ISSN 2348-375X

Unique Journal of Engineering and Advanced Sciences

Available online: www.ujconline.net

Research Article

A DETAILED STUDY AND ANALYSIS OF EARTHQUAKE PREDICTION AND PREVENTION

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Received: 14-12-2014; Revised: 12-01-2015; Accepted: 10-02-2015

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ABSTRACT

From time immemorial, nature has acted as an excellent friend to man. The relationship between man and nature has continued to be harmonious for a long period of time. However, as years passed by, the selfish nature of man has had an adverse impact towards environmental aspects. Massive destruction of trees and elimination of forest areas have contributed to nature striking back in various ways. One such way of retaliation deals with occurrence of volcanoes and earthquakes. This in turn leads to huge losses in lives and property across the globe. Hence, there is an urgent need in all sectors across the world to take some counteractive measures in controlling the same. A detailed analysis for identifying the possible causes needs to be carried out.

Keywords: Earthquake prediction, Clustering, Ground Acceleration, Fuzzy, Neural, Simulation.

INTRODUCTION

This work deals with analysis of earthquakes of various intensities occurring at a number of places at different points of time. A great deal of research has been conducted in earthquake prone areas. Huge amounts of time and money have been spent in identifying the possible causes at each juncture. Despite all the efforts, sufficient amount of research has not been conducted in evaluating inter-relationships between the various causes. Hence this work focuses on analyzing design practices performed by a number of teams. Enough emphasis has been given in studying the results of research obtained in more recent times.

2. Detailed Literature Survey and Analysis

2.1. Early Design Methods

In the late nineties and early part of the twenty first century, Hitoshi Furuta and Yasutoshi Nomura[1] worked on the Time Series prediction of earthquake input. With a range of mathematical models being designed for many applications, there was a tendency to continue with the same for earthquake prediction also. These models dealt extensively with a wide range of statistical methods. As statistical methods involved time heavy computation, a simple neural network was designed. In this paper an attempt has been made to develop this method by introducing Chaos theory, Neural networks and GMDH (Group Method of Data Handling) methods. But it could not present good results for such data with highly chaotic characteristics such as Logistic mapping. However, it requires a short time for predicting the time series data as opposed to design of mathematical models.

2.2. Digital natural observation (D-NOB) method

In 2007 February, Kan Okubo, Masakazu Takayama, and Nobunao Takeuchi[2] worked to clarify the relationship between earthquakes and electrical phenomena. The signals of three parameters were observed continuously in a specified region. They are Ground acceleration (GAC), Earth potential difference (EPD) and Electrostatic field in Atmosphere (EFA).The EPD variation induces EFA variation. This work mainly focused on the relationship between the average amplitude of EFA signals and that of EPD signals. Occurrences of coseismic signals were found to be evident. As a result of the study carried out, clear EPD variation signals generated by propagation of seismic waves were recorded at Sennan site of Akita Prefecture in Japan

2.3. A Semivariogram approach

In 2007 June, Elif Sertel, Sinasi Kaya, and Paul J. Curran[5] introduced the use of Semivariograms to identify Earthquake damage in an urban area. They mainly focused on the effect of Izmit Earthquake on the North Anatolian fault zone. This Semivariogram approach was used to quantify Earthquake induced spatial variation and thereby the degree of damage in the Adapazari inner city. These semivariograms were calculated for 24 transects on SPOT high resolution visible infrared panchromatic images obtained before and after the

Earthquake. The authors primarily focused on three parameters namely RANGE, NUGGET and SILL. These parameters were computed before and after the occurrence of the earthquake. A significant change in value has been observed for these parameters. For instance in the eighth transect, the RANGE has shown a change in value from 31m to 1398m. The NUGGET value during the same observation has changed from 0.1 to 50.6 DN^2. Observations of these studies indicated that the dominant earthquake induced changes which were textural rather than tonal. This work was able to highlight the variations in the degree of damage due to earthquakes as a result of semivariogram metrics.

2.4. Non-negative Matrix Factorization (NMF) method

It has been observed that Japan has continued to suffer extensive amount of damage as a result of earthquakes from time immemorial. The extent of damage is more intense in recent times. To come up with a necessary solution, Motoaki Mouri, Arao Funase and Ichi Takumi[8] proposed a method of Earthquake prediction using Electromagnetic radiation waves in year 2008. Besides, they also focused on eliminating signals not relating to Earthquakes. They adopted a method of non-negative matrix factorization and were able to improve effectiveness of prediction. Their method focused on Global Signal Elimination. Through this method, they tried to reduce False Positive and False Negative Values. An average anomaly parameter (α) has been computed based on the ratio of anomaly for three days as opposed to seven days has been taken into consideration. It has been observed that for α value of 2, the number of false positives has not shown any change. However, the percentage of false negatives has dropped from 7.41 % to 0. The false negative values have dropped from 18.86 % to 7.41 % for an α value of 3. This method has been able to reduce the false negatives significantly. However, its effect on false positives is negligible. Besides, it was found that the robustness of the method is limited.

2.5. Phase-correlation method

In 2010 May, the co-seismic surface displacements were obtained by satellite Synthetic Aperture Radar (SAR) Interferometry and satellite optical-Image correlation. A panchromatic sensor and a pixel sensor was used for research. It was observed that even though the research yielded significant results, level of clarity in image was moderate. With sensitivity issues creating several anomalies, the need of the hour is to improve the robustness. With this view in perspective, Pablo J Gonzalez and Marco Chini[11] adopted a way to study the deformation caused due to 1999 Izmit earthquake. In order to improve the quality of the image, they used phase correlation method. They found that this method does not require phase unwrapping. Apart from the proposed method, the authors analyzed images using two other methods. In each of the methods, analysis was carried out with quantization levels of six and eight bits. The authors analyzed the performance with three main error sources namely aliasing, quantization level and signal to noise ratio. Observations showed that in the case of the SPOT sensor, for up to two fifth of the complete bandwidth, the spectrum is not free from aliasing. Besides, it has been observed that the results were improved with a larger window size. The results were phenomenal only for a SNR value of more than 30dB. The increase in level of robustness turns out to be the key advantage in this method. Despite the significant improvement, the method fails to show its value for a small window size and also for a signal to noise ratio of less than 30 dB.

2.6. Clustering techniques

In the year 2010, A. Morales Esteban, F. Martinez-Alvarez, A. Troncoso, J.L. Justo and C. Rubio-Escudero[14] adopted clustering techniques to obtain patterns which model the behavioral aspects of seismic temporal data, which in turn can be used in predicting occurrences of medium to large scale earthquakes. This clustering involved the method of classification. Based on historic data, two specific seismographic areas were identified (namely Alboran Sea and Western Azores – Gibraltar). Although a wide variety of methods are available for choosing optimal number of clusters, this process continues to be under research. K – means clustering technique has been incorporated in the problem. A standard parameter (b) dealing with geophysical properties of variations in rock and fluid pressures has been computed. In the analysis for Alboran Sea, the value of b has changed by 0.047, 0.013 and 0.028 for each of the first three clusters. For the Western Azores area, the value of b has changed by 0.028, 0.005 and 0.035. Experimental results have shown that an intermediate increase in b has been observed before occurrence of large earthquakes. This is followed by a decrease in time period before the next occurrence. Detailed analysis led to computation of b value of 1.14. with a standard deviation of 0.05 for the Alboran Sea region as opposed to a b value of 0.7 with a standard deviation of 0.03 for the Western Azores region. The authors were able to conclude that higher value of b at Alboran sea region leads to the conclusion that the strength of the rocks in the region is much smaller thereby increasing the possibility of a reduced time before the occurrence of the next earthquake.

Later, in the year 2011, Morales Esteban along with C. Rubio-Escudero and J. Reyes improvised on the earlier techniques by determining the best set of seismicity indicators to predict earthquakes. Introduction of soft computing techniques in their research gave a new dimension in research pertaining to earthquake prediction.

It has been highlighted earlier in this survey the effect of Earthquakes in the region of Japan. A. Morales-Esteban , F. Martinez-Alvarez, A. Troncoso, J.L. Justo and C. Rubio-Escudero have taken sufficient amount of effort in prediction of factors leading to earthquakes. Despite their contributions, an earthquake of magnitude 9.0 struck Japan.

2.7. Fuzzy inference techniques

In the early months of 2012, P.K.Dutta, O.P.Mishra and M.K.Naskar[17] worked on decision analysis for earthquake prediction methodologies using a fuzzy inference algorithm for trust validation. They used a series of geo scientific tools and methodologies based on rigorous assessment of multi parameter for identifying precursors in different tectonic environments for earthquake prediction. To forecast Earthquakes, multi component analysis is involved that resolves decision making in a low-probability environment.

Using qualitative analysis in probabilistic information, an efficient trust model has been implemented through fuzzy inference rules. As the research focused on applications containing large number of dependent variables, the trust evaluation technique found its effectiveness. This analytic technique helped in arriving at a single most important pattern (or) anomaly leading to an earthquake. However, this method may not be suitable in many real world situations as elaborate semantic analysis is needed when a large number of interactions exist. A set of eighteen algorithms have been taken into consideration. Various approaches of modeling have been compared. The categories of modeling taken into consideration include Computational, Physical, Statistical and Geophysical. It has been observed that the method works well when a large number of dependent parameters are taken into consideration. However, this method fails to take into account mathematical interpretation of algorithms.

2.8. Differential Synthetic Aperture Radar interferometry (DInSAR)

In July 2012, Nestor Yague-Martinez and Michael Eineder[19] worked on Differential Synthetic Aperture Radar interferometry (DInSAR). Synthetic Aperture Radar (SAR) images from the Terra SAR-X satellite have been used to generate a ground motion map by means of correlation techniques. This technique was applied to study Tohoku-Oki Earthquake. Geophysical corrections due to solid Earth tide and atmospheric path delay effects have been applied. These corrections can reach up to 20 cm in the radar line of sight. Absolute displacements in the radar line of sight and in the satellite flight direction are determined. This paper shows the potential of correlation techniques for ground motion monitoring and a comparison with interferometric technique. Using multiple scenes, a wide area displacement map is generated and compared with GPS data. It was found out that in both the techniques, the variation amounted only to a few centimeters.

2.9. Artificial Neural Networks (ANN) application

In the latter part of September 2012, a new earthquake prediction system based on artificial neural networks is presented by J.Reyes, A.Morales Esteban and F. Martinez-Alvarez[21]. In this work, the input values are related to the b-value, the Bath’s law, and the Omori–Utsu’s law. Two kinds of prediction are provided in this study i.e. the probability that an earthquake of magnitude larger than a threshold value happens, and the probability that an earthquake of a limited magnitude interval might occur. In this work, a neural network is presented in Chile’s seismic regions with epicenters placed on meshes with dimensions varying from 0.5◦ × 0.5◦ to 1◦ × 1◦. This network predicts an earthquake every time the probability of an earthquake of magnitude larger than a threshold is sufficiently high. The threshold value has been adjusted with the aim of obtaining as few false positives as possible. By means of statistical tests and comparing with well-known machine learning classifiers, accuracy of the method has been assessed.

Four sets of information namely the specific location, time span, magnitude range and probability of occurrence must be provided by an earthquake prediction model. The added factor taken into consideration is the geographical aspect of Chile. As parts of Chile include mountainous areas, hardness of rocks in these areas also play a factor. Besides, wind speeds also vary between different regions in the same country. Based on all these characteristics, it was decided to partition the country into different geographical areas for the purpose of carrying out detailed analysis. The entire country was divided into four regions namely Pichilemu, Santiago, Talca and Valparaiso. A separate back propagation Neural network with feed forward facility has been constructed. Suitable values of threshold and learning rates have been chosen for analysis. True positives and negatives, False positives and negatives, Zero and One level hits and Specificity Rate were computed. The neural network was able to obtain satisfactory values for each of these parameters. For the region Pichilemu, P_0 and P_1 values were 83.6 % and 70.9 % respectively while for Talca, it was 81.1 % and 63 % respectively. The reasonably high values indicate a strong correlation between the input variables and the observed magnitude. Owing to the nature of rocks and its tectonics, predictions of earthquakes were found to be easier at Pichilemu. This is indicated by the lesser number of iterations to reach the solution. Since these values were below 95%, there was no over learning.

Although soft computing techniques were tried out albeit unsuccessfully earlier, the deep exploration of the correct choice of training function and learning rate has opened up a new opportunity for research.

2.10. Simulation of Optical Images

In January 2013, R. Michel, J.P. Ampuero, J.P. Avouac, N. Lapusta, S. Leprince, D. C. Redding, and S. N. Somala[26] discussed the possibility of imaging the propagation of seismic waves from a very large space-based optical telescope. This application would require ground displacement measurements at about every 100 m, with centimetric accuracy, and temporal sampling on the order of 1 Hz. A large field of view is required to measure the full extent of a large earthquake. A geostationary optical telescope with was used for this purpose. Numerical simulations, which account for these sources of noise show that key details of the seismic wave field, hardly detectable using ground-based instruments, would indeed be imaged by such a system.

2.11. Movement Detection Methodology

In the later part of the year 2013, WenLiu and Fumio Yamazaki[23] performed further intensive research in identifying the causes for the occurrence of the 2011 Tohoku Japan Earthquake. Their research was focused on capturing the surface movements. Initially, they extracted buildings from pre and post event images using a segmentation approach. Then, area based matching was performed for calculating the shifts. This method was able to detect crustal movement at sub-pixel level. Four areas namely Yamato, Rifu, Natori and Watori stations in Japan were simulated during a period of five months between the end of 2010 and the beginning of 2011. The displacements were found using the segmentation approach on the images. These values in turn had been used to predict the chances of an earthquake. This method could be enhanced for 3D images also.

CONCLUSION

It has been observed through the work performed by a series of scientists and geologists the various causes and effects of earthquakes in different countries across the world. The areas of study include complex imaging, mining techniques, statistical computations and few soft computing techniques. Enough emphasis has been placed on areas of seismic intensity. Regions in Japan, Chile and parts of Spain have been explored and causes of earthquakes have been predicted. Results indicate that certain areas seem to be affected by earthquakes to a much larger extent. The use of sophisticated technology has played a significant role in researching the widespread cause of earthquakes.

Future Work

Although a variety of instruments with high degree technology have been used in identifying the underlying causes, sufficient amount of research has not been conducted using mining and other soft-computing techniques. The appropriate use of these techniques could go a long way in not only reducing the possibility of earthquake occurrences but go miles forward in improving the safety of the people and their lifestyle at large.

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Source of support: Nil, Conflict of interest: None Declared