240
22	241	244	241
23	241	242	241
24	241	243	240
25	241	244	240
26	239	244	240
27	240	243	239
28	240	242	238
29	240	243	238
30	241	244	239
31	242	244	239
32	241	245	239
33	241	244	239
34	242	244	239
35	241	245	239

Average of x-axis=240.9
Average of y-axis=243.28
Average of z-axis=239.28
Whenever any displacement occurs its unit is always mm.

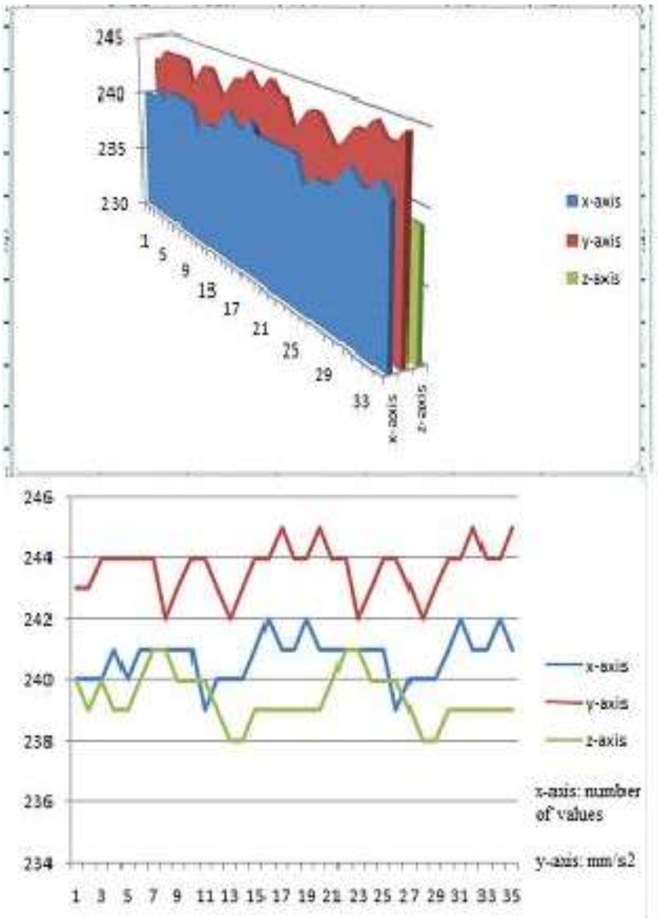


Fig. 4: Initial reading graph

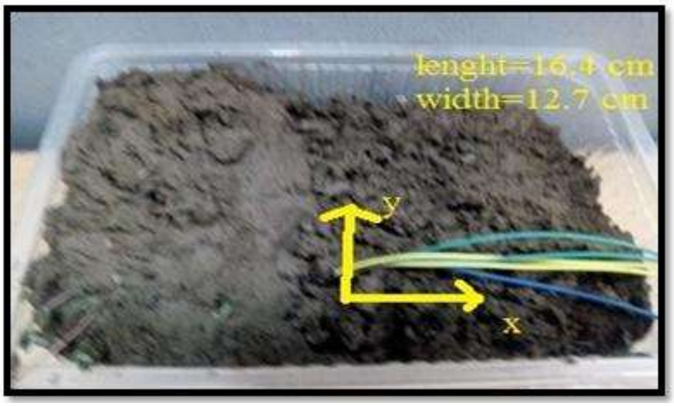


Fig. 5: Initial setup

Experiment 2: After operation T1 (Single hit-movement along the x-axis)
After performing experiment-1 that is the static condition, we did the experiment-2 in which we gave the vibration in the x-direction. The vibration is given through the hammer which means the applied force is given by the use of a hammer. So if there is any movement in x-direction then it will cause an add-on movement in the y-direction.

Table 2: After T1 Operation

S. no	X-axis (mm/s^2)	Y-axis(mm/s^2)	z-axis(mm/s^2)
1	253	246	239
2	254	245	240
3	254	246	241
4	255	245	241
5	257	246	240
6	257	246	240
7	259	246	240
8	259	246	239

9	260	246	238
10	260	246	238
11	260	246	239
12	260	246	239
13	261	245	239
14	261	246	239
15	261	247	239
16	261	247	239
17	261	247	240
18	261	247	239
19	261	247	240
20	261	246	239
21	261	247	239
22	261	247	240
23	261	247	241
24	261	247	241
25	261	247	240
26	261	247	240
27	261	247	240
28	261	247	241
29	262	248	241
30	261	247	240
31	261	247	240
32	261	247	240
33	261	247	241
34	261	247	241
35	261	247	241

Average of x-axis= 259.17
Average of y-axis=246.26
Average of z-axis=240.7
Whenever any displacement occurs its unit is always mm.

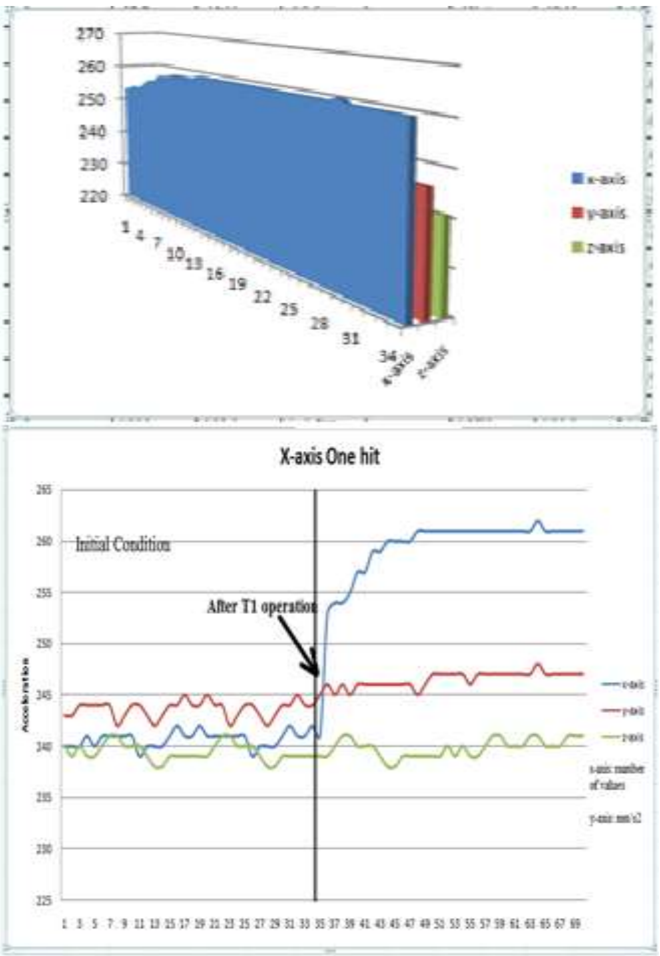


Fig. 6: Graph of T1 operation

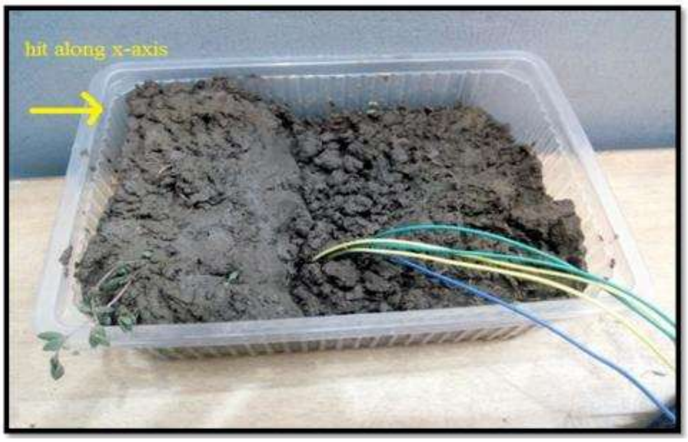


Fig. 7: Displacement after 1 hit

Experiment 3: After operation T2 (Single hit-movement along the y-axis)
After performing Experiment-2 that is giving the vibration in the x-direction, we then started giving hits on the y-axis. Which causes the increase in value for the y-axis and some additional movement was followed to the x-axis.

Table 3: After T2 Operation

S. no	X-axis (mm/s^2)	Y-axis(mm/s^2)	Z-axis(mm/s^2)
1	253	260	239
2	254	260	240
3	254	260	241
4	255	260	241
5	257	261	240
6	257	261	240
7	259	261	240
8	259	260	239
9	260	261	238
10	260	260	238
11	260	261	239
12	260	263	239
13	261	263	239
14	261	263	239
15	261	263	239
16	261	263	239
17	261	263	240
18	261	263	239
19	261	263	240
20	261	263	239
21	261	264	239
22	261	264	240
23	261	264	241
24	261	264	241
25	261	264	240
26	261	264	240
27	261	264	240
28	261	264	241
29	262	264	241
30	261	264	240
31	261	264	240
32	261	264	240
33	261	264	241
34	261	264	241
35	261	264	241

Average of x-axis=260.2
Average of y-axis=262.14
Average of z-axis=240.9
Whenever any displacement occurs its unit is always mm.

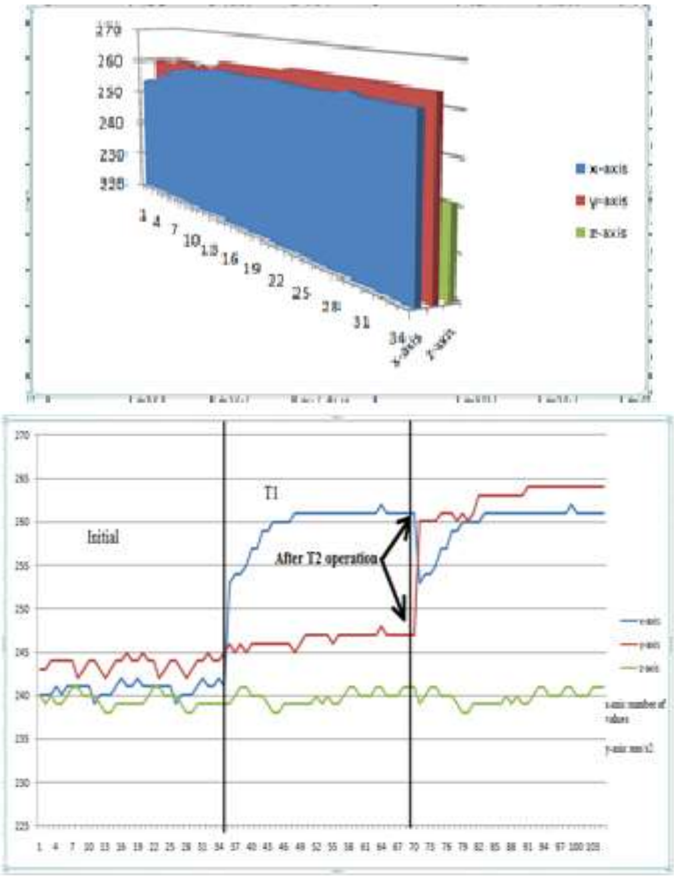


Fig. 8: Graph after T2 operations

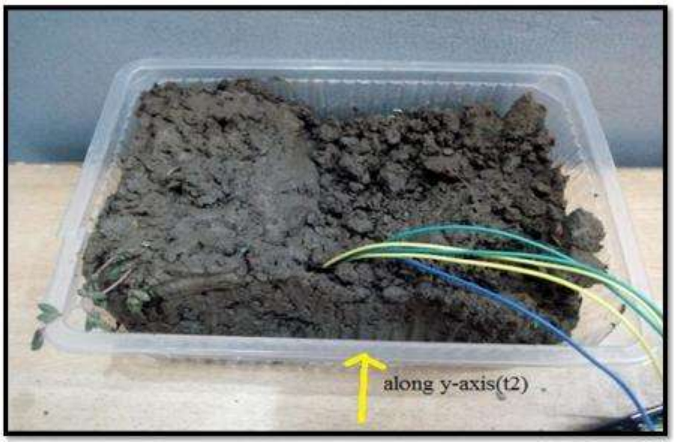


Fig. 9: Displacement along Y-axis

Experiment 4: After operation T3 (Two hits along the x-axis)

After experiment-3 we then started to experiment-4 in this we gave the vibrations in x-axis but the hit was given two times. So as this cause a quite continuous vibration and movement in the x-axis causing the add-on vibration y-axis.

Table 4: After T3 operation

S. no	X-axis(mm/s^2)	Y-axis(mm/s^2)	Z-axis(mm/s^2)
1	286	262	239
2	288	260	240
3	288	262	241
4	287	260	241
5	287	261	240
6	287	261	240
7	287	261	240
8	287	262	239
9	287	262	238
10	287	262	238
11	287	262	239
12	288	263	239
13	288	263	239
14	288	263	239
15	288	263	239
16	288	263	239
17	288	263	240
18	287	263	239
19	289	263	240
20	289	263	239
21	289	264	239
22	289	264	240
23	289	264	241
24	289	266	241
25	289	266	240
26	289	266	240
27	289	266	240
28	289	266	241
29	289	266	241
30	289	266	240
31	289	266	240
32	289	266	240
33	289	266	241
34	289	266	241
35	289	266	241

Average of x-axis=287.4
Average of y-axis=263.8
Average of z-axis=241.3
Whenever any displacement occurs its unit is always mm.

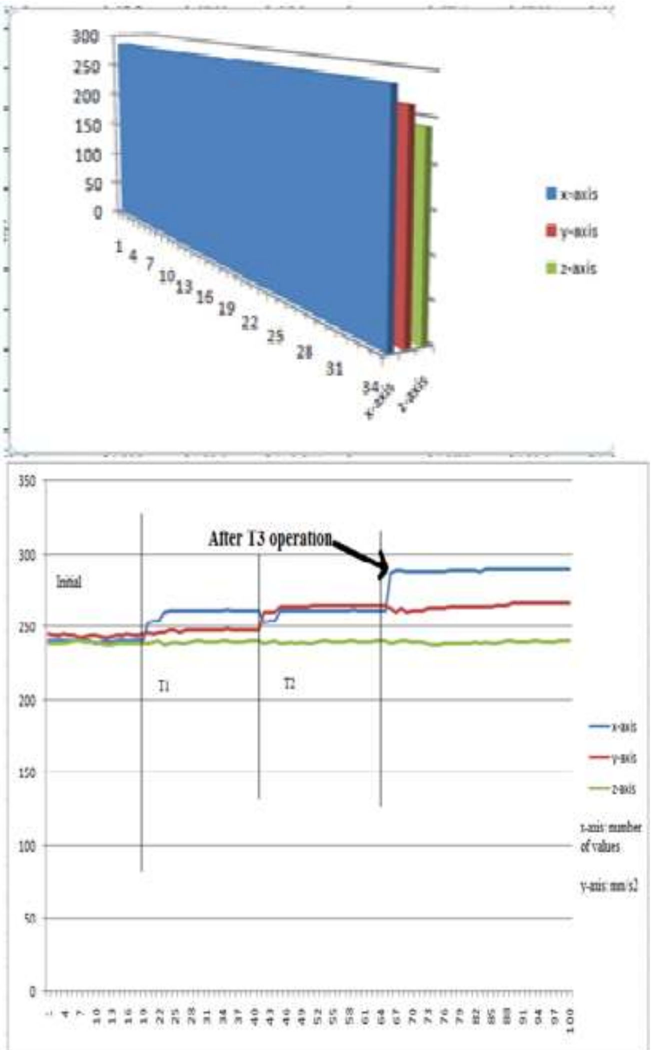


Fig. 10: Graph after T3 operation

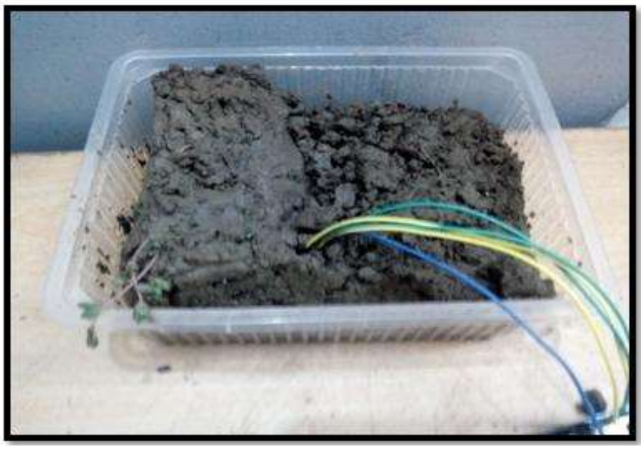


Fig. 11: Displacement after two hits along X-axis

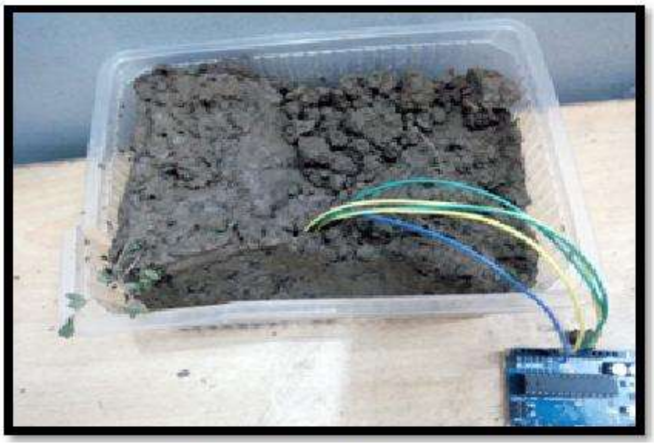


Fig. 12: Displacement after two hits along y-axis

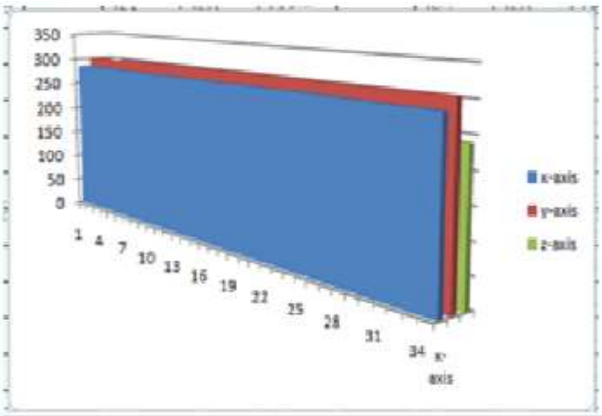
Experiment 5: After operation T4 (Two hits along the y-axis)

After experiment-4 we then started to experiment-5 in this we gave the vibrations in y-axis but the hit was given two times. So as this cause a quite continuous vibration and movement in the y-axis causing the add-on vibration x-axis.

Table 5: After T4 Operation

S. no	x-axis(mm/s^2)	y-axis(mm/s^2)	z-axis(mm/s^2)
1	286	299	239
2	288	302	240
3	288	302	241
4	287	300	241
5	287	303	240
6	287	304	240
7	287	305	240
8	287	305	239
9	287	305	238
10	287	305	238
11	287	305	239
12	288	305	239
13	288	305	239
14	288	305	239
15	288	304	239
16	288	305	239
17	288	305	240
18	287	306	239
19	289	306	240
20	289	306	239
21	289	306	239
22	289	306	240
23	289	306	241
24	289	306	241
25	289	305	240
26	289	305	240
27	289	306	240
28	289	306	241
29	289	306	241
30	289	307	240
31	289	306	240
32	289	307	240
33	289	307	241
34	289	307	241
35	289	307	241

Average of x-axis=288.3
Average of y-axis=304.6
Average of z-axis=242.9
Whenever any displacement occurs its unit is always mm.



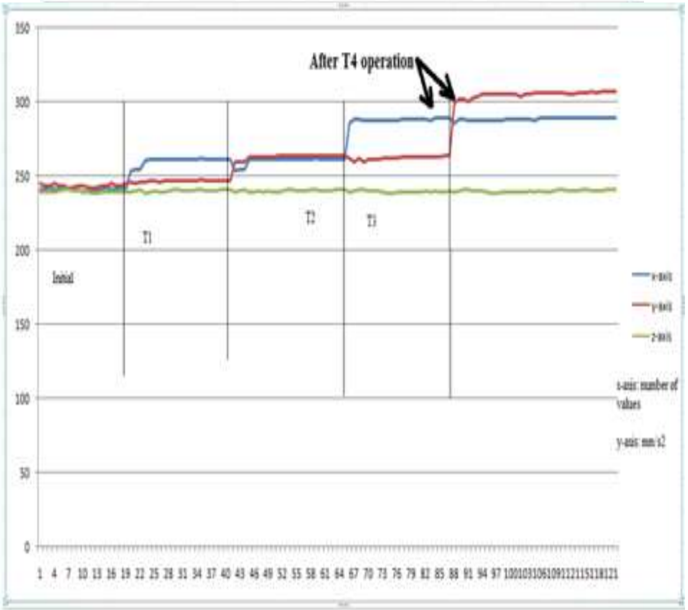


Fig. 13: Graph after T4 operation

5.2 Calculation of threshold value

After analysis of calculated values, the difference between the set of values after the force is applied can be observed. According to the observation, the average value of x, y, z-axis are: x-axis=240.9, y-axis=243.28, z-axis=239.28 when setup is at static state.

Along x-axis

After T1 operation (along x-axis) its value changes. That is the average value of x, y, z axis are: x-axis=259.17, y-axis=246.26, z-axis=240.7.

Difference between set of values along x-axis= 18.27mm
After T3 operation (along x-axis), the average value of x, y, z axis are: x-axis=287.4, y-axis=263.8, z-axis=241.3

Difference between set of values (T3-initial values) =46.5mm
Difference between set of values (T3-T1) = 28.23mm

Along y-axis
After T2 operation (along y-axis) the average set of values are x-axis=260.2, y-axis=262.14, z-axis=240.9

Difference between set of values along y-axis=18.86mm
After T4 operation, the average value of x, y, z axis are: x-axis=288.3, y-axis=304.6, z-axis=242.9

Difference between set of values (T4-T2) =42.46mm

5.3 Displacement in soil

Table 6: Values in displacement

Direction of force	Displacement (w.r.t initial condition)
Experiment 2: One hit along the x-axis	
x-axis	1.827 cm
y-axis	0.298 cm
Experiment 3: One hit along the y-axis	
x-axis	1.93cm
y-axis	1.886 cm
Experiment 4: Two hit along the x-axis	
x-axis	4.65 cm
y-axis	2.052 cm
Experiment 5: Two hit along the y-axis	
x-axis	4.74 cm
y-axis	6.132 cm

1. One hit along x-axis
- When T1 operation is performed (one hit along the x-axis) the value of x-axis changes by 1.827 cm.
- Due to this, there is a little displacement in y-axis i.e. 0.298 cm.

2. One hit along y-axis
When T2 operation is performed (one hit along the y-axis) the value of y-axis is cumulative of T2 and its preceding operations (i.e. T1)
- Value of y-axis is calculated as (262.14-243.28) =18.86 mm Here 262.14 is the cumulative value.
- Similarly, Value of x-axis is calculated as (260.2-240.9) =19.3 mm. Where 260.2 is the cumulative value.

3. Two hit along x-axis
When T3 operation is performed (two hit along the x-axis), the displacement value of x-axis is cumulative of T3 and its preceding operations.
- Value of x-axis is calculated as (287.4-240.9) =46.5 mm where 240.9 is the initial value of x-axis and 287.4 is the cumulative value.
- Value of y-axis=263.8-243.28=20.52 mm where 263.8 is the cumulative value

4. Two hit along y-axis
When T4 operation is performed (two hits along the y-axis), the displacement value of y-axis is cumulative of T4 and its preceding operations.
- Value of y-axis is calculated as (304.6-243.28)=61.32 mm. Where 243.28 is the initial value of y-axis and 304.6 is the cumulative value.
- Value of x-axis=288.3-240.9=47.4 mm. Where 288.3 is the cumulative value along x-axis.

6. METHODOLOGY

The following algorithm is used to implement the code in Arduino Uno board. It helps to achieve the working of the accelerometer to display data on the application and use of Thingspeak API's. Some new commands are also used while connecting with the GSM Module SIM900A with the Arduino.
- Set the initial values of the sensor
- Compare the values after displacement.
- Display values using GSM.
- ATCMGI connect
- Send Message
- AT HTTP URL(API URL)
- Connect with Thingspeak API
- Send A0,A1,A2,D11;
- End

7. RESULTS AND ANALYSIS

As discussed previously, using table 6, we get the cumulative values of displacement. The Data Acquisition is done and the values are measured. These values would be helpful in sending the alert to the mobile phone when the value exceeds.
- From Table 1, we get an initial set of readings and thus average is calculated.
- From Table 2, we get the readings after one hit along the x-axis
- From Table 3, we get the readings after one hit along the y-axis
- From Table 4, we get the cumulative readings after two hits along the x-axis
- From Table 5, we get the cumulative readings after two hits along the y-axis

Hence the difference between the values is calculated. These values help in generating alarm signals.

As we see the graphs from the above data, we get to know that the vibrations are cumulative which means that the values from the preceding operation or effect play an important role in the current operation. For example; When we perform the T1 operation the initial values are changed and it effects the quality of destruction so this shows that the X axis graph increases as the force is applied in lieu of x-axis while when we perform the T2 operation the value of Y increases but at the same time if there is force on X-axis than the value of X increases from its last T1 operation which can be easily verified by T3 operation and for Y axis T4 operation verifies.

The following figure shows the LCD Display of the Alarm message.

Fig. 14: LCD with display message

The values will be displayed on the mobile phone as follows:

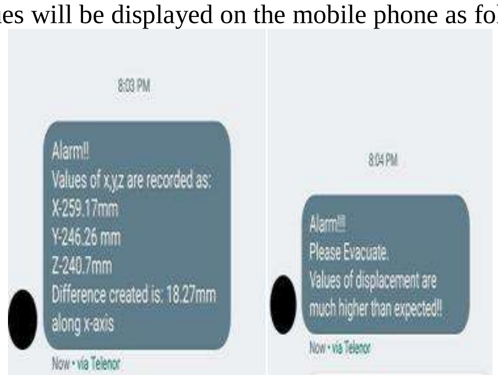


Fig. 15: Mobile phone SMS

8. CONCLUSION

The main goal of this project was to detect the unusual vibrations and generate the alert when the limit exceeds. This can be useful for emergency response planning. It is going to implement by using both hardware and software and thus its implementation is easy and economical.

- Emergencies can come without warning at any time. Being prepared is the best way to handle these unexpected incidents and disasters. Emergencies are the source of risk and therefore have the probability of causing an undesired event. The emergency shelter may be needed in some situation.
- After a disaster occurs, immediate action is taken to protect staff, visitors & collections and sending alert text messages to concern authority using SMS alert.
- Contact names and phone numbers must be listed for sending alert SMS.
- Since it is done on a small scale as it is lab-based analysis, it could further be implemented on real data.
- The volume of the container is not measured.

From all these analyses it is shown that the product can be used to detect minute vibrations and it helps to take preventive measures to avoid danger. Vibration indicator using Arduino has proved to be an economical and user-friendly product. Frequent monitoring of the system is also not necessary. Power requirements of the system are also kept low. Precautionary measures are required for this product and it can be easily operated by the user.

9. FUTURE WORK

This project involves the study using experimental setup within Lab. This instrumentation has scope to utilize analysis on real-world using real-world situation.

While carrying out an experiment it was felt the magnitude of the applied force is required to analyze the vibration created in the test bed. The amount of force applied to create vibrations can be measured for more accurate results.

The project can also include the sending of alarms on internet messaging services like (E-Mail or Twitter) so that the alarm could spread fast.

Duration of vibration can be put as a concern. What immediate actions should be taken upon notification of an emergency?

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