

Earthquake prediction in Iraq using machine learning techniques

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ABSTRACT

This study deals with addressing the scientific achievements and the history of earthquake prediction in Iraq, in addition to attempting to discuss the possibility of machine learning to predict earthquakes from a theoretical perspective. The idea of predicting earthquakes gives at least a little time to protect people and reduce earthquake damage. In Iraq, we notice an increase in the occurrence of earthquakes, especially in the southern regions, where they form a strange phenomenon because they are plain areas and far from the seismic fault line, due to the errors that accompany excessive oil extraction and in random and unstudied ways, and geological studies raise fears in predicting an increase in earthquakes for the coming years. We have explored the possibility of applying machine learning technology to predict earthquakes in Iraq, and follow-up recording of tremors at different stations in Iraq through three centers of seismic sensor networks. In addition to the earthquake catalog in Iraq (1900-2019). This study may pave the way for more research to develop an integrated and accurate earthquake prediction system using machine-learning technologies.

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1. INTRODUCTION

Iraq's exposure to critical natural processes such as earthquakes, dust storms, and drought has increased. Recent studies raise fears of the increasing impact of these dangers and their imposition of many human and financial losses on Iraq in the coming years. In this study, we emphasize earthquakes and the severe and advanced capabilities in determining their location, size, driving factors, and return period, which gives the necessary information to prevent and deal with them. It is known today that knowledge of geological and geophysical indicators and an attempt to understand critical conditions can predict the probability of earthquakes to identify risks and provide rapid warnings in the direction of earthquakes.

Over the past few years, a large body of new data on Iraq's location and rates of seismic activity has become available. Furthermore, machine learning is a direct reflection of this new data. However, it also reflects a somewhat different approach to how seismic hazards are identified and how to integrate data [1] responding to the abundant seismographic data recorded in seismic monitoring equipment. Continuous efforts are being made worldwide in the hope of predicting earthquakes, as past failures constitute a significant obstacle to forecasting. On the other hand, the claim to predict earthquakes, which is theoretically impossible, is far from the truth.

2. RESEARCH MOTIVATION

They are the following points: i) successful earthquake prediction can save many lives because natural disasters occur without warning; ii) rapid expansion of seismic data combined with advances in computational power; iii) the recent development of induced seismicity, as in the earthquakes in Basra Governorate, a plain area far from the seismic epicenter. Figure 1 shows the location of the seismic fault line closest to Iraq; iv) the characteristics of seismic areas usually limit the performance of forecasting methods, and v) geological studies raise concerns in predicting an increase in earthquakes for the coming years.



Figure 1. The location of the seismic fault line concerning to Iraq

3. EARTHQUAKES

Earthquakes are sudden disturbances in the earth's crust that cause heavy losses in lives and property. It is an essential natural phenomenon that affects the lives of living organisms and property. Most earthquakes occur due to the continental collision between the Arabian plate and the Iranian and Turkish plateaus [2]. As well as the danger of earthquakes and their effects on the sidewalks of bridges and buildings, especially the old ones.

With the increase in recorded and collected earthquake data, many researchers are trying to find a way to predict the earthquakes in the future, where earthquake prediction is to estimate the time, location, and size of the future earthquakes, as one of the theoretical foundations of geology and computer science [3]. In most earthquake prediction studies, eight seismic indicators are used, which are based on mathematical statistics, as follows [4], [5]:

- The time.
- Mean magnitude.
- The seismic root.
- Seismic energy.
- B-value.
- Mean square deviation.
- The maximum difference.
- The coefficient of variation.

4. EARTHQUAKES IN IRAQ

Iraq is not safe from seismic hazards, and new studies show that it is necessary to prepare for a wave of earthquakes in the coming years [6]. Ordinarily, seismic tremor event is controlled by different normal natural parameters. The area and time of past seismic tremors in a given range are similarly imperative in foreseeing future Soil movement. Most earthquakes occur because of the continental collision between the Arabian plate and the Iranian and Turkish plateaus [7].

On November 12, 2017, an earthquake struck Erbil Governorate with a magnitude of 7.3 on the Richter scale. It was considered the deadliest, as the death toll rose to more than 550 and thousands were injured, in addition to other environmental effects and the destruction of property and infrastructure, during the last two months of 2017. Iraq suffered more than seventy earthquakes between 4 and 7.3 [6]. The causes of the earthquakes, as mentioned earlier, are natural, while the following earthquakes are induced due to human activities.

At the beginning of 2011, the area north of Basra and south of the cities of Amarah and Kut witnessed seismic activity that lasted for a month, and the strongest earthquake reached (3.4) degrees on the Richter scale north of Amarah.

In October 2013, seismic monitoring recorded two earthquakes south of Basra, with a magnitude of (5.3). On March 3, 2014, three earthquakes struck the district of Ali Al-Gharbi and the Galt area, causing panic in the hearts of citizens and causing material damage to their homes and properties. Many citizens were displaced from the affected areas [8]. On August 18, 2014, two earthquakes that caused tall buildings to sway hit the city of Basra. On August 15, 2020, an earthquake struck Maysan Governorate with a magnitude of 5.3 on the Richter scale. On December 9, 2021, an earthquake struck eastern Maysan with a magnitude of 5, and on August 6, 2014, a magnitude of 4.4 Richter.

There is no doubt that the areas where the earthquakes mentioned above occurred are plain and not located on the seismic fault line. Thus, it became inevitable that these earthquakes were caused by errors in oil operations and hydraulic fracturing work, which included pumping vast amounts of fluids between the rock layers. Which threatens to slip and cause earthquakes [8]. Local experts and seismologists in the region see the possibility of such shocks in the future as the region has entered a new level of intensity, so future earthquakes will likely be of the same magnitude or higher [9].

5. MACHINE LEARNING

The recent development of machine learning (ML) technology in artificial intelligence is remarkable, and its application is being promoted in various situations such as image recognition, voice recognition, natural language understanding, and automatic movement [10]. In addition, computing power has dramatically improved, and many computer-learning libraries for ML are now freely available, creating an environment where ML can be easily used. Therefore, in the field of intelligent prediction of various natural phenomena such as weather [11] and earthquake as well, many studies are being conducted to apply the latest ML techniques for further development, such as probabilistic modeling procedures, which may contain errors when we need to ensure safety.

Over the past few decades, a large body of new data on the location and rates of seismic activity in the Iraq region has become available. They reflect a somewhat different approach to identifying seismic hazards and incorporating the data into the assessment. In addition, in Iraq, we did not find enough discussion about the direction of applying ML.

In the study [12], seismic characteristics were extracted, such as detecting the time of the main shock and extracting the time difference between stations to detect the earthquake location by suggesting an algorithm that deals with the internal signal using normalization and signal analysis. It gave good results by extracting the shock time using more seismic station readings. The consider uncovered that ML methods have the potential to memorize and gather the complex interrelationships between contributing parameters, in this way permitting them to address assorted issues in seismic tremor building that are challenging or unsolvable utilizing conventional strategies [13]. As famous amid the survey prepare, the crossing point of machine learning and engineering Seismology could be a unused but progressively energetic range of high-impact investigate where a wide extend and profundity of themes can be examined [14].

6. SEISMIC DATA IN IRAQ

6.1. Seismic monitoring stations

Natural disasters are rare events that occur infrequently, and it is difficult to obtain a sufficient amount of data related to disasters compared to regular times. The imbalance of data is a practical problem. The earthquake information recorded in Iraq was used as one of the sources of synthetic information.

The tectonic activity was recorded after 2014 by relying on seismic monitoring stations, and to this day, which is spread in most governorates of Iraq [15], where three sensor networks represent these stations:

- The North Iraq seismographic network (NISN) consists of 16 stations located in Khanaqin [16].
- The Iraqi broadband seismic network (ISN) owns six seismic monitoring stations in Baghdad, Rutba, Nasiriyah, Badra district in Wasit, Mosul, and Kirkuk, with the central station in the Jadiriyah complex in Baghdad [17].
- It consists of 9 stations, with the earthquake laboratory at Basra University/College of Science/Department of Geology at the center. The stations include: Basra, Nasiriyah, Samawah, Amarah, Karbala, Anbar, Kirkuk, Sulaymaniyah, Dohuk [18].

Furthermore, Figure 2 shows the locations of seismograph monitoring stations in Iraq.

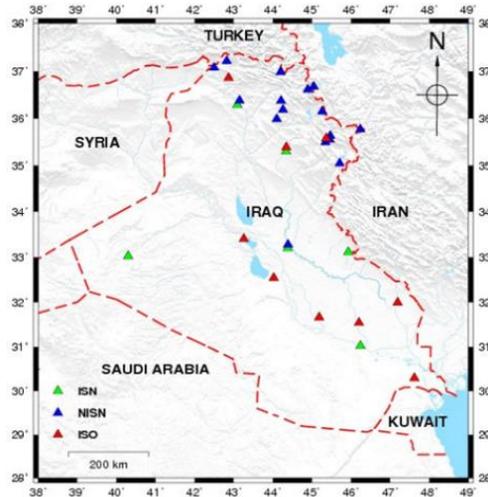


Figure 2. Locations of seismic monitoring stations in Iraq [Source: Prepared by Dr. Wathiq Ghazi Abdul Nabi]

6.2. Broadband seismometer

It is a ground motion sensor over a wide range of frequencies, recording weak motions from regional and seismic earthquakes and ambient noise [19]. It consists of a frame and a suspended protective block. As shown in Figure 3. The broadband seismometer should be installed in a well-designed basement. Carefully to ensure that spurious signals are minimized due to tilt caused by temperature and other environmental factors, over the years since this device was installed, the data has been collected in seismic signal catalogs [20], which is what machine learning and a great deal of seismic data are required for training and learning as shown in Figures 3(a) and (b).

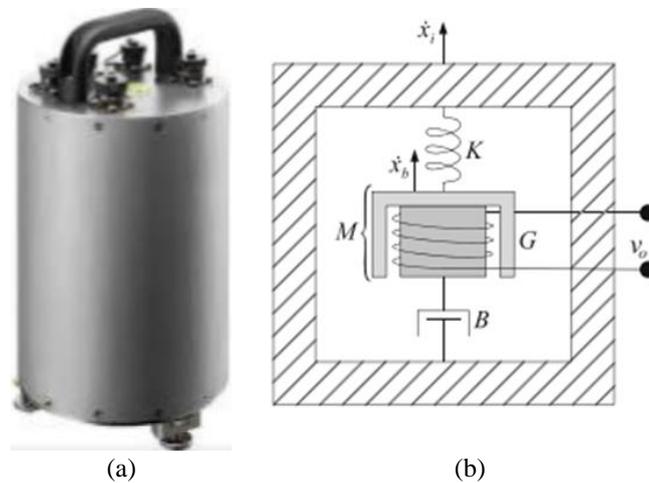


Figure 3. Broadband seismometer; (a) appearance of the device and (b) mechanical schematic

6.3. Nature of data

The network's waveforms (time-series) data are archived by the Seismological Laboratory of the University of Basrah (SLUB). The data collected was from a seismic unit network Magnitude primate wave (MP) in grid cache file (GCF) format, which must be converted to seismic analysis code (SAC) data format in the form of seismic signals or digital signals. The SAC data file also includes the header's basic station component information (ENZ). ENZ means the three components that record the movement of the earth, (E) east-west, (N) north-south and (Z) top to bottom [12] (see Figure 4).

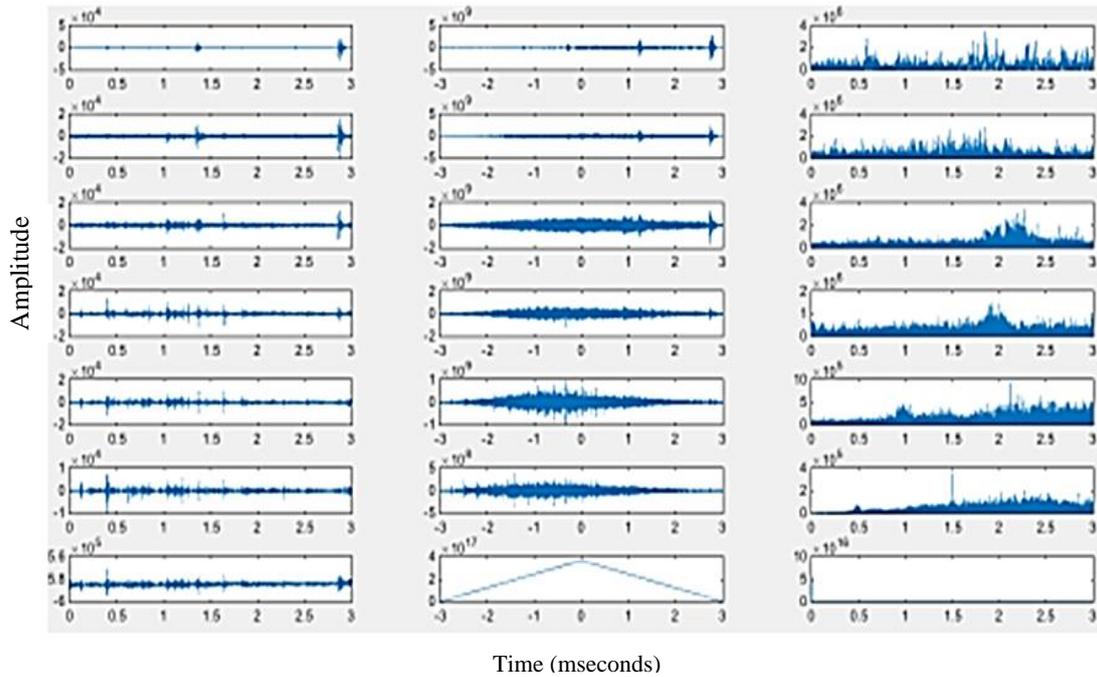


Figure 4. MP network data in GCF format converted to SAC data format

In addition to relying on the archive of earthquakes recorded for previous stations in a comprehensive catalog of earthquakes in Iraq for the period from 1900-2013, covering Iraq from 26-40 N and 36-51E, contains about 18,000 earthquakes, including 4,000 earthquakes of 4 degrees or more, as in Table 1 [15].

Table 1. Earthquake catalog for Iraq and surrounding region from 1900 to 2013

EVENTI D	ISC EVENTI D	SOUR CE	YEA R	MONT H	DA Y	TIME	LAT	LON	DEPT H (km)	AUTH OR	TYPE	MA G
10001	N/A	ZARE m	1900	2	24	30:00. 0	38.45	44.87	0	UNK	Mw(con v)	5.4
10002	N/A	ZARE	1900	4	17	17:00. 0	38	46	0	AMB	Mw(con v)	6.2
10003	N/A	ZARE	1900	10	10	00:00. 0	39.1	42.5	0	ISK	Mw(con v)	5.2
:	:	:	:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:	:	:	:
38641	6.05E+0 8	ISC	2013	12	29	33:03. 9	29.87 92	36.25 19	5	HLW	ML	3.9
38642	6.04E+0 8	ISC	2013	12	30	02:47. 9	37.84 66	38.32 89	6.7	AFAD	MW	3.7
38643	6.05E+0 8	ISC	2013	12	31	55:35. 6	29.65 94	36.42 95	10	HLW	ML	3.2

To better understand the long-term seismic activity in Iraq, it is necessary to have: historical earthquakes from the written records of previous civilizations and prehistoric earthquakes from the ancient record. Although this information has limited value in terms of statistical analyses, it does provide helpful insight into the locations of potentially destructive earthquakes in the future.

Important examples of long-term earthquakes and, therefore, seismic hazards are:

- On December 8, 1058 earthquake with a magnitude of 6.5-7.0 in eastern Iraq [21].
- September 22, 1666, Mw-7:0 earthquake near Mosul [22].
- Earthquake December 7, 1864 MW 6:5 southeast of Iraq [23].

7. RELATED WORK

Hason *et al.* [24], a delicate computing method called Molecule particle swarm optimization (PSO) is connected to develop figure models for crest ground speeding up (PGA). These models are produced taking after the Iraq structural locale, covering 187-chronicled records (2004–2020) from worldwide seismic stations to the closest epicenter remove. The most parameters included within the proposed models are the Richter seismic tremor minute size (MW), normal shear-wave speed (Vs30), central profundity (FD), and closest epicenter separate (REPi). The restriction of this ponder included a need of nearby data on the reaction PGA and chosen four parameters. So, a worldwide information set was utilized instep.

Said and Farman [2] was divided into two stages. The first stage was the collection of earthquake data records until the end of March 2016 and the application of processing this data to organize an index only for the seismic signal, while the second stage is the method of probabilistic seismic hazard analysis (PSHA) Seismic data was collected from four sources: the Iraqi, Iranian, and Turkish catalogs; and the CMT global catalog. The data's processing consisted of consolidation and consolidation into a single format tabular for time, date, location, and depth.

Al-Baghdadi *et al.* [25] is dedicated to predicting the locations of future earthquakes in the eastern part of Iraq, as it includes the establishment of a geographical information systems (data base) (GIS(DB)) database for previous earthquakes from 1985 to 2015, and the main stages of the study were data collection, processing, and analysis. The results of the study show that GIS is a powerful tool that can make an accurate prediction of upcoming earthquakes. Thus, it helps assess the risks and the preparedness of the government and people for early evacuation. It gives them time to save their lives, properties, and infrastructure against potential future earthquakes, and the accuracy assessment process reveals that about 80% of upcoming earthquakes will occur. The study also produced a map showing where the upcoming earthquakes are likely to occur in the eastern part of Iraq.

Al-Taie and Albusoda [6] that the soil has a strong tendency to liquefy if exposed to earthquake magnitudes within the ranges that struck Iraq in November 2017. Great attention should be paid to the future soil-based earthquake impact of all engineering projects set up in Iraq. The phenomenon of liquefaction can affect buildings, bridges, buried pipelines, and other constructed facilities, in addition to the nature of the movements of the earth's surface.

Saeel [26], geographic information systems (GIS) technology was adopted, and databases were created that helped facilitate the prediction of the effects resulting from earthquakes. Four earthquakes have been analyzed and given results such as location, time, and size. These earthquakes are:

- 12/11 2017 in Sulaymaniyah Governorate, with a score of 8.5 on the Richter scale.
- 1/1/2018 in Diyala Governorate with a strength of 5.5 degrees according to the Richter scale.
- 11/1/2018 in Baghdad governorate with a strength of 5.4 according to the Richter scale.
- 12/1/2018 in Baghdad governorate with a strength of 1.4 degrees according to the Richter scale.
- The data showed they were natural earthquakes, not caused by human action.

8. CHALLENGES

The challenges facing researchers are how to predict earthquakes and deal with natural phenomena. The following are the most critical challenges in dealing with seismic data:

- Noise, especially at low levels, is a concern due to interference with the seismic signal.
- Another challenge is enhancing the general application of models based on machine learning in different geographical areas. Models trained with datasets from one location should apply to discovery in other locations.
- The use of multiple stations provides more certainty in earthquake detection, but there is a temporal offset from when an earthquake arrives at each station due to wave propagation through the earth. This can vary greatly depending on the distance of the source giving rise to the earthquake from the stations.
- A scarcity of ground-based evaluation measuring devices Predictive periodic images to determine the location of earthquakes.
- Training in one location does not guarantee a high degree of accuracy in other locations.
- In addition to the complex nature of the phenomenon of earthquakes, in particular, induced earthquakes
- The limited number of earthquake sensing stations.
- Deploying a large number of seismic sensors in different locations and reducing the spacing between them will increase the reliability of seismic data and response time accuracy.
- Unfortunately, no proper general method for earthquake prediction has been found so far [27].

9. CONCLUSION

There is a lack of studies related to earthquakes in Iraq and their various effects. Machine learning methods have made a remarkable improvement in performance in recent years, and it is expected that they will be applied to various tasks. Machine learning models can predict and discriminate with higher accuracy than humans, but they are not very good at explaining the reasoning. This concern is often a barrier to the social application of machine learning, especially when using machine learning in situations that affect a person's life, such as disaster prevention and medical care. The recurrence of earthquakes raises fears and is caused by oil withdrawals, which may cause a collapse in the earth's crust and thus an increase in aftershocks. No place is exempt from earthquakes; all areas on the earth's surface are prone to sudden and unforeseen earthquakes. Finally, we find that the availability of continuous readings for seismic monitoring devices in different regions of Iraq for several years is one of the most essential requirements for applying machine learning techniques by designing a model for effective earthquake prediction with high accuracy and for as long a period as possible to be better than previous studies and that Iraq's exposure to any earthquake is a warning other earthquakes of the same size or higher will occur in the future.

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