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COMPARATIVE ANALYSIS OF COMPUTER MODELS FOR FORECASTING TIME SERIES

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Abstract. Computer models of time series forecasting are considered. The forecasting models are implemented in the form of computer programs. The results of computational experiments on estimating the error of short-term forecasting of time series are presented. Mathematical models used to solve forecasting problems are considered, including self-organizing models, models in the form of fuzzy inference systems, models of multilayer feed-forward neural networks, adaptive forecasting models, and piecewise polynomial approximation models. The main attention is paid to short-term forecasting of time series, in which forecasting is carried out one time interval ahead. As computer models of short-term forecasting, a model of an artificial multilayer neural network without feedback with a linear activation function, an exponential smoothing model with adaptation at each time step are considered in detail to time series data and a model of piecewise polynomial approximation, in which the approximating function is composed of individual polynomials of the same small degree (of the third degree – cubic splines). Each computer model is implemented as a computer program, for which a block diagram and program interface are given.

Keywords: computational experiment, short-term forecasting, time series, mathematical model, computer simulation, computer program

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Introduction

In the process of analytical activity of the EMERCOM of Russia, much attention is paid to both the issues of forecasting the occurrence of all emergencies, including fires, and the issues of forecasting fire hazards.

Forecasting is carried out on the basis of the analysis of a large amount of various information, but most often data are used that characterize the object (process, phenomenon) under study for a number of successive moments (periods) of time. Such data is called time series. A time series is a set of values of an indicator for several successive moments or periods of time.

The following mathematical models can be used to solve forecasting problems:

– models with the property of self-organization (method of group accounting of arguments);
– models using fuzzy logic (fuzzy inference systems);
– models using neural networks (multilayer neural networks of direct propagation);
– models using exponential smoothing (adaptive time series forecasting method);
– models using spline extrapolation (piecewise polynomial approximation method).

A computer model is a computer program that implements a mathematical model, which is a system of algebraic, differential or logical equations. The computer program solves this system of equations in order to simulate the forecasting process.

In this article, short-term forecasting of a time series is performed by computational experiments on the developed computer models and the forecasting error for each model is estimated.

The topic of the article is relevant, since the developed computer models can be used to predict the occurrence of emergencies.

The novelty of the research lies in the creation of computer programs, with the help of which computer experiments were carried out.

Short-range forecasting of time series

If forecasting is carried out one time interval ahead, then such a forecast is called short-term. In the case of forecasting for 5–10 time intervals ahead, the forecast is called medium-term. For long-term forecasting, it is carried out for more than 10 time intervals ahead. In this article, as a forecasting problem, the problem of short-term forecasting for one time interval is solved.

Let's consider the forecasting models mentioned above in more detail.

Computer models that implement the method of group accounting of arguments [1–3] are mainly used for medium-term and long-term forecasting; therefore, these models are not considered further.

Computer models that implement fuzzy logic (fuzzy inference systems) [4–6] carry out the process of short-term forecasting with a relative error of at least 10 %, so these models are also not considered further.

A computer model using neural networks is a model of an artificial multilayer neural network without feedback with a linear activation function [7–9]. At the training stage of the neural network (data interpolation), exponential data smoothing is used. The block diagram of the program is shown in fig. 1.

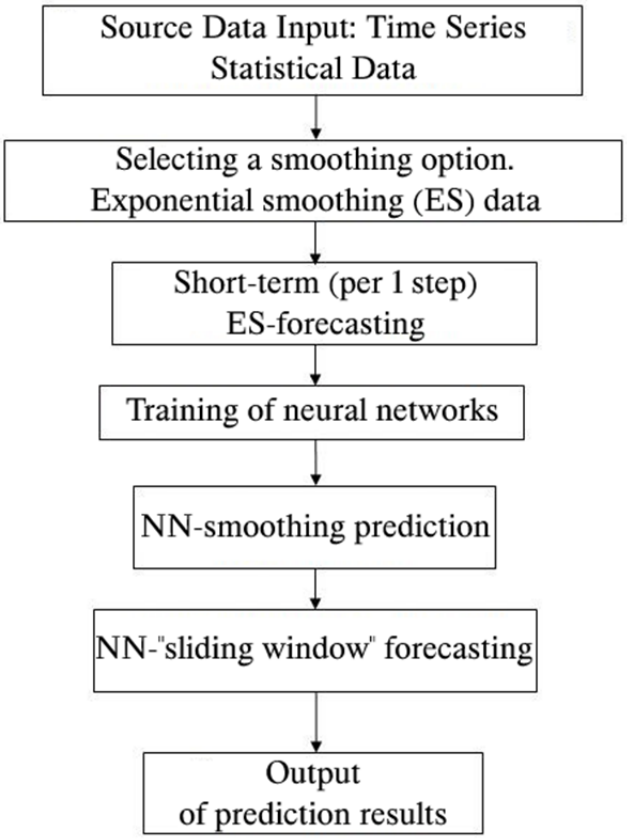


Fig. 1. **Program flowchart**

The interface of the computer program that implements this computer model is shown in fig. 2.

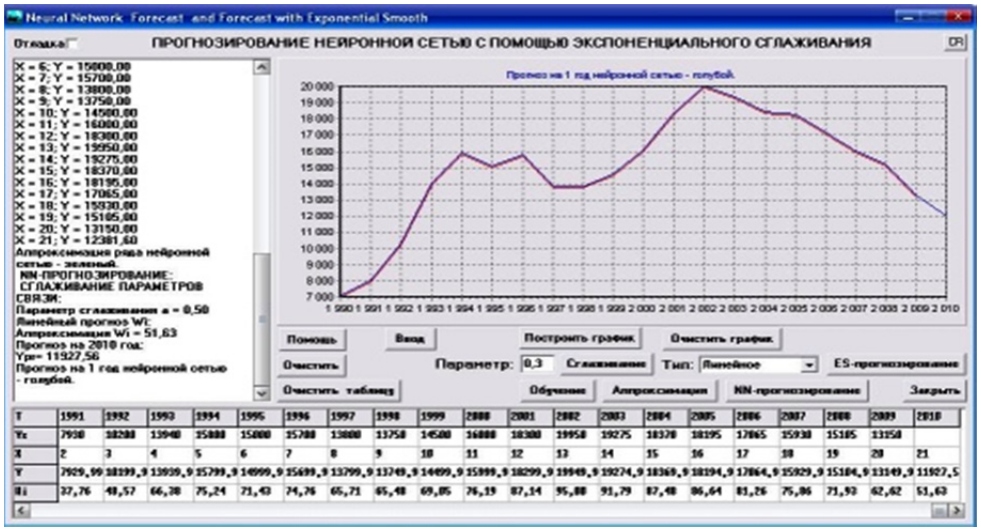


Fig. 2. **Computer program interface**

A feature of the computer model of exponential smoothing is that at each time step there is a process of adaptation to the time series data. Then the prediction error is determined, with the help of which compensatory changes are generated. Further, there is a forecast for the next point in time. As a result, the whole process is repeated. The block diagram of the program is shown in fig. 3.

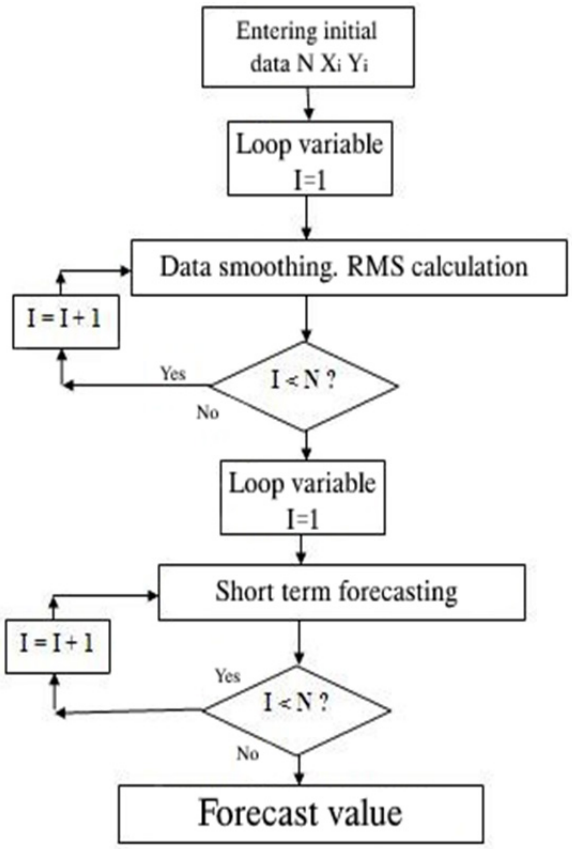
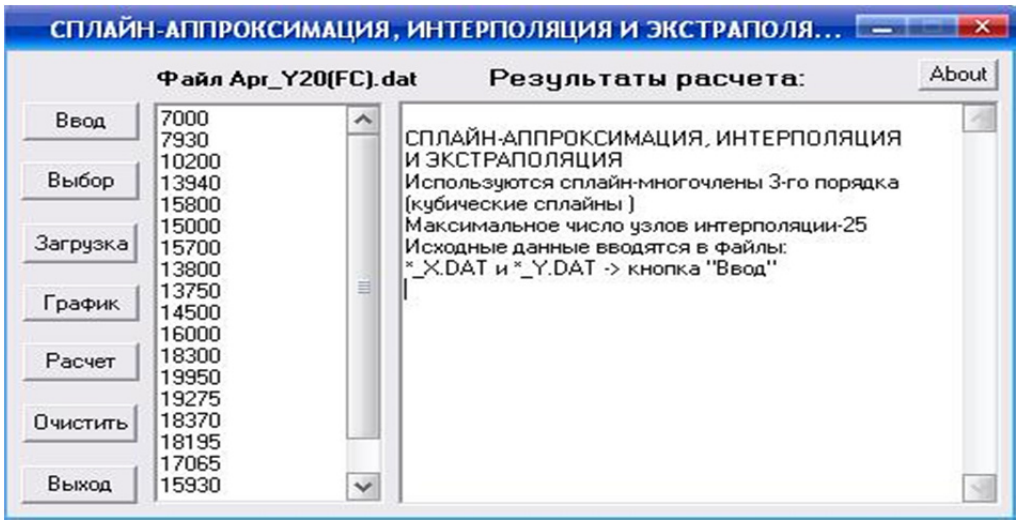


Fig. 3. **Block diagram of the program**

The computer model of exponential smoothing used for short-term forecasting was implemented as a computer program. The interface of the time series forecasting program using exponential smoothing is shown in fig. 4.

Fig. 4. **Interface of the time series-forecasting program using exponential smoothing**

A feature of the computer model of spline extrapolation is the implementation of piecewise polynomial approximation using polynomials of the third degree (cubic splines). The interface of the computer program using spline extrapolation is shown in fig. 5.



Fir. 5. **Interface of the time series-forecasting program using spline extrapolation**

The block diagram of the time series-forecasting program using spline extrapolation is shown in fig. 6.

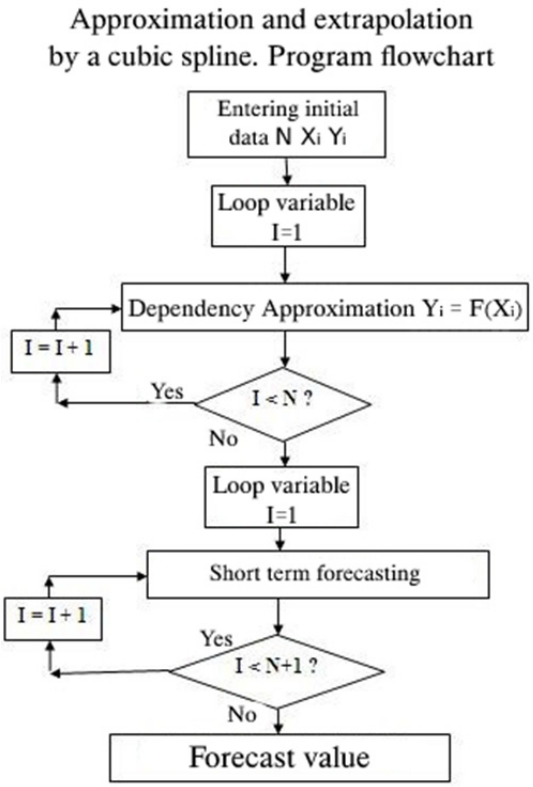


Fig. 6. **Flowchart of the program**

Results of computational experiments

The short-term forecasting programs discussed above were used to conduct computational experiments using data on the number of deaths in fires in the Russian Federation for the period from 2000 to 2020, taken from the website of the Russian Emergencies Ministry. The data is presented in the table 1.

Table 1

Year	Number of dead	Year	Number of dead	Year	Number of dead	Year	Number of dead
2000	7 000	2006	15 700	2011	18 300	2017	15 927
2001	7 930	2007	13 800	2012	19 906	2018	15 105
2002	10 200	2008	13 750	2013	19 275	2019	13 148
2003	13 940	2009	14 500	2014	18 371	2020	12 053
2004	15 800	2009	16 000	2015	18 194	–	–
2005	15 000	2010	18 300	2016	17 065	–	–

Time series data for 20 years, from 2000 to 2019, were used as a training sample. As a result of forecasting, the values of the number of deaths for 2020 were obtained, presented in table 2.

Table 2

The model that implements	Number of dead 2020 year	Absolute error	Relative error
neural network, traditional method	11 920	133	1,1 %
neural network, the method of «sliding windows»	11 974	79	0,66 %
exponential smoothing	11 295	758	6,3 %
spline extrapolation	11 750	303	2,5 %
Statistical data	12 053	–	–

Conclusion

With the help of computer programs that implement a neural network, exponential smoothing and spline extrapolation, computational experiments were performed, which showed that the relative error of short-term forecasting for the considered computer models is in the range from 0,66 % to 6,3 %. This result allows us to conclude that all the considered computer models provide acceptable accuracy of short-term forecasting of the time series.

The minimum error of short-term forecasting (0,66 %) in a computer model of forecasting using a neural network using the forecasting method «sliding windows» (windowing).

The maximum error of short-term forecasting (6,3 %) in a computer model of forecasting using exponential smoothing.

References

1. Mathematical modeling of complex technical systems: sat. articles. M.: MSTU im. Bauman, 1997.

2. Labinsky A.Yu., Podruzhkina T.A. Reduction of technogenic risks with predictive mathematical models // Natural and technogenic risks. 2013. № 3.

3. Kahneman D. Mathematical Modeling. New York and London, 2016.

4. Pegat A. Fuzzy modeling and control. M.: BINOM, 2013.

5. Labinsky A.Yu. Model of fuzzy forecasting // Problems of risk management in the technosphere. 2016. № 4.

6. Mamdani E.H., Assilian S. An experiment with a fuzzy logic controller // Cybernetics and Systems. 2014. № 15.

7. Tarkhov D.A. Neural networks as a means of mathematical modeling. M.: Radio engineering, 2006.

8. Labinsky A.Yu. Peculiarities of using a neural network for forecasting time series // Scientific and analytical journal «Vestnik Saint-Petersburg university of State fire service of EMERCOM of Russia». 2018. № 1.

9 Barron A.R. Neural net approximation // IEEE Transaction on Information Theory. 2016. Vol. 49.

10. Baldi P. A recurrent neural network // Neural Computation. 2018. Vol. 2.

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