Structural analysis using MPU6050 gyroscope

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***Abstract*—Many buildings are sensitive to earthquake and hurricanes, and it is easy to generate large deflection and dynamic response even through daily motion of a huge crowd. There are also structures with inappropriate distributions of strength and stiffness which performs poorly in case of any seismic activity and are one of the major causes of collapses leading to loss of lives. With these issues, there is a growing demand for the exploration of different methodologies to detect the prime areas in the structures that require improvement and repair, and with these early detection techniques, we can take suitable action that can, in turn, save a lot of lives. Previous research in this field mainly revolved around checking concrete strength and rust which was insufficient. Other devices which exist are expensive and they has to be equipped while constructing the building. In this paper we have summarised our study on finding the structural strength of buildings with the help of MPU6050 gyroscope. The MPU6050 gyroscope is a 3-axis gyroscope and a 3-axis accelerometer. The sensor measures the angular rotation from its axis and transfers it to the smartphone using a Bluetooth module.**

I. Introduction

We spend a major part of our life surrounded by four walls in different houses, in various buildings without having any idea how safe they are. The strength of a building comes from its foundation. The same foundation is built by human hands, the hands which are undoubtedly skillful but also prone to human errors. Looking at this grave situation we tried to find a solution that would help construction workers to build stronger buildings and help protect the family living in their houses. Currently there is no commonly used technique to analyse the strength of a single wall, a wall can get weakened by many factors such as wind, rust, heavy usage, weak material used etc [2]. Recognizing seismic tremors involving IoT gadgets progressively is a troublesome assignment for the accompanying reasons, it is obliged with the hard constant issue yet in addition because of the comparability of quake signals and the non-quake signals, (for example, heavy usage and wind). The exploratory aftereffect of the proposed model shows promising outcomes [1].

II. Related work

The past related works in this field were on quantitative measurement of structure analysis of buildings using gyroscope and are focused on MEMS-based gyro sensors for monitoring buildings structural performance, and calculation of response displacements using gyro. It is explained that responses utilizing the proposed strategy have sensible precision, and the orbital graphs in X-Y plane likewise can be appropriately obtained. Therefore, the given strength measuring system is useful for monitoring structural strength.[4].

Some review has likewise been done on the utilization of Piezoelectric Materials which incorporate minimal expense, high transmission capacity of administration, accessibility in an assortment of configurations as well as their ability to make electric fields from mechanical stress and the other way around. These properties assists us with involving them as sensors and the opposite impact as actuators [5].

The use of gyroscope for detection and monitoring of earthquakes is not new. Recent studies for the same has been done theoretically in the paper such as the Wireless Earthquake Alarm Design based on MEMS Accelerometer. This research proposed the use of MEMS accelerometer for monitoring earthquake. Since earthquake is caused by vibrations from earth's crust, the naturally occurring earthquakes are caused by tectonic plate movements. This idea was the steppingstone to various research and arguments [10,11].

Practical implementation of gyroscope for detection of small local earthquake has been done in Northern and Central Italy and discussed recently. This study assesses the seismic detection efficiency using an accelerometer prototype on microelectromechanical systems which is also known as MEMS technology. Multiple MEMS sensors were installed in infrastructures and their reading was stored, the readings recorded major earthquake and 9 smaller seismic events. This study concluded that the accelerometer are promising instruments which helps in seismic monitoring [12,13, 14].

III. Methodology

The proposed technique comprises of two segments, each covering a significant commitment to this paper. Before getting into the details of the two sections, we will discuss the concepts used.

A. Interquartile Range and Outlier Detection

Interquartile range (IQR) tells us about the spread difference between the 75th and 25th percentiles of the data. Values that lie outside the range obtained by adding 1.5*IQR to the third quartile and by subtracting 1.5*IQR from the first quartile are considered outliers [6].

$$\boldsymbol{IQR = Q3 - Q1}$$

where Q1 represent First Quartile and Q3 represent Third Quartile

B. MPU6050

We are utilizing the MPU6050 sensor which is a 3-axis gyroscope and a 3-axis accelerometer [7]. The MPU6050 object understands angular velocity and acceleration utilizing the InvenSense MPU-6050 sensor. The sensor estimates the precise revolution from its axis and moves it to the cell phone utilizing a Bluetooth module (HC-05).

C. Publisher/Subscriber Model

Publisher Subscriber model is used for implementing the notifications. In a pub/sub model, any message published to a subject is straight away received via all of the subscribers to the subject.

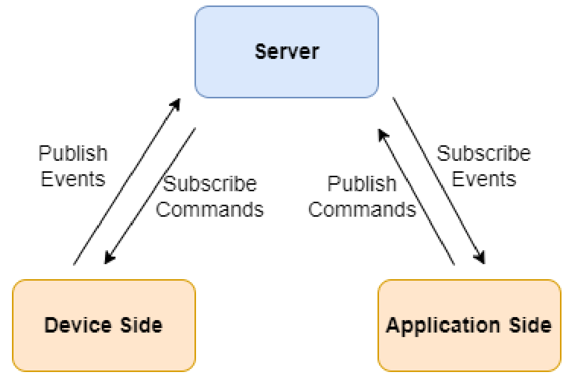

Fig. 1. Publisher-Subscriber Model

Pub/sub messaging can be used to enable event-driven architectures or to decouple programs so that you can growth overall scalability, reliability, and performance. Collected records from the sensors is transmitted to the application via Bluetooth module for similarly analysis. The end acquired from the analyzed statistics is then published to an event and correspondingly notifications are dispatched to all of the users that subscribed to the event [8].

D. Working

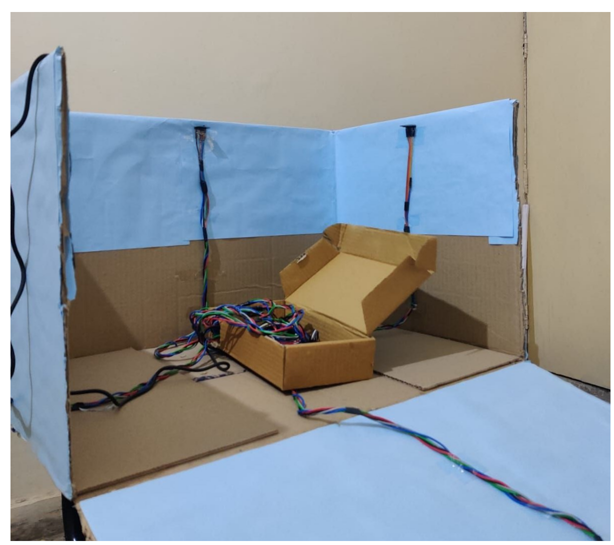

Fig. 2. Cardboard structure with 4 MPU6050 gyroscopes attached on all sides

1) Structural Analysis: For structural analysis of buildings, we are making use of the interquartile range. Values are collected from MPU6050 which depicts the vibrations in all three directions. An outlier detection strategy is used for determining the structural strength of a building. The outlier detection strategy works on the basis that if the values lie outside the range obtained by adding 1.5*IQR to the third quartile and by subtracting 1.5*IQR from the first quartile can be detected as an outlier. Detection of an outlier in any of the directions depicts the lack of structural integrity in that portion of the building.

2) Earthquake Detection: Earthquake detection is an additional property to the task of conducting structural analysis. If the vibrations in all the MPU6050 sensors satisfy the outlier detection criteria, then an earthquake warning is given to the user.

IV. Experimental Setup

In our experiment, we are making use of 4 MPU6050 sensors,1 Arduino nano, 1 HC-05 module, and an app for showing the data. MPU6050 sensor is attached to the I2C pins of the Arduino hardware. For collecting the data from the four MPU6050 sensors while using only one Arduino, we collected the reading from the sensors in a circular fashion. These sensors are fitted at the center of the 4 walls of the structure. All the MPU6050 sensors are connected in parallel to the Arduino nano pins 4 and 5. Data is collected in a circular fashion starting with the first sensor with an interval of 100ms.

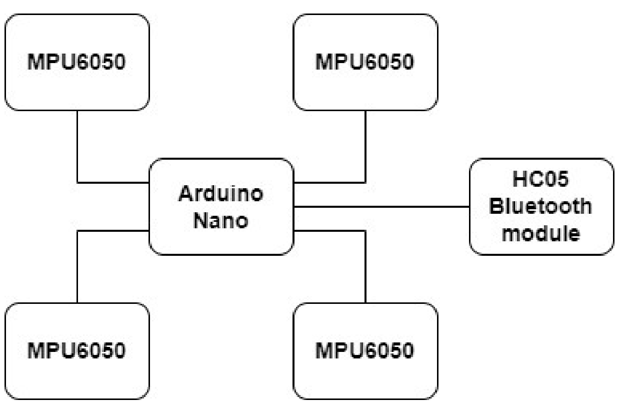

Fig. 3. Setup

Collected data is then transmitted to the app via Bluetooth module for further analysis. Publisher Subscriber model is used for implementing the notifications. Users can subscribe to the events following which they will receive notifications corresponding to the notifications published to that event. Any number of users can subscribe to an event and all users need not be connected via Bluetooth to the Arduino module.

V. Observation

We displayed the count of values, for all 4 corner of the structure, that lie outside the range got by adding 1.5*IQR to the third quartile and by subtracting 1.5*IQR from the first quartile. The corner having greater count has some issue and must be took care off before anything happens. We also displayed glowing bulb in the app, indicating that the reading at that particular moment is an outlier and some issue is there.

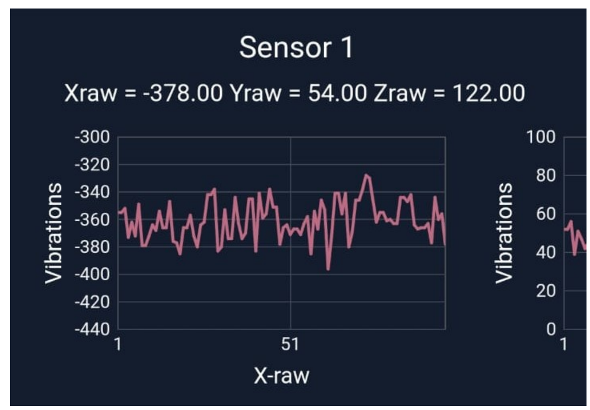

Fig. 4. Reading of sensor 1

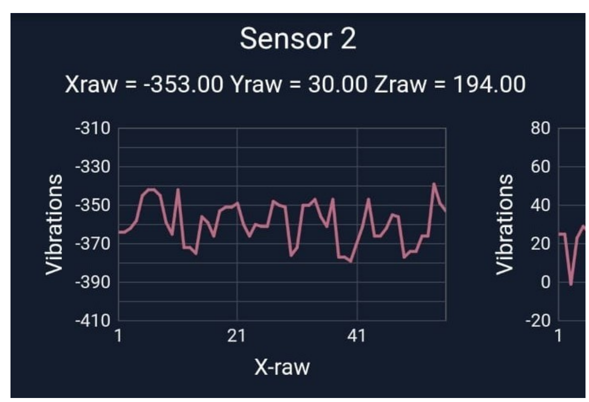

Fig. 5. Reading of sensor 2

These graphs indicate the readings of 4 MPU6050 gyroscopes along the x axis.

If the motion is violent enough during an earthquake and the readings satisfy the condition of the outlier in the interquartile range, then all the users who have subscribed to that particular topic will

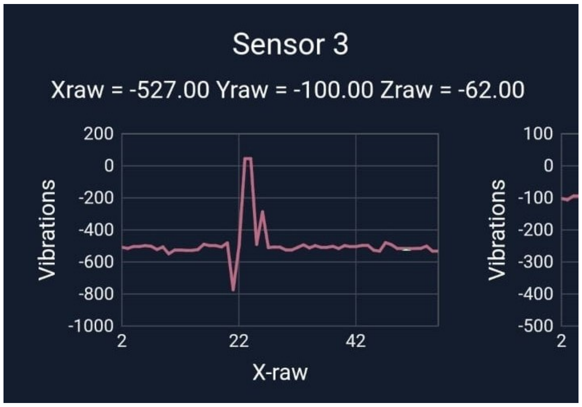

Fig. 6. Reading of sensor 3

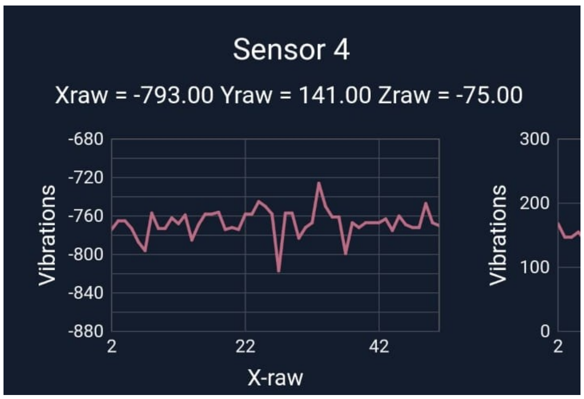

Fig. 7. Reading of sensor 4

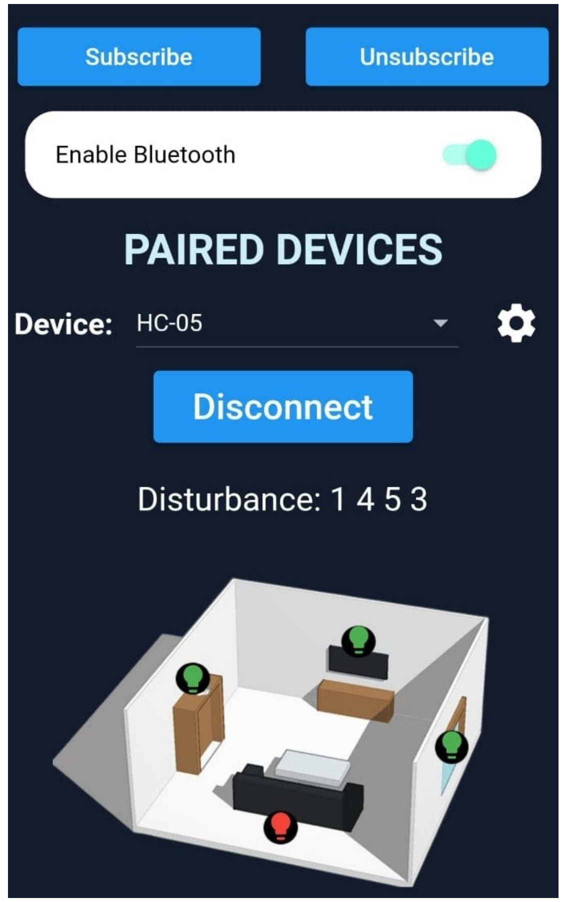

Fig. 8. Mobile Application

be alerted with a buzzer sounds notification with message. The Arduino-based earthquake detector utilizing gyroscope has been tried and it is working acceptably. Every component of the framework are viewed as working properly.

VI. Result

To obtain a comprehensive comparison, we built a cardboard structure and checked the parameters which worked well according to the disturbance we generated by shaking the structure. Accordingly, we came up with interquartile range provided with some initial values when the structure is in a stable position. Outliers of the interquartile range then gave good results in predicting earthquakes and reporting weak corners of the cardboard structure.

In this system, the Arduino Nano was used as a controller for all modules. The A4 pin of the Arduino Nano was connected to the SCL (Serial Cluck) pin of MPU6050 and the A5 pin was connected to the SDA (Serial Data) pin of MPU6050 sensors, while the AD0 pin of MPU6050 is used to control the 4 gyroscopes for I2C communication. The D3 pin of Arduino Nano was associated with the RX (receive) pin of HC05 and the D4 pin of Arduino Nano was associated with the TX (Transmit) pin of HC05. Arduino IDE software and Flutter is used for building mobile application.

The assessment is finished with the assistance of a cardboard design, the sensors are fixed and afterward we utilized a few examples of human exercises like strolling and standing by to add those readings too. This is on the grounds that the model con- verges too quickly in the presence of only noisy data and consequently can't get familiar with the underlying patterns of the data, particularly earthquake patterns. We then finally evaluated the model based on interquartile range, which showed the best results to detect earthquakes and weak parts of the structure, which in this case is a cardboard box [9].

This framework enjoys many benefits, like minimal expense, low power utilization and small size. This system consisted of earthquake detection and structural issues reporting using flutter mobile application. This system used 4 MPU- 6050 sensors, Arduino Nano, HC-05, and a mobile application. The occurrence of an earthquake was detected by 4 MPU- 6050 sensors which gave the accurate information and HC-05 bluetooth was used to send the data to mobile devices. In this, we tested the system on the card- board structure, which included various human activities, and then evaluated different parameters. This framework can be utilized in buildings with many users but with a solitary sending part as it is using a subscriber-publisher model. In light of the exploratory outcomes, the proposed parameter demonstrated gave good results. The chose model showed promising out- comes with a less chances of deceptions and is independent of the place where it is kept as its values are initialized every time. As a result, our approach can be used in the real environment without changing anything.

VII. Conclusion

This work, named "Structural analysis using MPU6050 gyroscope", is successfully developed and working agreeably. Accordingly, to summarize, we have presented this product with a view of reducing the destruction caused by earthquakes by alerting the people. It is economical and its building price is very less and thus it is affordable for each person. We have gave a clever technique to solve the automatic earthquake detection and alerting about the weak part of the structures by utilizing an Arduino-based gadget. In our framework, most of cases offer real practical advantages in case of an earthquake to safeguard lives and assets. We can without much of a stretch set up this framework for household purposes as it consumes less power. The proposed work maybe changed and utilized as a knock-and-tremble marker for ATMs, vehicles or door-break alerts.

Accordingly, we can infer that reconciliation of seismic activity with the interquartile range yields effective and significant outcomes and perhaps used to predict earthquakes, considering that a certain number of starting stable readings are available of the equivalent. Our endeavor perhaps named effective. The collaboration of additional gyroscopes can additionally be progressed to give precise alerts of earthquake. This detector can find minor shocks and caution you to clearn to a secure spot.

VIII. Future Works

As a future examination bearing, we will explore new elements and models that require less information support and less computational power whereas maintaining a very high disclosure capacity against the difficult initial stable readings.

Extensive testing in real time conditions is required to certify the applicability of the approach specified. Further analysis of data captured is required using different algorithms. Collection of data is required for implementing ML models for determining the structural strength of buildings. Exploration of more sensitive sensors is required for achieving much more accurate

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