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Research on a Prediction Algorithm of Bridge Engineering Mechanics Parameters based on Deep Learning

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Abstract

With the increase of the span of cable-stayed bridge, the influence of geometric nonlinear factors in engineering mechanics is becoming more and more obvious, so it is necessary to seek the construction alignment prediction method of long-span cable-stayed bridge considering the influence of geometric nonlinearity. In this paper, we analyze the basic principle and improvement measures of BP neural network algorithm, establish a prediction model with the help of Matlab language, and discuss its application in the construction control of long-span cable-stayed bridge. Taking a large span steel box girder cable-stayed bridge with a main span of 1088m as the engineering background, the rationality and feasibility of this method are verified, which provides a reference for the alignment control of the same type of bridge.

Keywords

Cable-stayed Bridge; BP Neural Network; Linear Prediction; The Construction Process.

1. Introduction

Since the 1980s, cable-stayed Bridges have begun to develop in the direction of larger span. At present, there are 4 cable-stayed Bridges whose main span is more than 800m, among which there are 2 cable-stayed Bridges over km. The construction control of cable-stayed Bridges is becoming one of the key technologies to ensure the successful construction of cable-stayed Bridges[1]. However, the construction process of cable-stayed bridge is a strong error lag system. When a large error is found and then adjusted, the adjustment effect will not be good. The best method is to establish a prediction model, predict the future error, according to the identified error and prediction error, determine the current stage of adjustment [2].

With the increase of the span of cable-stayed Bridges, the influence of geometric nonlinearity becomes more and more prominent. Therefore, it is necessary to explore the linear prediction method suitable for the geometric nonlinearity of very large span cable-stayed Bridges. The methods used for bridge construction control include least square method, Kalman filtering method, grey theory and so on. compared with artificial neural network, artificial neural network has the following characteristics: it does not need to establish a specific mathematical model, but just gives the existing data to the network. establish a multi-parameter and nonlinear mapping relationship between input and output.

The influence of noise is inevitable in the construction control of long-span cable-stayed bridge. Neural network can tolerate noise better than other methods and has good fault tolerance. When individual processing units are damaged or some information is lost, the impact on the whole system will not be too great, and the system can still work normally, so it has high robustness[3].

The neural network method predicts the specific factors that affect the construction control, analyzes the error of the control target through the error of the influencing factors, and can identify the influence of various parameters on the alignment and cable force. As long as the factors affecting construction control are correctly considered and reasonably selected, better predictive control of construction can be carried out.

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2. A brief description of BP neural network

For BP neural network algorithm, the three-layer perceptron model can solve the general engineering problems. The so-called three-layer model includes the input layer, the hidden layer and the output layer. The model structure is shown in Figure 1.

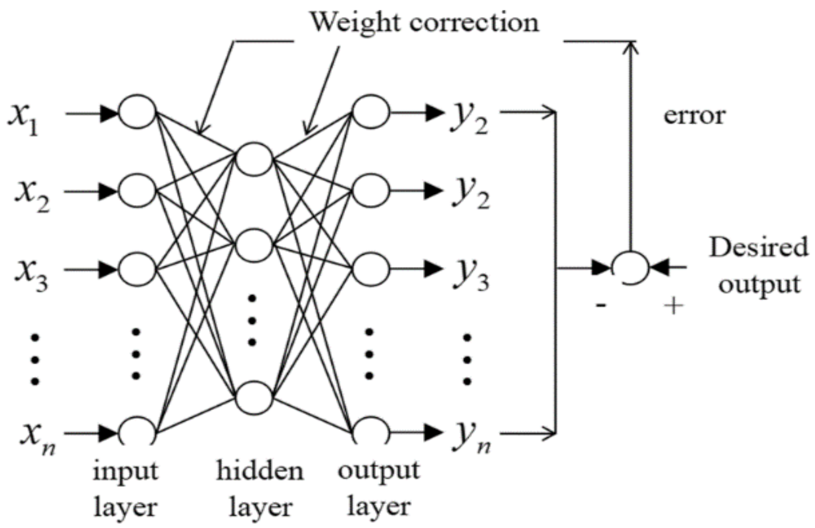

Figure 1. BP neural network

3. BP neural network model for linear Prediction of cable-stayed Bridges with large span steel box Girder

3.1 Calculation model

The span of a large span cable-stayed bridge is 100m + 100m + 300m + 1088m + 300m + 100m + 100m + 100m + 100m.The structure is arranged with concrete cable towers, flat streamlined steel box beams and spatial double cable planes. There are a total of 8×34 pairs of cable cables in the whole bridge, and 2 auxiliary piers are set on the side span. The construction process is as follows: the beam section of block no. 0 at the side span of about 340m and the cable tower adopts the construction method of floating transport and lifting, first simply supported and then continuous; Then, the double cantilever is constructed symmetrically to beam no. 10 to realize the side span closure. Then single cantilever construction to the middle span no. 34 beam section, to achieve the middle span closure.

3.2 Input and output parameters selection

According to the characteristics of structural behavior during the construction of large span cable-stayed bridge, the key factors affecting the bridge elevation are analyzed and screened comprehensively, and the input and output parameters are determined as follows.

3.2.1. Temperature T (℃) at the time of measurement

The temperature change has a great influence on the deformation of the bridge structure, especially for the steel box girder which is sensitive to temperature, the observed value of the elevation of the main beam is a function of temperature under different atmospheric temperature and different time conditions.

Generally speaking, the influence of temperature on bridge structure can be divided into two kinds: one is the influence of sunshine temperature difference, the other is the influence of seasonal temperature difference.

In order to minimize the influence of sunshine temperature difference on box girder, the construction process of steel box girder is generally arranged at night when the temperature field is relatively stable, and the measurement is also arranged at night when the temperature change is small.

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However, the influence of seasonal temperature difference is difficult to overcome in the process of construction, so only the influence of long-period variation of seasonal temperature is considered, and the field temperature measured during the installation of steel box girder is taken as the input parameter of the network model.

3.2.2. Theoretical cable force of construction beam section F (kN)

The cable is the main load-bearing member of the main beam, so the line shape of the main beam is greatly affected by the change of cable force.The change of cable force will directly affect the stress of steel box girder and the deformation of bridge deck. The cable force state is an index reflecting the internal force state of the whole bridge.Therefore, the theoretical cable force of the beam end during construction is taken as the input parameter of the network model.

3.2.3. Cantilever length L (m)

With the progress of construction and the installation of steel box girder, the distance between construction beam section and the center of Block 0 will be more and more distant, and the influence of construction unit on the elevation of cable-stayed bridge main girder will also increase.Therefore, the cantilever beam length is taken as the input parameter of the network model.

3.2.4. Construction beam dead weight G (kN)

The weight of the beam itself has a great influence on the alignment of the bridge deck, which has been explained in many literatures and will not be repeated in this paper.Therefore, the beam section weight is taken as the input parameter of the network model.

3.2.5. Beam section theoretical elevation H (m), beam section theoretical elevation (considering the effect of temperature) and measured elevation △H (cm)

Theoretical elevation is the key reference data of cable-stayed bridge alignment. During the whole construction process of box girder erection, the difference between measured elevation and theoretical elevation (considering the influence of temperature) reflects the error of actual bridge alignment and designed bridge alignment. Therefore, theoretical elevation is taken as the input parameter of the network model, and the difference between measured elevation and theoretical elevation (considering the influence of temperature) is taken as the output parameter of the model.

3.3 Matlab language implementation of BP neural network model

BP neural network needs to learn a certain number of samples before prediction to judge the quality of network training and test the reliability of the established network training model.In this paper, the parameter data of NJ11~NJ19 beam section of beitajiang River under single cantilever construction of the model are used as training samples to predict the linear error of NJ20 beam section.

The samples that need to be trained were injected into the model, and the network simulation was carried out. After the simulation output was obtained, the reverse normalization was carried out and compared with the target value, so as to verify the effect of network training and judge whether the network model could better reflect the objective law. The data comparison results are shown in Table 1.It is generally believed that the number of validation samples with relative error less than or equal to 10% accounts for more than 60% in the validation sample set, and the established model has practical value.As can be seen from the data in Table 1, the maximum difference between the simulation value and the target value is 0.16cm, with a relative error of 2.22%, indicating that the simulation value is in good agreement with the target value, and the network training and simulation can better reflect the actual linear deviation.

According to the above analysis, the structure of the network is reasonable and the convergence is good, so the network can be used for linear prediction. After the neural network learns the samples of the NJ11#~NJ19# beam section by itself, the network only needs to input the relevant parameter information of the NJ20 # beam section to output the predicted value of the linear deviation of the beam section after tension. the result is shown in figure 2. In order to better evaluate the prediction results of the BP neural network model, this paper predicts the alignment of the NJ20#~NJ23# beam section respectively.

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Table 1. Comparison table of simulation value and target value

Beam segment number	The target	Simulation value	Absolute difference	Relative difference
NJ11	8.08	8.16	0.08	1.00
NJ12	7.87	7.86	-0.01	0.18
NJ13	11.38	11.34	-0.04	0.31
NJ14	5.57	5.70	0.12	2.22
NJ15	19.82	19.83	0.01	0.05
NJ16	19.46	19.50	0.04	0.22
NJ17	10.87	10.78	-0.09	0.85
NJ18	11.48	11.64	0.16	1.41
NJ19	20.02	11.92	-0.11	0.53

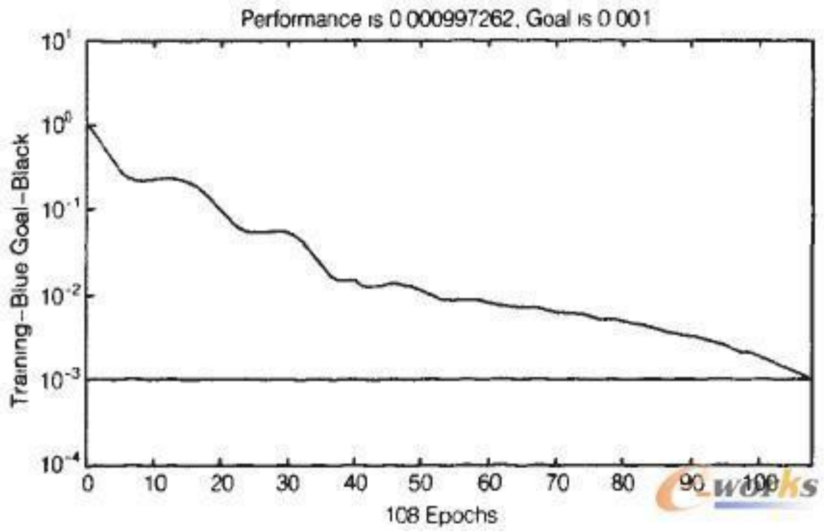

Figure 2. Prediction results of NJ20# beam section alignment

The prediction results are shown in Table 2. The prediction alignment deviation of the NJ21# beam section is the largest, which is-1.01cm, the relative error is 4.36%, and the other deviations are less than 1cm. Using BP neural network to predict the alignment in the construction process of long-span cable-stayed bridge is feasible and applicable.

Table 2. Comparison between predicted results and measured results

Beam segment number	The target	Simulation value	Absolute difference	Relative difference
NJ20	20.64	20.11	-0.53	2.57
NJ21	23.14	22.13	-1.01	4.36
NJ22	22.26	22.9	0.64	2.88
NJ23	19.25	18.69	-0.56	2.91

4. Conclusion

Due to the significant influence of geometric nonlinear factors, the traditional linear prediction method of long-span cable-stayed bridge is not suitable. BP neural network can consider the independent influence factors of cable-stayed bridge construction control at the same time, and has good nonlinear mapping characteristics, so it is suitable for complex network modeling and control. In this paper, according to the basic principle of BP neural network and with the help of Matlab neural network toolbox, BP neural network computer predictive control is realized. Taking a long-span cable-stayed bridge as a calculation model, the feasibility and practicability of this method in the

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construction control of extra-large span cable-stayed bridge are verified, and a good effect is obtained, which can be used as a reference for the construction control of the same type of bridge.

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