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Hybrid Models Application for Short Time Series Prediction Based on Social and Economic Indicators of Russian Federation

Igor KOLMAKOV[1], Victoriia SAVINOVA[2,*] and Alexandra VARFOLOMEEVA[2]

[1]Doctor of Science (Economics), Academic Department of Informatics, Plekhanov Russian University of Economics (PRUE). Address: Stremyanny lane, 36, Moscow, 117997, Russia

[2]Academic Department of Informatics, Plekhanov Russian University of Economics (PRUE). Address: Stremyanny lane, 36, Moscow, 117997, Russia

*Corresponding author

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Abstract. The key to the successful operation of companies in today's economy is the rapid decision-making process based on precise forecasts. However, key indicators do not usually have sufficient quality and quantity of source data, which leads to failure of standard methods and the prediction models in some areas of the economy. This main objective of this paper is to analyze the models for short series prediction that are based on multiple linear regression and neural networks (with two different learning algorithms: Back propagation and BFGS) on the example of socio-economic indicators in the Russian Federation.

Introduction

One of the most important successful functioning factors of the enterprises in the modern economy conditions is timely decision-making based on strategic development of separate company as well as the whole country. The precise forecast of the selected indicators (time series) is the key to success of decision-making process. However not all indicators have high quality of source data that results in impossibility to apply the standard methods and forecasting models in some fields of economy [1]. That is why the need to use new non-standard approaches appears [2]. One of them is based on artificial neural networks (ANN) which have a number of advantages for building predictive models. One of main advantages of ANN considers a capability to provide learning that is impossible for standard mathematical models. Nowadays different types of ANN architectures are designed and learning algorithms are developed. In this paper, the comparative analysis of the models constructed by means of econometrics methods (multiple linear regression) and neural networks with two various learning algorithms (Back propagation and BFGS) based on social and economic indexes of the Russian Federation is carried out. This paper is organized as follows: in Section 2, literature review is presented; Section 3 describes the multiple linear regression model; neural network is presented in Section 4; Section 5 and Section 6 contain the description of standard back propagation method and BGFS; the example of retro forecast is given in Section 7; and Section 8 is the conclusion.

Literature Review

The problem of building hybrid predictive models is widely discussed in papers of the leading Russian and international scientists. L. A. Demidov, A. N. Pylkin, S. V. Skvortsov and T. S. Skvortsova in their paper "Hybrid forecasting models of short time series" resolve the problem of short time series prediction by means of genetic algorithms and fuzzy logic [3]. However, none of the authors has proposed using artificial neural networks with different learning algorithms. In our research, we have analyzed models built on multiple linear regression and neural networks with back propagation and BGFS learning algorithms.

Multiple Linear Regression Model

The academic department of informatics, Plekhanov Russian University of Economics, has developed software complex "RIAMS", which allows you to build a multiple linear regression equations system of various economic indicators. As part of this complex model, the short-term forecast of socio-economic situation in Russia was proposed. Federal state statistic service has provided the source data for the forecast for the period of 2000-2015 [4]. The verification of the results was carried out. The accuracy criteria evaluated the average relative error:

$$\Delta = \frac{|F-C|}{F} \times 100\%, \quad (1)$$

where Δ - mean relative error F - actual or reported data, C - calculation results.

The quality of the constructed equations was estimated using the coefficient of determination (R2), the statistic criterion of the Durbin-Watson (DW) and Fisher (F-stat). As a result, the verification revealed that the forecast was not satisfactory. Based on the low quality forecast it was decided to use artificial neural network model.

Artificial Neural Networks

An artificial neural network is a parallel-distributed processor that includes a plurality of individual data processing units (neurons) that are associated with each other. Each neuron in turn, includes synapses (interconnection pattern), the adder, the result of which is the sum of the products of the input signals and the corresponding weights and the activation function of the axon that transmits the output signal (Fig.1).

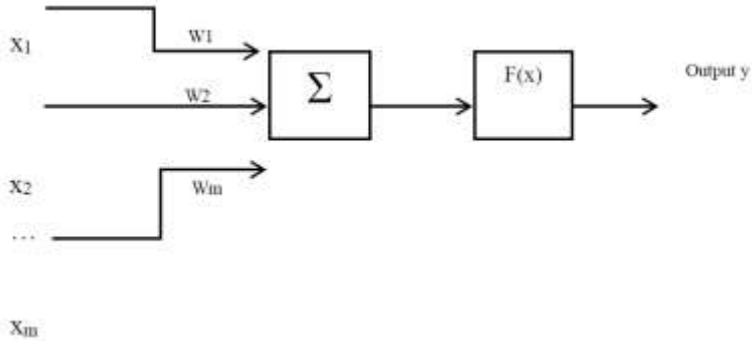

Figure 1. Neural Network.

Continuous functions that can be derived on all range of definition are chosen as the activation function. In current paper, the hyperbolic tangent is taken. In the research the architecture of full-coherent network of direct distribution – multilayered perceptron with one hidden layer is chosen for prediction. Neural network learning algorithms consider the configuration of the weights of synapses. Learning algorithm is the rule changing the weights of data. Its purpose is to minimize the error between the desired response and the actual output signal (y). As part of current research two learning algorithms were analyzed: back propagation and BFGS-method.

Back Propagation

The essence of this method is to find a minimum of the error function using the method of gradient descent. Back propagation learning algorithm is divided into four steps [4]:

1. Initially, all weights of the network are assigned random values.

2. All the data are divided into training and test samples. These data are processed by a neural network, so that network learning takes place directly.

3. The standard deviation of the actual values from the calculated is estimated:

$$E = \sum_k (y_{ik} - y_{li})^2 \qquad k = 1,..,. K \quad i = 1,..,. N \quad (2)$$

where y_{ik} - calculated value; y_{li} - actual value.

Next, the method of gradient descent is applied (values of the derivatives of error functions for each parameter are calculated). The obtained values of derivatives will enable us to calculate the corrections to the weights of the network.

$$\Delta w_{ik} = -\eta \times \frac{dE_t}{dw_{ik}} \qquad k = 1,..,. K \quad i = 1,..,. N \tag{3}$$

where w_{ik} - weight of the corresponding communications; η - the speed of the network training; E_t - resulting learning error.

BFGS-Method

Broyden Algorithm - Fletcher - Goldfarb - Shanno (or BFGS-method) is one of iterative optimization methods, the purpose of which is to find a local extreme (in the case of learning - minimum) of the nonlinear function. We can say that this is the modified algorithm of back propagation. The iterative algorithms consider approximation of the objective function using quadratic functions in the neighborhood of an arbitrary point. With each iteration we solve the problem of minimizing a local form:

$$\min_x \frac{1}{2} x^t H_x + c^T + b \tag{4}$$

where H - the symmetric positive definite matrix of second order partial and mixed derivatives (Hessian or Hessian), with - a constant vector, b - constant. The optimal solution of this problem is defined by finding the point at which the derivative function is equal zero. The main difference of this method lies in the fact that there is no direct calculation of the matrix H, and the use some approximation, which is produced by the formula:

$$H_{k+1} = H_k \frac{q^T q_k^T}{q_k^T s_k} - \frac{H_k^T s_k^T s_k H_k}{s_k^T H_k s_k}, \tag{5}$$

where $s_k = x_{k+1} - x_k$; $q_k = \nabla f(x_{k+1}) - \nabla f(x_k)$.

Creation of the Retro Forecast by Means of Neural Network Model

For preparing the forecast by means of neural networks, the following socio-economic indexes of the Russian Federation were chosen: savings in deposits and securities (percentage of the income of the population); purchase of currency (percentage of the income of the population).

As the software for the analysis the software package of Statistica Advanced 10 is taken. Models of neural networks with various configurations were constructed. For the purpose of verification, the retro forecast for the 4th quarter 2015 is performed. The average relative mistake served as criterion for evaluation of accuracy (Δ).

The result on savings in deposits and securities (percentage of the income of the population) is provided in Figure 2, on purchase of currency (percentage of the income of the population) – in Figure 3 (in red color calculated values are presented, in blue – actual figures are designated).

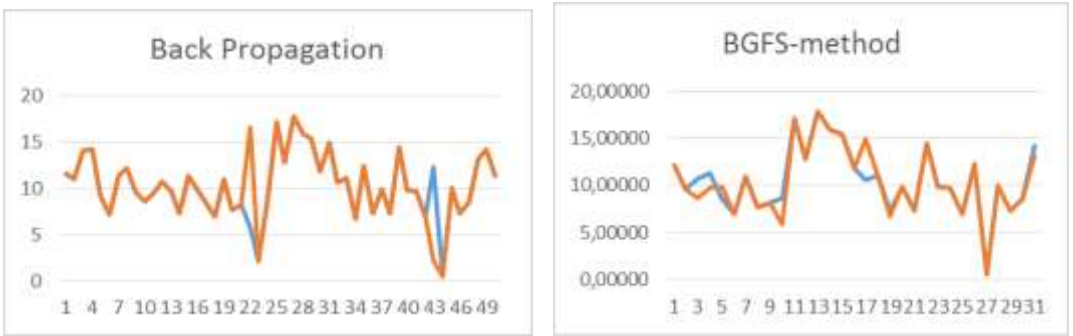

Figure 2. The comparative analysis of learning algorithms of Back Propagation and BGFS on the example of an indicator "Savings in Deposits and Securities (percentage of the income of the population)".

Figure 3. The comparative analysis of learning algorithms of Back Propagation and BGFS on the example of an indicator "Savings in Deposits and Securities (percentage of the income of the population)".

The most effective results are provided in Table 1.

Table 1. Average relative mistake (Δ), %.

Indicator	**Regression (multiple liner)**	**ANN (Back propagation)**	**ANN (BFGS)**
	Δ	**Δ**	**Δ**
Savings in deposits and securities (percentage of the income of the population)	36,5	3,5	2,3
Purchase of currency (percentage of the income of the population)	34	6,6	2,5

Summary

Neural networks models application allowed improving the accuracy of indicators, while the regression model did not provide satisfactory results. However making necessary configurations takes more time, than creating the regression equation. When comparing two training methods it is possible to note that the BFGS method allowed receiving more stable results, than back propagation algorithm. However, in case of an indicator "Purchase of Currency (percentage of the income of the population)" the alternative method performed better. It is possible to draw a conclusion on expediency of hybrid predictive model creation based on the presented algorithms, and expert system development with use of fuzzy logic tool, which will be able to estimate the predicted indicators and to perform the match of the most optimal methods for the forecast creation.

References

[1] Kitova O. V., Kolmakov I. B., Sharafutdinova A. R. Analysis of accuracy and quality of the short-term forecast of indicators of social and economic development of Russia.//Bulletin of Plekhanov Russian Academy of Economics. – No. 9. (2013) 111-119.

[2] Sharafutdinova A. R. Application of neural network models for improvement of quality of the forecast//the Bulletin of Plekhanov Russian Academy of Economics. – No. 8 (2012) 102-109.

[3] Demidov L. A., Pylkin A. N., Skvortsov S. V., Skvortsova T. S. Hybrid forecasting models of short temporary ranks. – M: The hot line – Teleom (2015)

[4] Official site of Federal State Statistics Service [An electronic resource]. Federal State Statistics Service, 1999–2016. URL: www.gks.ru (date of the address: 20.04.2016).

[5] Savinova V. M. Methodology and means of increase in accuracy and quality of the short-term

forecast of indicators of the social sphere of the Russian Federation//Scientific works of Free economic society of Russia. – T. 186 (2014) 311-316.

[6] Savinova V. M., Beskhmelnitsky A. A. Increase in accuracy and quality of the short-term forecast of indicators of the social sphere of Russia with use of artificial neural networks / Researches of young scientists: economic theory, sociology, industry and regional economy. (2015) 290-295.