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Wireless Sensor Networks for Earthquake Detection and Damage Mitigation System

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ABSTRACT: Earthquake early-warning systems detect the first quivering of a major quake, triggering alarm systems in advance of the most violent shaking. The Alert system that has been proposed for all over the world would use a network of digital seismometers deployed around the state to give populated areas up to a minute of advance warning (depending on the location of the epicenter). The alerts would allow businesses, residents and public agencies time to get ready. The purpose of the study focuses on the detection algorithm using the collected data to decide if an earthquake is occurring. The algorithm is adaptive in nature and is based on a probabilistic approach over a sliding window to maximize the detection of events by adjusting the probability of false alarms under a fixed rate. Finally experimental results are provided showing that the system will support the expected performance with both artificial and real seismic stimuli. A possible extension of the approach could be implementing geological wireless sensor networks using contemporary Smartphone for data acquisition.

KEYWORDS:earthquake warning system, embedded system, geological wireless sensor network, microelectromechanical sensor, piezoelectric sensor, real-time seismology.

I.INTRODUCTION

An earthquake consists of many individual elastic waves. The functioning of EWS is based on the principle that these waves have travelled from the epicentre to recombine at the recording site as a function of their respective velocities, focal distances, and propagation paths. Body waves propagate within a body of rock and appear in the first arrival.

A. SEISMIC WAVES

All earthquakes are made of two types of wave. The P-wave compresses the earth as it moves, like a sound wave. It moves fast but does not cause much damage. The S-wave that follows deforms rock up and down like an ocean wave. It delivers most of the tremor's violent energy .The fastest among these body waves is the primary or P-wave. The P-wave is the first elastic wave to reach the recording site. The secondary arrival contains body and surface waves such as S, Rayleigh, and Love waves. These later arriving waves often produce both horizontal and vertical ground motion. The combination of their peak velocities, peak accelerations, and duration of time they persist cause significant damage to infrastructures. As P-wave arrive onset of an earthquake, there are systems built for earthquake monitoring using P-wave based technique

B. *CAUSES OF EARTHQUAKES*

Most earthquakes are causally related to compressional or tensional stresses built up at the margins of the huge moving lithospheric plates that make up the earth's surface. The immediate cause of most shallow earthquakes is the sudden release of stress along a fault, or fracture in the earth's crust, resulting in movement of the opposing blocks of rock past one another. These movements cause vibrations to pass through and around the earth in wave form, just as ripples are generated when a pebble is dropped into water. Volcanic eruptions, rock falls, landslides, and explosions can also cause a quake, but most of these are of only local extent. Shock waves from a powerful earthquake can trigger smaller earthquakes in a distant location hundreds of miles away if the geologic conditions are favourable.

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C. DAMAGE CAUSED BY EARTHQUAKES

The effects of an earthquake are strongest in a broad zone surrounding the epicenter. Surface ground cracking associated with faults that reach the surface often occurs, with horizontal and vertical displacements of several yards common. Such movement does not have to occur during a major earthquake; slight periodic movements called fault creep can be accompanied by micro earthquakestoo small to be felt. The extent of earthquake vibration and subsequent damage to a region is partly dependent on characteristics of the ground. For example, earthquake vibrations last longer and are of greater wave amplitudes in unconsolidated surface material, such as poorly compacted fill or river deposits; bedrock areas receive fewer effects. The worst damage occurs in densely populated urban areas where structures are not built to withstand intense shaking. There, L waves can produce destructive vibrations in buildings and break water and gas lines, starting uncontrollable fires.Damage and loss of life sustained during an earthquake result from falling structures and flying glass and objects. Flexible structures built on bedrock are generally more resistant to earthquake damage than rigid structures built on loose soil. In certain areas, an earthquake can trigger mudslides, which slip down mountain slopes and can bury habitations below. A submarine earthquake can cause a tsunami, a series of damaging waves that ripple outward from the earthquake epicenter and inundate coastal cities.

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D. *WARNING SYSTEM*

The high precision sensor with trending advancements technology, dedicated damage mitigation control systems can be made. These systems can not only record seismic activity but can also take control measures to alleviate the disastrous effects of a catastrophic seismic event on critical infrastructures. Developing such a site-specific EWS that works on a threshold based triggering algorithm. In this site specific approach, seismic signals are processed locally for determining instantaneous tremor magnitude of earthquake. This approach is suitable because it intend to install thesystem on-site for damage mitigation in a EWS facilitated infrastructure, rather than a regional paradigm approach which takes into account the measurement of complex earthquake parameters e.g. locating epicenters, depth etc. The EWS can effectually be implemented in sensitive sites such as next to a nuclear reactor or a chemical depot. Use of embedded system keeps the development cost low, so that the system can be made available to households in earthquake prone zones in underdeveloped countries.It attempt to observe the beginning of the ground motion (mainly P wave) at the site using direct sensor fusion technology to detect the ensuing, weak ground motion. At the same site, no attempt is necessarily made to locate the event and estimate the magnitude. The system comprises of dual sensor monitoring the three components of peak ground acceleration (PGA) motion (east-west, north-south, and updown). The use of a high sensitivity microelectromechanical sensor (MEMS) allows fine recording of the PGA. Simultaneously, a piezoelectric sensor feeds vital data into the sensor fusion algorithm, allowing rejection of false alarms and issuing alerts that are more reliable.

II. LITERATURE REVIEW

1)Rui Tan Guoliang Xing Jinzhu Chen Wen-Zhan Song Renjie Huang proposed the work on **"***Quality-driven Volcanic Earthquake Detection using Wireless Sensor Networks*" .In this paper, proposed a novel quality-driven approach to achieving real-time, in-situ, and long-lived volcanic earthquake detection. By em-ploying novel in-network collaborative signal processing algorithms, the approach can meet stringent requirements on sensing quality (low false alarm/missing rate and precise earthquake onset time) at low power consumption. It has been implemented the algorithms in TinyOS and conducted ex-tensive evaluation on a test bed of 24 TelosB motes as well as simulations based on real data traces collected during 5.5 months on an active volcano. It shows that the approach yields near-zero false alarm/missing rate and less than one second of detection delay while achieving up to 6-fold en-ergy reduction over the current data collection approach.

2) Narasimha Prasad L V Shankar Murthy P Kishor Kumar Reddy C proposed the work on "Analysis of Magnitude for Earthquake Detection using Primary Waves and Secondary Waves".In this paper,Earthquake is a natural calamity, also known as quake or tremor, occurs due to release of sudden energy which is stored under stress field in the earth's crust. The stored energy is released due to imbalance in stress filed which creates three events called foreshock, main shock and aftershock. Each event is associated with some waves such as primary waves, secondary waves, Rayleigh waves, Stoneley waves and Love waves. As these waves travels from interior of earth to surface they degrades in magnitude and intensity, only a part of the original waves reach the earth surface originated in earth's crust which are recorded as seismograph. Till to date, many of the researchers applied different techniques like prediction based on radon emissions, prediction using extraction of instantaneous frequency from underground water. As the earthquake occurs

due to transmission of waves, hence feature extraction from the seismic signal is the efficient approach to predict the earthquake. The parameters of seismic signal are analyzed by using fast Fourier transform spectrum analysis. The magnitude which forms the base of analysis is used for the detection of earthquake. The minor quakes are neglected and the surface wave magnitude of the quakes that show impact on earth's surface is calculated and found it as 4.0. Hence, the occurrence of earthquake can be predicted if the magnitude exceeds 4.0.

3) MasafumihosokawaByeong-pyojeong , Osamu takizawa proposed the work on "earthquake intensity estimation and damage detection using remote sensing data for global rescue operations". In order to support global rescue operations, proposing a new earthquake damage detection method based on a combination of both the result estimated by using earthquake information (magnitude, location of source, detailed ground conditions, and distance attenuation equation), and change detection using multi-temporal SAR data. First, to find collapsed buildings and houses on the earth's surface, that adopt a difference image.

4) Takeshi Sakaki, Makoto Okazaki, and Yutaka Matsuo proposed the work on "Tweet Analysis for Real-Time Event Detection and Earthquake Reporting System Development". In this paper it is known that, Twitter has received much attention recently. An important characteristic of Twitter is its real-time nature. Investigating the real-time interaction of events such as earthquakes in Twitter and propose an algorithm to monitor tweets and to detect a target event. To detect a target event, it devise a classifier of tweets based on features such as the keywords in a tweet, the number of words, and their context. Subsequently, it produce a probabilistic spatiotemporal model for the target event that can find the center of the event location. Regarding each twitter user as a sensor and apply particle filtering, which are widely used for location estimation. The particle filter works better than other comparable methods for estimating the locations of target events. As an application, developing an earthquake reporting system for use in Japan. Because of the numerous earthquakes and the large number of Twitter users throughout the country, it is possible to detect an earthquake with high probability (93 percent of earthquakes of Japan Meteorological Agency (JMA) seismic intensity scale 3 or more are detected) merely by monitoring tweets. The system detects earthquakes promptly and notification is delivered much faster than JMA broadcast announcements. expensive in terms of area and speed.

III.PROPOSED METHODS

The Earthquake Warning System comprises of a sensor unit and a base unit. The seismic data is logged and processed in real time in the sensor unit. The base unit controls relays and is connected to the server. A graphical illustration is presented in Fig.1. To ensure system integrity, the fused sensor reading from the dual sensors is analyzed over a sliding time window from the first P phase arrival. It terms this window as the "loop-window." This loop executes only if the sensor fusion algorithm triggers and exceeds the pre-set threshold window size for at least once. Once triggered, the fused sensor readings collected over a 2s loop duration are stored in an electrically erasable programmable read-only memory (EEPROM). Simultaneously, a "threshold-exceed counter" records the number of times the sample values exceed the threshold in real time. It finds that enlarging the time window size may effectively increase system integrity but also reduce crucial warning time.

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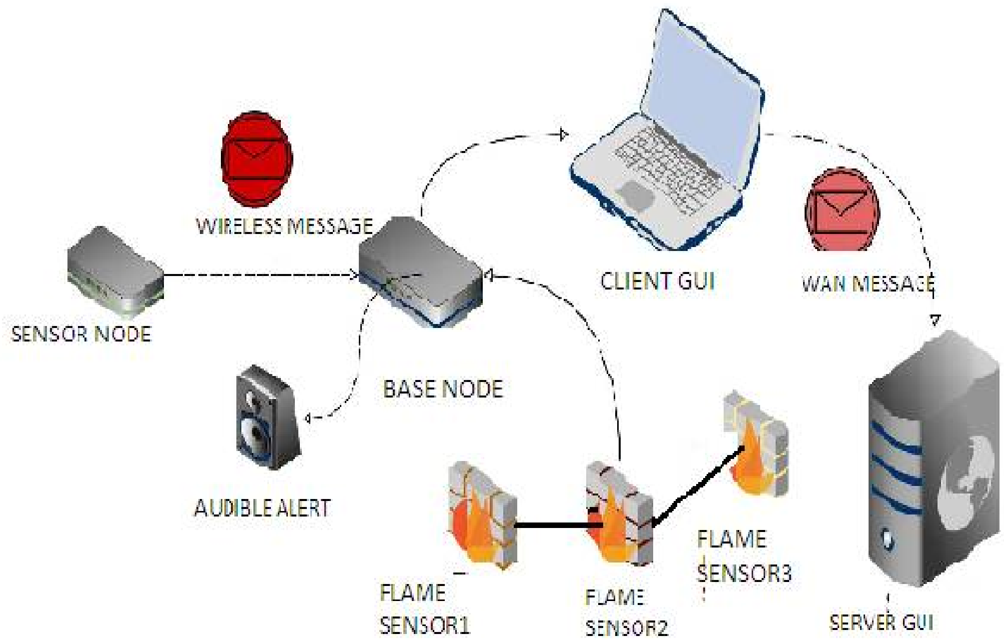

FIG1- GRAPHICAL REPRESENTATION OF THE SYSTEM

The base node controls all the necessary relays and solenoids controlling gas and electricity lines. There are added features which enable the coalition of multiple systems in the same geographic region to a local server. It developed a graphical user interface (GUI) for both the user end and the server end, which can be located under the surveillance of an emergency response team. Any alert issued at the user end will be automatically transmitted to the server end. The packet includes a unique user identification number and location. Integrating multiple flame sensors in the system to detect fire occurrence in as many as 8 different zones of the infrastructure where the sensors are installed. The system has a password protected drill-test-mode which, when activated, will deactivate the server connection temporarily. Meanwhile the system performs all necessary relaying action as it does in case of an actual event.

IV.TECHNICAL DESIGN

Earthquake detection at the onset of its occurrence is a challenge because the ground movement is very weak. Such a detection process requires very high precision sensors. Also, the sensors need to be installed in the correct orientation to perfectly detect the ground motion, and hence the alignment of the sensor is a factor that needs critical thinking. To detect the ground motion in the low frequency range, the system uses microelectromechanical and piezoelectric system sensors. The MEMS sensor is a high precision, digital 3-axis silicon accelerometer with an excellent sensitivity of 0.0039g/LSB, and similar models of these sensors are widely used in contemporary smartphones. The sensitivity of this sensor is superlative for detecting an earthquake of magnitude M 4.0 or higher which corresponds to a peak ground acceleration. The second sensor is a piezoelectric sensor, which is a piezo film element laminated to a sheet of polyester (Mylar). It can produce a useable electrical signal output when forces (in this case ground movement) are applied to the sensing area [10]. To fit this sensor in the design, a charge amplifier is incorporated that can detect ground movement in the frequency band [0.075-3] Hz. The output of this charge amplifier is limited to safe voltage levels. The piezo film sensor's response can be adjusted by adding test mass at the tip of the sensor. As test masses are added, the baseline sensitivity of the piezo film sensor increases .A test mass of 2.7g gives a resonant frequency of about 3Hz, and fits in

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the experiment. Increasing the baseline sensitivity also reduces the resonance frequency to a much lower value. The sensor has high output impedance and requires a high-impedance buffer amplifier.

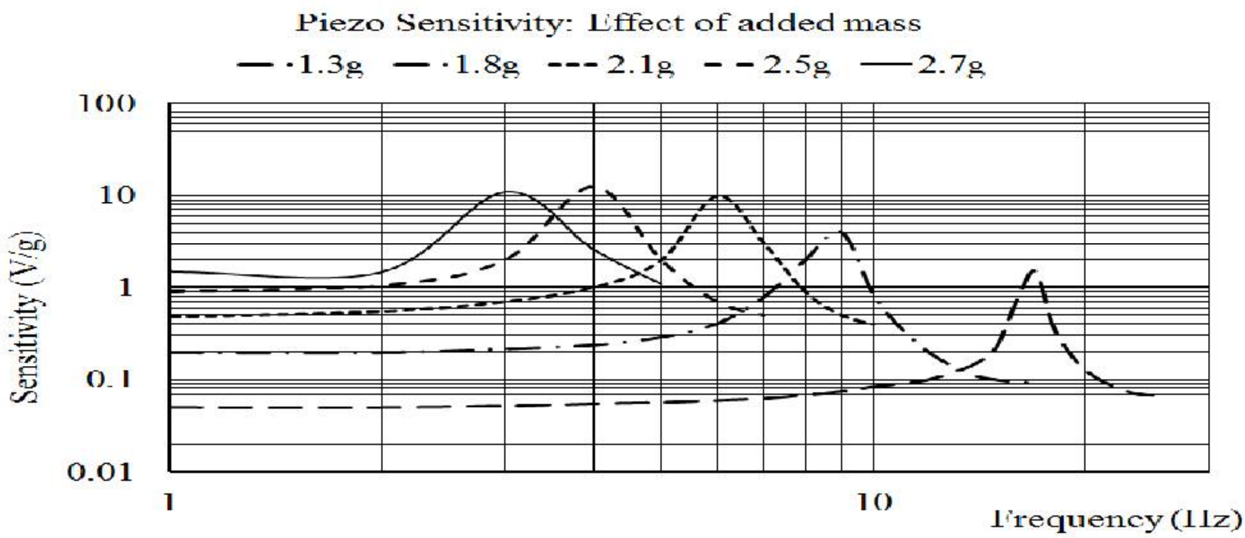

Fig2-Sensitivity analysis of the piezoelectric sensor

E. *GRAPHICAL USER INTERFACE*

The graphical user interface as in Fig3.(below) allows the user to interact with the system in an interactive manner as well as transmit an alert signal to the central server. With the incorporation of programmable logic controller (PLC) support, the customizable GUI can easily integrate into industrial systems with the added functionality of individual speed control of two DC motors. Upon any fault detection e.g., earthquake or fire, the client software transmits a distress note(with contact information assimilated) to the server.

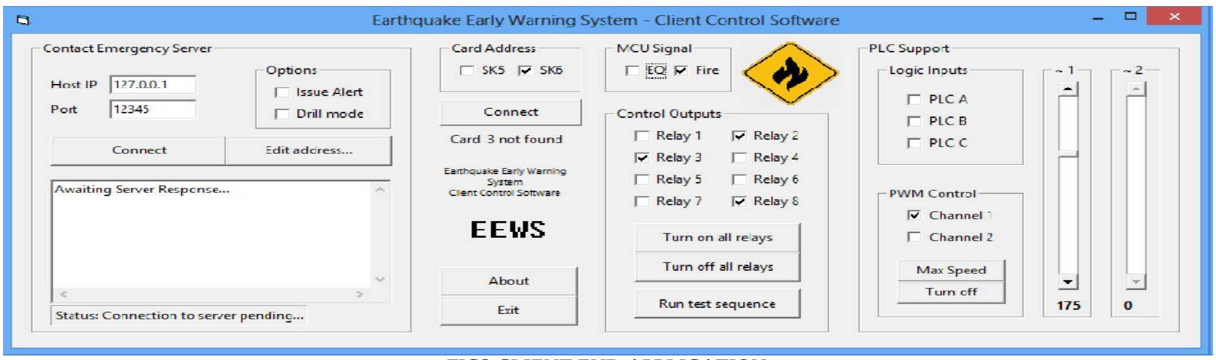

FIG3.CLIENT END APPLICATION

Fig. 4 illustrates trace waveform recorded by the EWS for an earthquake recorded on May 21 2014, 04:21:54 PM GMT,magnitude M 5.9, Bay of Bengal, N18.20 W88.02, depth: 44km [10]. The threshold trigger counter records the number of times the ground movement exceeds an acceptable threshold window and ticks a counter increment every time the signal does so. The counter value at the end for every sample set is used to calculate the state transition probabilities. For the event on May 21, 2014, the system recorded a “threshold-trigger” counter value of 89%, averring that the fused sensor data resulted to be significantly larger than 70%, and positive alerts were issued effectively.

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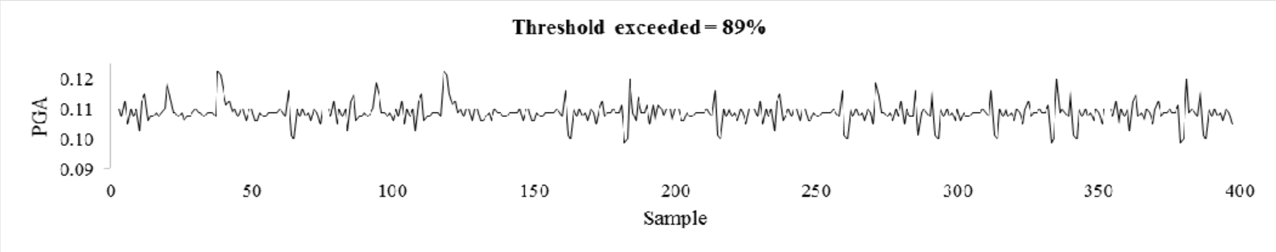

Fig4-Fused sensor traces of ground movement from an earthquake recorded on May 21 2014, 04:21:54 PM GMT, ***M*** 5.9, Bay of Bengal, N18.20 W88.02, depth: 44km [10]. The amplitude of the signal traces in the vertical axis is shown in arbitrary scale in terms of g-force (m/s2).

VI.CONCLUSION

The EWS that developed can trigger local security policies (alarms, disconnect hazardous equipment) to lower the impact of a seismic episode. The originality of the approach was to focus on local processing of data, and detection test. In comparison with commercially available seismic networked sensors, the system can allow simpler algorithm and implementation on cheap and low-power hardware, and yet maintain a relatively fair level of accuracy and efficiency. The EWSs developed or effectuated so far provide only warnings regarding the severity of strong motion. They lack the technology to provide information about the characteristics of the ground motion, either spectrum or time series, and trigger alert to minimize casualties. This is a potential drawback for sophisticated applications such as predictive active structural control, where it may appear desirable of EWS to provide comprehensive information, such as the event mechanism, ground motion spectrum, and time series. As more cutting-edge systems are implemented and tested in real time, it will discover novel usage of reliable earthquake early warning information, which will significantly contribute to more effective earthquake damage mitigation system.

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BIOGRAPHY

Pratiksha P. Kamble received the B.E. and degree in Electronics and Telecommunication from Babasaheb Naik college of Engineering, Pusad from SGBAU in 2013. She is now pursuing M.Tech. degree from Govt. college of Engineering, Amravati from SGBAU. Her interest is in Wireless Commnication and Digital signal processing.