Alqalam Journal of Medical and Applied Sciences. 2025;8(2):637-645
https://doi.org/10.54361/ajmas.258214

Review article

Advancements in Seismic Wave Monitoring Technologies Using Artificial Intelligence

Enas Altalhe, A'laa Khalid*, Naima Mohammed, Heba Mansour, Kolthom Ahmed

Department of Civil Engineering, Faculty of Engineering, Omar Al Mukhtar University, Al-Baida, Libya
Corresponding Email. alaakhalid3875@gmail.com

Abstract
In recent years, artificial intelligence (AI) technologies have emerged as a promising tool for enhancing earthquake statistics evaluation and improving earthquake prediction structures. This paper evaluates the utility of AI in earthquake facts evaluation, earthquake prediction, and hazard evaluation. Various research has demonstrated the effectiveness of device getting to know and deep learning algorithms, inclusive of Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Support Vector Machines (SVM), in processing and reading seismic alerts. AI techniques have been utilized to identify styles in earthquake records, predict earthquakes, and assess seismic hazards greater accurately as compared to standard techniques. Additionally, AI-primarily based early warning systems for earthquakes have been advanced, providing timely signals and improving disaster preparedness. Research additionally highlights the combination of Explainable AI (XAI) to enhance the interpretability of seismic models, thereby improving decision-making in seismic risk evaluation and management. The software of AI in seismic studies introduces a brand-new measurement to earthquake monitoring and mitigation, promising quicker, greater accurate, and cost-effective solutions.
Keywords. Seismic Monitoring Technologies, Artificial Intelligence, Seismic Wave Analysis, Deep Learning, Earthquake Detection.

Introduction

Due to the problem of predicting and coping with natural screw ups which include earthquakes, volcanoes, and tsunamis, they constitute one of the most extensive demanding situations dealing with nations. Consequently, governments allocate great resources to enhance their response and preparedness talents. While superior tracking gear, which includes aerial structures and far-off sensing, can be applied to predict natural disasters like hurricanes or warmth waves, earthquakes and seismic tsunamis remain significantly greater complex to reveal. This complexity arises because their assets lie underneath the Earth's surface, making real-time tracking extraordinarily difficult. Despite preceding attempts to predict earthquakes with the aid of reading precursor phenomena, which include animal behavior, variations in electric fields, and atmospheric conditions, those techniques lack accuracy [1-4].

In recent years, researchers have sought to correlate earthquake occurrences with different factors, along with seismic activity styles, unusual cloud formations, and the awareness of gases, inclusive of radon and hydrogen, in soil and groundwater. However, appropriately determining the timing, location, and value of a distant earthquake remains a first-rate unresolved undertaking in seismology. In this context, the need for extra advanced technology to display seismic hobby and decorate earthquake prediction competencies has end up increasingly more vital. This necessity has driven the adoption of a multidisciplinary technique that integrates physics, computer technology, arithmetic, and digital engineering. Digital communication networks (DCNs) play a pivotal role in helping seismic networks by facilitating the detection and transmission of seismic indicators, improving early earthquake warning systems (EEWS), and improving disaster control. These networks offer rapid processing skills, enabling the issuance of early warnings even in regions close to the earthquake's epicenter, where alert possibilities are confined. These systems perform via more than one stations that provide localized warnings for robust floor motions and facilitate the speedy and green transmission of alert messages the use of various communication technology. Furthermore, DCNs can enhance earthquake catastrophe management using leveraging avenue infrastructure and ensuring rapid verbal exchange with far flung seismic stations, thereby accelerating event detection and mitigating risks. Additionally, digital conversation networks make a contribution to estimating seismic source parameters and predicting ground shaking intensity in remote regions using regional ground motion models. Moreover, present-day technology, which includes artificial intelligence (AI) plays a critical role in studying seismic statistics and distinguishing earthquakes from different phenomena. Advanced mathematical strategies, including optimization techniques, further beautify the performance of seismic networks by way of enhancing wave analysis, securing information transmission, and increasing processing speed and accuracy [5].

The objective of this evaluation paper is to focus on previous research which have explored the function of artificial intelligence in seismic wave detection and earthquake prediction. We assessment and examine studies that has implemented AI strategies, along with deep neural networks and device learning, to analyze seismic records and discover hidden patterns in floor motion. Additionally, we have a look at efforts through

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

https://doi.org/10.54361/ajmas.258214

researchers to expand predictive models based on ancient and real-time information, in addition to the usage of optimization algorithms to lessen false alarms and beautify early caution strategies.

Early Works and Foundations

In 2018, Zachary E. Ross and his colleagues performed a take a look at on P-wave arrival picking and first-motion polarity identification the usage of deep mastering. They used a convolutional neural network (CNN) to accurately examine seismic statistics. The version became educated on 18.2 million seismic facts from Southern California and tested on 1.2 million impartial records. The results confirmed that the common distinction between computerized and manual estimates become 0.023 seconds, with a 95% accuracy fee in identifying first movement polarity. As an end result, twice the variety of focal mechanisms had been extracted as compared to the guide evaluation. The version tested its capacity to carry out responsibilities with accuracy similar to or exceeding that of human seismologists, making it a precious device for seismic information analysis and improving earthquake early Warring systems. [6]
According to Kong et al. (2019), machine studying techniques have plenty of promise for the discipline of seismology when you consider that they could make use of state-of-the-art class and analytical strategies to forecast seismic waves and beautify earthquake detection. The look was on five primary regions: seismic geodesy, ground motion prediction, seismic tomography, early warning systems, and earthquake detection. As verified via the findings, integrating records-driven methods with conventional physical methods can improve prediction accuracy and cause new insights into geological behaviors. To decorate early caution structures, the researchers recommended broadening studies into new programs, enhancing records best, fostering extra cooperation among seismology and system mastering experts, and growing faster analysis gear [7].

AI for Earthquake Detection and Phase Picking

In a study completed by means of Perol et al. (2018), the ConvNetQuake model changed into developed as a convolutional neural network designed to detect and locate earthquakes the use of a single seismic waveform, aiming to improve seismic hazard evaluation in the United States. The test showed that the model needs to hit upon 17 times more earthquakes than previously recorded in the catalog of Oklahoma, reaching a large superiority in pace and performance as compared to conventional methods. The researchers endorsed integrating synthetic intelligence and deep getting to know strategies into seismic monitoring techniques to improve the accuracy of catalogs, emphasizing the want to extend the take a look at to different areas stricken by induced seismicity, thereby contributing to the development of extra effective early caution systems.[8]
In 2019, Zhu and Beroza evolved a deep neural community-primarily based definitely approach called “PhaseNet” for selecting the advent times of seismic waves. This device selects arrival times for each P and S waves thru studying 3-issue seismic facts and generating opportunity distributions for P and S waves, in addition to noise. Tests have shown that “PhaseNet” outperforms conventional techniques in terms of accuracy and don't forget rate, especially for S waves. The version modified into knowledgeable on a big dataset containing over 700,000 earthquake samples recorded over 30 years. “PhaseNet” is expected to decorate the accuracy of region strength of mind and shear wave pace models, in the end enhancing predictions of robust floor movement effects. [9]
In 2019, S. Mostafa Mousavi and his colleagues conducted a study titled “Unsupervised Clustering of Seismic Signals Using Deep Convolutional Autoencoders,” where they utilized deep neural networks for unsupervised clustering of seismic data, optimizing the feature space alongside the clustering process. They designed two neural networks to distinguish waveforms based on hypocentral distance and first-motion polarity, achieving accuracy comparable to supervised methods without requiring labeled data or large training sets. An autoencoder was used to reduce dimensionality and extract features, with the bottleneck layer size influencing clustering accuracy. The method demonstrated its ability to differentiate between upward and downward motions, offering potential improvements in classification results for supervised methods.[10]

AI for Seismic Signal Denoising and Enhancement

The researcher Chen et al (2024). In a have a look at on enhancing seismic statistics denoising with artificial intelligence created the MCA-SCUNet model, which mixes multiscale channel interest and Swin Transformer to beautify noise removal accuracy at the same time as preserving geological statistics. The shortcomings of conventional strategies, which be afflicted by complicated noise and the shortage of important signal functions, are addressed in this artwork. The findings showed that the advocated model performed higher than traditional strategies in improving the signal-to-noise ratio (SNR) at the same time as efficiently keeping prone seismic indicators. To decorate the model's universal performance in severa seismic conditions, the researchers endorsed extending finding out and making use of switch getting to know [11].
Lei Lin and pals (2024) used the SeisGAN version, which is based totally on Generative Adversarial Networks (GANs), to enhance the resolution of seismic images and decrease random noise. The effect of noise on

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

geological interpretation and the difficulty of low seismic information decision have been both addressed in the study. The findings validated that SeisGAN performed better than traditional processes like CNNs and filtering strategies, helping inside identify small-scale faults and enhancing the readability of geological layers. Even when the model becomes educated solely on simulated data, field records checking out tested its efficacy. To enhance the precision of seismic interpretation, the researchers endorse, together with extra records, which include properly logs, and extending SeisGAN education to include more complex geological factors [12].

AI for Earthquake Early Warning Systems

A observe by Kanamori (2008) examined the trouble of obscure earthquake importance evaluation and its results, namely slow earthquakes that would cause unanticipated tsunamis. Using cutting-edge equipment, the challenge sought to improve earthquake readings, improve understanding of fault movements, and create early warning structures. Results indicated that lengthy-duration seismic waves aided in detecting sluggish earthquakes and their connection to tsunamis, and in addition, they extended the accuracy of earthquake importance estimation. Additionally, real-time tracking structures advanced warning capacities and response instances. Developing early warning structures, deliberating the effect of slow earthquakes in building design, investigating their relationship to the most important earthquakes in addition, and bolstering seismic danger mitigation strategies through greater monitoring techniques and greater accurate seismic records analysis were all cautioned with the aid of the observation [13].

Allen et al. (2009) examined the effectiveness of Earthquake Early Warning (EEW) structures in regions that include California, Mexico, and Japan, emphasizing their important function in mitigating harm and casualties via imparting timely signals earlier than seismic events occur. The observer highlighted key demanding situations, consisting of the confined time to be had for protection measures at some point of unexpected earthquakes and the limited accuracy of certain warning systems due to inadequate funding and coverage. To decorate EEW structures, they have a look at proposed several enhancements, consisting of expanding seismic sensor networks, integrating artificial intelligence, utilizing primary wave (P-wave) analysis equipment, and increasing public awareness of response protocols. Additionally, the researchers encouraged securing long-term funding for those structures, promoting international collaboration for statistical trade, helping research and development tasks, and enforcing public awareness campaigns to improve preparedness and decrease panic at the point of seismic events. [14]

The look at by Satriano et al. (2011) examines the difficulties in predicting earthquakes because seismic generating approaches are complicated and emphasizes the price of Earthquake Early Warning (EEW) systems in minimizing both economic and human losses. The take a look at specializes in primary EEW device types: the on website online approach, which analyzes the traits of an earthquake as it happens via at once measuring P-waves at multiple locations, and the regional approach, which makes use of a network of seismic stations near the earthquake supply to decide the location and value of the earthquake. The examine additionally addresses methods to improve length estimation accuracy, decrease false alarms, boost public recognition, and integrate the two techniques for exceptional effects [15].

The researcher Chiang et al (2022). Convolutional Neural Networks (CNN) to broaden an effective ground movement prediction model that enhances the functionality of on-site earthquake early warning structures. The study focused on the difficulties that traditional methods that use preset standards, which can be decided on based on enjoyment or instinct, face, that could result in prediction errors like missing or deceptive signals. In order to forecast the value of ground shaking, the researchers advanced the ISMP (Intelligent Strong Motion Prediction) version, which uses primary P-wave statistics from earthquakes. A version was evaluated the use of latest seismic facts from 2020 to 2021 after being knowledgeable on actual seismic statistics from Taiwan from 1991 to 2019. The accuracy of the suggested ISMP model turned into better than that of the conventional approach, and the false alarm fee turned into decreased. And the capability to assume significant ground movements earlier, lowering cloth and human losses. The researchers endorse imposing the model in seismically energetic regions and sporting out in additional experiments to affirm its performance in numerous settings [16].

AI for Seismic Waveform Analysis

In a previous have a look at, Bertrand Rouet-Leduc et al. (2017) applied system studying strategies to laboratory earthquake information to stumble on hidden indicators previous seismic occasions. The have a look at confirmed that studying acoustic emissions from a laboratory fault could correctly predict failure timing without relying on the previous records of the signal. Surprisingly, the effects revealed that gadget mastering recognized a low amplitude sign, formerly considered insignificant noise, which sincerely originates from the non-stop motion of fault grains. This technique could beautify the information of fault physics and improve failure time prediction, paving the manner for its application in actual seismic statistics analysis. The examination also emphasized that machine learning reduces human bias by robotically identifying styles across a wide range of variables and can be applied to broader fields, together as landslide prediction and mechanical failure detection [17].

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

https://doi.org/10.54361/ajmas.258214

AI for Seismic Hazard Assessment

Mousavi et al. (2020) advanced a deep mastering model based on the Hierarchical Attention Mechanism to combine information derived from complete seismic signals and earthquake stages (P and S) in a preceding study titled "Earthquake Transformer-An Attentive Deep-Learning Model for Simultaneous Earthquake Detection and Phase Picking". The version was created with an innovative network architecture that uses Transformers to investigate seismic records with great accuracy, even in the presence of noise. The look at located that the model outperformed both traditional and modern algorithms, detecting twice as many earthquakes as traditional procedures at the same time as the usage of less than one-third of the seismic stations. The researchers suggested adapting the version to other seismically active places to boost early detection, reduce reliance on seismic infrastructure, and include it in worldwide seismic monitoring structures to improve seismic event reactions and mitigate associated hazards [18].

Ratiranjan Jena et al. Carried out a take a look at in 2023 on earthquake spatial probability estimation and danger assessment in the Arabian Peninsula the using explainable AI (XAI) techniques. They have a look at aimed to assess Seismic Probability Assessment (SPA) and Earthquake Hazard Assessment (EHA) through machine gaining knowledge of and XAI models, analyzing the impact of 12 seismological and geophysical elements. Two devices gaining knowledge of fashions, Light Gradient Boosting Machine (LightGBM) and Recurrent Neural Networks (RNN), were utilized along with three XAI methods: Smart Predictor, Smart Explainer, and Local Interpretable Model-Agnostic Explanation (LIME). The outcomes confirmed that the LightGBM model carried out an 89% accuracy, at the same time as RNN executed 87%. Among the XAI fashions, Smart Predictor provided the most dependable spatial outputs, figuring out magnitude variation and earthquake frequency as the strongest factors, even as intensity variant, seismic gap, and epicenter density were identified as great influencing factors. The spatial chance maps indicated that regions inclusive of the Gulf of Aden, Red Sea, Iran, and Turkey fall beneath the best SPA index (0.991–1), even as the Arabian Gulf, coastal regions of Saudi Arabia, and fault zones along with Zagros and Anatolia have been categorized as high-chance earthquake zones. The study advocated expanding AI model training datasets to deal with demanding situations associated with information scarcity, privacy, and security. It additionally highlighted the significance of XAI in ensuring transparency and interpretability in earthquake risk estimation, which can result in future improvements in geological and seismological research [19].

AI for Seismic Imaging and Inversion

In 2011, Emilson Pereira Leite and Alexandre Campane Vidal created a machine for transforming seismic reflection records into three-dimensional models of effective porosity. This technique includes an iterative frequency-area inversion procedure after converting 3D seismic amplitude information into an acoustic impedance version using the Sparse-Spike Inversion algorithm. By the usage of Kriging Interpolation to contain acoustic impedance records from nicely logs, after which education a feedforward neural network to create correlations between acoustic impedance and powerful porosity values, the model is further progressed. With a correlation coefficient of 0.84 among the neural network predictions and the actual porosity values, the outcomes showed an excessive degree of accuracy, highlighting the usefulness of the counseled approach in reservoir characterization. Additionally, the take a look at highlighted the capability to extend this approach to other reservoir properties, together with water saturation, whilst emphasizing the need to beautify vertical decision due to barriers in seismic data excellent compared to properly logged data. [20]

Gholami (2016) carried out a take a look at on multi-channel blind seismic inversion, in which he evolved an automated and speedy set of rules to repair acoustic impedance (AI) and seismic waveforms from seismic reflection data problem turned into solved inside a limited optimization framework, using an iterative technique among AI estimation via general version (TV) regularization, which produces a blocky model with low-frequency constraints, and seismic wave estimation using a wavelet-domain sparsity condition to get better correct mixed-section wavelets. The take a look at applied Bregman generation and the discrete cosine remodel (DCT) to make seismic inversion greater green and quicker, with the number of iterations mechanically decided using the generalized go-validation (GCV) criterion Tests on 2D artificial information from the Marmousi model and discipline facts established that the proposed approach outperformed traditional techniques in as it should be convalescing AI fashions and seismic waveforms, even within the presence of noise, making it an effective tool for computerized seismic inversion [21]

Lukas Mosser et al. (2018) superior a way based totally on generative opposed networks (GANs) to decorate seismic pace inversion and seismic statistics modeling, imparting a quicker and extra cost-powerful opportunity to standard physical strategies like full-waveform inversion (FWI). This method relies on seismic area switch, in which deep convolutional neural networks are skilled on artificial 2D information to generate accurate seismic tempo models whilst carried out to real data. The consequences tested the model's generalization ability, because it produced particular geological fashions even if knowledgeable on noisy and erroneous datasets, making it a promising tool for seismic records assessment and enhancing the accuracy of geological predictions with immoderate efficiency and speed [22].

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

Li et al. (2019) conducted a study on the use of deep neural networks (DNNs) for seismic data inversion and direct velocity model reconstruction from seismic data. The study aimed to overcome the challenges faced by traditional methods, such as poor nonlinear representation and solution non-uniqueness The researchers proposed SeisInvNet, a deep learning network that operates in an end-to-end manner, where each seismic trace is enhanced with neighboring and contextual information to achieve accurate spatial alignment of extracted features. The model was evaluated using the SeisInv dataset, which includes 12,000 pairs of seismic data and velocity models. Results demonstrated that SeisInvNet outperformed traditional models in terms of velocity accuracy, geological structure representation, and layer interface alignment, based on quantitative metrics and visual analysis. The study also discussed the mechanism of the model and its potential generalization to more complex data. The authors suggested that integrating physical constraints could be a viable approach to enhancing the accuracy of deep models when applied to field data [23].
In 2022, Abdullah AlAli and Fatai Anifowose reviewed the role of gadget mastering in seismic pace modeling within the context of digital transformation. The look at investigated how speed estimation from well logs and seismic statistics can be improved using artificial intelligence strategies. It checked out the advantages and drawbacks of traditional strategies, like Full Waveform Inversion (FWI) and Normal Moveout (NMO) velocity analysis, highlighting their high expenses, time-consuming tactics, and nonlinearity problems. Machine getting to know's contribution to automating NMO pace choice, enhancing FWI convergence, and directly making use of FWI to seismic data was highlighted. A variety of devices gaining knowledge of methodologies, inclusive of supervised, unsupervised, and semi-supervised gaining knowledge of, have been examined. The authors endorsed the development of advanced methodologies to reap complete automation and accelerated accuracy in seismic speed estimation. They have a look at concluded that synthetic intelligence offers promising solutions to improve the velocity and accuracy of seismic statistics evaluation, reinforcing its applications in oil and gas exploration [24].

AI for Seismic Anomaly Detection

Gregorius Airlangga et al., in 2023, conducted a examination on making use of the Isolation Forest algorithm, an unsupervised device gaining knowledge of method, to identify seismic anomalies in Indonesia without relying on predefined thresholds. Using a decade of seismic information from the Indonesian BMKG Agency, the set of rules diagnosed 874 enormous anomalies that might suggest seismic risks, demonstrating its performance in coping with complicated statistics in comparison to standard methods. The observe highlights the role of artificial intelligence in enhancing earthquake monitoring and disaster preparedness and indicates future studies on improving characteristic selection, integrating deep mastering, and utilizing satellite tv for pc imagery for extra complete analysis, emphasizing the importance of collaboration with geoscientists for powerful end result interpretation [25].

AI for Seismic Data Interpretation

Betül Ağaoğlu et al., in 2024, performed an observation on seismic statistics analysis of the usage of deep getting to know models, exploring strategies that include UNet, ResNet, and hybrid techniques for deciphering complex seismic data. Seismic statistics is important for information about subsurface structures and is widely used in fields like oil exploration, geological studies, mining, and environmental monitoring, but its analysis is often complicated and time-consuming. The consequences showed that deep studying fashions correctly handle information complexity, reduce noise, and automate function extraction, enhancing the accuracy and performance of seismic interpretation. The study highlights the ability of deep learning to be used in future underground resource research, in particular in packages along with petroleum reservoir estimation [26].

AI for Seismic Network Optimization

Researcher Seongheum Cho and his colleagues conducted a study in 2022 to enhance the Earthquake Early Warning (EEW) system on the Korean Peninsula. This study focused on analyzing the characteristics of primary waves (P-waves) generated by earthquakes in the region over four years to determine optimal threshold values for improving system performance. The researchers utilized the ElarmS algorithms and introduced modifications by adding quality control modules to improve detection accuracy and reduce false alarms. System performance was evaluated through earthquake event simulations, and the results showed that the upgraded system version significantly reduced false alarms. The study recommended developing algorithms to adjust threshold values based on the locations of monitoring stations and improving the system's code to classify seismic stations more accurately. It also emphasized the importance of collecting more seismic data to support sustainable improvements [27].
Junlun Li et al., (2022) created a real-time seismic monitoring system with AI support, utilizing newly constructed low-power 4G nodal stations to automate data processing and transmission. Within seconds to minutes, the system can locate earthquakes, determine their magnitudes, analyze their source mechanisms, and identify them. It is very simple to install. It was effectively used to track the aftershocks of the 2021 Yangbi MS 6.4 earthquake in China, identifying 7,905 aftershocks over 22 days, significantly more than

Received*: 28-02-2025 -* ***Accepted****: 09-04-2025 -* ***Published****: 16-04-2025*

standard seismic networks could record. This method greatly reduces seismic hazards by enabling real-time seismic monitoring without the need for human involvement. In anticipation of a new era of Real-time Intelligent Array Seismology (RIAS), the study suggests broadening the use of this technology in a variety of contexts to improve monitoring and comprehension of both anthropogenic and natural subsurface dynamic processes.[28]

Mohamed S. Abdalzaher et al. Carried out an examination in 2022 aiming to apply far-off sensing, information communication networks, synthetic intelligence (AI), and optimization methodologies in seismology. The observer sought to develop greater smart and green structures for earthquake prediction and risk control. It emphasized the significance of integrating these present-day technologies into Earthquake Early Warning Systems (EEWS) to triumph over every day demanding situations and mitigate seismic dangers. The research provided a comprehensive review of the position of advanced communication networks, which includes the Internet of Things (IoT) and social media, in improving earthquake tracking accuracy and real-time information transmission. Additionally, it highlighted the significance of optimization methodologies in seismic wave analysis and increasing the lifespan of seismic networks, alongside AI's role in improving seismic tracking systems. The study recommended leveraging gadget gaining knowledge of (ML) for earthquake detection, making use of the speedy advancements in IoT to triumph over the restrictions of conventional monitoring structures, strengthening the position of EEWS, and developing an integrated gadget based totally on AI, IoT, and optimization strategies for effective disaster management and chance mitigation. [29]

AI for Seismic Risk Assessment

Sufyan Ghani et al. (2022) carried out a take a look at on liquefaction threat assessment in high-depth earthquakes the use of artificial intelligence models, specializing in fine-grained soils alongside the Ganges River. Several computational models have been as compared, with the artificial neural network (ANN) model demonstrating the highest prediction accuracy amongst them, making it an effective device for liquefaction threat assessment The observe analyzed the impact of geotechnical soil houses, consisting of liquid restriction (LL) and plasticity index (PI), which had effects of 14% and 16%, respectively. Meanwhile, the SPT N-price had the best effect at 21%. A huge 27.04% discount inside the component of safety (FL) turned into found whilst the earthquake intensity multiplied from 6 to 7, with an extra 30.5% decrease whilst growing from 7 to eight. The examination provided liquefaction hazard maps using AI, contributing to better prediction and preparedness for earthquake-induced liquefaction dangers. The researchers emphasized that making use of AI in seismic soil reaction studies gives a green alternative to assist geotechnical engineers in designing civil structures in seismic-prone areas.[30]

Ratiranjan Jena et al. (2022) conducted a look at on earthquake risk evaluation in Eurasia the use of deep gaining knowledge of and transfer learning through an included version called GRU-SRU. The gated recurrent unit (GRU) is used to estimate the spatial opportunity of earthquakes (SPA), whilst the simple recurrent unit (SRU) evaluates earthquake vulnerability (EVA). The outcomes of SPA and EVA have been mixed to create Hazard Map A, whilst earthquake danger assessment (EHA) became combined with EVA to supply Hazard Map B, which verified higher accuracy. The examine determined that excessive-chance areas include valuable Eurasia, consisting of Japan, Indonesia, China, India, Pakistan, Iran, Turkey, and components of Europe, all located within the Alpide-Himalayan seismic belt, recognized for its excessive seismic interest The maps showed that 6.3 million km² of Eurasia had been categorized as high-chance below Hazard Map A, however this location reduced to at least one.7 million km² below Hazard Map B, which carefully resembled Global Earthquake Model (GEM) chance maps. Despite the effectiveness of the proposed model, the take a look at did no longer account for key elements such as soil residences, liquefaction, and geological faults, that can effect evaluation accuracy The examine highlights the importance of AI in enhancing earthquake chance predictions and reducing computational complexity as compared to traditional fashions, making it a precious device for choice-making in geotechnical engineering and urban making plans in seismic-prone areas [31].

Vagelis Plevris carried out an observation in 2024 exploring the function of synthetic intelligence (AI) in earthquake risk mitigation and the way it could rework traditional seismic risk management systems by improving early warning systems, structural fitness tracking, and presenting multi-hazard hazard checks. The take a look at proves that AI-driven innovations can considerably improve earthquake-resilient design via the use of generative design algorithms and predictive analytics to reap a top-of-the-line balance among protection, cost, and sustainability. It also emphasised the importance of comprehensive and numerous schooling datasets to ensure model accuracy, in conjunction with a focal point on moral issues related to transparency, responsibility, and bias mitigation. Looking ahead, the researcher recommended the improvement of complete datasets, integrating AI with Internet of Things (IoT) and 5G networks to decorate real-time responsiveness, and adopting AI-based equipment in catastrophe management plans and constructing codes. The examine highlighted the need for a sturdy regulatory framework to ensure the secure and ethical use of AI in this area [32].

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

Applications of Artificial Intelligence in Seismic Signal Interpretation and Earthquake Prediction

A 1989 have a look at on using synthetic intelligence tactics in seismic sign interpretation was completed by way of C. Chiaruttini, V. Roberto, and F. Saitta. The check focused on using blackboard systems as a model for hassle-fixing, imparting a flexible and effective manner to mimic professional strategies for seismic information processing. In order to evaluate records from a nearby seismic community, the look at provided the Seismic Network Analyser (SNA), an expert device constructed in this method. The results indicated that this method achieves superb sensitivity and robustness, making it capable of managing facts with a low signal-to-noise ratio. They have a look at moreover established that the device's flexibility and overall performance are advanced through using nonpredefined management mechanisms, which allow simple calculations earlier than everything and cast off greater complex calculations later. Furthermore, the modular layout makes expansion and renovation smooth and permits the incorporation of additional understanding components. According to an observer, the tool's ability to protect its findings makes it less difficult to understand the way it behaves, makes finding out and debugging easier, and makes it a beneficial device for instruction and schooling. The report has cautioned that SNA should be further evolved to enhance its seismic sign evaluation capabilities. [33]

Maria Moustra et al. (2011) conducted a look at to evaluate the overall performance of synthetic neural networks in predicting earthquakes in Greece the using of two styles of input data: time series of earthquake magnitudes and Seismic Electric Signals (SES). In the first case, have a look at the neural community used handiest significance information, achieving an accuracy of 80. Fifty-five% for all seismic occasions however dropping to fifty-eight.02% for fundamental earthquakes (M ≥ five.2). In the second case look at, SES facts have been used, resulting in an accuracy of 84.01% for predicting importance on my own and ninety-two.96% for predicting the time lag between SES and the earthquake. The findings advise that well educated neural networks can generalize and predict unknown seismic events with reasonable accuracy, even though the dearth of enough SES facts posed a sizable project. The have a look at recommends obtaining greater complete datasets to enhance prediction accuracy and highlights the capacity of neural networks as an powerful device whilst skilled with reliable and sufficient statistics. [34]

Conclusion

Current scientific evidence indicates that artificial intelligence (AI) represents a groundbreaking solution in the field of earthquake analysis and prediction. Artificial intelligence (AI) strategies, like as device learning and deep mastering, have been examined to benefit success in managing huge datasets and complicated seismic data, which can be hard for traditional structures to interpret. By making it viable to select out styles and traits that traditional strategies can bypass, those technologies increase forecast accuracy and offer superior threat management answers. The capacity of AI to deal with noisy or inadequate data is an essential element to remember. Artificial intelligence (AI)-based techniques can conquer the difficulties furnished with the useful aid of using fragmented or noisy seismic statistics, generating accurate and honest effects that are a useful resource in properly knowledgeable catastrophe reaction decision-making. AI, moreover, has an incredible deal of promise to beautify early warning systems. Artificial intelligence (AI)-powered structures can enhance brief reaction talents by comparing real-time data and forecasting earthquake or aftershock occurrences, in the long run reducing the financial and human losses related to seismic catastrophes. Even though AI has made large strides, there are even though several problems that need to be resolved. Enhancing the interpretability of present-day models and comparing their suitability for numerous geological settings are key challenges. Furthermore, an important first step in enhancing the thoroughness and precision of seismic research and forecasting is the integration of AI with global seismic monitoring structures. In give up, more effective and protected answers to support earthquake generation are predicted to be advanced because of ongoing studies in AI-driven seismic evaluation. But it is also critical to make certain that those dispositions consider ethics, mainly almost approximately statistics validation, accuracy, and responsible use. AI can drastically beautify public safety and catastrophe preparedness through placing a balance between moral duty and technological innovation, maximizing its quality social effects.

References

1. Cho S, Ahn JK, Hwang EH. Optimization of network-based earthquake early warning systems on the Korean Peninsula. IEEE Access. 2022;10:83931-9.
2. Moustra M, Avraamides M, Christodoulou C. Artificial neural networks for earthquake prediction using time series magnitude data or seismic electric signals. Expert Syst Appl. 2011;38(12):15032-9.
3. Grant RA, Halliday T. Predicting the unpredictable; evidence of pre-seismic anticipatory behaviour in the common toad. J Zool. 2010;281(4):263-71.
4. Adeli H, Panakkat A. Recent efforts in earthquake prediction 1990–2007. Nat Hazards Rev. 2008;9(2):70-80.
5. Abdalzaher MS, Elsayed HA, Fouda MM. Employing remote sensing, data communication networks, AI, and optimization methodologies in seismology. IEEE J Sel Top Appl Earth Obs Remote Sens. 2022;15:9417-38.

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

https://doi.org/10.54361/ajmas.258214

6. Ross ZE, Meier MA, Hauksson E. P wave arrival picking and first-motion polarity determination with deep learning. J Geophys Res Solid Earth. 2018;123(6):5120-9.
7. Kong Q, Trugman DT, Ross ZE, Bianco MJ, Meade BJ, Gerstoft P. Machine learning in seismology: Turning data into insights. Seismol Res Lett. 2019;90(1):3-14.
8. Perol T, Gharbi M, Denolle M. Convolutional neural network for earthquake detection and location. Sci Adv. 2018;4(2):e1700578.
9. Zhu W, Beroza GC. PhaseNet: a deep-neural-network-based seismic arrival-time picking method. Geophys J Int. 2019;216(1):261-73.
10. Mousavi SM, Zhu W, Ellsworth W, Beroza G. Unsupervised clustering of seismic signals using deep convolutional autoencoders. IEEE Geosci Remote Sens Lett. 2019;16(11):1693-7.
11. Chen J, Chen G, Li J, Du R, Qi Y, Li C, et al. Efficient seismic data denoising via deep learning with improved MCA-SCUNet. IEEE Trans Geosci Remote Sens. 2024.
12. Lin L, Zhong Z, Cai C, Li C, Zhang H. SeisGAN: Improving seismic image resolution and reducing random noise using a generative adversarial network. Math Geosci. 2024;56(4):723-49.
13. Kanamori H. Earthquake physics and real-time seismology. Nature. 2008;451(7176):271-3.
14. Allen RM, Gasparini P, Kamigaichi O, Bose M. The status of earthquake early warning around the world: An introductory overview. Seismol Res Lett. 2009;80(5):682-93.
15. Satriano C, Wu YM, Zollo A, Kanamori H. Earthquake early warning: Concepts, methods and physical grounds. Soil Dyn Earthq Eng. 2011;31(2):106-18.
16. Chiang YJ, Chin TL, Chen DY. Neural network-based strong motion prediction for on-site earthquake early warning. Sensors. 2022;22(3):704.
17. Rouet-Leduc B, Hulbert C, Lubbers N, Barros K, Humphreys CJ, Johnson PA. Machine learning predicts laboratory earthquakes. Geophys Res Lett. 2017;44(18):9276-82.
18. Mousavi SM, Ellsworth WL, Zhu W, Chuang LY, Beroza GC. Earthquake transformer—an attentive deep-learning model for simultaneous earthquake detection and phase picking. Nat Commun. 2020;11(1):3952.
19. Jena R, Shanableh A, Al-Ruzouq R, Pradhan B, Gibril MBA, Khalil MA, et al. Earthquake spatial probability and hazard estimation using various explainable AI (XAI) models at the Arabian peninsula. Remote Sens Appl Soc Environ. 2023;31:101004.
20. Leite EP, Vidal AC. 3D porosity prediction from seismic inversion and neural networks. Comput Geosci. 2011;37(8):1174-80.
21. Gholami A. A fast automatic multichannel blind seismic inversion for high-resolution impedance recovery. Geophysics. 2016;81(5):V357-64.
22. Mosser L, Kimman W, Dramsch J, Purves S, De la Fuente Briceño A, Ganssle G. Rapid seismic domain transfer: Seismic velocity inversion and modeling using deep generative neural networks. In: 80th EAGE Conference and Exhibition 2018. European Association of Geoscientists & Engineers; 2018. p. 1-5.
23. Li S, Liu B, Ren Y, Chen Y, Yang S, Wang Y, et al. Deep-learning inversion of seismic data. arXiv:1901.07733 [Preprint]. 2019.
24. AlAli A, Anifowose F. Seismic velocity modeling in the digital transformation era: a review of the role of machine learning. J Pet Explor Prod Technol. 2022;1-14.
25. Airlangga G. Unsupervised machine learning for seismic anomaly detection: Isolation forest algorithm application to Indonesian earthquake data. J Lebesgue. 2023;4(3):1827-36.
26. Ağaoğlu B, Askerzade İ, Bostancı GE, Medeni İT. Seismic data analysis with deep learning models: Methods, applications, and future perspectives. In: SETSCI-Conference Proceedings. 2024. p. 120-4.
27. Cho S, Ahn JK, Hwang EH. Optimization of network-based earthquake early warning systems on the Korean Peninsula. IEEE Access. 2022;10:83931-9.
28. Li J, Yao H, Wang B, Yang Y, Hu X, Zhang L, et al. A real-time AI-assisted seismic monitoring system based on new nodal stations with 4G telemetry and its application in the Yangbi MS 6.4 aftershock monitoring in southwest China. Earthq Res Adv. 2022;2(2):100033.
29. Abdalzaher MS, Elsayed HA, Fouda MM. Employing remote sensing, data communication networks, AI, and optimization methodologies in seismology. IEEE J Sel Top Appl Earth Obs Remote Sens. 2022;15:9417-38.
30. Ghani S, et al. Comparative and parametric study of AI-based models for risk assessment against soil liquefaction for high-intensity earthquakes. Arab J Geosci. 2022;15(14):1262.
31. Jena R, et al. An integration of deep learning and transfer learning for earthquake-risk assessment in the Eurasian region. Remote Sens. 2023;15(15):3759.
32. Plevris V. AI-driven innovations in earthquake risk mitigation: a future-focused perspective. Geosciences. 2024;14(9):244.
33. Chiaruttini C, Roberto V, Saitta F. Artificial intelligence techniques in seismic signal interpretation. Geophys J Int. 1989;98(2):223-32.
34. Moustra M, Avraamides M, Christodoulou C. Artificial neural networks for earthquake prediction using time series magnitude data or seismic electric signals. Expert Syst Appl. 2011;38(12):15032-9.

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*

https://doi.org/10.54361/ajmas.258214

في ال سنوات الأخيرة، برزت تقنيات الذكاء الا صطناعي كأداة واعدة لتعزيز تقييم إح صاءات الزلازل وتح سين هياكل التنبؤ بها. تقيّم هذه الورقة البحثية فائدة للذكاء الا صطناعي في تقييم بيانات الزلازل والتنبؤ بها وتقييم المخاطر. وقد أثبتت العديد من الأبحاث فعالية خوارزميات التعرف على الأجهزة والتعلم العميق، بما في ذلك ال شبكات الع صبية التلافيفية والذاكرة طويلة المدى قصيرة المدى وآلات المتجهات الداعمة، في معالجة وقراءة التنبيهات الزلزالية. وقد ا ستخدمت تقنيات الذكاء الا صطناعي لتحديد الأنماط في سجلات الزلازل والتنبؤ بها وتقييم المخاطر الزلزالية بدقة أكبر مقارنة بالتقنيات التقليدية. بالإ ضافة إلى ذلك، تم تطوير أنظمة الإنذار المبكر للزلازل القائمة على الذكاء الاصطناعي، مما يوفر إشارات في الوقت المناسب و يحسّن التأهب للكوارث. كما تسلط الأبحاث الضوء على دمج الذكاء الا صطناعي القابل للتف سير لتح سين قابلية تف سير النماذج الزلزالية، وبالتالي تح سين عملية اتخاذ القرار في تقييم وإدارة مخاطر الزلازل. يقدم برنامج الذكاء الاصطناعي في الدراسات الزلزالية مقياسًا جديدًا تمامًا لرصد الزلازل والتخفيف من آثارها، مما يعد بحلول أسرع وأكثر دقة وفعالية من حيث التكلفة.

***Received**: 28-02-2025 - **Accepted**: 09-04-2025 - **Published**: 16-04-2025*