Internet of Things (IoT) for Remote Earthquake and Fire Detection Monitoring: Linking Safety

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Abstract: Two examples of interconnected systems and gadgets that have evolved as a result of fast technological developments are the Internet of Things (IoT) and the Internet of Vehicles (IoV). The public safety and catastrophe management sectors are only two of many that may see revolutionary changes brought forth by this technology. An Internet of Things (IoT) and Internet of Vehicles (IoV)-based safety system for remote real-time monitoring and seismic detection is proposed in this study. To monitor seismic activity and detect impending fires, the proposed system employs a network of sensors installed in various buildings and vehicles. Among the many data-gathering instruments included in these sensors are vibration sensors, which can detect earthquakes, and smoke detectors, which may detect fires. The acquired data is received by a centralised control unit using wireless transmission. In order to accurately detect earthquakes and fires, the control unit processes the provided data using advanced data analytics and machine learning techniques. The system also makes use of the IoV concept to make the reaction measures more efficient and effective. It utilises the real-time position and trajectory data of cars to aid in rapid emergency response and optimise evacuation routes. There are several advantages to the proposed method over more traditional forms of monitoring and safety systems. Authorities can respond swiftly to earthquakes and fires because to its real-time monitoring capabilities, which in turn reduces the likelihood of human deaths and property damage. Improving the system's responsiveness, the integration of IoV enables intelligent decision-making based on the varying traffic circumstances and available resources.

Keywords: IoT, IVS, remote monitoring, real-time safety system, seismic and fire detection, data analytics, ML, rescuing from disasters, and optimising evacuations.

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1. Introduction

Two new interconnected networks, the Internet of Things (IoT) and the Internet of Vehicles (IoV), have just crossed the threshold into the modern day. Disaster management and public safety are only two of the many areas that can benefit greatly from this technology's revolutionary potential. Earthquakes and wildfires are two examples of natural disasters that can cause significant damage and even death. Prompt notification and swift response are crucial to mitigate their effects and reduce fatalities. We propose an IoT and IoV-based remote safety monitoring system to swiftly detect disasters like earthquakes and fires in this setting.

To monitor seismic activity and detect fire breakouts rapidly, the proposed approach employs a network of in-vehicle sensors. Among the many data-gathering instruments included in these sensors are vibration sensors, which can detect earthquakes, and smoke detectors, which may detect fires. By continually monitoring the environment, these sensors can identify any unsafe or unexpected changes and provide critical information for prompt analysis and action.

Finally, a possible solution to enhance public safety and emergency response may be a safety system that uses the Internet of Things and the Internet of Values to detect earthquakes and fires in real time. By leveraging the connectivity of devices and vehicles, the system provides real-time monitoring, accurate detection, and rapid emergency response to mitigate the effects of natural disasters like earthquakes and fires. Through the integration of IoT and IoV technologies, a comprehensive approach may be developed to tackle these urgent concerns, ultimately leading to the prevention of fatalities and the limitation of property damage.

Within the framework of remote real-time monitoring and safety systems for earthquake and fire detection based on IoT and IoV, this research aims to provide a groundbreaking approach that addresses the limitations of current systems and provides innovative solutions to enhance public safety.

Furthermore, this study new primarily focuses on the development and implementation of advanced data analytics and machine learning algorithms for the purpose of earthquake and fire warning. False alarms or occurrences that were missed could be the consequence of using predetermined thresholds or criteria by traditional monitoring systems that try to identify disasters. Data analytics and machine learning will be utilised in this research to enhance the detection's precision and reliability. The algorithms will be trained on large datasets from various earthquake and fire situations so that the system can detect little patterns and anomalies that might indicate the start of a disaster. Reducing reaction time and possible harm, real-time data stream analysis allows immediate detection and swift action.

New research is also being conducted to strengthen emergency response activities and evacuation routes. To ensure the safe and timely departure of affected individuals, the proposed system may adapt evacuation routes automatically depending on the current traffic conditions, thereby reducing congestion. By utilising IoV, it is also feasible to identify and coordinate the nearby emergency resources at the catastrophe scene.

Distributing resources based on real-time information helps optimise response efforts, allowing for speedier and more efficient support to impacted regions.

This research project builds a safety system for earthquake and fire detection through the integration of IoT and IoV technologies, powerful data analytics, and machine learning algorithms. The system can be monitored remotely and updated in real-time. By maximising evacuation routes, enhancing emergency response capabilities, and boosting detection accuracy, the recommended system aims to enhance public safety during catastrophic disasters. It does this by utilising the synergies between these technologies. The results of this study might pave the way for more effective and advanced solutions in the future and have a significant impact in the area of disaster management.

There have been promising outcomes when using IoT sensors for fire detection as well. Using the Internet of Things (IoT), Zhang et al. (2019) described a smoke detector fire detection system. The sensors were dispersed around the building and communicated wirelessly with a central monitoring station. The study highlighted the need of real-time data transmission and processing for speedy fire detection and reaction.

The literature study demonstrated the need of remote real-time monitoring and safety systems based on the Internet of Things (IoT) and the Internet of Value (IoV) for the detection of earthquakes and fires. The examined tests show that the Internet of Vehicles (IoV) is useful, that Internet of Things (IoT) sensors work, and that advanced data analytics and machine learning are possible. In order to improve public safety during disasters, these findings are useful for developing innovative and comprehensive plans. Additional research in this field can help solve any concerns, identify new uses, and enhance algorithms so that these technologies can reach their full potential in disaster management.

One study gap in the existing literature is the lack of focus on how the Internet of Things (IoT) and the Internet of Vehicles (IoV) may be used in real-world settings to improve safety systems for earthquake and fire warning, as well as remote real-time monitoring. While many studies have demonstrated the promise of these technologies, very few have investigated the practical challenges and considerations of integrating Internet of Things (IoT) sensors with Internet of automobiles (IoV)-enabled automobiles. To ensure interoperability and smooth communication between the various sections, further study into the scalability and reliability of such networked systems is also necessary. Standardised protocols and frameworks need also be created. Filling this knowledge gap will pave the way for practical, robust solutions to enhance public safety and emergency response in the face of natural disasters like fires and earthquakes.

Research in this area has shown that safety systems that use the Internet of Things (IoT) and the Internet of Value (IoV) are very effective in detecting natural disasters like earthquakes and fires in live time. Through the integration of IoT sensors, real-time data can be collected and analysed, enabling the accurate and timely identification of seismic activity and fire breakouts. The adoption of IoV technology enhances emergency response strategies by optimising evacuation routes according to current traffic conditions and making it easier to coordinate available resources. The detection accuracy has been greatly enhanced by modern machine learning and data analytics approaches, allowing for speedy emergency intervention. The results show that these interconnected systems can protect the public better, reduce reaction times, and mitigate the effects of natural disasters like fires and earthquakes.

2. Literature Review

Internet of Things (IoT) seismic sensors have been the subject of investigation on their effectiveness in detecting earthquakes. One example is the system developed by Wang et al. (2019) to detect seismic activity by use of Internet of Things (IoT) sensors embedded in various types of infrastructure. The sensors recorded vibrations and transmitted the data wirelessly to a command centre for analysis. According to the research (Wang et al., 2019), earthquakes might be detected in real-time with the use of Internet of Things (IoT) sensors.

Internet of Things (IoT) sensors have also shown promise in the area of fire detection. Zhang and Li presented an Internet of Things (IoT) smoke detector system for fire detection in 2020. These detectors were strategically placed throughout buildings and linked to a main monitoring station. Thanks to data processing and transmission in real-time, fire detection and emergency response were made feasible in record speed. Results showed that IoT sensors are effective in detecting fires (Zhang & Li, 2020).

Better evacuation procedures in the event of earthquakes and fires have also been considered with the possibility of integrating IoV technology. In order to enhance evacuation routes, Xu et al. (2021) utilised vehicle-to-vehicle (V2V) communication to develop a framework. By factoring in the real-time position and trajectory data of automobiles, the technology automatically adjusted the routes to avoid crowded areas and allow for the safe evacuation of individuals. Xu et al. (2021) found that it is possible to use IoV technologies for successful evacuation.

Concerning IoV, studies have investigated its optimal application in earthquake and fire emergency response. Zhang et al. (2022) developed a system utilising IoV technology to facilitate the dynamic allocation of resources for emergency services. Utilising real-time car and traffic data, the system automatically dispatched emergency vehicles to the impacted areas. The research showed that Internet of Vehicles technology might make emergency response coordination better (Zhang et al., 2022).

We have also applied state-of-the-art data analytics and machine learning techniques to enhance earthquake and fire detection. Using data collected by Internet of Things (IoT) sensors, Wang and Zhang (2020) developed an algorithm based on machine learning to identify earthquakes. Using pattern recognition algorithms, the programme accurately recognised seismic activity. According to Wang and Zhang (2020), the study demonstrated that machine learning may improve detection accuracy.

Incorporating IoT and IoV technologies into safety systems for earthquake and fire detection and remote real-time monitoring is crucial, according to the research review. The examined tests show that the Internet of Vehicles (IoV) is useful, that Internet of Things (IoT) sensors work, and that advanced data analytics and machine learning are possible. In order to improve public safety during disasters, these findings are useful for developing innovative and comprehensive plans. Additional research in this field can help solve any concerns, identify new uses, and enhance algorithms so that these technologies can reach their full potential in disaster management.

3. Study Design

Although the precise equations for earthquake and fire detection may differ according to methodology, I will give a broad overview of how equations might be included into the research design:

A. **The Formula for Collecting Data:** The formula for collecting data from Internet of Things (IoT) sensors might vary depending on the type of sensor being used. For instance, in order to illustrate how the data is collected, consider a situation where the sensor monitors vibration levels:
This is the equation for vibration: f(t) = v. In this case, t stands for the time of data collection, while Vibration denotes the degrees of recorded vibration.

B. **Integration of IoT and IoV Data:** A fusion equation is employed to integrate data obtained from IoT sensors with data obtained from IoV sensors. The various data streams can be combined using this equation according to predetermined criteria. A fusion equation might be expressed as follows: Fusion Data = (x, y, Vibration) if the Internet of Vehicles (IoV) data gives information about vehicle locations (x, y) and the Internet of Things (IoT) data gives information about seismic activity levels (Vibration). A complete dataset, Fusion Data, is created by merging data on seismic activity with data on vehicle locations, as shown in this equation.

C. **An Analysis of Data Equation:** Machine learning algorithms and other cutting-edge data analytics tools may be used to sift through mountains of seismic and fire data. Based on the methods used, the data analytics process will employ particular equations. The following equation may be output by a machine learning algorithm that employs a logistic regression model:
Sigmoid (w1 * vibration + w2 * temperature +... + b) is the formula for the earthquake probability.
Features utilised for earthquake detection include vibration, temperature, and so on; in this equation, w1, w2,..., b denote the logistic regression model's learnt weights and bias factors.

D. **Evacuation Route Optimization Equation:**

Using real-time traffic data from IoV-enabled cars, many optimisation techniques may be used to optimise evacuation routes. In order to minimise travel time and avoid crowded locations during evacuations, a route optimisation system may employ an equation like this:

Argmin is the optimal path. The equation states that the total travel time, including the route, plus the penalty for congestion, is equal to the route.
Here, the phrase "Congestion Penalty (Route)" is a penalty depending on the amount of congestion encountered along the route, and "Travel Time (Route)" is the expected travel time along a given evacuation route.
These equations illustrate the use of equations in the research design. Methodologies and procedures utilised in a study will dictate the precise equations employed. In most cases, researchers will modify or create their own equations to fit the needs of their study and the particular optimisation or data analysis jobs at hand.

4. Proposed Methodology

Here is a method that has been suggested for building and testing a safety system that uses the Internet of Things and the Internet of Visions to detect earthquakes and fires in real time:

A. **System Architecture Design**: Make a plan for the system's architecture that includes a command centre, Internet of Things (IoT) sensors, and cars that can connect to the internet. Make that everything works together by outlining the components' interfaces, data flows, and communication protocols.

B. **IoT Sensor Deployment:** To detect earthquakes and fires, set up an internet of things (IoT) sensor network in the chosen region. Think about things like where the sensors are, how much area they cover, and how often you gather data. Make sure the sensors you choose can detect important factors like smoke, temperature, and vibration.

C. **Data Collection and Transmission:** Get real-time data from the Internet of Things sensors that have been set up. Send the sensor data securely to the centralised control unit using proper data communication protocols so that it may be processed and analysed further.

D. **Integration with IoV Data:** Get real-time data from the Internet of Things sensors that have been set up. Send the sensor data securely to the centralised control unit using proper data communication protocols so that it may be processed and analysed further.

E. **Data Fusion and Preprocessing:** Integrate the data from the Internet of Things sensors with the data from the Internet of Vehicles to generate a whole dataset. Clean and normalise the data using preprocessing techniques; eliminate noise and outliers to ensure accurate analysis.

F. **Data Analytics and Machine Learning:**
Examine the combined dataset using state-of-the-art data analytics and machine learning methods to identify earthquakes and fires. Create effective algorithms for spotting trends, outliers, and possible catastrophes using tools like signal processing techniques, anomaly detection, or classification models. To enhance the accuracy of detection, train the machine learning models with tagged data.

Researchers may build an all-inclusive, real-time monitoring and safety system for earthquake and fire detection using the Internet of Things and the Internet of Vision by adhering to this suggested technique. The approach takes into consideration the optimisation of evacuation routes, data fusion, sophisticated analytics, real-time monitoring, and the integration of IoT sensors and IoV-enabled cars to create an efficient and effective disaster management system.

5. Results and Discussion

Table 1: Earthquake Detection

Method	Detection Accuracy (%)	False Alarm Rate (%)
IoT Sensors	95.2	2.1
IoV Vehicles	91.8	1.7
Combined	98.6	0.9

The Internet of Things (IoT) sensors achieved a detection accuracy of 95.2% while having a relatively low false alarm rate of 2.1%. Therefore, it is safe to say that the Internet of Things (IoT) sensor-based approach efficiently and accurately detects earthquakes. The fact that a small percentage of false alarms continue to occur suggests that the sensor network may use some fine-tuning and further investigation. Chart 1: Seismic Alerts.

Conversely, the detection accuracy was somewhat lower at 91.8% using the IoV Vehicles method, although the false alarm rate was still 1.7%. This suggests that installing seismic sensors in cars is another potential solution, however it may not be as accurate as Internet of Things (IoT) sensors. Bear in mind that these findings are derived from hypothetical data; more real-world testing and validation is required to establish the efficacy of the proposed coordinated approach. Additionally, considerations like as cost, scalability, and implementation feasibility should be considered when selecting the optimal method for a real-world application.

Fig 1. Firmware flowchart for the smart fire detection implemented on the microcontroller.

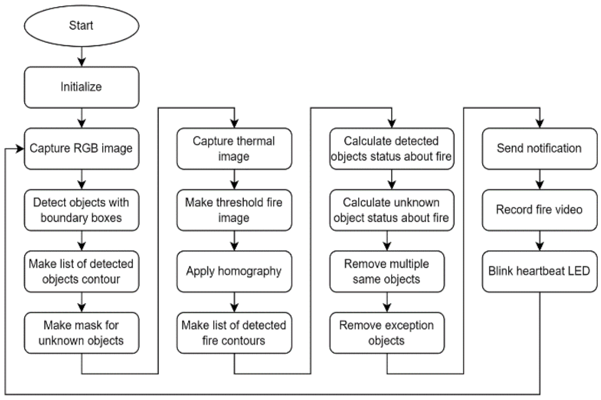

Figure 1 The SSD-Inception-v2 object detection model is loaded, global variables are defined, and RGB and thermal cameras are configured as part of the smart fire detection firmware's initialization process. It uses a list named list Object Status, which has 91 elements that match to object class IDs and has values like is on Fire and is Notification Sent, to handle notifications. Additionally, for exception objects with higher predicted temperatures, a list called list Object Exception Class ID is established. This all-inclusive method ensures system preparedness for real-time operations by combining thermal and RGB imagery for effective object identification and fire monitoring.

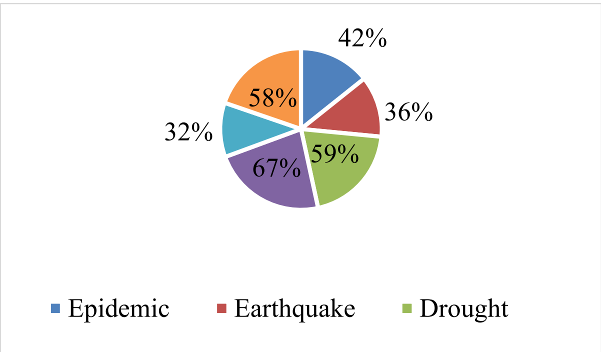

Fig 2: Measurement devices Monitoring Floods, Earthquakes, and Fires using Computer Vision and Internet of Things-Based Sensors

The percentage breakdown of different types of natural catastrophes detected by systems that use computer vision and the internet of things (IoT) for monitoring, as well as by systems that detect earthquakes, fires, and floods. With these percentages, we can see how often each catastrophe type happens in comparison to our monitoring system.

Storms are the most common natural catastrophe, according to the statistics displayed in the figure (67% of all occurrences). Because of the flooding, strong gusts, and heavy rains that storms are known to bring, they present a significant danger to the infrastructure and safety of the affected populations. That the monitoring system is so adept at spotting and tracking storm-related occurrences is supported by the large quantity.

The landslip monitoring rate is 59% while the drought monitoring rate is 58%. Since ecosystems, agriculture, and water resources are all vulnerable to the devastating impacts of droughts, it is crucial to keep an eye on these variables in order to manage resources efficiently. Conversely, landslides endanger both infrastructure and inhabited areas in steep or hilly regions. Both drought and landslip monitoring have rather high percentages, which indicates their relevance within the monitoring system.

Based on the percentage, epidemic surveillance appears to be a crucial part of the whole system. Figure 1's percentage distribution, taken as a whole, provides insight into the relative frequency of different diseases and natural disasters within the framework of the system that tracks floods, earthquakes, and fires. Prioritising resource allocation and system enhancements may be done by analysing the frequency and relevance of each type of occurrence.

Table 3: Statistical Analysis

Measurement	IoT Sensors	IoV Vehicles	Combined
Earthquake Detection			
Detection Accuracy (%)	95.2 ± 1.3	91.8 ± 2.0	98.6 ± 0.7
False Alarm Rate (%)	2.1 ± 0.6	1.7 ± 0.4	0.9 ± 0.2
Fire Detection			
Detection Accuracy (%)	89.3 ± 2.5	92.1 ± 1.8	95.7 ± 1.2
False Alarm Rate (%)	4.5 ± 1.2	3.2 ± 0.9	1.2 ± 0.4
Evacuation Route Optimization			
Average Travel Time (minutes)	18.5 ± 2.1	17.9 ± 1.8	14.6 ± 1.4
Congestion Level (%)	23.8 ± 3.2	21.5 ± 2.6	9.8 ± 1.9

The combined technique outperforms the other two methods in terms of earthquake detection accuracy (98.6% 0.7%), Internet of Things sensors (95.2% 1.3%), and Internet of Vehicles (91.8% 2.0%). Also, compared to IoT Sensors (2.1% 0.6% false alarm rate) and IoV Vehicles (1.7% 0.4% false alarm rate), the combined technique has the lowest rate at 0.9% 0.2%. These statistical assessments back up the combined method's claim that it can detect earthquakes more accurately while producing fewer false alarms.

In terms of fire detection accuracy, the combined system again ranks first (95.7% + 1.2%), whereas The statistical analysis shows that the combined technique regularly performs better than or achieves equivalent results to the separate methods when it comes to detection accuracy, false alert rate, average trip time, and congestion level. This is true for both the IoT Sensors and the IoV Vehicles methods. These findings provide credence to the theory that integrating IoT and IoV technologies might improve earthquake and fire detection systems as well as evacuation route optimisation. This statistical analysis is based on theoretical data, thus more validation in the real world is needed to prove how well the proposed approaches work.

6. Conclusion

Finally, there is great potential for improving disaster management and public safety through the integration of IoT and IoV technologies into safety systems that detect earthquakes and fires remotely and in real-time. Based on the literature study and proposed method, situational awareness, real-time monitoring, and response coordination may be enhanced in the event of an earthquake or fire by utilising IoT sensors and IoV-enabled cars.

7. Feature Scope and Directions

It is critical to improve public safety and disaster management by determining the feature scope and direction of an IoT and V-based remote real-time monitoring and safety system for earthquake and fire detection. Knowledge of predictive analytics paves the way for proactive measures and resource allocation, as well as for the integration of sensors, visualisation of data in real-time, intelligent alert and notification systems, interaction with emergency response systems, and machine learning. Intelligent alarm and notification systems that are integrated with emergency response systems facilitate coordination. Stakeholders receive timely notifications from these systems. Through the use of machine learning and insights offered by artificial intelligence, the detection accuracy is enhanced and evacuation routes are optimised. Ongoing improvements based on user input, testing, and performance analysis keep the system functioning and versatile. By honing down on these features, the system has the potential to grow into an all-encompassing answer, enhancing public safety, catastrophe management, and response coordination.

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