Original Research Article

Research on the spatiotemporal effects of algorithms in predicting deformation of foundation pits

Ying Liu

Hebei University of Engineering, Handan, Hebei, 056038, China

Abstract: This research investigates the spatiotemporal effects of algorithms in predicting the deformation of foundation pits, which are critical structures in construction. Accurate prediction of deformation is essential for ensuring safety and structural integrity during excavation and building processes.The study explores various algorithmic approaches, including machine learning techniques such as regression models, neural networks, and support vector machines, alongside traditional finite element analysis (FEA) and time series analysis. By employing spatial analysis techniques, such as interpolation and geographic information systems (GIS), the research delineates deformation patterns, while temporal analysis aids in forecasting future changes. Case studies demonstrate successful implementations of these predictive models, highlighting lessons learned and best practices.Despite advancements, challenges such as data quality, model complexity, and external influencing factors remain. Future directions include the development of hybrid modeling approaches and improved real-time data integration systems. Overall, this research contributes to enhancing predictive accuracy and risk mitigation strategies in foundation pit engineering.

Keywords: Foundation pits; Algorithms; Spatiotemporal effects

1. Introduction

We emphasize the importance of integrating real-time data collected from advanced sensor technologies and remote sensing methods, allowing for a comprehensive understanding of deformation mechanisms influenced by soil behavior, groundwater fluctuations, and construction activities.Researching the spatiotemporal effects of algorithms in predicting deformation of foundation pits involves several key aspects:

2. Introduction to foundation pits

Foundation pits are excavated areas for building foundations, often susceptible to deformation due to various factors such as soil properties, groundwater conditions, and construction activities.

3. Deformation mechanisms

Understanding the primary causes of deformation, including:

Soil settlement

Lateral earth pressure

Groundwater fluctuations

Construction-induced vibrations

4. Importance of prediction

Accurate prediction of deformation can help in:Preventing structural failures; Enhancing safety protocols; Reducing costs associated with over-excavation or reinforcement.

4.1. Time effect

The time effect of excavation deformation is mainly reflected in the rheological and creep properties of the soil. Under long-term loading, soil will undergo slow deformation, which gradually increases with time, especially in soft soil areas where the rheological properties of soil are more significant. The time effect also manifests as the influence of excavation exposure time on deformation. The longer the exposure time of the excavation surface, the greater the deformation caused by soil creep, thereby increasing the risk of foundation pit instability. Therefore, in foundation pit engineering, arranging the construction schedule reasonably and reducing the exposure time of the excavation surface are important measures to control the deformation of the foundation pit.

4.2. Spatial effects

The spatial effect of foundation pit deformation is mainly related to the size and shape of the foundation pit. The planar shape, size, excavation depth, and excavation steps of the foundation pit have a significant impact on its deformation and stability. For example, the corners of a foundation pit are constrained in multiple directions, and their deformation is usually smaller than that of the central part of the pit. This phenomenon is called the pit corner effect. In addition, the spatial effect of the foundation pit is also reflected in the interaction between the retaining structure and the soil. The stiffness and arrangement of the retaining structure directly affect the deformation mode of the foundation pit, while the properties of the soil determine the size and distribution of the deformation.

4.3. Comprehensive analysis of spatiotemporal effects

In practical engineering, the temporal and spatial effects of foundation pit deformation are often interrelated and influence each other. For example, excavation depth and excavation sequence not only affect the spatial deformation mode of the foundation pit, but also alter the stress state of the soil, thereby affecting the time effect. Therefore, in the design and construction of foundation pits, it is necessary to comprehensively consider time and spatial factors, adopt spatiotemporal effect analysis methods, and comprehensively predict and control the deformation of foundation pits. By optimizing the construction plan and supporting structure design, the deformation of the foundation pit can be effectively reduced, and the safety and economy of the project can be improved.

5. Algorithms for prediction

Machine Learning Models:Regression techniques (e.g., linear regression, polynomial regression); Neural networks (e.g., feedforward, recurrent); Decision trees and ensemble methods (e.g., Random Forest, Gradient Boosting); Finite Element Methods (FEM):Simulating physical behavior under various loading conditions.Time Series Analysis:Analyzing historical data to predict future deformation trends.

5.1. Common monitoring techniques and methods

Deformation monitoring of foundation pits is an important part of ensuring engineering safety. Common monitoring techniques include horizontal displacement monitoring, vertical displacement monitoring, and deep lateral deformation monitoring. Horizontal displacement monitoring mainly uses equipment such as total stations and inclinometers to measure the horizontal displacement of the enclosure structure and soil, and detect abnormal situations in a timely manner. Vertical displacement monitoring mainly uses equipment such as level gauges and settlement meters to evaluate the stability of the foundation pit by measuring the settlement of the surrounding ground and buildings. Deep lateral deformation monitoring mainly uses inclinometers to measure the deformation of the retaining structure along the depth direction and understand the deformation mode of the foundation pit.

5.2. Use of monitoring instruments

The total station is mainly used for measuring horizontal displacement in foundation pit monitoring, and its high-precision measurement capability can accurately reflect the deformation of the foundation pit. The inclinometer is used to measure the lateral deformation of the enclosure structure. By embedding inclinometers in the enclosure structure, deformation data along the depth direction can be obtained. In addition, equipment such as settlement gauges and level gauges are widely used in foundation pit monitoring to evaluate the stability of the pit by measuring the settlement of the ground and buildings.

5.3. Data processing and analysis

The accuracy and reliability of monitoring data are directly related to the safety management of foundation pit engineering. In the process of data processing and analysis, it is necessary to use scientific methods for error analysis and processing. The principle of indirect adjustment is a commonly used data correction method, which improves the accuracy and reliability of monitoring data by establishing a mathematical model to correct it. In addition, it is necessary to conduct statistical analysis on monitoring data, draw deformation curves and trend charts, timely detect abnormal situations, and take corresponding measures to deal with them

6. Spatiotemporal analysis

Data Collection:

Use of sensors (e.g., inclinometers, piezometers) to gather spatial data on deformation over time.

Spatial Analysis Techniques:

Geographic Information Systems (GIS) for mapping deformation patterns.

Temporal Analysis:

Time-dependent behavior of soil and structures to identify trends and anomalies.

7. Integration of data sources

Combining data from different sources (e.g., remote sensing, ground surveys) to improve model accuracy.

8. Case studies and applications

Review of successful implementations of predictive algorithms in real-world projects.

Discussion of lessons learned and improvements made.

9. Challenges and limitations

Addressing uncertainties in data collection, model assumptions, and external factors influencing deformation.

10. Future research directions

Development of more sophisticated algorithms that incorporate real-time data.

Exploration of hybrid models combining machine learning and traditional engineering methods.

11. Conclusion

Predicting deformation in foundation pits using advanced algorithms offers significant potential for enhancing construction safety and efficiency. Ongoing research is essential to refine these models and adapt to evolving engineering challenges. This case demonstrates that the spatiotemporal effect has a significant impact on the deformation of foundation pits in soft soil areas. By implementing reasonable construction organization and technical measures, the deformation of the foundation pit can be effectively controlled, ensuring the safety and smooth progress of the project. In addition, real-time analysis and feedback of monitoring data are of great significance for timely detection and handling of abnormal situations. Future research should further explore the mechanisms and influencing factors of spatiotemporal effects, and develop more accurate prediction models and control techniques.

References

[1] Wei Xing, Chen Rui, Cheng Shitao, et al. Rainfall stability analysis and deformation prediction of deep foundation pits in expansive soil areas of Chengdu [J]. Geotechnical Mechanics, 2024, 45 (S1): 525-534. DOI: 10.16285/j.rsm. 2022.0791

[2] L ü Linhai, Jiang Mingjie, Xie Zhongming, et al. Multi case analysis and deformation prediction formula for underground tunnels caused by excavation of foundation pits [J/OL]. Industrial Construction, 1-14 [2024 September 28] http://kns.cnki.net/kcms/detail/11.2068.TU.20240828.1402.001.html.

[3] Bao Wei, Xinzhe. Numerical simulation analysis of open-pit mine slope stability [C] / / Beijing Mechanics Society. Proceedings of the 28th Annual Conference of Beijing Mechanics Association (II). School of Mechanics and Building Engineering, China University of Mining and Technology (Beijing) ;, 2022: 4.

[4] Wang He. Slope stability analysis of Wushan copper-molybdenum mine based on information method and displacement monitoring prediction [D].Northeast University, 2021.

[5] Liu Cheng, Liu Yong, Rong Wenzheng, et al. Research on deformation prediction of foundation pit based on CNN Attention LSTM [C]//Process Control Professional Committee of the Chinese Society of Automation, Chinese Society of Automation. Proceedings of the 35th China Process Control Conference. School of Automation and Information Engineering, Sichuan University of Light Chemical Technology; Sichuan Key Laboratory of Artificial Intelligence;, 2024:1.DOI:10.26914/c.cnkihy.2024.020078.

[6] Mei Yuan, Zhang Miaomiao, Zhou Dongbo, et al. Deformation analysis of narrow deep foundation pits in Xi’an collapsible loess area [J]. Journal of Chongqing Jiaotong University (Natural Science Edition), 2024, 43 (07): 17-25.