Equipment Management Performance Evaluation Method Based on Improved Wavelet Neural Network

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Abstract. Because there are many factors affecting enterprise equipment management, the performance evaluation of equipment management is uncertain, and the existing evaluation methods are too subjective. In order to improve this problem, this paper proposes a new method of equipment management performance evaluation using sparrow search algorithm to improve wavelet neural network. Firstly, according to the characteristics of equipment management, the performance evaluation index system of equipment management is established. Secondly, the Sparrow Search Algorithm is used to improve the evaluation accuracy and convergence speed of the Wavelet Neural Network. Finally, the equipment management performance evaluation model is constructed, and the case analysis is carried out. The analysis shows that compared with other neural networks, the improved Wavelet Neural Network has faster convergence speed and better fitting effect, and can effectively carry out equipment management performance evaluation.

Keywords: equipment management · performance evaluation · neural network

1 Introduction

As an important part of enterprise management, equipment management is an important link for enterprises to improve productivity. With the continuous improvement of enterprise equipment level in recent years, the effect of equipment management largely determines the productivity level of enterprises. Accurate and efficient performance evaluation of equipment management is helpful to measure the quality of equipment management and optimize the content of equipment management.

Equipment management in a broad sense includes not only enterprise equipment management, but also other equipment management. At present, the performance evaluation of equipment management has been studied deeply and comprehensively at home and abroad. Li et al. [1] carried out a performance evaluation for maintenance, Maintenance, Repair &Operations (MRO) management of high-end equipment and established a performance evaluation model of the MRO management index by using Decision Making Trial and Evaluation Laboratory (DEMATEL) and improved Analytic Network

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Process (ANP). Huang et al. [2] used ANP to establish an evaluation model for equipment management in the petrochemical industry, focusing on analyzing the company's financial performance, logistics support, service level, learning and innovation, risk control, and other aspects of petrochemical equipment management. Tsarouhas et al. [3] evaluated the effectiveness of equipment management based on reliability indexes such as availability and mean time between failures. Lu et al. [4] evaluated the key indicators of medical equipment by acquiring the basic data on the operation of equipment and using the information system to measure the management performance in the operation of equipment. Through the analysis, it is found that for the evaluation process of equipment management performance evaluation, scholars at home and abroad generally establish the evaluation index system first, then select the evaluation method, and finally construct the evaluation model. In view of the performance evaluation of weapons and equipment management, scholars at home and abroad have also carried out beneficial exploration. Shen and Zhang [5] carried out an equipment management performance evaluation for synthetic troops based on the cloud model and evidence theory, effectively overcoming the shortcomings of fuzziness and uncertainty in the evaluation process. Shen and Zhang et al. [6] proposed an equipment management performance evaluation index system based on the three-dimensional integration of "management culture", "management process" and "management effect" in the construction of the index system of military equipment management. Su [7] used a fuzzy comprehensive evaluation method to evaluate the management performance of radar equipment of the Air Force to overcome the subjective randomness in the evaluation process. Xu et al. [8] established an evaluation index system based on input and output, improved Data Envelopment Analysis (DEA), and applied it to the performance evaluation of radar equipment management. The above literature evaluates the performance of different equipment management tasks, but the methods adopted are mostly analytical, and it is difficult to overcome the influence of personal experience on the evaluation results during the evaluation process. As a new performance evaluation method that has developed rapidly in recent years, neural network can avoid the difference of evaluation results caused by subjectivity, but it is rarely used in the performance evaluation of enterprise equipment management.

Therefore, this paper proposes a performance evaluation method of equipment management based on sparrow search algorithm and wavelet neural network. This method takes enterprise equipment management as the research object, constructs the equipment management performance evaluation index system considering the process and effect of equipment management.

2 Basic Knowledge

2.1 Sparrow Search Algorithm

Sparrow Search Algorithm (SSA) [9] is an intelligent search algorithm proposed by Xue in 2020 to simulate sparrow foraging and anti-predation. This algorithm has the advantages of good searchability, strong robustness, and fast convergence. The algorithm has the following definition.

Definition 1 Discoverer position update policy

$$X_{i,j}^{t+1} = \begin{cases} X_{i,j}^{t} \cdot \exp\left(-\dfrac{i}{\alpha \cdot iter_{\max}}\right) & R_1 < ST \\ X_{i,j}^{t} + Q \cdot L & R_1 \geq ST \end{cases} \tag{1}$$

t represents the number of iterations; $iter_{\max}$ represents the maximum number of iterations; $X_{i,j}^{t}$ represents the position of sparrow i in dimension j at moment t; α and Q are random numbers; R_1 and ST represent the early warning value and the safety value respectively. When the early warning value is higher than the safety value, the sparrow needs to escape from the predator as soon as possible; otherwise, it means that it can search for food. L is a matrix of 1*m.

Define 2 Accession location update policy

$$X_{i,j}^{t+1} = \begin{cases} Q \cdot \exp\left(\dfrac{X_{worst} - X_{i,j}^{t}}{i^2}\right) & i > \dfrac{n}{2} \\ X_{\mathrm{p}}^{t+1} + \left|X_{i,j}^{t} - X_{\mathrm{p}}^{t+1}\right| \cdot A^{+} \cdot L & \text{others} \end{cases} \tag{2}$$

X_{p} represents the current optimal position; X_{worst} is the current worst position; A^{+} represents a matrix of 1*m, where each element is randomly assigned 1 or -1, and $A^{+} = A^{T}\left(AA^{T}\right)^{-1}$; When i > n/2 indicates that sparrow i has not obtained food and needs to go elsewhere to find food.

Define 3 Alert position update strategy

$$X_{i,j}^{t+1} = \begin{cases} X_{best}^{t} + \beta \cdot \left|X_{i,j}^{t} - X_{best}^{t}\right| & f_i > f_g \\ X_{i,j}^{t} + K \cdot \left(\dfrac{\left|X_{i,j}^{t} - X_{worst}^{t}\right|}{(f_i - f_w) + \varepsilon}\right) & f_i = f_g \end{cases} \tag{3}$$

X_{best}^{t} is the current global optimal; β is the parameter that controls the step size; K is a random number between -1 and 1; ε is an extremely small constant to avoid having a zero denominator; f_i represents the fitness value of the current sparrow; f_g and f_w represent the current best and worst fitness values respectively. If f_i and f_g are equal, the sparrow is in the middle of the population. If they are not equal, the sparrow is dangerous and on the edge. Vigilance generally accounts for 10% ~ 20% of the population.

2.2 Wavelet Neural Network

Wavelet Neural Network (WNN) is a neural network based on BP neural network. It replaces the Sigmoid activation function of the hidden layer in the BP Neural Network with a wavelet function. The WNN can realize careful search of local information through scaling and shifting and has better fitting and optimization ability. Its topology is shown in Fig. 1.

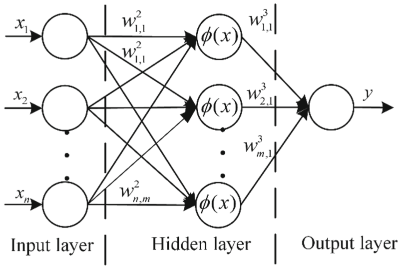

Fig. 1. Topology of wavelet neural network

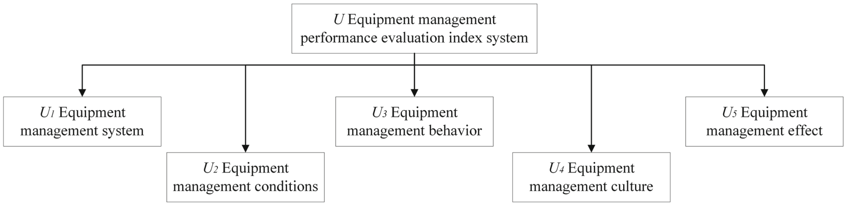

Fig. 2. Equipment management performance evaluation index system

3 Construction of Equipment Management Performance Evaluation Index System

According to relevant literature and construction principles, the equipment management index system has five evaluation indexes, which are equipment management system, equipment management conditions, equipment management behavior, equipment management culture, and equipment management effect, as shown in Fig. 2.

The specific meaning of each indicator is shown in Table 1.

4 Construction of Equipment Management Performance Evaluation Model Based on Improved Wavelet Neural Network

4.1 Index Data Measurement

Because of the different measurement standards of each index in the equipment management performance evaluation index system, it is not convenient to use the original data directly to train the neural network. Based on G.A. Miller's hierarchical quantization theory and extending it, the collected original data are quantified on a unified scale from 10 to 1 according to the effect.

(1) Equipment management system

The equipment management system mainly investigates the inspection and supervision and system standards in the process of carrying out equipment management. Assume that the equipment management unit carries out annual equipment management inspection times of C_i (i = 1,2,3) in the first three years respectively. In the case

Table 1. Meaning of evaluation index

Index type	Indicator meaning
Equipment management system	The main investigation is equipment management in the process of system standards and inspection and supervision.
Equipment management conditions	It mainly investigates the human, material and financial resources required in the process of equipment management.
Equipment management behavior	It is used to investigate whether the measures taken in the process of equipment management are helpful to the management of equipment.
Equipment management culture	Measure whether the publicity and education work in equipment management is in place.
Equipment management effect	It is used to investigate the management effect, technical performance, and intact degree of equipment.

of a standardized management system, the preliminary test score is 10 points, and the deduction system is adopted. For the lack of equipment use management system, equipment storage system, equipment grading system, and other systems, 0.2 ~ 1 point is deducted for each missing item, and the sum of deduction points is I. The performance score of the equipment management unit in the equipment management system is shown as (4).

$$U_1 = \begin{cases} \dfrac{\frac{\sum_{i-1}^{3} C_i}{3c} \times 10 + (10 - I)}{2} & 3c > \sum_{i-1}^{3} C_i \\ \dfrac{10 + (10 - I)}{2} & 3c < \sum_{i-1}^{3} C_i \end{cases} \tag{4}$$

(2) Equipment management conditions

Equipment management conditions mainly investigate the construction of manpower, material resources, financial resources, and other elements used to carry out equipment management. The main measurement criteria include whether the types and quantities of goods used for equipment management meet the standards, whether the number of people carrying out equipment management meets the standards, and the necessary funds for equipment management. The unit's performance score in equipment management condition can be expressed as (5).

$$U_2 = \frac{\sum_{i=1}^{5} \frac{f_i}{F_i}}{5} \times 10 \tag{5}$$

$f_1 \sim f_5$ respectively represents the type of equipment, the quantity of equipment, the number of equipment management personnel, the number of professional pairs of management personnel, and the status of equipment management funds, and represents the theoretical status of each index of the unit.

(3) Equipment management behaviour

Equipment management behavior refers to whether the equipment training rate and training plan implementation rate meet the standard. Set the equipment training rate as P_1 and the training plan implementation rate as P_2. . The performance score of the unit's equipment management behavior can be expressed as (6).

$$U_5 = \frac{R_1 + R_2}{2} \times 10 \tag{6}$$

(4) Equipment management culture

Equipment management culture mainly refers to the management atmosphere and publicity and education. A questionnaire survey was used to measure employees' average satisfaction with management atmosphere and publicity and education. The unit equipment management culture score can be expressed as (7).

$$U_4 = S \times 10 \tag{7}$$

(5) Equipment management effect

The device management effect refers to the state in which the device maintains working performance through management, which is mainly measured by reliability indicators such as availability and integrity. Make unit equipment available, and integrity. The unit equipment management effectiveness score can be expressed as (8).

$$U_5 = \frac{R_1 + R_2}{2} \times 10 \tag{8}$$

4.2 Equipment Management Performance Evaluation Model Based on SSA-WNN

By combining the wavelet neural network with the sparrow search algorithm, the initial optimal parameter set in the wavelet neural network is determined by using the good searchability and robustness of the SSA algorithm. Then the initial optimal parameter set is input into WNN, and the excellent local optimization ability of WNN is used to carefully search for the optimal solution, and the final parameters are determined. Finally, SSA-WNN is used to evaluate maintenance support capability. Figure 3 shows the running flow of SSA-WNN.

In SSA-WNN, $X = (x_1, x_2, \ldots, x_n)^T$ is the input, $Y = (y_1, y_2, \ldots, y_k)^T$ is the output, n is the number of nodes at the input layer, k is the number of nodes at the output layer, l is the number of hidden layers, m is the number of neurons at the hidden layer,

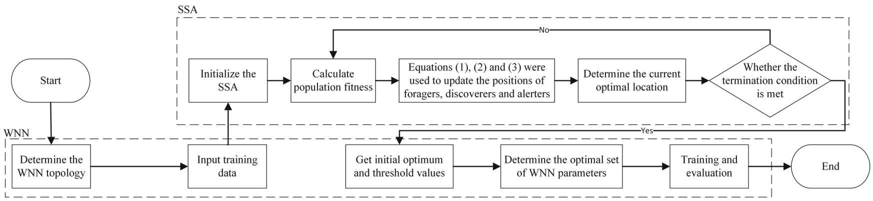

Fig. 3. SSA-WNN Running flowchart

W is the weight of each node, and V is the weight of the output node. The input of the hidden layer can be expressed as:

$$x_j^{l+1} = \sum_{i=1}^{n} W_{ij}^l x_i^l \tag{9}$$

The output of the hidden layer can be expressed as:

$$Z_j^l = \phi\left(\frac{x_j^l - b_j^l}{a_j^l}\right) \tag{10}$$

a_j^l and b_j^l represent translation and scaling parameters respectively. The initial optimal solutions of weight parameters and telescopic translation parameters can be determined by Eqs. (1) ~ (3). Is the wavelet basis function. Referring to the wavelet basis function in literature [10], this paper selects $\phi(x) = x \cdot \exp\left(-0.5x^2\right)$, the partial derivative of the Gaussian function, as the parent wavelet function.

The output of Wavelet Neural Network can be expressed as:

$$y(k) = \sum_{j=1}^{m} v_j^k Z_j^{l\max} \tag{11}$$

For each input sample, its single data error e_k is expressed as:

$$e_k = y_k - y_k' \tag{12}$$

where, y_k represents the actual value and y_k' represents the predicted value.

The total error function E is expressed as:

$$E = \frac{1}{n} \sum e_k^2 \tag{13}$$

4.3 Equipment Management Performance Evaluation Process

The performance evaluation process of equipment management is shown in Fig. 4.

1) Construct an evaluation index system. According to the construction principle and process of the index system, the evaluation index system is established.

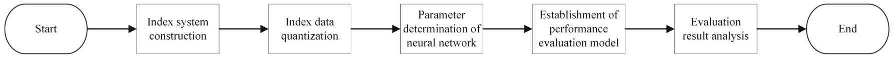

Fig. 4. Equipment management performance evaluation flow chart

2) Quantitative data indicators. The index data is quantified to facilitate neural network training.
3) Optimize neural network parameters. Using the quantized data, the neural network is trained to determine the optimal parameter set.
4) Establish an evaluation model. Construct a complete equipment management evaluation model.
5) Analysis of evaluation results.

5 Example Analysis

The collected 75 groups of equipment management capability evaluation data of an equipment management unit within a period were quantified according to Sect. 4.1, and the first 50 groups were used to train the neural network. The last 25 groups are taken as test data, as shown in Table 2.

To verify the superiority of this method, the proposed method is compared with BP Neural Network and unimproved Wavelet Neural Network. The predicted values of the three neural networks were compared with the actual values, and the errors of 25 groups of test data were collected. Take the absolute value of the error and plot the image. The

Table 2. Competency assessment test data set

Serial number	U_1	U_2	U_3	U_4	U_5	Actual appraisal value	Serial number	U_1	U_2	U_3	U_4	U_5	Actual appraisal value
1	8.2	8.4	9.8	8.4	9.3	8.7	14	8.9	9.8	8.0	10.0	9.2	9.1
2	9.6	10.0	9.2	8.0	10.0	8.7	15	8.2	8.0	9.7	7.7	9.2	8.4
3	8.2	8.6	8.1	10.0	9.6	8.6	16	8.5	9.1	9.2	9.3	9.9	9.2
4	9.2	10.0	7.1	9.3	9.7	8.6	17	8.2	8.8	8.7	7.4	9.8	8.3
5	6.4	7.6	10.0	9.2	9.5	9.0	18	6.7	7.2	7.8	10.0	10.0	7.8
6	8.1	8.8	8.3	10.0	9.8	8.8	19	8.2	8.7	8.6	10.0	10.0	9.1
7	7.7	8.0	9.0	9.9	9.5	8.9	20	7.7	7.5	8.8	9.3	10.0	8.5
8	6.9	8.9	9.5	9.7	10.0	8.6	21	7.5	9.8	7.4	9.2	8.1	8.1
9	9.0	8.9	9.0	10.0	8.2	9.2	22	7.3	8.3	9.1	6.8	7.1	7.2
10	8.8	6.1	8.0	10.0	7.5	7.8	23	8.0	9.9	8.1	9.9	10.0	8.8
11	8.5	7.0	8.4	9.5	8.3	8.2	24	6.5	7.9	8.8	7.1	7.6	7.2
12	7.2	6.9	8.8	8.6	8.3	7.5	25	9.5	8.9	9.2	7.0	9.5	8.1
13	9.6	8.7	10.0	8.6	9.0	9.2							

prediction results of the three neural networks are shown in Table 3, and the error curve is shown in Fig. 5.

As can be seen from Table 3 and Fig. 5, BP neural network has the worst fitting effect. The maximum error is 27.7% and the average error is 7.1%. The error fluctuation of wavelet neural network is better than that of BP neural network. The average error is 3.6%. The wavelet neural network optimized by Sparrow search algorithm has the smallest fluctuation, and the average error is only 2.4%. The improved wavelet neural network is the best in the stability and accuracy of prediction, which proves that this method is very suitable for the performance evaluation of equipment management.

Table 3. Comparison of prediction results by different methods

Serial number	BP Neural Network	WNN	Improved WNN	Actual estimated value	Serial number	BP Neural Network	WNN	Improved WNN	Actual estimated value
1	9.0	8.7	8.7	8.7	14	8.7	8.6	8.7	9.1
2	9.0	8.3	9.1	8.7	15	8.4	8.5	8.3	8.4
3	7.9	8.5	8.4	8.6	16	8.8	8.8	9.1	9.2
4	8.1	8.4	8.5	8.6	17	7.0	8.2	8.2	8.3
5	8.0	8.4	9.0	9.0	18	8.1	8.1	7.7	7.8
6	7.7	8.5	8.5	8.8	19	8.8	8.7	8.7	9.1
7	8.7	8.5	8.6	8.9	20	8.4	8.1	8.4	8.5
8	8.6	8.7	8.8	8.6	21	8.6	7.3	8.0	8.1
9	8.9	8.7	9.0	9.2	22	8.6	7.6	7.4	7.2
10	9.0	8.1	7.8	7.8	23	8.6	8.6	8.6	8.8
11	6.9	8.2	8.1	8.2	24	9.2	7.2	7.2	7.2
12	7.2	8.0	7.9	7.5	25	7.4	8.4	8.4	8.1
13	9.4	8.9	9.1	9.2					

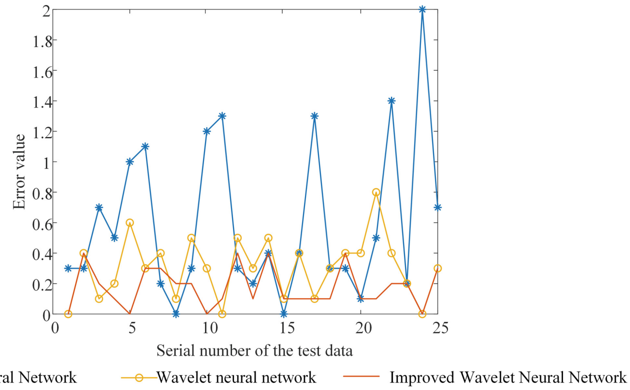

Fig. 5. Error comparison graph of prediction results

6 Conclusion

The main work and conclusions of this paper are as follows:

(1) Using Sparrow Search Algorithm to improve the wavelet neural network, so that it can overcome the subjectivity and randomness of traditional methods.
(2) Using the hierarchical quantization theory, the original data is quantified and scaled to make the data easier to be used for evaluation.
(3) Example analysis shows that this method has better stability and better evaluation effect compared with other neural network methods.

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