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Safety Risk Assessment Analysis of Bridge Construction Using Backpropagation Neural Network

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Abstract: The evaluation of construction safety risks has become a crucial task with the increasing development of bridge construction. This paper aims to provide an overview of the application of backpropagation neural networks in assessing safety risks during bridge construction. It introduces the situation, principles, methods, and advantages, as well as the current status and future development directions of backpropagation-related research.

Keywords: Backpropagation neural network; Bridge construction; Safety risk assessment

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1. Introduction

The development of bridge engineering and the scale of construction is continuously expanding in China. The risk factors for bridge engineering projects are more complex compared with other engineering project constructions. Since bridges are an integral part of modern transportation infrastructure, ensuring their construction safety is of paramount importance. The number of studies on risk analysis for bridge engineering projects by researchers has been increasing year by year globally, but there still is no authoritative project risk evaluation model. Traditional methods for evaluating construction safety risks often rely on statistical analysis and expert judgment that have subjective limitations and may not comprehensively consider various factors. Identifying and analyzing the risk factors for bridge engineering projects, proposing reasonable and feasible control measures, guiding accident prevention during the project construction process, and achieving safe construction of the project have become important aspects of bridge engineering project management. With the rapid development of artificial intelligence technology in recent years, backpropagation neural networks have been increasingly applied in bridge project risk assessment to reduce bridge construction risks and ensure bridge construction safety.

2. Status of domestic and international research

2.1. Research on project risk management based on AHP

The analytic hierarchy process (AHP) is a decision analysis method that groups decision factors into different hierarchical levels. It establishes a judgment matrix based on the importance of factors to calculate eigenvectors and eigenvalues, thereby obtaining the weight of the importance of decision schemes. The AHP method is logical and practical, making it a widely used risk analysis tool currently. In recent years, numerous researchers have verified the feasibility of using AHP for project risk evaluation and analysis. Wang et al. confirmed that the improved AHP is a feasible method for project risk evaluation [1]. Sun analyzed and summarized the characteristics of water project risks, establishing a multi-level fuzzy comprehensive risk assessment model to quantitatively evaluate the risk analysis of water projects, verifying the feasibility of project risk management based on AHP [2]. Zhang combined the fuzzy comprehensive evaluation method and AHP to establish a comprehensive evaluation model for large-span bridge projects, verifying the effectiveness and practicality of AHP [3]. Shang established the feasibility of applying AHP to project risk analysis by quantitatively analyzing the risk of a construction project using AHP and a fuzzy comprehensive evaluation method [4]. Pu identified potential risk sources and proposed preventive measures by utilizing AHP to analyze the risk factors of an oilfield project, [5].

2.2. Research on bridge project risk management

With the necessity of risk evaluation in bridge projects being increasingly emphasized since the 1980s, researchers have actively conducted risk analyses on bridge engineering [6]. Skorupka established a risk rating system for bridge projects and applied it to some bridge constructions [7]. Alberto and Dan analyzed the hazardous states of bridge projects and established a risk assessment system [8]. Sexsmith and Reibd achieved constructive results for bridge construction safety through the risk research of temporary works [9].

Domestic research on project risks has also developed rapidly, with various researchers conducting risk analyses on different types of bridges. Zhang proposed risk schemes under different circumstances based on the characteristics of bridge construction and the theoretical study of risk control [10]. Xu conducted in-depth research and analysis on the project risks of bridges, establishing a risk management manual [11]. Gan researched bridge project risks, establishing a project risk evaluation system, a project risk safety control system, and an emergency management system for unexpected construction disasters [12]. Zhang used AHP and fuzzy comprehensive evaluation methods to conduct safety evaluations on bridge construction through model establishment [13].

2.3. Research on project risk based on neural networks

With the rapid development of artificial intelligence in recent years, people have conducted extensive research on machine algorithms. The backpropagation neural network is a machine algorithm currently widely used as a prediction model.

The BP neural network is a multi-layer artificial neural network that has been widely applied in various complex systems due to its strong non-linear mapping capability and learning function. This demonstrates its significant application value in pattern recognition, image processing, and machine learning. As the theoretical research on artificial neural networks has become increasingly complex, it has been widely applied domestically and internationally, such as in function approximation and pattern recognition [14,15]. A BP neural network model typically completes specific application problems through mathematical transformation, utilizing mathematical optimization to analyze input and output based on training samples [16]. The structure of the BP neural network consists of three layers, the input layer, the output layer, and the hidden layer [17]. Neurons in the same layer have no connection, allowing the BP neural network to extract more information in the input layer and perform more complex information processing [18]. A typical BP neural network uses the Sigmoid function to process the hidden layer and employs linear functions in the output layer. The BP neural network learns through the error backpropagation algorithm, with the network correcting layers according to errors. In theory, BP neural networks can be used for risk prediction. In recent years, researchers domestically and internationally have begun combining BP neural networks with project risk control, researching the application of models in project risk management. Sanchez applied an artificial neural network model to predict project cost risks, providing a basis for project risk control by contractors [19]. Hu established an improved self-adapting algorithm-based BP neural network model, studying its feasibility in bridge construction control [20]. Zhang predicted formwork elevation through a BP neural network model, realizing project risk control [21]. Liu constructed a risk assessment system for large-span bridges and adopted a BP neural model for evaluation, providing a reference for the feasibility of applying BP neural network models to large-span bridge engineering evaluations [22].

From the above research, it is shown that overseas risk control research started earlier and has more complexity. Although domestic-related research began later, it has been gradually narrowing this technological gap in recent years alongside the prosperity of the bridge field. Risk control in bridge engineering projects has been integrated into project management, forming a relatively complete theoretical system of risk management.

3. The advantages of BP neural networks in bridge construction safety risk assessment

BP neural networks offer numerous advantages as a tool in the safety risk assessment of bridge construction contributing to the improvement of construction safety and controllability [23].

3.1. Adaptability

The adaptability of BP neural networks is a crucial factor ensuring their widespread application in diverse construction environments and conditions. Traditional risk assessment methods often require manual adjustments based on specific scenarios, whereas BP neural networks can autonomously learn and adapt to changes in input data. This implies that BP neural networks can flexibly adjust to different geographical locations, seasons, and construction processes, thus providing accurate assessments based on the latest data.

3.2. High accuracy

BP neural networks excel in providing high-precision safety risk assessments. Their training process relies on a substantial amount of historical data, and through iterative processes and backpropagation algorithms, the output data becomes closer to real-world situations. This characteristic enables BP neural networks to assess construction risks with high accuracy, aiding decision-makers in gaining a more precise understanding of potential risks and safety issues.

3.3. Consideration of multiple factors

BP neural networks can simultaneously consider multiple factors that influence construction safety, including weather conditions, geology, and construction processes. Traditional methods often struggle to handle even a limited number of variables, making it challenging to consider complex interactions among multiple factors comprehensively. BP neural networks can process a large number of input features, analyzing various factors through the connection weights between the factors, leading to a more comprehensive risk assessment.

3.4. Real-time capability

The real-time capability of BP neural networks is another advantage. Leveraging historical data and real-time monitoring data, BP neural networks can achieve real-time risk assessments to monitor the safety status of construction sites continuously. This provides crucial support for implementing necessary safety measures promptly to prevent accidents and ensure the smooth progress of engineering projects.

4. Principles and methods of safety risk assessment for bridge construction based on BP neural networks

In the field of bridge construction, safety risk assessment is a critically important task for ensuring the smooth progress of projects and avoiding potential hazards. The application of BP neural networks as a powerful tool in this domain has garnered widespread attention.

BP neural networks are a type of feedforward neural network composed of input layers, hidden layers, and output layers. Each neuron is connected to neurons in the next layer, with weights assigned to these connections, with crucial parameters being continually adjusted during the training process. The training of BP neural networks is based on supervised learning that minimizes the error between the model's output and actual targets through the backpropagation algorithm. This iterative optimization process gradually refines the ability of the model to approximate desired outputs, enabling it to perform tasks such as classification and regression based on data.

As there are no connections between neurons within the same layer, the BP neural network can extract more information from the input layer and undertake more complex information processing. The transfer functions commonly used in BP neural networks are typically the Sigmoid function and linear functions. In a typical BP neural network, the Sigmoid function is employed in the hidden layer, while the linear function is used in the output layer. The BP neural network learns through the error backpropagation algorithm, with the network correcting itself layer by layer based on errors. **Figure 1** depicts the workflow diagram of the BP neural model.

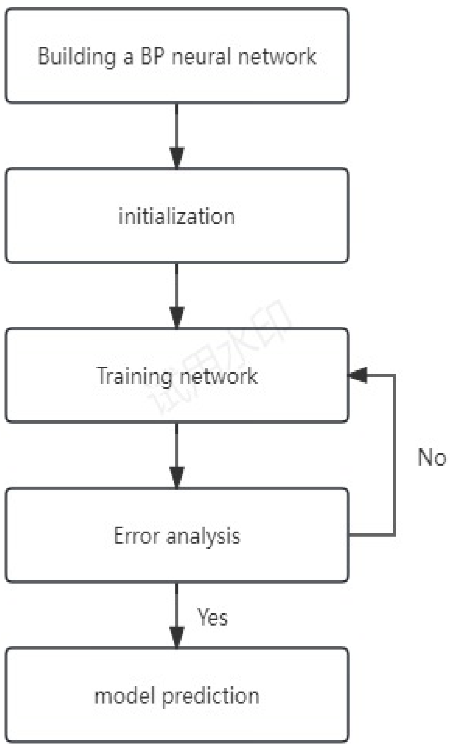

Figure 1. The BP neural model flow

In the safety risk assessment of bridge construction, the application process of BP neural networks can be divided into several steps. Firstly, data preprocessing is required. Data needed for safety risk assessment may include geological conditions at construction sites, meteorological data, construction plans, historical accident data, and various other information [24]. As these data often come from different sources, standardization and normalization processes are necessary to ensure data consistency and comparability.

Next, the process involves feature selection. Not all features in extensive datasets are equally important for safety risk assessment. The goal of feature selection is to identify the most representative and relevant features, reducing data dimensions to enhance the efficiency and accuracy of the model. This requires a deep understanding of field knowledge and data analysis to determine which features are crucial for risk assessment.

Subsequently, the model training process of BP neural networks utilizes training data that typically comprises historical construction data that includes information on safety events and accidents under different construction conditions. By inputting this data into the BP neural network, the model adjusts connection weights through the backpropagation algorithm, enabling the model to assess construction safety risks based on input data. While this process may require substantial computing resources and time, it ultimately produces a risk assessment model with high accuracy.

Finally, the last stage involves prediction and assessment. Once the training of the BP neural network model is complete, it can accept new construction site data and output corresponding safety risk levels. This output data assists engineers and decision-makers in understanding potential risks and taking appropriate measures to mitigate them. Moreover, the real-time nature of the model allows continuous monitoring of safety conditions during actual construction processes, facilitating timely adjustments and feedback.

However, there are certain limitations to utilizing BP neural networks for rapid estimation. The supervised learning method needs the model to be trained with relevant data and then tested with a certain number of samples. If the sample number is insufficient, it will affect the model prediction results. Hence, the construction of a BP neural network model requires extensive relevant data for training. Issues such as limited information sharing and data collection exist in some engineering project sample data. So the simulation capability of the BP neural network is highly dependent on the training samples, making it somewhat over-reliant on these samples. If the samples are selected improperly, it may result in poor performance of the BP neural network model, failing to achieve the expected performance. Due to the complexity of engineering projects and the multitude of factors influencing project costs, selecting different influencing factors as indicators may lead to varying prediction results.

5. Current research status and future directions

Presently, BP neural networks have achieved some success in the field of safety risk assessment for bridge construction [25]. However, as the field continues to evolve with increasing demands, there are still challenges and issues that need to be addressed for future development.

First, one key direction for future research is the improvement of data collection and processing technologies. The environment of bridge construction is complex and dynamic, which poses numerous challenges to data collection, including wide geographical distribution and high deployment costs of sensor networks. Therefore, researchers need to focus on enhancing data collection devices to improve the quality and real-time nature of the data. The application of next-generation sensor technologies, remote sensing techniques, and Internet-of-things technologies is expected to enhance the efficiency of data collection and transmission, providing more reliable data support for risk assessment.

Secondly, future research could explore how to integrate other artificial intelligence technologies, such as deep learning and reinforcement learning to further enhance the accuracy and efficiency of risk assessment. Deep learning excels in handling complex data and pattern recognition, which is suitable for feature extraction and model training. Reinforcement learning can assist models in learning from continuous trial and error, continually optimizing risk assessment strategies. Combining these technologies with BP neural networks holds the potential to further improve the performance and adaptability of the model.

Lastly, the integrated application of multimodal data is a promising direction for future research. In addition to traditional data types like numerical and textual data, multimodal data sources such as images, sounds, and videos contain rich information for a more comprehensive risk assessment. For instance, image recognition technology can be used to monitor the physical status of construction sites, sound data can detect abnormal noises, and video data can facilitate real-time monitoring of construction processes. Combining these multimodal data with BP neural networks can achieve a more comprehensive risk assessment and prediction.

6. Conclusion

The BP neural network possesses strong capabilities in pattern recognition and data fitting as an artificial neural network. Its application in bridge engineering project safety management continuously exhibits its functionality, thus attracting an increasing number of researchers to delve deeper into the subject. A substantial amount of researches indicate that applying BP neural networks to bridge engineering management significantly improves the accuracy of project cost estimates, hence effectively controlling corporate costs.

In conclusion, BP neural networks, have broad prospects in the safety risk assessment of bridge construction as an effective artificial intelligence technology. Through continuous research and improvement, their application in this field can be further enhanced, ensuring the safe progress of bridge construction projects.

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