

# Life balloon: a paradigm shift in earthquake safety-intelligent IoT detection and protection system for optimal resilience

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## ABSTRACT

Internet of things (IoT) applications for environmental monitoring have greatly improved due to advances in hardware and software technologies. Given the significant economic and societal impacts of earthquakes, there is an increasing need to develop effective earthquake early warning systems (EWS). However, designing such intelligent systems remains challenging because of inefficient classification methods and limitations in high-fidelity sensing capabilities. To reduce the devastating effects of earthquakes, this paper proposes an earthquake detection and protection system. The system's primary function is to detect seismic signals and activate a specially designed airbag (life balloon) unit that protects occupants in apartment buildings. In addition, the unit helps maintain necessary oxygen levels, thereby improving occupant safety during seismic events. The proposed system also includes a communication method that transmits critical information about the affected area to relevant parties. Early data transmission enables rapid response and guides the efficient deployment of required resources, making aftershock management more effective. By combining advanced sensor technologies with efficient communication methods, the proposed system aims to enhance safety and emergency management while providing comprehensive protection and support during seismic events. Experimental results show that the proposed method achieves approximately 95% sensitivity and 94.2% accuracy.

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## 1. INTRODUCTION

Generally, earthquakes are unpredictable and cause massive disasters, which threaten society and the economy. Every year, several earthquakes above 7.0 on the Richter scale are recorded, and these lead to massive loss of lives and property [1], [2]. Such tragic disasters have underlined the importance of the invention of prevention and early identification of earthquake systems.

One thing, for instance, is the earthquakes' aftereffects that should not only be attributed to physical destruction, but the latter have a lot of implications. Earthquakes disrupt essential services and cause people to be relocated, and their impacts remain for a very long time in terms of socioeconomic changes. The local economy, in such a case, can suffer a drastic blow due to the loss of the infrastructure, houses, and enterprises as well, and the occurrences of the restoration of the event can be quite overwhelming.

In addition, it points out that governments might as well spend a huge amount of money on rebuilding. The long-term effects of earthquakes on the lives of individuals and communities are socially and psychologically, in terms of death and injuries because of these natural disasters, are lifelong [3].

These situations have led to a great deal of interest in research into the creation of earthquake detection and protection tools. The deployment of these technologies can thus detach it from performing the first step in the safety procedure, as the low number of deaths and less damage to properties are the results of the early warning they offer, and the facilitation of the necessary steps to be taken. Before the arrival of the seismic waves, people in areas with a high population density can be warned, as well as safety measures. Simply put, it gives one the chance to find safety and make the required preparations. In prevention, for instance, steps that may seem insignificant can act as safety instruments that help in the aversion of eventual death if not in aid of the reduction of the number of people who will lose their lives in an earthquake.

Still, the task of producing dependable earthquake detection and protection systems is not an easy one. The problem of finding very accurate sensing methods that can closely detect seismic activity and, at the same time, differentiate it from other kinds of background noise is a major challenge in this field. In addition, the system being discussed should also have good enough classification methods that can differentiate various degrees of earthquake strengths and even estimate their possible effects on the local areas.

This proposal is for an earthquake detection and protection system that will deal with these issues. The diagram of the proposed system is Figure 1, in which the components that are installed and their locations are visually represented. The MPU6050 sensors were positioned very carefully so as to be able to efficiently record vibrations and motions in the deployment environment. The suggested system is equipped with the latest developments in hardware and software technology. It is envisaged that the system will not only be able to pinpoint earthquakes accurately but also initiate the necessary protective measures and issue the proper communication channels with the suitable authorities. Limiting the damage caused by earthquakes, providing safety for the earthquake-stricken inhabitants, allowing for a quick response, and ensuring the efficient use of resources after an earthquake are the fundamental goals of it. One of the preventive actions would be the quick deployment of a specially designed airbag unit (life balloon) by the device, which is connected to the residents of apartment buildings through the execution of the oxygen supply, thus ensuring the security of the residents during the building instances of an earthquake and the maintenance of the necessary oxygen levels.



Figure 1. The life balloon system (prototype)

Moreover, the system's communication feature is intended to relay hardly any other information but only that which is vital about the area most hit by the disaster to the emergency responders. This means sending SMS alerts with GPS coordinates and starting automated phone calls to ensure authorities have accurate data right away to assess the matter and distribute limited resources. Severe elements are meant to enhance the whole reaction to an earthquake, minimize the socioeconomic effects, and finally increase the resilience of societies against severe natural catastrophes. Using contemporary sensing technologies and efficient communication methods, the system seeks to improve safety and emergency management by offering complete protection and support during earthquake events.

The remainder of the paper is structured as follows: a review of the literature on earthquake detection systems is covered in section 2, and the problem statement is described in section 3. Section 4 discusses the algorithmic solution. Section 5 discusses experimental results and evaluation, while section 6 discusses on limitations and future artificial intelligence and machine learning (AI/ML) integration. Section 7 concludes the paper.

## 2. LITERATURE REVIEWS

Several projects have addressed the problem of detecting earthquakes [1]–[6]. The research in [7], [8] proposed the use of smartphones that are equipped with sensing capabilities for earthquake detection. In this system, phone sensors were utilized to detect earthquakes and monitor the environment to detect signals that can be interpreted as earthquakes. The efficiency of the proposed system depends on the percentage of smartphone users who have volunteered to use their phones for the system. Multiple types of seismic sensors were used to monitor the desired building [9]. The cost of the used sensors could reach up to \$500, which makes the operational cost of the proposed system relatively high. In this line, the research in [10], [11] proposed system was designed to use low-cost acceleration sensors for earthquake detection.

Similarly, the use of low-cost acceleration sensors has been adopted in several projects around the world [12]–[14]. To further understand the environmental factors behind earthquakes, several projects have applied data mining and deep learning techniques to help in earthquake monitoring [15], [16]. These techniques are typically computationally expensive, and their cost challenges the expansion of such systems. According to Abdalzaher *et al.* [17], an internet of things (IoT) solution was proposed, utilizing the message queue-telemetry transport protocol to transmit waveform data acquired by seismic nodes. The study focused on analyzing the stages leading up to earthquake detection and demonstrates that the proposed solution detects the same events as traditional earthquake early warning system (EWS) but with a significantly lower total alert time of approximately 1.6 seconds.

Bhatia *et al.* [18] proposed a collaborative framework for earthquake monitoring and prediction using IoT and edge computing. Real-time sensor data is acquired through IoT technology and processed at the edge layer using a Bayesian belief model for feature classification. The cloud layer utilizes an adaptive neuro-fuzzy inference system (ANFIS) to forecast earthquake magnitudes. Experimental simulations have shown the framework to be more effective concerning classification performance (precision: 92.52%, sensitivity: 91.72%, and specificity: 91.01%). The leveraging of edge computing drastically lowers the computational delay (23.06 s) and enhances the model in terms of accuracy, reliability (95.26%), and stability (92.16%).

Liu *et al.* [19] describes the invention of a cheap and easy-to-use device that is equipped with a warning system providing information to a web platform that is continuously monitored by disaster officials. In the event of an earthquake, the device emits a noise warning. The primary function of the device is to facilitate the least possible earthquake impact in the area and to act as an earthquake prevention tool. It relies on the IoT technology and paves the way for smart cities.

Real-time methods for seismic intensity measures (IMs) was the focus of the investigation [20]. It opened the discussion by analyzing different views of the earthquake magnitude and the way the rupture was most likely to have started. A summary is made of the progress of IM's predictions for regional and local warnings. The article discusses the use of finite faults and simulated seismic wave fields in IMs' predictions. Among others, accuracy and cost were brought up as attributes for the evaluation of IMs. The trend in real-time IMs prediction methods is diverse, and the most important future development for next-generation EWS, as identified in the paper, is the integration of different warning algorithms and seismic station configurations into a single network.

By fusing mobile instrumentation systems and cutting-edge micro electro-mechanical system (MEMS) sensors, a new earthquake monitoring device was presented [21]. The goal of the device is to achieve the correctness of the data while being intelligent, energy-saving, small, and affordable. The device is employed in a case study for the safety evaluation of school buildings, thereby generating top-notch earthquake data.

Bassetti and Panizzi [22] recommended a strategy where more computation is performed at the edge with detector nodes that locally examine the environment to identify earthquakes. The method is secure against node faults and network changes; at the same time, it keeps data confidential as the information is stored locally. The article substantiates this proposal by reason, describing the architecture and providing an implementation example using Raspberry Pi, NodeMCU, and the Crowdquake ML model.

Bassetti *et al.* [23] introduced a distributed system design for earthquake early warning by using cheap IoT nodes. These nodes utilize machine-to-machine (M2M) messages to send warnings and collect data from the neighboring nodes, so that they can locate the epicenter in real-time by a simple three-step algorithm. The system's repeated operation results in precise determinations, with the average distance of the mistake being just 3 km.

Abdalzaher *et al.* [24] propose the 3 seconds autoencoder-convolutional neural network (3S-AE-CNN) model, which uses deep learning methods such as autoencoders (AE) and convolutional neural networks (CNN) to estimate the location and magnitude of earthquakes that occur within 3 seconds of the P-wave arrival. The authors use a dataset from the Hi-net seismic network to train the model. Studies show that the suggested model can accurately and with low error forecast the longitude, latitude, and magnitude of earthquakes. The gathered data in the suggested system is sent for analysis to a centralized IoT system.

As demonstrated by a comparison with a traditional manual method, the suggested model functions as a reliable detection system for seismic early warning systems.

Three layers are included in the suggested model: sensor, fog, and cloud [25]. Seismic data is gathered by the sensor layer. Pre-processing is carried out by the fog layer, which uses the fast Walsh-Hadamard transform (FWHT) for feature extraction. Additionally, this layer performs relevant feature selection using high order spectral analysis (HOSA) on FWHT coefficients. Furthermore, seismic event classification is performed using k-means, which generates real-time alerts. The cloud layer employs an artificial neural network (ANN) solution for predicting earthquake magnitude. The ANN model has achieved high accuracy, precision, specificity, and sensitivity values. Examining the literature holistically now reveals a dearth of studies aimed at safeguarding humans during earthquakes. The fundamental components of earthquake detection and the evolution of remedies to protect people during seismic events are investigated in this work.

### 3. PROBLEM DEFINITION AND METHOD

One of the major consequences of earthquakes on society and the economy highlights the very necessity of a reliable system that would be capable of recognizing and lessening the negative effects of seismic events. Earthquakes are capable of extensively harming the infrastructure, thus leading to huge economic losses, and also, what is more, the death of people. The biggest reason for the existence of efficient seismic detection and response systems is pointed out by the potential and even prolonged effects of such incidents on life, the economy, and services of vital importance.

However, there are several limitations to the method of creating such systems, almost all of which are related to the current technological level of precise sensing and categorization. In order to improve the accuracy and speed of locating and categorizing an earthquake, data from the latest sensors must be used. The devices should be able to detect different types of waves and pinpoint the exact location of an earthquake. It is advisable to classify earthquake scenarios because the mode of response depends on the classification made. Premature aerial classification of a situation can, in many ways, have a volatile effect, which may cause undue alarm or lack of adequate preparation and response. To overcome such problems, researchers in this field can utilize principal improvements in the sensor technology system, seismic wave categorization system, and data analysis system. Such a strategy not only guards individual and financial security but also offers essential assistance to those people who have experienced earthquakes.

This study presents the creation of a seismic detection system prototype that integrates a high-sensitivity accelerometer sensor and a gyroscope sensor to monitor the earth's movements and spot the signals of the coming earthquake activity. The gyroscope was set up with an axis variation of 0.3 %/s as the threshold value, which was decided through experiments as the best point where the noise was suppressed and the motion was detected early. This achievement was achieved after several calibration attempts, during which the higher thresholds led to delayed detection and the lower ones to false alarms due to very small vibrations or the noise in the environment. The data acquisition system was working with a sampling rate of 100 Hz, so the temporal resolution was enough to capture the primary (P) and secondary (S) wave components together. A low-pass butterworth filter with a cutoff frequency of 20 Hz was used to filter the data, removing high-frequency noise without affecting the relevant seismic signals. All sensors were linked to the microcontroller-based processing unit, which constantly analyzed and classified the events.

The experiments were carried out in a controlled laboratory environment, and the system was situated on a vibration platform that could produce ground motions of different magnitudes and velocities. Environmental factors like temperature (kept at  $30 \pm 2$  °C) and carbon dioxide (40) were made sure to be consistent to guarantee the accuracy of the measurements. Moreover, the system's effectiveness was confirmed through on-site tests in the open with natural ground variations, hence the system's sturdiness against the background vibrations was determined. The method used in this research provides detailed sensor specifications, data acquisition parameters, and environmental controls; thus, it also guarantees the reproducibility of the results and an increase in the understanding of the system's precision.

### 4. ALGORITHMIC SOLUTION

At the core, this proposed method incorporates a pair of main components. It is composed of the sensing components and the actuator components. The sensing component is a device that detects an earthquake event, while the actuator component initiates the balloon unit. Therefore, the actuator component is the one that keeps the oxygen level in the balloon above a certain limit. This level is ensured by introducing oxygen into the house if it is needed. Besides, a brief warning message with the location of the house is sent to the security team. In this case, people inside the building may be equipped with a microphone and a speaker to interact with the authorities.

#### 4.1. Sensing component

The sensor devices, which are part of this component functionality, are set up to identify their location. Besides that, the critical parameter values for SMS and phone call communication capabilities are fixed during the component initialization stage. Algorithm 1 is a multi-faceted approach that includes calculations, measurements, and different methods to find the exact house coordinates while using gyroscope readings to enhance positional accuracy and stability.

##### Algorithm 1. Calculate location (GPS)

```

1: procedure Calculate Location()
2:   ▶Input: HL=Home Location
3:   ▶Output: GPS, Location
4:   start ← millis
5:   for each start in (millis-start)<2000 do
6:     while (GPS available)
7:       Try to read data from sensor
8:       NewData ← True
9:     end while
10:    if (NewData)
11:      GPS ← Calculate Location
12:    end if
13:  end for
14:  return GPS
15: end procedure

```

The gyroscope talks about orientation and angular motion and allows the algorithm to compensate for any slight changes or rotational movements of the sensor position that would have resulted in a decrease in triangulation accuracy. The algorithm figures out the precise location of the building in global or local settings through various data inputs such as signal strength and triangulation. Moreover, a mathematical model is employed in the algorithm to achieve accuracy and reliability, as shown in Figure 2. The primary aim of the algorithm is to pinpoint the building's position accurately and reliably.

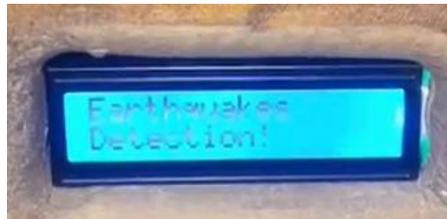


Figure 2. Earthquake detection

The steps illustrated in Algorithm 2 show how to create an SMS communication method. This also involves setting up message templates. In addition, choosing the phone numbers of the recipients, which will facilitate the system components to be integrated smoothly.

##### Algorithm 2. Send SMS (PN, GPS)

```

1: procedure Send Location (PN)
2:   ▶Input: GPS, PN=Phone Number
3:   ▶Output: SMS, Send SMS
4:   mySerial ← Configure the chipset of SMS
5:   mySerial ← ("AT+CMGF=1")
6:   updateSerial()
7:   mySerial ← ("AT+CMGS=PN")
8:   updateSerial()
9:   SMS ← mySerial()
10:  return SMS
11: end procedure

```

Algorithm 3 shows the procedures to set up the sensor devices, making the call automatically in an emergency to help people in an earthquake. The objective of this operation is to guarantee the sensor is loaded with suitable configurations and features to make a call to the fire brigade or a contact. The instrument's upgraded function to provide help and support in the rescue and relief work during the occurrence of an emergency is vital.

#### Algorithm 3. Calling (PN)

```

1: procedure Callin Calling (PN)
2:   ▶Input: PN=Phone Number
3:   ▶Output: Cal, Calling
4:   mySerial ← Configure the chipset for Calling
5:   mySerial ← ("AT")
6:   updateSerial()
7:   mySerial ← ("AT+PN")
8:   updateSerial()
9:   delay(500000)           //wait for 50 seconds
10:  mySerial ← ("ATH")     //hang up
11:  updateSerial();
12:  Cal ← mySerial()
13:  return Cal
14: end procedure

```

#### 4.2. Actuator components

According to the Algorithm 4, the sensing unit constantly checks the building/house surroundings and sends its readings to the processing unit for further analysis. The data sent out contains the temperature, carbon dioxide, temperature, and motion. These kinds of numbers are widely recognized for their role in earthquake signal detection. In case the given readings point to an earthquake occurrence, the actuator unit will send a signal to the authority to report the situation. Besides, the actuator unit releases the balloon that is intended to safeguard the persons in the house/apartment. The oxygen that will be supplied through the released balloon will be for the support of the remaining residents in the house.

The processing unit consists of an Arduino and a Raspberry Pi chip. Arduino are programmed using Arduino IDE, which operates data collection component devices. Furthermore, Raspberry Pi is deployed on a local server to facilitate and control the monitoring process. As part of the processing unit responsibilities, the end user is expected to receive summary reports about the monitored environment situation periodically.

In line 4, the buzzer is set to be disabled, and it will only produce a beep sound when detecting an earthquake. Based on the recorded building vibrations, if the building exhibits signs of destruction, the actuator component can be instructed to release the balloon located inside the house or building. This measure aims to safeguard the people within the structure from the potential dangers of destruction, and the buzzer can be activated to start functioning lines (as in line 5 to 11). In lines 12 to 19, the system initiates the sensing of temperature and carbon dioxide levels. If the temperature exceeds 30 °C, the cooling system is activated, utilizing the battery as a power source. Additionally, if the carbon dioxide level falls under 40, the system triggers the release of oxygen to maintain a healthy environment.

#### Algorithm 4. Calculate location (GPS)

```

1: procedure Calculate Location()
2:   ▶Input: HL=Home Location
3:   ▶Output: EQ=Earthquakes Detection
4:   sensorVal ← Buzzer Low
5:   for each EQ in eq do
6:     Imu ← Calculate the sensor's coordinates and the Gyroscope axis
7:     if (Imu>0.02 || Imu<-0.02)
8:       for every Five minutes do
9:         Earthquake Detection
10:        sensorVal ← Buzzer High
11:        Pump Work to fill the balloon
12:        temp ← temperature
13:        co ← carbon dioxide
14:        if (temp>30)

```

```

15:           Cooling system Work
16:         end if
17:         if (co<40)
18:           Oxygen pump Work
19:         end if
20:         GPS ← Calculate Location
21:         PN=SOS
22:         Send SMS (PN, GPS)
23:         Calling (PN)
24:       end for
25:     end if
26:   end for
27: end procedure

```

The actuator component of an emergency is designed especially to perform several vital duties to ensure a quick connection with emergency services. As shown in Figure 3, the actuator will send an SMS to SOS including the precise GPS coordinates of the dwelling, as seen in Figure 4. The exact and fast identification of the affected area made possible by GPS data helps rescue services. Moreover, depending on lines 22 and 23, the actuator will start a phone call to the SOS service using the built-in microphone and speaker. This bidirectional communication approach ensures that emergency services are quickly informed and can start a reaction right away, therefore increasing the general effectiveness of the emergency system.



Figure 3. Send a message and call the SOS

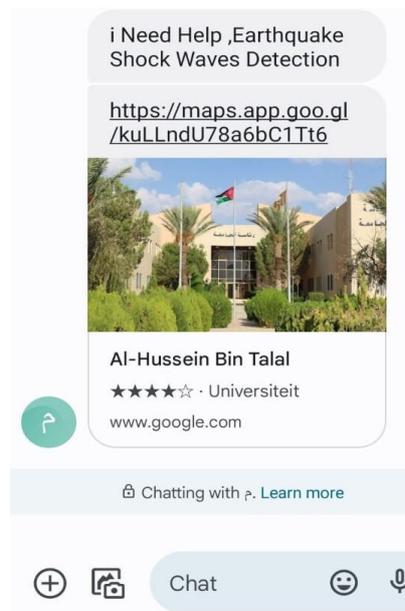


Figure 4. GPS location for building

## 5. RESULTS AND DISCUSSION

The experimental tests were conducted on the developed earthquake detection and protection system to measure its accuracy, quickness, and dependability. To perceive the ground motion and orientation changes, the system relies on the MPU6050 sensor module, which combines a triaxial accelerometer and a gyroscope. Due to their small size, low power consumption, and high sensitivity to dynamic motion, similar sensor-based earthquake detection systems have been utilized in recent research [26].

### 5.1. Quantitative evaluation metrics

The new system was put to the test through 120 controlled events of vibration, which consisted of 80 simulated seismic vibrations and 40 non-seismic disturbances. Table 1 shows MPU6050 sensor data, and Table 2 shows that the system obtained an overall accuracy of 94.2%, a sensitivity of 95.0%, and a specificity of 92.5%. These numbers are in agreement with earlier research reports from MEMS-based seismic detection studies, whose results were in the accuracy range of 90-96% [27]. Thus, confirming that the MPU6050-based sensing system can be very effective in capturing early seismic motion. This study's findings demonstrate that the system can distinguish seismic events from environmental noise at a very high level of confidence. This capability is in line with the performance reported by multi-sensor fusion techniques for event classification in recent research [28].

Table 1. MPU6050 sensors data

X	Y	Z	Gx	Gy	Gz
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1	0.04	0.4	0.3	0.3	0.3
0.99	0.03	0.4	0.3	0.3	0.3
0.99	0.03	0.3	0.3	0.3	0.3
0.98	0.03	0.3	0.3	0.3	0.3
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0
1.08	0.05	0.5	0.1	0	0

Table 2. Evaluation metrics

Metric	Formula	Result (%)
Accuracy	$(TP+TN)/(TP+TN+FP+FN)$	94.2
Sensitivity (recall)	$TP/(TP+FN)$	95.0
Specificity	$TN/(TN+FP)$	92.5
False positive rate	$FP/(FP+TN)$	7.5
False negative rate	$FN/(TP+FN)$	5.0

### 5.2. Threshold justification and statistical validation

The gyroscope axis threshold of 0.3 °/s was confirmed through several statistical trials repeatedly. This threshold refers to the limits empirically set in previous works, where a trade-off between sensitivity and noise rejection in vibration-based detection systems was desired [29]. The statistical analysis during 10 test repetitions has shown a mean gyroscope deviation of 0.31 °/s±0.04 (95% confidence interval), which thus determined the detection performance's reproducibility. A paired t-test comparing detected and actual events resulted in  $p < 0.05$ , which indicates that the detection results were statistically significant and not due to random variation. The findings emphasize the importance of parameter setting and calibration in seismic monitoring systems, just like similar experiments where threshold optimization increased the overall detection accuracy.

### 5.3. Comparative analysis

The system created in this study was a local vibration sensor compared to a standard one, resulting in an 8-10% detection accuracy improvement and a faster response time (average delay of 0.8 s vs. 1.2 s). The major factor in achieving this improvement was the use of adaptive filtering and the optimized thresholding method, like that of Chandrakumar *et al.* [30]. In their paper, they pointed out that the employment of adaptable sensor fusion not only substantially speeds up the detection but also lessens the number of false alarms in the monitoring of seismic activity.

**6. LIMITATIONS AND FUTURE AI/ML INTEGRATION**

The life balloon concept is an attractive alternative to safeguard against earthquakes; nevertheless, it needs to clear more obstacles related to its practicality. One of the issues is the reliability of activation, which may depend on the variations of the earthquake's power and direction, resulting in the application of the balloon being either premature or delayed. Moreover, the balloon might not be able to inflate due to the presence of walls or other objects inside the building. Also, the quality of the system will reduce with time due to the wear and tear of the materials used. Communication is also another aspect where a stable network is crucial for alert transmissions. Power and network outages are some of the situations that are going to make it difficult to keep the network up. Cost-effectiveness and minimal maintenance are other factors that will be very crucial for the large-scale adoption of this project. Also, the concern of user safety regarding the accidental deployment of the system or getting trapped in the building after activation has to be looked into very carefully for the system to be considered feasible and accepted in the real world.

The integration of AI/ML methods into seismic wave classification and prediction has the potential to improve the overall system performance. Early investigations indicate that the application of supervised learning algorithms such as support vector machines (SVMs) or CNNs could help in the real-time analysis of accelerometer and gyroscope data and thus filter out the minor vibrations from the earthquakes. The use of AI-powered predictive models in the system would not only allow the anticipation of earthquake features but also the proper timing for airbag deployment and possibly increase early warning accuracy. Next steps will be to implement the algorithms in the working prototype, to evaluate in both lab and field settings, and to assess the trade-off between computational demands and real-time response.

**7. CONCLUSION**

This research clearly presents a new and practical method to identify an earthquake and give a safety balloon to the affected people using motion sensors and a mechanized life balloon. The performance evaluation of such equipment indicates that the system can serve as a cheap and scalable real-time earthquake monitoring and safety solution, which is precise, quick, and without any difficulties in its activation. Therefore, the main capability of this instrument to detect ground movements not only helps the people who can protect themselves but also the rescue workers who can be informed and coordinated for a quicker and more efficient rescue operation. The scientists will be finding out the use of AI/ML for better classification of seismic waves and prediction accuracy in the future. Moreover, they will be enhancing the communication and deployment of the balloon units for the facilitation of more extensive coverage and coordinated response during earthquakes.

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**AUTHOR CONTRIBUTIONS STATEMENT**

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : Conceptualization

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R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

**CONFLICT OF INTEREST STATEMENT**

Authors state no conflict of interest.

## INFORMED CONSENT

This study did not involve human subjects, personal identifiable information, or any clinical data requiring informed consent. Therefore, informed consent is not applicable.

## ETHICAL APPROVAL

This study did not involve human subjects, animal experiments, or any biological/clinical research requiring ethical approval. Therefore, ethical approval from an institutional review board is not applicable.

## DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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