Combined Forecasting Method of Ammunition Consumption Based on Wavelet Network

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Abstract. In order to solve the problem that the result of a single algorithm for ammunition consumption prediction is not accurate enough, a combination forecasting method of ammunition consumption based on a wavelet network is proposed. This paper combines three classical methods, namely, task volume estimation method, battle case estimation method and ammunition consumption standard estimation method, which are most commonly used in ammunition consumption prediction, and takes the prediction result of a single method as the input of neural network. By replacing the transfer function of traditional neural network with wavelet basis function, a combined forecasting model of ammunition consumption based on wavelet network is established. The calculation of the example shows that the fitting speed of this method is fast and the accuracy of the result is higher.

1. Introduction

The prediction of ammunition consumption is the premise and basis of ammunition supply guarantee, which can provide a direct basis for ammunition financing, reserve and replenishment. At present, the trend of equipment combat diversification is obvious, how to quickly and accurately predict ammunition consumption is an important problem in the current ammunition supply support[1]. Although many scholars have done extensive research on the prediction method of ammunition consumption, there are still some problems in practical applications, such as low accuracy, limited adaptive range and so on. Through the analysis of the commonly used ammunition consumption prediction methods, it is found that each single method has certain characteristics and advantages in ammunition consumption prediction[2]. By using the combination forecasting method, we can make comprehensive use of the advantages of many methods and effectively adapt to the complex situation, and further improve the accuracy and adaptability of ammunition consumption prediction.

The commonly used prediction methods of ammunition consumption mainly include task volume estimation method, battle case calculation method, ammunition consumption standard estimation method and so on[3-4]. In view of the different characteristics of the war, they focus on different factors, such as operational tasks, operational stages, operational topography, campaign (combat) style, duration, types, quantity, and tactical and technical performance of enemy and our combat equipment[5]. Because the above method is a single linear or nonlinear model, the highly nonlinear characteristics of each variable are not fully considered, so there are some problems in ammunition prediction, such as insufficient consideration of complex factors and insufficient accuracy of the results. Especially in the prediction of high-tech ammunition consumption under modern battlefield conditions.

If only one prediction method is used to predict ammunition consumption, the information used will not be comprehensive enough, while the comprehensive use of various prediction methods in combination forecasting is more systematic and comprehensive than a single prediction method. It is
expected to achieve more accurate prediction results of ammunition consumption[6]. Wavelet neural network (WNN) is a new neural network model based on wavelet analysis theory. It uses wavelet basis function as the transfer function of nodes in the hidden layer of neural network. It makes full use of the good localization property of wavelet transform and combines the self-learning function of neural network, and has stronger approximation and fault tolerance ability[7-8]. These advantages of wavelet network provide a good technology for solving the complex problem of ammunition consumption combination forecasting. For this reason, this paper designs the combined prediction of ammunition consumption by using wavelet network technology according to the three classical methods: task volume estimation method, battle case estimation method and ammunition consumption standard estimation method, which are most commonly used in ammunition consumption prediction. In order to achieve the accurate prediction of ammunition consumption.

2. Common Methods for Predicting Ammunition Consumption and Their Comparison

2.1. Typical Forecasting Method of Ammunition Consumption

At present, the typical methods of ammunition consumption prediction are task volume estimation method, battle case estimation method, ammunition consumption standard estimation method and so on. The task volume calculation method needs to consider the combat tasks according to the basic theoretical data and relevant calculation formulas, such as the number of weapons and equipment, tactical and technical performance, tactical means, operational characteristics of both sides of the enemy and us, and so on, according to the number of weapons and equipment, tactical and technical performance, tactical means, operational characteristics of both sides, and so on. Although this method has a high degree of quantification, it has a large amount of calculation and high error, and it is difficult to fully reflect the basic situation of the campaign[9].

The calculation method of combat examples is mainly based on the tasks and basic conditions of this operation, refers to similar examples of wars, and makes necessary corrections according to the development trends and characteristics of the war, and predicts the ammunition consumption of this operation. Although this method is simple and adaptable, it needs to choose the corresponding typical war cases of universal guiding significance. If there are no corresponding typical war cases, this method is no longer applicable.

The ammunition consumption standard estimation method forecasts the ammunition consumption with reference to the wartime ammunition consumption standard issued by the military authority. The ammunition consumption estimated by this method is the "standard consumption" under the predetermined combat intensity, and the conditions of any operation can not be completely similar to the standard conditions, so there will be a large error[10].

2.2. Comparison of Forecasting Methods of Ammunition Consumption

In addition to the above typical ammunition consumption prediction methods, there are more widely used methods, such as the combined prediction method used in this paper, each of which has its own advantages and disadvantages, as shown in Table 1[10].

| Table 1. Comparison of ammunition consumption forecasting methods |
|---------------------------------------------------------------|
| Prediction method | Advantages | Shortcomings |
| Task volume estimation method | Simple and easy to do | Adapt to specific combat tasks and styles |
| War case deduction method | It is simple and easy to operate, and the speed of calculation is fast. | Detailed and reliable actual combat statistics are required, and forecasters are required to be experienced. |
| Standard estimation method of ammunition consumption | It is simple and easy to operate, and the speed of calculation is fast. | It is highly dependent on the standard of ammunition consumption. |
| Combined prediction method | Making comprehensive use of the advantages of various methods, the prediction accuracy is high. | Need to use a variety of prediction methods, complex and tedious. |
3. Algorithm and Principle of Wavelet Network

3.1. Structure and Design of Wavelet Network

In this paper, the wavelet network structure shown in figure 1 is used to study the combined prediction of ammunition consumption[11].

The wavelet network can be expressed by the following formula:

\[ y = \sum_{j=1}^{L} w_{ij} \psi_{a_j b_j} (x) + \theta_j \]  

(1)

Of which:

\[ \psi_{a_j b_j} (x) = \psi\left(\frac{x-b_j}{a_j}\right) \]  

(2)

The expansion is as follows:

\[ y(t) = \eta \sum_{j=1}^{L} w_{ij} \psi_{a_j b_j} \sum_{k=0}^{M} w_{jk} x_k (t) + \theta_j \quad (i = 1, 2, \ldots, N) \]  

(3)

In the formula, \( \eta \) is the learning rate of the wavelet network; \( w_{jk} \) is the weight between the hidden layer and the input layer; \( w_{ij} \) is the weight between the hidden layer and the output layer; \( a_i \) and \( b_i \) are the translation factor and expansion factor of the wavelet base of the \( i \) hidden layer node, respectively; \( \theta_j \) is a zeroing parameter; \( M \) is the number of nodes in the input layer; \( N \) is the number of nodes in the output layer; \( L \) is the number of wavelet bases (that is, the number of neurons in the hidden layer).

The parameters of the wavelet network \( a_i, b_i, w_{ij}, w_{jk} \) and \( \theta_j \) are optimized by the mean square error energy function of the following minimum network.

\[ E_n = \frac{1}{2P} \sum_{p=1}^{P} \sum_{j=1}^{N} (y_{jp} - \hat{y}_{jp})^2 \]  

(4)

In the formula: \( P \) is the number of training samples; \( \hat{y}_{jp} \) is the target output value of the \( P \) th sample. The error expansion of the above formula is:

\[ E_n = \frac{1}{2P} \sum_{p=1}^{P} \sum_{j=1}^{N} |d_p^j| \ln y_p^j + (1 - d_p^j) \ln(1 - y_p^j) \]  

(5)

\( d_p^j \) is the \( P \) expected output of the \( i \) pattern in the equation; \( y_p^j \) is the \( P \) actual output of the \( i \) mode[12].

3.2. Prediction Process of Ammunition Consumption Based on Wavelet Network

By inputting a large number of ammunition consumption data samples and using the basic principle of wavelet network parameter adjustment, after the wavelet network achieves the optimal solution, we can begin to predict the ammunition consumption. The parameters of the wavelet network are adjusted as shown in figure 2.
Figure 2. Schematic diagram of parameter adjustment of wavelet network

The flow of the algorithm for predicting ammunition consumption based on wavelet network is shown in figure 3.

1) input and output samples \((x_k, y_k)\) for a given ammunition consumption, \(k = 1, 2, \cdots, m\), \(x_k \in R^n\), \(y_k \in R^n\).

2) initialize the wavelet network parameter \(\theta(0)\), let the number of input and output nodes \(M = N = 2\), number of iterations \(n = 1000\).

3) normalization of input and output data.

4) Wavelet network training, First cumulative error \(\varepsilon\), Then train the network cyclically and adjust the weights \(w_j\) and \(w_k\) of the wavelet network.

5) the network predicts ammunition consumption, For a given \(L\), the Morlet mother wavelet error is used to inverse calculate the optimal parameter \(W_j\), \(W_k\), \(a_i\), \(b_i\), and then predict the consumption of ammunition.

4. Prediction of Ammunition Consumption Combination Model based on Wavelet Network

4.1. Combined Forecasting and Analysis Model of Ammunition Consumption based on Wavelet Network

The principle of ammunition consumption combination prediction based on wavelet neural network is that the results of various ammunition consumption prediction methods are taken as the input vector of wavelet network, and the actual value of ammunition consumption at the corresponding time is taken as the output of wavelet network. Then enough ammunition consumption data samples are used to
train the wavelet network, so that a mapping relationship between the predicted value and the actual value of various ammunition consumption prediction methods is obtained. After continuous learning and training to achieve a certain accuracy, the wavelet network can effectively carry out the combined prediction of ammunition consumption[13].

In this paper, three typical ammunition consumption prediction methods are selected, which are task volume estimation method, battle case prediction method and ammunition consumption standard estimation method. Based on this, a combination forecasting model of ammunition consumption based on wavelet network is established, as shown in figure 4.

Figure 4. Combined forecasting model of ammunition consumption based on wavelet network

4.2. Evaluation of the Effect of Combination Forecasting

In order to test the effect of combination forecasting, this paper uses the sum of squared residuals (SSE), mean square error (MSE), mean square error (MSPE), average absolute error (MAE) and average absolute percentage error (MAPE) as evaluation indexes.

1) Sum of squares of predicted residual error of ammunition consumption

\[ SSE = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \]  (6)

In the formula: \( y_i \) is the actual value of ammunition consumption, \( \hat{y}_i \) is the forecast of ammunition consumption. Same as below.

2) Mean square error of ammunition consumption prediction

\[ MSE = \frac{1}{n} \sum_{i=1}^{n} (\hat{y}_i - y_i)^2 \]  (7)

3) Mean square percentage error of ammunition consumption forecast

\[ MSPE = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{\hat{y}_i - y_i}{y_i} \right)^2 \]  (8)

4) Absolute error of ammunition consumption prediction

\[ MAE = \frac{1}{n} \sum_{i=1}^{n} |\hat{y}_i - y_i| \]  (9)

5) Average absolute percentage error of ammunition consumption forecast

\[ MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{\hat{y}_i - y_i}{y_i} \right| \]  (10)
4.3. Example Analysis

Here, we choose to use more Morlet basis wavelet function as the hidden layer node function of the wavelet network, the number of invisible nodes is 6, the number of iterations is 1000, and the iterative accuracy is 0.001. From the predicted values of the three ammunition consumption prediction methods, 18 data are selected as training samples (case data are shown in Table 2), and 2 data are selected as prediction samples.

Table 2. Related data of 18 ammunition prediction examples

| Data number | ammunition consumption estimation method | task volume estimation method | battle case estimation method | Practical data |
|-------------|--------------------------------------|-------------------------------|-------------------------------|----------------|
| 1           | 595                                  | 592                           | 587                           | 597            |
| 2           | 188                                  | 185                           | 180                           | 190            |
| 3           | 302                                  | 299                           | 309                           | 304            |
| 4           | 527                                  | 524                           | 534                           | 529            |
| 5           | 360                                  | 357                           | 367                           | 362            |
| 6           | 233                                  | 230                           | 240                           | 235            |
| 7           | 266                                  | 263                           | 273                           | 268            |
| 8           | 394                                  | 391                           | 411                           | 396            |
| 9           | 440                                  | 437                           | 447                           | 442            |
| 10          | 110                                  | 107                           | 117                           | 112            |
| 11          | 588                                  | 595                           | 595                           | 590            |
| 12          | 245                                  | 252                           | 252                           | 247            |
| 13          | 67                                   | 74                            | 74                            | 69             |
| 14          | 103                                  | 110                           | 109                           | 105            |
| 15          | 242                                  | 249                           | 248                           | 244            |
| 16          | 203                                  | 210                           | 209                           | 205            |
| 17          | 198                                  | 205                           | 203                           | 200            |
| 18          | 186                                  | 193                           | 191                           | 188            |

Eighteen ammunition consumption prediction examples are used to train the wavelet network. After about 1000 iterations, all the models converge and the network training ends. The fitting values of 18 examples and wavelet network are compared as shown in figure 5. As can be seen from figure 5, the fitting effect is better.

Figure 5. Training case

The data related to data 19 and data 20 are sorted out into a wavelet network input mode, and the trained network is used to predict it. The analysis and prediction results are shown in Table 3. The evaluation of the prediction effect is shown in Table 4, which gives the effect evaluation of each single prediction method at the same time. As can be seen from the table, the ammunition consumption combination forecasting method based on wavelet network can get more accurate results.
At the same time, BP neural network and wavelet network are constructed to train the samples. It can be seen from Table 5 that the wavelet network has faster convergence speed and can get the prediction results faster.

Table 3. Results of wavelet network analysis and prediction

| Data number | ammunition consumption standard estimation method | task volume estimation method | battle case estimation method | Combination forecasting method |
|-------------|--------------------------------------------------|------------------------------|------------------------------|-------------------------------|
| 19          | 270                                              | 277                          | 282                          | 264                           |
| 20          | 450                                              | 457                          | 462                          | 480                           |

Table 4. Evaluation table of prediction effect

| Evaluation index of prediction effect | SSE | MAE | MSE | MAPE | MSPE |
|--------------------------------------|-----|-----|-----|------|------|
| ammunition consumption standard estimation method | 72  | 2   | 0.47| 0.0095| 0.0027|
| task volume estimation method         | 450 | 5   | 1.18| 0.0238| 0.0067|
| battle case estimation method         | 741 | 5.72| 1.51| 0.0249| 0.0071|
| Combination forecasting method        | 13  | 2.5 | 1.80| 0.0071| 0.0050|

Table 5. Comparison of Convergence Speed between BP Network and Wavelet Network

| Sample number | 1     | 2     | 3     | 4     | 5     |
|---------------|-------|-------|-------|-------|-------|
| Convergence times of BP network        | 3265  | 2484  | 1963  | 1784  | 1551  |
| Convergence times of wavelet network   | 6418  | 1352  | 624   | 678   | 689   |

5. Conclusion

The accurate estimation of ammunition consumption affects the outcome of the war. In this paper, a combination forecasting model of ammunition consumption based on wavelet network is established by using wavelet network with strong learning function and good localization property, and three typical methods of ammunition consumption prediction are integrated to predict ammunition consumption. The analysis of an example shows that this method shows high accuracy and fast speed, and the results are in line with the actual situation, and can be used to predict ammunition consumption.

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