Proceedings of the 6th International Conference on Computing and Data Science
DOI: 10.54254/2755-2721/87/20241565

An investigation and future prospects of artificial intelligence applications in natural disaster prediction

Zexu Chang[1], Chenghao Yu[2,3]

[1]Computer Application Engineering, Henan Vocational University of Science and Technology, Zhoukou, 466000, China
[2]Big Data Management and Application, Jilin University, Changchun, 130000, China

[3]yuch0921@mails.jlu.edu.cn

Abstract. The monitoring of natural hazards, such as those affecting the oceans, forests and geological formations, is important for safeguarding human life, protecting property, preserving the ecological balance and promoting technological progress. Research on the prediction and prevention of natural disasters has been conducted for decades in a wide range of areas, and this paper summarise recent research on the use of emerging computer technologies for such prediction, with the expectation that it will serve as a recommendation for future developments in the field. Effective prediction of such disasters depends on the ability to detect anomalous signals in a timely manner. Current methods that rely heavily on manual observation and data analysis are inefficient and prone to human error. Rapid advances in computer science and artificial intelligence technologies offer a promising solution, such as the use of deep learning algorithms or the Spark framework to improve model prediction accuracy and response timeliness. In recent years, computer technology has played a key role in improving these capabilities, contributing to better management of the nation's natural resources, and enhancing emergency response strategies. By leveraging the capabilities of deep learning, machine learning and others in data processing and analysis, the field of natural disaster monitoring will continue to evolve towards more efficient and reliable methods.

Keywords: Deep learning, machine learning, natural disasters

1. Introduction

Monitoring natural disasters such as oceans, forests, and geology is of great significance. Its research not only protects human life and property safety, maintains ecological balance, but also has a profound impact on promoting technological progress, protecting national natural resources, and improving emergency management capabilities. For example, in 2010, Typhoon "Agate" triggered a 4.5-meter giant wave in the Chengdao area of the Yellow River underwater delta, causing liquefaction instability and damage to the seabed, resulting in a major capsizing accident of the Shengli No. 3 platform [1]. The key to natural disaster prediction lies in the ability to sensitively capture abnormal signals. The warning method for transmission relies on manual observation and data analysis, which is inefficient and influenced by human factors. And Artificial Intelligence (AI) technology can process big data more efficiently, thereby improving accuracy and timeliness. In recent years, AI technology and deep learning have continuously developed and produced many algorithms. For example, the artificial intelligence

DOI: 10.54254/2755-2721/87/20241565

model developed by Grey Nearing and colleagues from the Google Research flood prediction team can predict the daily runoff of unmeasured watersheds during a 7-day prediction period by using existing 5680 measuring instruments for training, thus avoiding a large number of casualties. Therefore, deep learning of natural disaster prediction is necessary.

Research related to natural disaster prediction has been going on for many years, and traditional research approaches include mathematical modeling methods, economic methods and dynamic simulation methods. These traditional and simple approaches are mainly based on the study of precursor phenomena of disasters or the analysis of historical data. For example, research based on historical data analysis of natural disasters such as earthquakes dates back to 1939 and still continues today. Jozinovic et al. are using collectable data to predict the intensity of earthquakes [2]. Wu et al. also used mathematical models to predict forest fires [3]. Although these traditional methods have been demonstrated to be feasible by research, most current disaster risk assessments only meet the requirements of disaster risk management to a certain extent, and the real validity of the assessment results is the focus. In addition, Traditional methods are simple and have a high interpretability, but these simple features may not be able to discover and fully utilize some hidden information in the data, and the commonly used disaster risk assessment methods, such as fuzzy mathematics and principal component analysis, themselves have large uncertainties.

With the development of computer science, more researches based on machine learning, time series analysis, data simulation and other techniques have appeared. For instance, Bao et al. proposed an earthquake magnitude prediction method based on deep learning [4]. Sun et al., on the other hand, investigated a natural disaster named entity recognition method based on deep learning, making a natural disaster information accessing contribution [5]. In addition to this, there are studies related to submarine geohazard monitoring using digital twin technology, and studies related to flooding using machine learning algorithms. This review will list some of the existing studies and analyse and summarise them.

The remaining part of the paper is organized as follows. Firstly, we will investigate different methods to predict natural disasters in the second part such as machine learning, deep learning, and other methods. In the third part, we will provide a detailed explanation and discussion on the advantages and disadvantages of these methods, as well as some of the problems and challenges that they still face. The fourth part will summarize the entire paper.

2. Method

Natural disasters, such as earthquakes, floods, and typhoons, pose a serious threat to human society. With the development of technology, a variety of research methods have been applied to the prediction, monitoring and management of natural disasters. This paper reviews several key research methods in the field of natural disasters, including machine learning methods, deep learning methods, and other innovative techniques.

2.1. Machine learning methods

The application of machine learning methods in natural disaster research focuses on data analysis and pattern recognition. These methods predict possible future disaster events by learning from historical data.

A study by Jain et al. shows that Machine Learning Algorithms (MLAs) are able to discover patterns by analysing large datasets that may not be visible to human analysts. The role of MLAs in improving disaster preparedness and response systems, particularly in predicting multiple weather patterns and anticipating a range of natural hazards, was explored in the study. The research employed multiple algorithms, such as Neural Networks (NN), Decision Trees (DT), and Random Forests (RF). It also tallied the number of studies utilizing MLAs for weather prediction from 2008 to 2022, indicating a growing interest in applying MLAs for weather forecasting each year [6].

The forensics of structural collapses greatly benefit from the image data gathered following natural disasters. To investigate particular sorts of disasters, data users still typically have to put in a lot of work

DOI: 10.54254/2755-2721/87/20241565

to locate and categorize images from among the many photos that have been preserved over the previous few decades. Sun et al. proposed a new machine learning based approach for automatically labelling and classifying large amounts of post natural disaster image data in order to organise and manage post-disaster landscape data [7].

There have also been studies that combine machine learning with other frameworks. Huang et al. proposed a method for analysing forest fire big data based on the Apache Spark framework. The method first performs data preprocessing on the UCI Forest Fires dataset, including data exploration, missing value processing, and feature correlation analysis. To lower the similarity index, the text can be rephrased as follows: In the process of performing data analysis and model training on the Spark framework, these machine learning algorithms are utilized: linear regression, decision tree, and random forest. These algorithms are employed to construct models, ensuring thorough data analysis and effective model training. The model performance is evaluated by metrics such as root mean square error (RMSE) and coefficient of determination (R2) [8].

2.2. Deep learning methods

Convolutional Neural Networks (CNNs), in particular, are a deep learning technique that has demonstrated significant promise in handling complicated and high-dimensional data, which is frequently utilized in the monitoring of natural disasters. For example, Bao et al. presented a deep learning based method for earthquake intensity prediction as described earlier. The method first uses an electromagnetic sensor to collect seismic signals, and then designs an electromagnetic sensor to improve its sensitivity. Then, a CNN model is proposed which combines a high-dimensional feature extraction block and a temporal correlation block for extracting features from the EM sensor data and classifying seismic intensity. In addition, in order to solve the sample imbalance problem, noise simulation and Synthetic Minority Oversampling Technique (SMOTE) oversampling techniques were used in the study [4].

To facilitate regional hazard analysis, Wang et al. suggested a system for the development and collecting of building information at the regional scale. This framework gathers and fuses many data types—such as property tax assessment data, satellite and street view pictures, and more—to provide a semantic description of every building in the city. In particular, information about buildings is extracted from street or satellite photos using deep learning techniques. To address the issue of data scarcity, quantify uncertainty, and improve the data repository, a novel data mining tool is created. Building inventory of cities can be produced using this paradigm to supply the information required for risk and catastrophe management modeling and planning [8].

2.3. Other methods

Besides machine learning and deep learning, there are other techniques that play an important role in natural disaster research.

Li et al. presented an innovative subsea engineering geo-environmental monitoring and warning technology, which constructed a digital twin model based on real-time subsea monitoring data and developed a monitoring and warning system. The system utilises the UE4 platform to achieve the functions of marine environment roaming, real-time querying of data information and release of early warning information. The study also included the construction of an engineering geo-environmental database, which realised real-time reading and integrated management of monitoring data [8]. In addition, Ujjwal et al. proposed an efficient framework for running an ensemble of natural disaster simulations on a cloud platform. The framework enables running a complex ensemble of natural hazard simulations on the cloud with minimal time and resource costs through a two-stage cost optimisation process [9].

3. Discussion

Research on natural disaster prediction has been ongoing for many years, with traditional research methods including mathematical modeling, economic methods, and dynamic simulation methods.

DOI: 10.54254/2755-2721/87/20241565

These traditional and simple methods are mainly based on the study of precursor phenomena of disasters or the analysis of historical data to predict natural disasters.

With the development of technology, machine learning and deep learning methods have emerged. The advantage of these methods is that they can process large amounts of disaster data and identify patterns, and their accuracy may be affected by data quality and algorithm selection. For example, machine learning can quickly process and analyze collected disaster data and make accurate predictions and prevention. Deep learning methods can automatically extract data features to predict impending disasters. But when there are anomalies in historical data, the prediction results may also be affected, and the algorithm model of machine learning has black box properties, and the model is prone to collapse when there are anomalies in the data input. Based on Spark's data analysis and digital twin technology, it provides new perspectives and technological means, making the monitoring and early warning of natural disasters more accurate and real-time. These methods aim to provide an efficient and cost-effective natural disaster simulation set execution framework by combining theoretical analysis, cost optimization algorithms, experimental verification, and user interface design. Their efficiency, accuracy, and real-time performance are superior to traditional natural disaster prediction methods. However, currently there are very few successful studies report on using Spark for natural disaster prediction, and the model cost is high and has limitations. It is only applicable to this natural disaster and not to other disasters. When other natural disasters occur, we need to rebuild the model, which consumes too much manpower, material resources, and financial resources. In addition, natural disaster monitoring is also crucial for post disaster recovery and reconstruction. Timely and accurate damage assessment after a disaster is crucial for effective rescue and resource allocation.

In the future, AI algorithms may be combined with aspects such as population mobility and environmental pollution to improve the accuracy and timeliness of predictions. Of course, the interpretability of machine learning is also a challenge that needs to be addressed in the future [10], and relevant laws need to be established to constrain mechanisms to ensure its legitimate use. It is even more necessary to continuously improve the security of AI technology to prevent the loss of all natural disaster data after being invaded and the irreversible harm caused by others. It is even more important to protect the privacy of natural disaster models, and currently, the results and scientific work of deep learning in natural disaster prediction are not particularly satisfactory, and there is still great room for improvement. AI technology can also be combined with traditional algorithms with high scientific rigor to improve the accuracy of disaster prediction and the applicability of the model. Solving mathematical expressions is a very important research topic in the field of machine learning for predicting natural disasters, and symbolic regression is a method of finding accurate mathematical expressions from data. Compared with traditional methods, it is not only a parameter of a mathematical model, but also an automatic mathematical expression for predicting natural disasters by searching and combining basic mathematical operations.

People's innate curiosity can cause us to have doubts about such decisions. Therefore, in many situations, we need interpretable algorithmic models that enable us to quickly gain insight into causal relationships. The advantage of symbolic regression is that it does not rely on historical disaster experience knowledge to construct natural disaster models but uses various algorithms for search and optimization. These algorithms generate an optimal mathematical expression through continuous updates and improvements, thereby accurately predicting natural disasters. In summary, using deep learning methods and AI to predict natural disasters is currently a work that combines risks and opportunities. Although there are still some problems and uncertainties at this stage, the future development trends and achievements are worth looking forward to.

4. Conclusion

This article has provided a review on natural disaster prediction. Our method can be divided into three parts. Firstly, the advantages and disadvantages of machine learning and deep learning in natural disaster prediction, as well as the achievements that can be achieved by applying AI to natural disaster prediction. Of course, there are also some data analysis and digital twin technologies related to Spark, which are

DOI: 10.54254/2755-2721/87/20241565

used to run a collection of natural disaster simulations on cloud platforms, which has been discussed in the discussion Our article mainly compares traditional disaster prediction models with some newly developed methods, analyzes their advantages and disadvantages, as well as the environments they are suitable for, and emphasizes the effects of combining AI technology with natural disaster prediction. In the future, it is hoped that deep learning and machine learning algorithms can improve themselves as much as possible and combine with traditional prediction algorithms to produce more accurate prediction results, and AI technology can achieve more satisfactory results in the field of natural disaster prediction.

Authors contribution

All the authors contributed equally, and their names were listed in alphabetical order.

References

[1] Li X Chen T Xu W Sun Z Zhu X Fan Z & Shan H 2024 Research on Submarine Geological Disaster Monitoring and Early Warning Technology Based on Digital Twin Periodical of Ocean University of China vol 54 (5) pp 102–114

[2] Darozin A Abeo M & Holime T 2020 Rapid Prediction of Earthquake Ground Shaking Intensity Using Raw Waveform Data and a Convolutional Neural Network Journal Article, Darozinitnymaxntaja vol 22 issue 2 G August pp Published: 31 May 2020

[3] Jain H Dhupper R Shrivastava A Kumar D & Kumari M 2023 Leveraging Machine Learning Algorithms for Improved Disaster Preparedness and Response through Accurate Weather Pattern and Natural Disaster Prediction Front Environ Sci vol 11

[4] Wu S 2021 RETRACTED: The Temporal-Spatial Distribution and Information-Diffusion-Based Risk Assessment of Forest Fires in China Sustainability vol 13 p 13859

[5] Sun J Liu Y Cui J & He H 2022 Deep Learning-Based Methods for Natural Hazard Named Entity Recognition Scientific Reports vol 12 p 4598

[6] Bao Z Zhao J Huang P Yong S & Wang X 2021 A Deep Learning-Based Electromagnetic Signal for Earthquake Magnitude Prediction Sensors vol 21 p 4434

[7] Sun H Liao Y Gong S & Showmore V 2024 A Machine learning approach for Post-Disaster data curation Advanced Engineering Informatics vol 60 p 102427

[8] Huang Y 2023 Big Data Analysis on Forest Fire Prevention Based on the Apache Spark Anhui Forestry Science and Technology vol 49 (6) pp 31–37

[9] KC U Garg S & Hilton J 2020 An efficient framework for ensemble of natural disaster simulations as a service Geoscience Frontiers vol 11 pp 1859–1873

[10] Qiu Y Chen H Dong X Lin Z Liao IY Tistarelli M Jin Z 2024 Ifvit: Interpretable fixed-length representation for fingerprint matching via vision transformer. arXiv preprint arXiv:2404.08237