Research on High Accuracy Prediction of Ship Attitude Based on Improved Neural Network Method

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Abstract: In view of the difficult problem of ship attitude prediction accuracy and the features of ship attitude change, a prediction model of high accuracy of ship attitude based on the improved neural network is proposed. Firstly the data of ship attitude is collected and de-noised. Then the high accuracy approximation to the features of ship attitude changes is carried out by using the improved neural network, some defects of which are improved. Finally the simulation experiment of ship attitude prediction is conducted. The experimental results show that the improved neural network can improve the accuracy of the ship attitude prediction and overcome the disadvantages of the large errors in the other ship attitude prediction models and the advantages of the ship attitude effect are very obvious.

1. Introduction
During the ship navigation process, the requirements on the ship working environments are very high. In order to ensure the safety of the ship navigation, it is necessary to collect the real-time attitude data of ships and predict the future attitude of ships. And the ship attitude prediction results can provide ship managers with important information needed for the ship navigation.

The current ship attitude prediction methods are modeled by statistical theory. The initial method is multivariate linear regression method, which is modeled based on the relevant data of ship attitude and then estimates and predicts the future attitude of the ship according to the model. For the ship attitude in less complicated working environments, better prediction results can be obtained by using it. With the complexity and time-varying variation of the ship environments, the defects of the multiple linear regression method are reflected. It can only predict the linear change of the ship attitude, but it can't do anything about the nonlinear change features. So the reliability of ship attitude prediction result is rather low and the error of the forecast is quite large. Then the neural network-based ship attitude prediction model emerges. By learning the relevant data of the ship attitude, the ship attitude change situations are excavated from the data, and the ship attitude prediction accuracy is significantly better than the multiple linear regression method, especially the application of pulse-coupled neural networks is more extensive. The pulse-coupled neural network parameters have an important impact on the results of ship attitude prediction. At present, the values of the parameters are determined by the staff through their experiences, so the effects of ship attitude prediction need to be further improved.

In order to get higher precision of the prediction results of ship attitude, one ship attitude prediction model based on the improved neural network is proposed. The adaptive genetic algorithm is used to accurately estimate the parameters of the pulse-coupled neural network. The effectiveness of the ship attitude prediction model in this paper has been tested through simulation experiments. The superiority of this model is verified by carrying out the tests compared with the other models.
2. The improved neural network

2.1 The pulse-coupled neural network

The pulse-coupled neural network is a neural network that mimics the visual conduction features of the cat’s cerebral cortex. Compared with the traditional neural network, the pulse-coupled neural network does not need to learn the training samples, so the learning speed is obviously accelerated and the threshold can be adaptively adjusted, which is very flexible and has better versatility. The standard pulse-coupled neural network consists of three parts: the input area, the connection area and the pulse area. The interior of a pulse-coupled neural network can be seen as a leakage integrator $I(V_x, \tau_x, t)$, whose details are as follows:

$$I(V_x, \tau_x, t) = V_x \exp(-t / \tau_x), t \geq 0$$

(1)

Where, $V_x$ and $\tau_x$ respectively represent the amplification factor and time attenuation constant.

The number of neurons in the pulse-coupled neural network is set as $f$ and $l$, $W$ and $M$ as weights, $l$ as connection input, and $E$ as threshold; then the model of the leakage integrator can be described as following equation:

$$F_k(t) = \sum_{i=1}^{f} \left\{ M_{ik} Y_i(t) + S_k(t) \right\} \otimes I(V_F, \tau_F, t)$$

(2)

$$L_k(t) = \sum_{i=1}^{l} \left\{ M_{ik} Y_i(t) \right\} \otimes I(V_L, \tau_L, t)$$

(3)

Where, $Y$ represents pulse output and $S$ represents external stimulus input.

The internal activity term $U_k(t)$ of the neuron is expressed as:

$$U_k(t) = F_k(t) \{1 + L_k(t)\}$$

(4)

The calculation method of pulse output $Y$ is:

$$Y_k(t) = \begin{cases} 1, & U_k(t) \geq E_k(t - 1) \\ 0, & otherwise \end{cases}$$

(5)

The change mode of threshold value is:

$$E_k(t) = Y_k \otimes I(V_E, \tau_E, r) + E_0$$

(6)

By analyzing the above equations, it can be found that the pulse-coupled neural network has the following advantages compared with traditional neural network:

(1) The connections between neurons in the pulse-coupled neural network are more complex and have nonlinear features, which can effectively fit the changing features of the nonlinear system.

(2) The weighted term is a combination of internal neurons and external neurons with regional features.

(3) The output value is only relevant to the internal activity item settings.

In the working process of the pulse-coupled neural network, the influence of amplification coefficient, time attenuation constant and the weighted coefficient on the performance of the pulse-coupled neural network are very important. At present, the experience method is mainly used to determine these parameters, which has some blindness. To solve the blindness problem of pulse-coupled neural network parameters, this paper chooses the adaptive genetic algorithm for parameter optimization, improving the precision of pulse-coupled neural networks.

2.2 Adaptive genetic algorithm

Genetic algorithm (ga) is a search algorithm simulating Darwin’s theory of evolution. It starts by randomly generating multiple individuals, which represent potential solutions to the solving problems. And it evaluates the pros and cons of these individuals, whose evaluation function is usually related to
the goal of solving the problems. And then it continuously generates new individuals through the operations such as selection, crossover and mutation, whose selection operation is used to save the optimal individual into the next generation of population to conduct crossover and mutation and produce superior individuals and eliminate those with poor quality so as to realize the operation of survival of the fittest. Finally, solving the problems is stopped when the maximum evolutionary algebra is achieved.

Traditional genetic algorithms (ga), crossover probability \( p_c \) and mutation probability \( p_m \) adopt a fixed way in the evolutionary process. At the later stage of evolution, the population will be single and the search is prone to stagnation, which increases the probability of finding the local optimal solution. In order to solve the defects of traditional genetic algorithm, the adaptive change mechanism of crossover probability and mutation probability is adopted, whose details are as follows:

\[
P_c = \begin{cases} 
P_{c0}, & N \leq N_f \\ 
P_{c0} + (\alpha - P_{c0}) \frac{N - N_f}{N}, & N > N_f 
\end{cases} \quad (7)
\]

\[
P_m = \begin{cases} 
P_{m0}, & N \leq N_f \\ 
P_{m0} + (\beta - P_{m0}) \frac{N - N_f}{N}, & N > N_f 
\end{cases} \quad (8)
\]

Where, \( P_{c0} \) and \( P_{m0} \) are the initial values of crossover and mutation probability.

3. The ship attitude prediction model of the improved neural network

1. The ship attitude sensor is adopted to collect ship attitude prediction data, and then the data are transmitted to the computer through RS485 data communication link.

2. The training samples and test samples of ship attitude prediction are constructed. The training samples are usually larger in number and the test samples are relatively smaller in number, which are determined by the ratio of 3:1 in this paper.

3. Training samples of ship attitude prediction are studied by pulse-coupled neural network.

4. Adaptive genetic algorithm is adopted to determine the values of amplification coefficient, time attenuation constant and weighting coefficient.

5. The ship attitude prediction model is adopted to analyze the optimal parameters.

6. The test samples of ship attitude prediction are adopted to analyze the validity of the model.

4. Test results and their analysis

In order to test the performance of the ship attitude prediction model based on the improved neural network, a ship's transverse inclination/degree was selected as the research object and the data change curve was shown in Figure 1. In Figure 1, it can be seen that there is a very obvious non-stationary change feature in the ship's heeling data.

![Fig.1 The data of ship heeling angle](image)

The improved neural network was used to model the data of ship transverse inclination angle and the last 25 data were selected as test samples. The prediction results were shown in Figure 2. From the analysis of Figure 2, it can be found that the prediction value of the ship heeling angle of the improved
neural network is very close to the actual value of the ship heeling angle, and the change curves of the two values have reached almost overlap. It shows that the improved neural network model can approximate the change trend of the ship heeling angle in high precision and can obtain the ideal prediction results of the ship attitude.

Fig. 2 The prediction results of ship heeling angle based on the improved neural network model

In order to test the superiority of ship heeling inclination angle prediction based on the improved neural network model, multiple regression analysis method and that based on the improved neural network were selected to conduct comparative test of ship heeling angle prediction. The test results are shown in Table 1. To make the comparison results more convincing, the ship's longitudinal inclination angle was selected as the test object and the results are also shown in Table 1. As can be seen from Table 1, compared with the comparative ship attitude prediction model, the ship attitude prediction based on improved neural network method has a higher accuracy, which effectively reduces the error of ship attitude prediction and provides an effectively modeling and analysis tool for ship attitude prediction with high accuracy.

Table 1 The comparison of the ship attitude prediction accuracy (%) with other models

| Model Name                        | Tilt Angle | Trim Angle |
|-----------------------------------|------------|------------|
| Multiple regression analysis method | 86.55      | 87.27      |
| Basic neural network method       | 90.75      | 90.45      |
| Improved neural network method    | 95.33      | 95.91      |

5. Conclusions
In order to solve some problems existing in the current ship attitude prediction process, a ship attitude prediction model based on the improved neural network was designed, and the following conclusions were obtained through experiments:

(1) The self-learning ability of neural network can be used to fit the features of ship attitude changes with infinite accuracy and establish a ship attitude prediction model with high precision.

(2) Aiming at the defects of the neural network parameters determined by experiences, the adaptive genetic algorithm is introduced to optimize and estimate them, which can improve the effect of ship attitude prediction.

(3) Compared with the other ship attitude prediction models, the ship attitude prediction model based on the improved neural network has a much better overall prediction effect and a broader application prospect.

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