Research on Combination Forecast Model of Aerospace Relay’s Storage Life

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Abstract. With the rapid development of China space industry, relay is widely used in aerospace control system, thus it has a higher request for the relay reliability. The space relay is stored for a long time and may have a storage life of 15-20 years or much longer. In order to ensure that the relay always keeps in the activated state, it has very practical significance to predict the storage life of relay. Firstly, a single prediction model of space relay storage life is established, such as gray system theory prediction model and neural network prediction model. Then the prediction results are analyzed and the model error evaluation is carried out. According to the results of comparison, the advantages and disadvantages are obtained and improved. Finally, the storage life combination model of space relay is established, and Matlab software is used for the simulation and prediction of gray neural network to improve the accuracy of the prediction model.

1. Introduction
Space relay is a kind of relay with special functions. It is mainly used in carrier rocket, artificial satellite, spacecraft and its supporting non-air measurement and control equipment. It can complete the functions of signal transmission, executive control and system distribution, and it plays an important role in space electronic system. Space relay has the characteristics of "long-term storage and one-time use". Therefore, the correct prediction of the storage time of relay is of great practical value for ensuring the normal use of space equipment in the whole life cycle.

2. Gray prediction model
Gray prediction is to forecast the change trend of the behavior of the system. According to the known or uncertain information in the past or now, a GM (m,n) model extending from the past or now to the future is established to determine the corresponding trend of the development and change of the system in the future. It is to predict the gray process that changes within a certain range and is related to time series and obtain the corresponding statistical rules of data. The storage life prediction of space relay can be regarded as a gray system. Through the generation, development and mining of a small amount of known information, the variation trend of system behavior can be predicted. Matlab is used to compile the following procedures to calculate the measured contact pressure drop between the contact points of the space relay to find out the law of data collection and predict the unknown storage life of the space relay. The process is as follows:

a: Input data;
2.1. Gray prediction modeling

Grey system theory is mainly a method of modeling and dealing with system problems under poor information. For example, this topic can predict the storage life of space relay as a gray system. It can be seen from the data that the gray system theory is applicable to the study of small samples and the model accuracy is relatively high. It mainly used gray generation or the sequence operator to process the raw data, eliminate the ambiguity of data sequences, and sum up the related law. Firstly, gray differential equation is defined. The whitening equation is discretized to obtain gray difference equation and the transformation of differential and difference is realized. Then the continuous dynamic differential equation is established by discrete data sequence, so as to realize the establishment of the system dynamic model.

2.2. Matlab simulation and analysis process

In Matlab, there are a lot of matrix calculations about gray prediction. Matlab is the first choice for gray prediction, and gray prediction program is written by software. The calculation is conducted according to the steps of gray prediction model:

a: Aerospace relay at 125 ℃ contact pressure drop between the measured value of accumulation;
b: Then the accumulation matrix B and the constant vector are constructed;
c: Solving gray parameters a and b;
d: The gray parameters a and b obtained were input into the prediction model for data prediction;
e: Input the program into the Matlab window and run the program to get new predicted data. The contact pressure drop value (mv) is columns 1 through 192.

| Data       | Probability |
|------------|-------------|
| 0.8310     | 0.003       |
| 0.8842     | 0.010       |
| 0.8863     | 0.020       |
| 0.8883     | 0.050       |
| 0.8904     | 0.750       |
| 0.8924     | 0.900       |
| 0.8945     | 0.950       |
| 0.8965     | 0.990       |
| 0.8986     | 0.997       |
| 0.9007…..1.3441 | 0.003   |
| 1.3472     | 0.010       |
| 1.3503     | 0.020       |
| 1.3535     | 0.050       |
| 1.3566     | 0.750       |
| 1.3597     | 0.900       |
| 1.3628     | 0.950       |
| 1.3660     | 0.990       |
| 1.3691     | 0.997       |
3. Bp neural net prediction model

BP neural network is a multi-layer forward feedback network with one-way transmission. The neural network consists of input layer, hidden layer and output layer. When input neurons are given to the learning sample, the activation value of the neuron will realize one-way propagation. When the learning sample is input to neurons, the activation value of neurons will realize one-way propagation, from the input layer through the middle layer to the output layer, and the input response of the neural network can be obtained from each neuron in the output layer.

3.1. Matlab BP neural network

The Matlab toolbox is used to realize BP neural network and set important parameters, such as the target error of neural network training. The target error of contact pressure drop between aerospace relay contacts is 0.01 and the training times is 1000. Set the maximum number of iterations, etc. Skilled use of Matlab toolbox to operate, specific steps are as follows:

a: Click the application to find the Neural Net Fitting to operate;
b: Import data and set the proportion of training data, verification data and test data;
c: Determine the hidden layer neurons and the algorithm;
d: Carry out training and obtain corresponding calculation results as shown in figure 3.

![Figure 3 Results of neural network prediction](image)

4. Gray neural network composite model of storage life

According to the actual situation, GM(1,1) model with different dimensions needs to be established in the first part of gray neural network combined prediction model. The second part of the combined prediction model is the phase of BP neural network fitting process using Matlab toolbox.

a: Gray system theory GM(1,1) model gray prediction method is to establish a GM model extending from the past or the present to the future based on the known or uncertain information in the past or the present, so as to determine the corresponding trend of the system's development and change in the future and provide more accurate basis for planning decisions.

b: Establish input vector prediction time P=(forecast date1, forecast date2, forecast date3), set various parameters of BP neural network, and establish BP neural network prediction model. Setting appropriate training parameters for network training until the target accuracy is achieved. When using the combination prediction model of gray neural network in actual prediction, only the combination model established by the data input of the predicted data sequence is needed. The predicted value is
taken as the input sample of BP neural network, and the simulation and operation are carried out by Matlab to output the results of the combined prediction model of gray neural network. As shown in figure 4.

![Figure 4 Results of the combined forecast](image)

5. Conclusion
According to the above research on each model, the final prediction results are obtained and the model is compared. As shown in table 1 and 2.

| Model Category     | Variance ratio C        | Model accuracy level |
|--------------------|-------------------------|----------------------|
| Grey model         | C = 0.479294030377280   | II                   |
| Combined model     | C = 0.001097646698275   | I                    |

| Model Category     | Training: R  | Validation: R | Test: R   | All: R   |
|--------------------|--------------|---------------|-----------|----------|
| Neural network     | 0.92179      | 0.8747        | 0.82677   | 0.89883  |
| Combined model     | 0.99957      | 0.99973       | 0.9996    | 0.9996   |

Based on the comparison between table 1 and 2. It can be concluded that the performance of the combined prediction model of gray neural network is better than that of the single algorithm. The combined prediction model can optimize the single prediction model to make the prediction results more accurate, the model accuracy is higher, the stability of the system can be improved, which is more conducive to the future research and development of the storage life of the space relay and makes contributions to the future development of the space industry.

Acknowledgments
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