ANALYSIS OF THE METHOD FOR PREDICTING THE TECHNICAL CONDITION OF AIRCRAFT EQUIPMENT

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Abstract: *This report analyzes the accuracy of predicting by the method of least squares and neuron networks. This study compares the errors and deviations of the predicted results from the actual ones. Considered are three options - when the parameter is defined by linear, quadratic and exponential law.*

KEYWORDS: *NEURON NETWORKS, PREDICTING, TECHNICAL CONDITION, AIRCRAFT EQUIPMENT*

АНАЛИЗ НА МЕТОДИ ЗА ПРОГНОЗИРАНЕ НА ТЕХНИЧЕСКОТО СЪСТОЯНИЕТО НА АВИАЦИОННОТО ОБОРУДВАНЕ

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Abstract: *В настоящия доклад е направен анализ на точността на прогнозиране чрез метода на най-малките квадрати и невроните мрежи. При изследването се сравняват грешките и отклоненията на прогнозните резултати от реалните. Разглеждат се три варианта – когато изменението на параметъра се описва чрез линеен, квадратичен и експоненциален закон.*

KEYWORDS: *НЕВРОННИ МРЕЖИ, ПРОГНОЗИРАНЕ, ТЕХНИЧЕСКО СЪСТОЯНИЕ, АВИАЦИОННО ОБОРУДВАНЕ*

1.Introduction

Recently, the interest in predicting the technical condition and reliability of technical systems has greatly increased. Of particular interest is the task of individual forecasting. It's solution allows not only to obtain an assessment of the condition and reliability of each particular site, but also under certain conditions to move from service to time and resource to conditional operation.

In modern aviation equipment (AE), different types of reservations are used to increase flight safety. Despite the measures implemented, it is not entirely possible to exclude the possibility of AE failures. Even the malfunction of the device that switches between the main and the backup unit can be considered a failure.

The condition of the AE is assessed by the specific values of the initial parameters determining its working capacity. These parameters, influenced by various factors depending on the conditions of storage and operation, change their values following random law.

The determination of the law of variation of a given parameter in the task of predicting is based on one of the basic postulates of physics formulated by K. Shenon. This postulate is based on the assumption that the fundamental patterns observed in the past will be preserved in the future.

The general task of predicting the change in the parameters characterizing AO is to predict the characteristics of the random process y (t) at a certain future time using the results of the control. [1]

The most common methods for solving this task are the various methods of approximation, regression analysis and analysis of time series.

This report discusses three variants of possible changes in the analyzed parameter when it is described following linear, quadratic and exponential laws. In order to predict the future values of the parameter, two methods are used - the least squares method and neural networks.

2 Experimental part

2.1 Model of control parameter

Here is considered a control parameter that varies over time:

-by linear law:

$$y(t) = a_0 + a_1 t + \varepsilon \quad (1)$$

- by quadratic law:

$$y(t) = a_0 + a_1 t + a_2 t_2 + \varepsilon \quad (2)$$

- by exponential law:

$$y(t) = a_0 e^{a_1 t} + \varepsilon \quad (3)$$

where a_0, a_1 and a_2 are random parameters, and ε is an error in measuring the value of the parameter, having a random value and a normal distribution.

2.2 Assessing the accuracy and reliability of predictions

An important milestone in predicting is the assessment of the accuracy and reliability of the predictions. [2]

The measure of accuracy of the prediction is the value of the error, which is determined by the difference between $\overline{y_t}$ the estimated and the y_t real value of the survey parameter.

This approach is possible only in two cases:

1.the determining period is known, it is finished and the researcher has the actual values of the parameter being analyzed.

2. a retrospective prediction is compiled, i.e. the values of the parameter for a period of time, for which we have real values, are

calculated. This is done in order to verify the developed prediction method.

In this case, all available information is divided into two parts in a ratio of 2/3 to 1/3. Some of the information (the first 2/3 of the time line) serves to create the prediction model. The second part of the information (the last 1/3 of the time line) serves to assess the accuracy of the prediction.

In this article, the two methods used for predicting are compared using Mean Squared Error (MSE) values and Tale's inaccuracy coefficients.

Mean Squared Error (MSE) –

(4) $$S = \sqrt{\frac{\sum_{t=1}^{n} (y_t - \overline{y}_t)^2}{n}}$$

Tale's inaccuracy coefficient - determined as the ratio of the MSE to the square root of the real values [3,4] .

(5) $$U = \sqrt{\frac{\sum_{t=1}^{n} (\overline{y}_t - y_t)^2}{\sum_{t=1}^{n} y_t^2}}$$

At U=0, we have a complete match of predicted and actual values.

At U=1, an MSE value comparable to the error obtained by applying the most common extrapolation methods is obtained.

At U>1, the estimated values manifest very large deviations from the actual ones and the mathematical model used for predicting must be rejected. The coefficient has no upper limit.

2.3 Prediction models

The least squares method (LSM) is one of the most common methods in performing a time series data regression analysis. The criterion, following which the model is created, is to minimize the sum of the squares of the error between the actual and the calculated value.

The neural network is a parallel processing system that has the ability to store and use experimental knowledge. The information in a neural network accumulates in the learning process, and the strength of neuronal connections is modeled with the weights of the relevant relationships that are used to store information. This article uses NARX (Nonlinear autoregressive with external input) networks. It can learn to predict one time series given past values of the same time series, the feedback input, and another time series called the external or exogenous time series.

2.3.1 Predicting the values of a parameter that is modified following a linear law

When extrapolating on the values of a parameter that is changed following linear law (1), the differences and errors between the methods of the LSM and the Neural Networks are minimal.

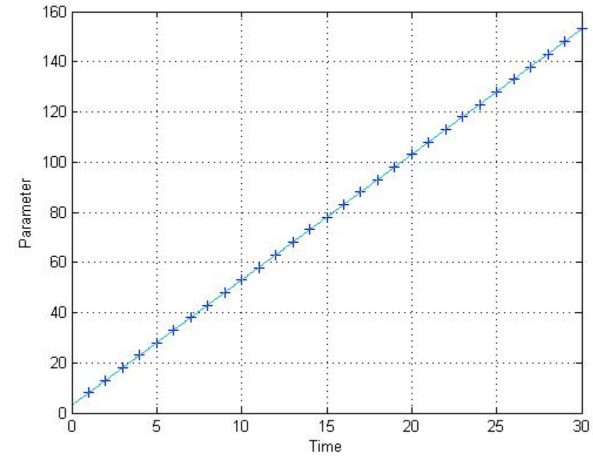

Fig. 1 *Approximation of a parameter that is modified following a linear law*

Determination of accuracy:

Mean Squared Error (MSE)

-LSM

S=1.3923

-Neural Networks

S=0.730198

Tale's inaccuracy coefficient

-LSM

U=3.1e-003

-Neural Networks

U=3.51e-004

2.3.2 Predicting the values of a parameter that is modified following a quadratic law

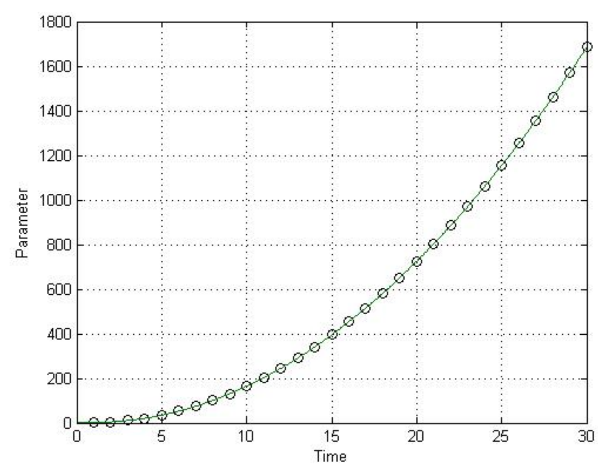

Fig. 2 *Approximation of a parameter, which is modified following quadratic law, by the LSM*

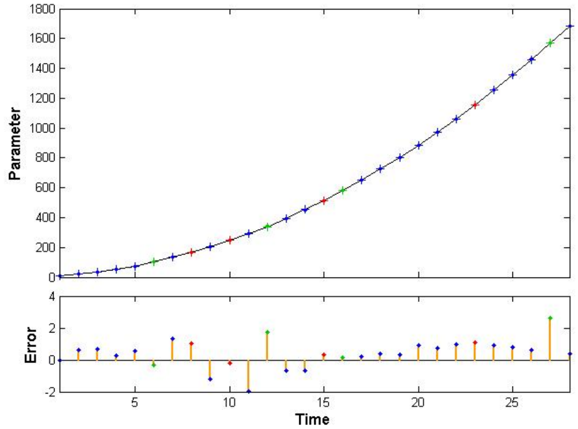

Fig. 3 *Parameter approximation, modified following quadratic law, through Neural Networks*

Determination of accuracy:

Mean Squared Error (MSE)

-LSM

S=1.3923

-Neural Networks

S=0.693653

Tale's inaccuracy coefficient

-LSM

U=4.4293e-004

-Neural Networks

U=4.8375e-005

2.3.3 Predicting the values of a parameter that is changed following exponential law

In the approximation of LSM 3rd and 4th degree polynomials are used. With higher degree polynomials, the error starts to grow.

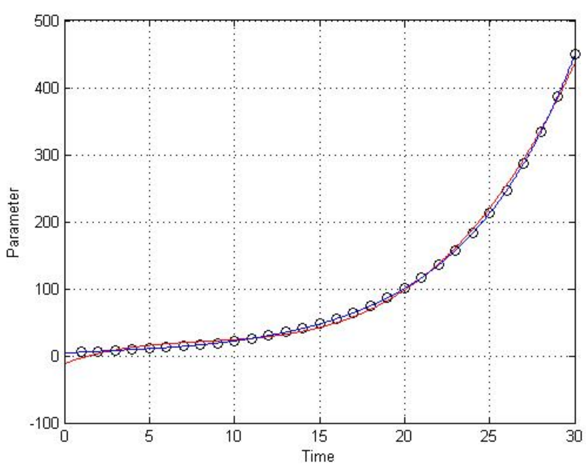

Fig. 4 *Approximation of a parameter, which is modified following exponential law, by the MNC*

Red - polynomial of 3rd *degree*

Blue - polynomial of 4th degree

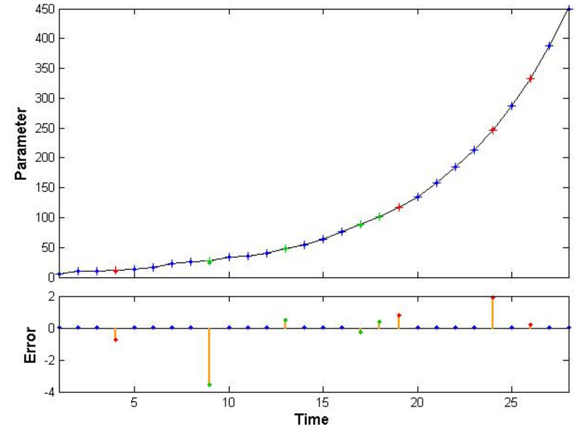

Fig. 5 *Approximation of a parameter that changes following exponential law through Neural Networks*

Determination of accuracy:

Mean Squared Error (MSE)

-LSM

S_3=5.3557

S_4=1.5662

-Neural Networks

S=6.9036e-005

Tale's inaccuracy coefficient

-LSM

U_3=9.1e-003

U_4=2.7e-003

-Neural Networks

U=8.1804e-006

3. Conclusion

The analysis of the prognostic results that are obtained using neural networks and the LSM method shows that with the use of the neural network apparatus, more accurate prediction can be achieved than with the classic LSM. When the character of the change of the examined parameter is described following a linear or quadratic law, the difference between the two methods under examination is minimal, but the neural networks manifest a smaller error. When the research parameter is described following exponential law, the difference in favor of neural networks is of the order of 10^2-10^3 times smaller error.

This in turn makes it possible to perform a much more accurate assessment of the condition of the aviation equipment and to reduce the probability of in-flight failure.

4. Literature

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