Earthquake prediction technique: a comparative study

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ABSTRACT

Earthquakes are one of the most dangerous natural disasters facing humans because of their occurrence without warning and their impact on their lives and property. In addition, predicting seismic movement is one of the main research topics in seismic disaster prevention. In geological studies, scientists can predict and know the locations of earthquakes in the long term. Therefore, about 80% of the major global earthquakes lie along the Pacific Ring belt, known as the Ring of Fire. Machine learning methods have also been used for short-term earthquake prediction, and studies have applied the random forest method to determine the factors that precede earthquakes. The machine learning method was based on various decision trees, each of which predicted the time to the nearest oscillation. The third group of scientists used the hybrid prediction method, which combines machine learning and geological studies. This research deals with a review of most of the geological studies and machine learning techniques applied to earthquake data sets, which showed a total lack of prediction of potential earthquakes through one approach, so studies designed by geologists were combined with machine learning.

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1. INTRODUCTION

Earthquake is an important natural phenomenon affecting an organism's life and property. It is the sudden release of energy transmitted by waves from the ground, it destroys large areas in a few minutes and leads to huge losses in lives and property, and the idea of predicting earthquakes gives at least a little time to protect people and reduce earthquake damage [1]. The seismic movement forecast innovation is being created to foresee the vibration caused by seismic tremors to contribute to progressing the exactness of the seismic movement forecast innovation utilised in seismic tremor chance appraisal to prepare for future seismic tremor catastrophes and seismic tremor early caution promptly after the seismic tremor. This will lead to further improvement, prevention and mitigation of earthquake disasters, represented in the continuous comparison between geological studies and machine learning (ML) [2]. Geologists consider earthquakes a difficult task, and their probable prediction in a given period is based on knowledge of all the data on the tectonic activity of a region. By recording the Earth's seismic movement, seismologists try to obtain information about the physical processes inside the Earth. The central target of attention has historically been the source of the earthquake [3]. Scientists applied a method of earthquake prediction using data recorded from a number of seismic stations and machine learning methods to determine the factors that precede an earthquake based on the random forest method. It was based on different decision trees, and machine learning algorithms were used to train and analyse a pattern of acoustic data to predict earthquake occurrence [4].

Powerful computational techniques for big data analysis have emerged, and scientists have also been able to apply a hybrid combination of machine learning and seismic prediction formulas based on traditional physical models to improve the accuracy of seismic motion prediction while solving the problem of unbalanced data learning that has a significant bias in such data [5]. This study was represented by a survey of previous studies of earthquake geologists in observing the tectonic activity of the plates in the region, the seismic history and various other studies. Nevertheless, accurate prediction of the timing of earthquakes has been difficult to achieve, so researchers in the field of machine learning worked after recording readings of earthquake data by designing and developing algorithms and techniques that allow computers to have the learning feature in analysing sound and seismic waves of plate movement and predicting an earthquake with the simulation process. Both the geological and informational studies did not reach the accuracy of predicting short-term earthquakes unless the two studies were combined in one approach, and in terms of this research, a review of earthquake prediction studies for each of the two studies and the combination of the two studies in a hybrid study to improve the final performance of earthquake prediction to a large extent. To this end, the review included the studies within three tables for each approach.

2. RELATED WORK

Researchers are doing their best to predict earthquakes, and several studies have presented different forecasting methods and compared them to find the best prediction results. The following are the most important studies related to the topic of research in comparing the most successful methods,the study by Maqsoom *et al*. (2022) suggested two integrated frameworks: analytic network process (ANP)- artificial neural network (ANN) and ANP- convolutional neural network (CNN), and 16 factors contributing to earthquake risk were selected. Using geographic information system (GIS) to formulate it, a database was created for training and testing models, thus designing earthquake hazards in North Pakistan, and the area under the curve (AUC) values for ANN and CNN were 0.843 and 0.878, respectively, and this shows good performance [6]. The study aims for Tehseen *et al*. (2020) to identify and compare the methods, models, frameworks and tools used to predict earthquakes using criteria based on 70 studies published in 2010-2020. It showed that most of the proposed models were long-term predictions. An analysis was conducted based on bibliometric and meta-information by classifying articles according to research type, experimental type, approach, target area, and system-specific parameters [3]. The study by Ogata (2013) describes the prospects for research in the ability to predict earthquakes to achieve scientific prediction soon, techniques for predicting earthquakes based on anomalies have been proposed, and we find that there is growing momentum for seismologists to develop an organised research program on the possibility of exploring possibilities in earthquake prediction [7]. In the study developed by Pushan *et al*. (2012), The method of linking the evaluative parameters to the analysis of the data set used and the success rate of 18 of the most applicable algorithms was developed by comparing different models for earthquake prediction [8].

3. METHOD

Earthquakes are part of the life of the Earth and a sad part of human history, and they are sudden disturbances in the Earth's crust, as not a year goes by without hearing dozens of earthquakes, some of them strong and destructive, wiping out entire cities, so the question of predicting their occurrence seems very important. Predicting an earthquake means making an accurate prediction based on three factors: when the earthquake will occur, where it will occur, and how large it will be. Until recently, one of the challenges researchers faced was how to predict earthquakes and deal with a natural phenomenon. In the study [9] that there is no valid prediction in the short term, as the reason for the short-term expectation is to enable crisis measures to reduce traffic and destruction, leading to false prediction and disappointment to give caution in the event of a major earthquake tremor may lead to legal obligation or habit vice versa bad in case of a false warning of seismic tremor [10]. It is necessary to improve the spatial and temporal resolution and accuracy of seismic activity prediction algorithms based on statistical and physical models. Furthermore, build a mechanism for evaluating and validating those algorithms. In order to efficiently implement these matters, it is essential to continue organically combining software, seismic data quality control, and seismic activity prediction algorithms. Statistical hypothesis testing methods and ML approaches, namely, polynomial logistic regression and the support vector machine (SVM) for earthquake data, may be used in regression classification and analysis to determine the probability of an earthquake [11].

4. PREDICTION OF EARTHQUAKES USING MACHINE LEARNING

The world started using ML at the beginning of this century to predict earthquakes, where ML makes accurate data-based predictions of events and factors affecting each other in a complex way. However, it is indicated that ML is not good at predicting events that are not included in the training data often and occur infrequently. If there is a large bias in the training data, then the prediction through ML will also be biased [12]. The application of unsupervised ML to analyse the full expression of earthquakes in these catalogs is the fastest way to improve earthquake prediction; recent years have seen accelerating efforts in applying ML to earthquake problems due to large data sets that will constitute a new generation of earthquake catalogs as well as computational power [13]. The amount of data should be sufficient when analysing and predicting information about earthquakes using any technique of ML. There is a problem that it is not possible to secure enough data, especially for learning deep learning models, because large earthquakes are rare events. Compared with the frequency of events observed in normal times, the low frequency of disasters is inevitable, so it is necessary to take some measures in practice. It is worth noting that earthquakes of (7-7.9) on the Richter scale, which cause great damage over a wide area, occur in the world every 18 years and that earthquakes of (8-9.9) on the Richter scale, which cause great damage up to thousands of miles, occur once one in the world every 20 years [14]. Table 1 presents earthquake prediction studies using ML methods.

Table 1. Machine learning studies for earthquake prediction

Algorithm	The method used	Results
ANN	– Data acquisition, preprocessing, feature extraction, and neural network training and testing [9]. – Seismic coefficients are used, the b value, Bath's law, and Omori - Utsu's law [15].	– Studying the data collected from previous earthquakes provides a better prediction accuracy of 32%. – The high success rate achieved supports the suitability of the soft computing application.
Support vector regressor (SVR) and random forest	– By developing this mathematical model based on the training data set [16].	– The accuracy obtained for the stacking model is higher at 83%.
Supervised machine-learning	– Using earthquake catalogs for analysis and prediction [13].	– The fastest way to improve earthquake prediction.
Deep learning	– Training a deep learning model with large amounts of data using a CNN [17]. – Use of historical seismic events SVM and CNN [18].	– Transfer learning and meta-learning were introduced to build general earthquake detection models – The proposed strategy performs well without physical planning, including vectors, as within the conventional neural organise strategy.
Artificial bee colony (ABC) algorithm	– Using the ABC algorithm that simulates the intelligent search behavior of a honeybee swarm [19].	– The experimental result showed that multilayer perceptron (MLP)-ABC performed better than MLP- backpropagation (BP) for time series data.

5. GEOLOGICAL EARTHQUAKE PREDICTION

An earthquake is an effect of destroying the fault in the epicenter. Predicting earthquakes is in answer to the following questions: the first, where the earthquake will occur, and the second: what is its expected intensity, by studying the historical and instantaneous seismic activity of the study area and drawing its seismic maps. As for the answer to the third question, it is the most difficult, and no methods have been found so far that enable accurate prediction of the time of earthquakes in a specific area, but some indicators are used as new indications for earthquakes to happen soon. The change in the geomagnetic field [20], temperature [21], groundwater level [22], radon emission [23], and unusual animal behaviors [24] included the emergence of new cracks and the growth of previous cracks.

Various attempts have been made for earthquake prediction, but a very reliable prediction has not yet been achieved. The root cause of significant uncertainties in predicting current earthquakes is the severe lack of experience with previous earthquake events and precursor phenomena. However, the most important reason is that we have to make predictions based on empirical methods due to insufficient understanding and modeling of the earthquake generation process and irregular and multi-scale phenomena. If seismology develops and it becomes possible to understand better the seismic phenomenon, its internal structure and the movement of the Earth where earthquakes occur, earthquake prediction with a completely different approach can be descriptive. Prediction efforts may be possible, and although there is a limit to the empirical approach, it is possible to obtain sufficiently useful information by accumulating much information over a long period.

The seismic motion prediction equation predicted the seismic motion strength index [25], [26]. The seismic motion prediction equation models the effects related to earthquake shaking based on knowledge of geophysics, an equation obtained by performing regression analysis using previous recordings, assuming functional form connects parameters such as distance. Because of the ease of computation, the earthquake motion prediction equation is used for simple calculation of earthquake motion in the engineering field, especially for earthquake risk assessment that requires a great deal of computation and for early warning of earthquakes immediately after an earthquake speed of computation. Since the seismic motion prediction formula expresses a physical model based on academic knowledge to date, it is believed that it will exhibit some prediction performance even when predicting irregularly occurring events. In Table 2, earthquake prediction studies using geological methods are presented.

Table 2. Geological studies for predict earthquakes

Algorithm	The method used	Results
Bayesian ML	Create a probabilistic model to predict long-range earthquakes for each seismic zone [27].	Research's ML models predict a new period of strong earthquakes over several years for seismic zones.
Teaching machine learning in geophysics	Re-measure disappointment times as a portion of the seismic cycle, compare the dissemination of preparing inputs, and test information. In expansion to giving logical bits of knowledge into blame forms within the research facility and their relationship to the advancement of factual properties of related seismic information [28].	Google's ML competition platform, Kaggle, was used to engage the worldwide community of ML in all the world and ML applications in Earth sciences.
GIS and the program (Geo tool)	A geological and topographical study of the northern border region with the Islamic Republic of Iran; via waveform analysis [29].	The data found that it was a natural earthquake not caused by any human action.
Ground movement expectation conditions for utilisation in probabilistic seismic danger evaluations (PSHA)	The study is to support the modernisation of the building code and to meet the need in Iraq for a contemporary assessment of seismic risks in terms of spectral acceleration. [30].	The greatest danger is located in the northern cities of Sulaymaniyah, Erbil, Badra and Al-Amarah fault areas.
Use of three seismic catalogs, namely European Mediterranean Seismological Centre (EMSC), Incorporated Research Institutions for Seismology (IRIS), and the Iranian Seismological Center (IRSC)	The seismic history of Diyala Governorate during 10 years (2004-2014) [31].	The Badra-Amarah fault extends from the city of Al-Amarah in the southeast to the city of Mandali in the northwest. It is the most seismically active fault in Iraq.
Seismic source parameters from different catalogs and official stress inversion technique	Study of the seismic history and focal solutions to the Badra Al-Amarah fault. [32].	The fault is about 200 km long and may be as deep as the basement rocks, which are about 10 km long. The fault extends to the northwest to reach the city of Mandalay.
Ground motion prediction equation (GMPE)	Consider comparing the proposed demonstration with NGA-West2 models and examining the territorial variety in soil movement in terms of unearthly shape, size scale, separate scale, profundity scale, blaming mode, and area impacts [33].	The cruel and single standard deviations of the ground speeding up top are displayed, and the pseudo-dispersed range speeding up reaction arranges 5% for the cruel of the direction- independent even component of ground movement RotD50 for a ghostly period of 0.01–10 s.
Polynomial logistic regression, SVM, and Naïve Bayes	This work uses historical data on medium to long-term earthquakes and compares the performance of machine learning algorithms [34].	In predicting future earthquakes, the SVM excels and produces large distances and magnitudes for the current earthquake report.

6. HYBRID METHOD

Forming the joint research of machine learning experts and seismologists, we succeeded in predicting earthquakes, as ML detected small signals treated as noise in traditional seismology. However, many difficulties must be overcome before they can be applied to earthquakes. The hybrid method combines the advantages of a seismic survey and motion prediction formula based on the physical model, such as stability in predicting rare events. It allows for more accurate predictions than a newly developed method [35].

It utilises both ML and geological studies, which enables highly flexible and accurate prediction according to the data, and the seismic motion prediction formula, which ensures the prediction performance of events that occur somewhat erratically based on physical models. To foresee seismic movement, we considered a half-breed expectation strategy that combines all of them. Particularly, after the first-stage expectation is performed, utilising the current seismic movement forecast equation; the second-stage forecast is actualised by ML in a frame that completes the imperfect portion, the combination of which is the ultimate. Yield as an expectation. Various methods have been used, for example, random trees as a ML method, one of the random forest derivation algorithms that do collective learning using multiple decision trees that do classification and regression using a tree structure, random forests perform decision tree branching during training to maximise gains. In contrast, highly random trees do so at random. Table 3 shows a presentation of earthquake prediction studies using hybrid methods.

Table 3. Studies of hybrid methods for earthquake prediction

Algorithm	The method used	Results
Regression algorithms combined with group learning in the context of big data	Prediction of earthquake magnitude within the next seven days. The Apache Spark framework, the water library in the R language, and the Amazon cloud infrastructure were used [36].	Very promising results that help in processing 400 huge data simultaneously with a large number of variables.
Deep learning model for earthquake prediction (DLEP) combines explicit and implicit features	It uses seismic indices (explicit features) designed by geologists and feature vectors (implicit features) extracted from deep learning methods [37].	Experimental results on eight datasets from different regions show the effectiveness of the proposed DLEP for earthquake prediction.
Highlight extraction (mRMR) and crossover neural organize (HNN) (SVR)	Sixty seismic highlights were calculated utilising seismological concepts, such as Gutenberg-Richter law, seismic rate varieties, stun recurrence, seismic vitality discharge, and add up to redundancy time [5].	The prediction performance of all studied regions improved compared to previous prediction studies.
Classification and regression tree (CART) algorithm classification and regression tree	Generate current mathematical and statistical features directly as seismic indicators. Moreover, a regression tree algorithm predicts the main shock's naming [38].	Experimental results of two historical seismic records in China show the effectiveness of features based on initial patterns proposed with the specific CART algorithm for earthquake prediction.
A hybrid approach to ML and the traditional ground motion prediction equation	This hybrid approach of ML technology and the physical model underestimates the importance of strong movements [39].	Better prediction than any of the individual methods applied alone

7. CONCLUSIONS

Geological studies in predicting earthquakes predict for a long period that may exceed months or years, and it is approximate and inaccurate in determining the location, size, and time of the earthquake, as the time of the fault movement is measured before and predicts the future in the frequency of earthquakes. The result of using ML is to improve the performance of seismic motion prediction technology, and we believe that ML will continue to grow and become more important in all areas of Earth sciences. Improved earthquake prediction through historical seismic data has also been used. The most promising approach is using artificial intelligence and ML to gain more knowledge, and just applying ML can cause problems when anticipating events that occur infrequently. The mere application of ML may cause problems when predicting events that occur irregularly. We found new horizons for seismic research in training ML algorithms with signs of an upcoming earthquake based on the sound produced. This research approach to solve this problem by combining the geophysical model and machine learning can be applied in other fields. In addition, earthquake prediction requires dynamism in application and self-adaptation in adjusting to the inferred variables.

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