Performance Evaluation of Force Combat Training Based on AHP and BP Neural Network

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Abstract. In order to solve the problem of low accuracy and low efficiency of the actual combat training performance evaluation of the troops, a performance evaluation model of actual combat training based on AHP and BP neural network is proposed. AHP is used to establish a three-layer evaluation model, an indicator system is established, and the weights of each indicator are calculated and determined. The weights determined by AHP are used to score the actual combat training results of the troops, and ten sets of data are obtained for training BP neural network and evaluation, by calculating the relative error between the evaluation value and the real value, proves that the performance evaluation model of the actual combat training based on AHP and BP neural network effectively improves the accuracy and efficiency of the actual training performance evaluation, and has strong practical value.

Construction of Military Training Performance Evaluation Model Based on AHP and BP Neural Network

AHP

The steps of AHP are as follows [1]:

Establishing the Target Layer - the Criterion Layer - the Implementation Layer Structure.
The target layer is the analytical goal to be achieved, the criterion layer is the quasi-side on which the goal is achieved, and the implementation layer is the implementation plan or evaluation indicator.

Establish a Pairwise Comparison Matrix. According to the degree of importance, each factor of each layer is compared to and given a comparison matrix. The degree of importance is usually determined by the “9 scale method”.

Consistency Test and Weight Calculation.
Step1: Computational consistency indicator CI

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]  
\( \lambda_{\text{max}} \) is the largest eigenvalue of the comparison matrix, \( n \) is the matrix dimension.

Step2: For \( n = 1, 2, ..., 9 \), corresponding to the value of the mean random consistency indicator RI.

Step3: Calculate the consistency ratio CR

\[ CR = \frac{CI}{RI} \]

BP Neural Network

Principle of BP Neural Network [2,3]

In the BP neural network, the output signal of the previous layer is calculated as the input signal of the latter layer, and the input and output signals are calculated as (3)(4).
\[
Input_j = \sum_{i}^{N} w_{ij} x_i + b_j
\]  

(3)

\[
Output_j = f(Input_j)
\]  

(4)

Where \( Input_j \) and \( Output_j \) represent the input and output of the first neuron, \( j \) represents the weight between the \( i_{th} \) neuron of the previous layer and the \( j_{th} \) neuron of the latter layer, and \( b_j \) represents the threshold of the \( j_{th} \) neuron, \( x_i \) is the value of the input layer, \( f(x) \) is the sigmoid function, and the expression is

\[
f(x) = \frac{1}{1 + \exp(-x)}
\]  

(5)

**Force Training Performance Evaluation Model Based on AHP and BP Neural Network**

**Establish a Practical Training Hierarchical Model**

First, the problems of actual training evaluation are organized and hierarchical, and the three-layer structure model shown in Figure 1 is constructed.

Target layer: Target A is the performance evaluation of actual combat training.

Criteria layer: In order to achieve the goal A, the six criteria of B1~B6 are established, which are: B1 tightly combined with regulatory requirements, B2 importantness, B3 is good for assessment, B4 is comprehensive, B5 can be realized, and B6 is real-time assessment.

Scheme layer: Including the core training evaluation (C1), and the important training evaluation (C2). The core training evaluation indicators include: independent combat capability (D1), weapon operation capability (D2), technical support capability (D3), and protection emergency response capability. (D4), military skills (D5), and logistics support capabilities (D6). Important training evaluation indicators include: training attitude (D7), training method (D8), training ability (D9), professional knowledge application (D10), political work ability (D11), battlefield adaptability (D12).
Establish BP neural network

The neural network is set to a three-layer structure. The number of neurons in the input layer is 12, corresponding to D1~D12, and the number of neurons in the output layer is 1. Corresponding to the actual combat training performance of the troops, the number of intermediate layers is 5, which is determined according to the empirical formula (3); the neural network parameters are set to: the learning rate is 0.01, the training error is 0.001, and the maximum number of learning is 1000 times.

Instance Verification

Weight Determination

Establish judgment Table. According to the degree of influence of the criterion layer B1~B6 on the target A, the target layer—the criterion layer (A-B) judgment table is determined.

| A | B1 | B2 | B3 | B4 | B5 | B6 | W_{bi} |
|---|---|---|---|---|---|---|---|
| B1 | 1 | 1/3 | 1/3 | 1/5 | 1/5 | 1/5 | 0.43 |
| B2 | 3 | 1 | 1 | 1 | 1/3 | 1/3 | 0.15 |
| B3 | 3 | 1 | 1 | 1 | 1/3 | 1/3 | 0.15 |
| B4 | 3 | 1 | 1 | 1 | 1/3 | 1/3 | 0.15 |
| B5 | 5 | 3 | 3 | 3 | 1 | 1 | 0.06 |
| B6 | 5 | 3 | 3 | 3 | 1 | 1 | 0.06 |

According to the different degrees of influence of the six criteria B1~B6 on C1 and C2, the criterion layer—measurement layer (Bi-C, i=1, 2, ..., 6) judgment table is determined.

| Bi | C1 | C2 | W_{bi} |
|---|---|---|---|
| C1 | 1 | 1/5 | 0.833 |
| C2 | 5 | 1 | 0.167 |

| Bi | C1 | C2 | W_{bi} |
|---|---|---|---|
| C1 | 1 | 1/2 | 0.67 |

According to the different degrees of importance of D1~D6 and D7~D12, determine the measure layer—measurement layer (C1-D, C2-D) judgment table.

| C1 | D1 | D2 | D3 | D4 | D5 | D6 | W_{Ci} |
|---|---|---|---|---|---|---|---|
| D1 | 1 | 1 | 1 | 1/3 | 1/5 | 1/5 | 0.27 |
| D2 | 1 | 1 | 1 | 1/3 | 1/5 | 1/5 | 0.27 |
| D3 | 1 | 1 | 1 | 1/3 | 1/5 | 1/5 | 0.27 |
| D4 | 3 | 3 | 3 | 1 | 1/3 | 1/3 | 0.09 |
| D5 | 5 | 5 | 5 | 3 | 1 | 1 | 0.05 |
| D6 | 5 | 5 | 5 | 3 | 1 | 1 | 0.05 |

| C2 | D7 | D8 | D9 | D10 | D11 | D12 | W_{Ci} |
|---|---|---|---|---|---|---|---|
| D7 | 1 | 1/3 | 1/3 | 1/5 | 1/5 | 1/3 | 0.38 |
| D8 | 3 | 1 | 1 | 1/3 | 1/3 | 1 | 0.16 |
| D9 | 3 | 1 | 1 | 1/3 | 1/3 | 1 | 0.16 |
| D10 | 5 | 3 | 3 | 1 | 1 | 3 | 0.07 |
| D11 | 5 | 3 | 3 | 1 | 1 | 3 | 0.07 |
| D12 | 3 | 1 | 1 | 1/3 | 1/3 | 1 | 0.16 |
Consistency Test

The judgment matrix is listed according to the comparison judgment table, and the maximum feature roots \( \lambda_{\text{max}} \), CI, and CR are calculated, and the calculation results are shown in Table 4.

| matrix indicator | A-B | B1-C | B2-C | B3-C | B4-C | B5-C | B6-C | C1-D | C2-D |
|------------------|-----|------|------|------|------|------|------|------|------|
| \( \lambda_{\text{max}} \) | 6.081 | 2 | 2 | 2 | 2 | 2 | 2 | 6.081 | 6.081 |
| CI | 0.0016 | 0 | 0 | 0 | 0 | 0 | 0 | 0.016 | 0.016 |
| RI | 1.24 | 0 | 0 | 0 | 0 | 0 | 0 | 1.24 | 1.24 |
| CR | 0.013 | 0 | 0 | 0 | 0 | 0 | 0 | 0.013 | 0.013 |

As can be seen from Table 6, the judgment matrix satisfies the consistency requirement.

The total weight calculation formula is as follows

\[
W_n = \sum_{i=1}^{6} W_{bi} W_{bic} W_{cidn}, n = 1,2,...6
\] (6)

\[
W_n = \sum_{i=1}^{6} W_{bi} W_{bic} W_{c2dn}, n = 1,2,...6
\] (7)

The values of \( W_n \) can be calculated from equations (6) and (7) as shown in Table 5.

| D   | D1  | D2  | D3  | D4  | D5  | D6  | D7  | D8  | D9  | D10 | D11 | D12 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Wn  | 0.18| 0.18| 0.18| 0.07| 0.04| 0.12| 0.05| 0.05| 0.02| 0.02| 0.05|     |

Data Collection

According to 12 indicators of D1~D12, the results of 10 actual combat trainings of A troops were tracked, the raw data of each indicator were collected, and the weighted scores were obtained according to the weights of Table 6, as shown in Table 6.

| Indicators | sample | D1   | D2   | D3   | D4   | D5   | D6   | D7   | D8   | D9   | D10  | D11  | D12  | performance |
|------------|--------|------|------|------|------|------|------|------|------|------|------|------|------|-------------|
| 1          | 85.43  | 94.51| 80.87| 88.68| 98.23| 91.11| 80.19| 82.78| 89.87| 77.14| 99.08| 75.94| 86.30 |             |
| 2          | 76.24  | 84.74| 83.83| 82.41| 94.39| 84.47| 82.53| 98.08| 81.56| 81.56| 88.67| 97.13| 84.14 |             |
| 3          | 97.57  | 81.04| 95.53| 93.62| 87.17| 95.29| 86.77| 85.76| 90.07| 95.03| 88.03| 97.83| 90.95 |             |
| 4          | 98.62  | 85.10| 75.39| 79.72| 85.90| 88.32| 80.76| 79.62| 92.78| 75.73| 80.79| 94.90| 85.37 |             |
| 5          | 87.27  | 77.41| 76.08| 92.17| 86.17| 83.77| 96.11| 97.62| 80.54| 98.22| 87.22| 77.47| 84.61 |             |
| 6          | 87.23  | 78.30| 79.22| 79.59| 82.66| 98.48| 79.87| 99.49| 77.94| 93.26| 90.60| 81.55| 83.08 |             |
| 7          | 83.44  | 98.55| 91.23| 84.21| 87.71| 96.90| 80.65| 85.97| 82.42| 87.22| 91.98| 83.38| 88.31 |             |
| 8          | 97.50  | 98.90| 93.29| 90.64| 87.77| 88.75| 79.27| 77.78| 82.97| 89.46| 84.89| 91.99| 91.19 |             |
| 9          | 84.23  | 89.38| 91.19| 94.51| 95.44| 90.56| 80.69| 81.45| 85.60| 80.93| 84.19| 78.41| 86.98 |             |
| 10         | 77.78  | 76.49| 86.27| 77.03| 94.87| 89.68| 85.89| 85.22| 87.70| 86.47| 99.70| 93.03| 83.40 |             |

Performance Evaluation

The data needs to be normalized before the assessment; after the assessment, the results of the assessment need to be restored by denormalization. The normalized and denormalized formulas are (8)(9).

\[
x' = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (8)
\]

\[
x'' = \min(x) + x' [\max(x) - \min(x)] \quad (9)
\]
Where, $x$ is the original data, $x'$ is the normalized data, $x''$ is the inverse normalized data, $\min(x)$ is the minimum data, and $\max(x)$ is the maximum data.

In order to objectively reflect the accuracy of the assessment, the relative error between the evaluation result and the standard value is calculated, and the calculation method is as shown in equation (10).

$$E_{RE} = \frac{y'(t) - y(t)}{y(t)}$$  \hspace{1cm} (10)

$y(t)$ and $y'(t)$ are the actual and evaluated values of the sample t, respectively.

The BP neural network was trained using the data in Table 8 and evaluated, and the predicted and output values of the neural network and their errors were obtained as shown in Table 7. For visual representation of the prediction results, Figures 2 and 3 were plotted.

| Test sample | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Actual value| 86.3| 84.14| 90.95| 85.37| 84.61| 83.08| 88.31| 91.19| 86.98| 83.4 |
| Assessed value| 87.064| 85.41| 89.287| 82.003| 85.730| 84.242| 89.033| 88.922| 89.848| 83.607 |
| Relative error| 0.009| 0.015| -0.018| -0.039| 0.013| 0.014| 0.008| -0.025| 0.033| 0.002 |

Table 7. Evaluation results and errors.

Figure 2. Comparison between evaluation outcomes and realistic value of BP neural network.

Figure 3. Fig.2 Relative error BP neural network.
Summary

Combined with AHP and BP neural network, AHP is used to determine weights, establish standardized evaluation criteria, ensure the standardization and standardization of data samples, use BP neural network for performance criticism, avoid the subjectivity of artificial scoring, and make up for the AHP method's insufficient. Effective evaluation of the actual training performance. Provide objective and accurate evaluation indicators and assessment methods for practical training performance evaluation.

References

[1] Peng Jing-yi, Zhou You, Liu Yu-Ming. Evaluation of enterprises' ability to create value based on analytic hierarchy process—a case study of China's household appliance industry [J]. China Collective Economy, 2019 (09): 96-99.

[2] Fengye Hu, Lu Wang, Shanshan Wang, Xiaolan Liu, Gengxin He. A Human Body Posture Recognition Algorithm Based on BP Neural Network for Wireless Body Area Networks[J]. China Communication, 2016, 13(08):198-208.

[3] Hecht-Nielsen, Robert. Theory of the Backpropagation Neural Network. Neural Networks[C]//Proceedings of the International Conference on Neural Networks. International Joint Conference on Neural Networks. Washington, DC, USA. 1989: 593-611.