Research on the Prediction of Geometric Irregularity of Railway Track Based on BP Neural Network

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Abstract. Traditional data analysis methods and methods are difficult to effectively mine and analyze a large number of Rail Geometry state data, which makes the value of data cannot be fully utilized and played. Based on this, this paper first analyses the characteristics of railway track geometric irregularity, then studies the BP neural network prediction method and steps of railway track geometric irregularity, and gives its prediction effect.

Keywords: Geometric Irregularity, BP Nerve Network, Railway Track

1. Introduction

With the iterative progress and maturity of intelligent tech represented by nerve network, it has been widely and deeply studied and applied in many fields, especially in the transportation field represented by railway track, which greatly promotes the development and progress of railway track [1]. As one of the important measures to ensure the normal operation of railway track, the scientific maintenance of railway track is an important matter of railway public works management. In order to ensure the scientific development and implementation of the maintenance plan of railway track, an important premise is the reasonable and accurate evaluation and prediction of the quality of railway track. As one of the important indicators to reflect the quality of rail, the geometric state of rail track will be affected by many internal and external factors as shown in Figure 1 below.
For this reason, mainly through the use of dynamic and static detection methods, such as manual static detection and rail car dynamic detection to obtain the track geometry state data.

On the other hand, with the continuous growth and progress of domestic railway transportation, the current railway track operation has accumulated a lot of track state data. However, the traditional data analysis methods and methods are difficult to effectively mine and analyze a large number of track geometry state data, which makes the value of data cannot be fully utilized and played. At present, there are mainly regression analysis, fractal theory, double analysis method, Kalman filter method and non-equal time interval grey time-varying parameter model for the prediction and analysis of rail geometry [2]. These research methods lay a more scientific research data support for the prediction of rail geometric state, but the above methods cannot well meet the prediction of Rail ride comfort of heavy haul railway.

BP nerve network has AI intelligent characteristics, which can accurately predict the change law of rail state based on the detection data of rail state [3]. According to the typical trend and characteristics of Rail ride, combined with BP nerve network, it can effectively verify the track irregularity detection data of heavy haul railway, and establish a prediction model to realize the iterative optimization of the prediction model.

In short, with the development of high-speed passenger railway and heavy haul freight railway, the current railway system puts forward more stringent requirements for the safety, stability and efficiency of the track. Under the development background of high speed and heavy load, the railway track bears more impact and load, which makes its geometric smoothness greatly affected [4]. Therefore, the prediction and analysis of railway track geometric irregularity is helpful to the scientific analysis of railway track failure speed and failure law, so as to provide a reasonable basis for the effective railway maintenance plan. Therefore, the trend prediction of track irregularity based on BP nerve network has important practical value for arranging rail maintenance plan and realizing reasonable allocation of maintenance resources.

2. Irregularity of geometric shape and position of railway track

2.1. Definition and basic properties of track irregularity

Track irregularity refers to the deviation of track geometry, size and spatial position from its normal state [5]. For example, if the straight track is uneven or not straight, the deviation from the correct size of the track center line position, height and width; if the curved track is not smooth, the deviation from
The correct curve center line position and the correct superelevation, gauge and slope change value. In addition, the irregularity of track geometry has universality, randomness, and dynamics and wavelength characteristics, as shown in Table 1 below.

Table 1. Properties of track irregularity

| Features          | Properties                                      | Influence factors                          |
|-------------------|-------------------------------------------------|--------------------------------------------|
| Universality      | Irregularity is common in any track structure   | Complexity of railway track structure     |
| Randomness        | Track irregularity waveform is a kind of complex random wave | Rail wear and damage, sleeper spacing |
| Dynamism          | The amplitude and wavelength of track irregularity are different | The influence of dynamic factors |
| Wavelength        | The random track irregularity is wavy variation | Status and grade of the line |

2.2. Types of track irregularity

There are many types of track geometric irregularity, which can be effectively divided according to the direction of its exciting effect on locomotives and vehicles; according to the wavelength characteristics of track irregularity; according to the shape characteristics of track irregularity and whether there is wheel load effect when showing records [6]. According to the direction of excitation to railway vehicles, track irregularity can be divided into height, level, twist, track gauge, track direction and composite irregularity. Among them, the height irregularity refers to the vertical irregularity in the length direction of the rail top surface, which can be further divided into left rail and right rail. Secondly, horizontal irregularity refers to the height difference of the corresponding points of the left and right rails on each cross section of the rail top length direction.

In addition, the track plane twist irregularity refers to the twist state of the top surface of the left and right rails relative to the corresponding track plane, which can be measured by the algebraic difference of the horizontal amplitude of two cross sections separated by a certain distance, as shown in Figure 2 below. Track gauge irregularity is due to the deviation of the inner distance between the left and right rails relative to the standard track gauge at the same cross section of the track [7]. Track irregularity refers to the lateral convex concave irregularity of the rail gauge point along the length direction relative to the baseline, and the lateral uneven residual deformation accumulation of the track row. The actual track irregularity is generally compound, including both track irregularity and horizontal irregularity.
2.3. Evaluation and prediction method of track smoothness

The influence and experience of track irregularity on locomotive and vehicle response is an important basis for evaluating and diagnosing track irregularity [8]. At present, the common evaluation methods of track irregularity are local irregularity amplitude overrun score method and track quality index method. The former evaluates the track quality by calculating the total deduction points according to the track local irregularity overrun level from the angle of track geometric dimension index and dynamic index. The latter reflects the deterioration degree of track state from the perspective of discreteness and track quality balance, and is a comprehensive index to measure the overall quality state of track section, which is an important means for macro management and quality control of track quality state. The standard deviation of the single geometric irregularity amplitude is called single index, and the sum of single index is used as the track quality index to evaluate the comprehensive quality state of track irregularity of the unit section, as shown in the following formula 1:

$$TQ = \sum_{i=1}^{7} \sigma^i = \sum_{i=1}^{7} \sqrt{ \frac{1}{n} \sum_{j=1}^{n} (x_{ij} - x^i)^2 }$$  \hspace{1cm} (1)

3. Prediction of geometric irregularity of railway track based on BP nerve network

3.1. The structure of BP nerve network

The structure of BP nerve network includes multilayer feedforward network, input-output relationship and so on [9]. Among them, the multilayer feedforward network includes all the neurons between the front layer and the back layer, and there is no connection between the neurons in the same layer. Its structure is shown in Figure 3 below. At the level of input-output relationship, the activation function usually adopts S-shape function; at the level of output, the activation function mostly adopts purelin function. Generally speaking, BP network with one hidden layer can approximate any nonlinear function with any precision.
3.2. Learning algorithm process of BP network

The learning algorithm of BP network inputs the specimens into the nerve network to get the actual output of the network. If the error between the output value and the expected output does not meet the accuracy requirements, the error is back propagated from the output layer, so as to adjust the weight and threshold, so that the error between the output value and the expected output of the network is gradually reduced until the accuracy requirements are met. The learning process is signal forward propagation + error back propagation [10]. In the process of BP learning, firstly, the specimens are selected, the initial weight matrix is determined randomly, and the network output is calculated by using the specimens to get the error. Secondly, the sensitivity of each layer is calculated by using the error, and the weight and threshold are updated until the error meets the accuracy requirements.

3.3. Prediction of BP nerve network

BP nerve network is used in the process of prediction. Firstly, the training set / test set is generated. Secondly, create / train BP network, create or train RBF network and train PNN network. In addition, the simulation test is carried out to complete the performance evaluation. The training specimens are used for network training, and the test specimens are used to test the generalization ability of the network. The fundamental task of training nerve network is to ensure that the trained network model has high generalization adaptable to the non-training specimens, that is, to effectively approach the inherent laws contained in the specimens, rather than to see the fitting ability of the network model to the training specimens.

3.4. BP nerve network prediction steps of railway track geometric irregularity

Firstly, specimens are collected, normalized, training specimens and test specimens are randomly selected to carry out BP network newff / train. Secondly, at the performance evaluation level, test specimens are used to calculate the prediction error, which is used to evaluate the generalization ability of the network. If the generalization ability meets the requirements, the trained BP nerve network can be used for prediction / classification. Otherwise, it should to adjust the network parameters to continue learning until the generalization ability reaches the requirements. In addition, both BP and RBF networks can be used in the prediction, and each has its own advantages and disadvantages; the performance comparison test set error of the two networks is given in the model evaluation.
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Based on the change characteristics of track irregularity, aiming at the track irregularity state, BP nerve network is used to predict the section standard deviation of the detection data, and the double hidden layer BP network model has higher prediction accuracy. The increase of the number of hidden layers is helpful to improve the accuracy of network prediction. In a word, to master the dynamic quality of track irregularity from the data of track inspection vehicle is helpful to guide the line maintenance work scientifically and realize the scientific maintenance and management of track.

4. Conclusion

In summary, the prediction and analysis of railway track geometric irregularity based on BP nerve network is helpful to the scientific analysis of railway track failure speed and failure law, so as to provide a reasonable basis for effective railway maintenance plan. Based on the study of the irregularity of railway track geometry, this paper analyzes the definition, basic properties and evaluation method of track irregularity. Through the analysis of the definition and basic properties of track irregularity, the prediction method and steps of BP nerve network are studied, and the prediction effect is analyzed.

Acknowledgments

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