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Development of hybrid models and a system for forecasting the indicators of the russian economy

Desarrollo de modelos híbridos y un sistema para pronosticar los indicadores de la economía rusa

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ABSTRACT:

Scenario forecasting of social and economic indicators is highly important for strategic planning of the country's economic development. In this regard, it is very important to build a forecasting system for a model of the main economic indicators of the country and/or region for experts. At present time there is lack of such systems on the market. The article describes a hybrid system of models and a prototype of an analytical forecasting system Horizon that is based on using a hybrid forecasting approach, has learning capabilities and adaptability. Over the past 3 years, many works have been published on the development of time series forecasting models by means of artificial networks and deep learning. Unfortunately, the models developed are not implemented in an information system, but rather as separate mathematical calculations using various analysis packages or Python libraries. The authors' system of econometric models of the Russian economy indicators and the process of development of the Horizon system are described. Hybrid forecasting models were developed within the framework of the Horizon system for 70 indicators of Russian economy. The forecasts calculated in the

RESUMEN:

El pronóstico de escenarios de indicadores sociales y económicos es muy importante para la planificación estratégica del desarrollo económico del país. En este sentido, es muy importante construir un sistema de pronóstico para un modelo de los principales indicadores económicos del país y / o la región para expertos. En la actualidad hay falta de tales sistemas en el mercado. El artículo describe un sistema híbrido de modelos y un prototipo de un sistema de pronóstico analítico Horizon que se basa en el uso de un enfoque de pronóstico híbrido y tiene capacidades de aprendizaje y adaptabilidad. En los últimos 3 años, se han publicado muchos trabajos sobre el desarrollo de modelos de pronóstico de series de tiempo por medio de redes artificiales y aprendizaje profundo. Desafortunadamente, los modelos desarrollados no se implementan en un sistema de información, sino más bien como cálculos matemáticos separados que utilizan varios paquetes de análisis o bibliotecas Python. Se describe el sistema de autores de modelos econométricos de los indicadores de la economía rusa y el proceso de desarrollo del sistema Horizon. Los modelos de pronóstico híbridos se desarrollaron en el marco del sistema Horizon para 70 indicadores de la

system showed high accuracy for 80% of indicators.
Keywords: Forecasting models, Hybrid systems, Artificial neural networks, Russian economy indicators, Forecasting software.

economía rusa. Los pronósticos calculados en el sistema mostraron una alta precisión para el 80% de los indicadores.
Palabras clave: Modelos de pronóstico, Sistemas híbridos, Redes neuronales artificiales, Indicadores de economía rusa, Software de pronóstico.

1. Introduction

Nowadays, strategic planning is one of the most important factors of the country's economic development. Scenario forecasting of social and economic indicators is one of the most important directions in making decisions at the federal and regional levels. In order to carry out scenario forecasting, it is necessary to build models that would allow obtaining the most accurate values of forecasts of the studied indicators, as well as to study the development tendencies of the country as a whole and its regions (Balynskaya et al., 2017).

One of the most common approaches to scenario forecasting of Russian economy indicators is the construction of interrelated regression equations that characterize various aspects of the country's economic activity. This approach forms the concept of a country model. Similar models have been described in the writings of famous scientists (Klein and Goldberger, 1955; Johnston and DiNardo, 1997; Pindyck and Rubinfeld, 1999; Hastie et al., 2009).

In the Russian market there is a number of vendors of information and analytical systems and BI platforms for situational centers, but they do not include models for predicting economic indicators. The leader in this area is the information and analytical platform Prognoz of the company Foresight. The platform Prognoz has a time series forecasting module but in order to develop systems of regression equations or fulfill procedures of intellectual analysis it requires programming in Python, which requires deep knowledge in both analytical methods and programming.

At the same time, in many organisations, in analytical departments and universities experts use in-house forecasting software not described in the scientific press.

In this regard, it is very important to build a forecasting system for a model of the main economic indicators of the country and/or region which can be developed by experts.

Author's team of the Department of Informatics of the Plekhanov Russian University of Economics (PRUE) had developed a country model based on the system of econometric models for forecasting socio-economic indicators and the information analytical system "RIMEXPROGNOZ" using the programming language Visual Basic for Application (VBA) (Kitova et al., 2012; Kolmakov et al., 2015).

However, this system had significant shortcomings, both methodological and technological.

The disadvantages in terms of methodology are the following:

- the system uses exclusively regression models while these modules cannot predict some kinds of indicators (Kitova et al., 2012);
- the system does not have the ability to include models of another type.

At the same time, forecasting models developed by a number of researchers on the base of artificial neural networks, deep learning and cognitive maps demonstrate very promising results for economic time series (Bisoi and Dash, 2015; Laletina, 2015; Lesik, 2015; Miao et al., 2007; Nguyen and Cripps, 2001; Wang and Wu, 2012; Wang, and Ning, 2015).

Technological disadvantages of the system are:

- the inconvenience of uploading data from files to the system;
- lack of user-friendly user interface;
- lack of integration with other systems.

The goal of this study is to build a hybrid system of models and a prototype of an analytical decision support system Horizon that is based on using a hybrid forecasting approach, has learning capabilities, adaptability. The system should be easily integrated with other systems and have low computing requirements to the user computer. The system should be built as a cross-platform.

The system being developed is aimed at an expert user who, when solving problems of economic analysis, can carry out scenario forecasting based on pre-configured hybrid models. The system is open both in terms of adjusting parameters for existing models and inclusion of new models (Kitova et al., 2015a, 2015b; Kitova et al., 2016).

For the first implementation of the system its integration with the information system of the PRUE Situational Center is considered.

Using a hybrid approach to modeling time series and neuro-fuzzy logic for the system of economic indicators of the Russian Federation is not described in the literature and represents the scientific novelty of the study.

In the Horizon system, indicators for the social sphere were calculated. The regression models provided sufficient quality and accuracy of forecasts for 47 out of 70 indicators. For 7 of the remaining indicators, models based on artificial neural networks were developed which gave satisfactory results.

The theoretical significance of the research is the development of adaptive models for forecasting systems of time series of economic indicators of the Russian Federation. The practical significance of the work is demonstration of the performance of the Horizon prototype system on a full set of social indicators.

The article further presents a literary review of publications on modeling and forecasting economic time series. In the Materials and Methods section, the structure of the socio-economic indicators model as well as software development tools are described. The Results section covers statistical characteristics of the forecasts of indicators of the social sphere, confirming their high accuracy. In the further section the results obtained and the prospects for using the system are discussed. The last section contains conclusions.

2. Literature review

The problem of creating analytical software for socio-economic forecasting was discussed in the works of many scientists. In the article "Hybrid Models for Forecasting Short Time Series" L.A. Demidova, A.N. Pylkin, S.V. Skvortsov and T.S. Skvortsova (Demidova et al., 2015) described the development of a forecasting module on the basis of the fuzzy sets theory, genetic algorithms and artificial immune systems. The works of A.N. Averkin and S.A. Yarushev discuss the construction of prediction models using fuzzy neural networks, deep learning and cognitive maps (Averkin and Yarushev, 2017; Yarushev and Averkin, 2018). Similar models based on cognitive maps were also considered in the works of other authors (Papageorgiou and Poczęta, 2017; Singh, 2015).

Over the past 3 years, many works have been published on the development of time series forecasting models by means of learning models (Kong et al., 2018). Prediction using artificial neural networks (Iwaniec and Atink, 2015; Dulcet, 2015; Sarajevo and Lezina, 2015; Kolesnikov and Konkin, 2015) became a popular topic.

The problem of building hybrid models is also one of the important scientific issues in predicting neural networks (Kavousi-Fard et al., 2014). According to the authors, hybrid models can significantly improve the quality of forecasts (Yarushev and Efremova, 2014).

Earlier works are devoted to predicting linear time series using artificial neural networks and consider the positive and negative features of these approaches (Zhang, 2001; Medeiros and Pedreira, 2001). Some authors raise the problem of criteria for choosing forecasting methods when building a model (Buchatskaya, 2012).

However, all considered forecasting models have several disadvantages:

1. Some models can only be used for processing big data.

2. All the models developed are not implemented in an information system or its module, but rather as separate mathematical calculations using various analysis packages or Python libraries.

3. The quality of models is assessed manually.

Some of the developed models are not supported by empirical data.

3. Materials and methods

Currently, the main forecasting methods in the system are multiple linear regression and artificial neural networks. The basis of the regression equations is the classical method of least squares. Models of neural networks are presented by multilayer perceptron with one hidden layer. The network training method used in the system is the back propagation method, based on the correction of weights by minimizing the learning error of the output neuron. The basis of this method is the method of gradient descent.

The functionality of the Horizon system is based on hybrid forecasting models developed for indicators of the Russian economy (Kolmakov and Domozhakov, 2016). The main block of indicators in the model system is a block of scenario conditions. These indicators characterize possible scenarios of a country's development and are set by an expert. Scenario conditions are determined by the Ministry of Economic Development of the Russian Federation and are used to build forecasts in the framework of the described model.

The system also includes blocks of indicators characterizing the socio-economic situation of the Russian Federation: macroeconomic indicators, indicators of the financial sector, indicators of the standard of living of the population, labor and employment, indicators of foreign economic activity, indicators of research and innovation. For each block of indicators, regression forecasting models were developed, representing systems of interrelated equations.

However, not all indicators can be predicted with sufficient quality and accuracy using regression models. In this regard, for these indicators intelligent models were used based on artificial neural networks. (Kolmakov and Domozhakov, 2015) Thus, a system of hybrid forecasting models was built, which formed the methodological basis for creating a prototype of the Horizon information system.

The significance of the model is determined by the criteria of its accuracy and quality. As a part of the Horizon system the quality of the equations was determined by calculating the coefficients of determination (R2), Darbin-Watson (DW) and Fisher's criterion (F). Accuracy was assessed by constructing a retro-prediction and calculating the mean relative error (MAPE). The values of the criteria of accuracy and quality, under which the model was considered suitable for forecasting, were set expertly (Table 1).

Table 1
Criteria of quality and accuracy

Quality assessment criteria		
coefficient of determination (R2),	> 0,4	
values of Fisher statistics (F-stat)	> 5,0	
The Durbin-Watson criterion (DW)	0,8 < DW< 3,2	
Accuracy estimation criteria (Δ)		
High	Middle	Low
<0,06	0,06< Δ <0,16	>0,16

In order to determine the quality of intelligent models, the calculation of the average learning error (MAPE for training and test samples) and the coefficient of determination is used. The accuracy of intelligent models is determined by a method similar to the method for calculating the quality of regression models.

The development of the Horizon system is based on the .Net Core platform using the means of the MS Visual Studio 2017 development environment. This platform is universal and has open source. The platform is supported by Microsoft and the .NET community using the GitHub resource. It is cross-platform, which means that it can support Windows, macOS and Linux, and can be used to create applications for any devices, cloud applications, as well as Internet of things applications. The main advantages of the platform are also the following:

1. Consistency between architectures, that is, the code runs the same way, regardless of the processor architecture.

2. The possibility of flexible development, in which the platform can be embedded in the application or installed in parallel at the user level.

3. The platform is compatible with the .NET Framework, Xamarin and Mono thanks to .NET Standard.

This platform supports C #, Visual Basic and F #. These languages are integrated into the development environments of Visual Studio, Visual Studio Code, Sublime Text and Vim.

Postgress and Microsoft SQL Server are used as database management systems for the developing software. At least 1000 users are expected to work in the system.

It is implemented as a SPA (Single page application) and it is used by the VTE.js (javascript framework for creating user interfaces). HTML5 and CSS3 technologies.

The development of the Horizon system is carried out using the SCRUM technology. SCRUM is an Agile framework, which implies the following events:

- Sprint planning (a short period of time to solve a specific task);
- Daily Scrum (short meetings to discuss the results);
- Sprint review (status meeting of the team to discuss the results, distribution of tasks);
- Sprint retrospective (discussion of the quality of teamwork).

This technology is characterized by a small team size, as it provides flexibility, but sufficient to solve complex problems.

The listed advantages of the Scrum technology make it possible to develop the system as flexibly as possible and each subsequent stage allows to obtain a visible result.

The planning of each stage (sprint) includes the formation of the backlog of the current sprint, evaluates the team's future performance opportunities and calculates the current performance. Backlog includes functional requirements for a specific task that must be implemented within the system. Requirements for each task are formalized and a software component is designed that solves the current task. As a visual representation of the functionality of the component being developed, the UML notation is used.

After designing, a development process is underway, during which a daily scrum is held, a periodic sprint review is carried out to evaluate the results and to evaluate the team's performance.

At the moment, the following modules of the Horizon system have been developed:

- Authorization of users
- Uploading data to the system
- Data quality assessment (calculation of descriptive statistics)
- The regression equation module
- The module of artificial neural networks.

The system is deployed on the server, which presents the bulk of the calculations. Access to the system is provided via the web interface which allows to connect to it from any modern device. After registration, users can store their data sets and built models in the system database.

Currently, the developed modules are working in test mode for students of the PRUE.

4. Results

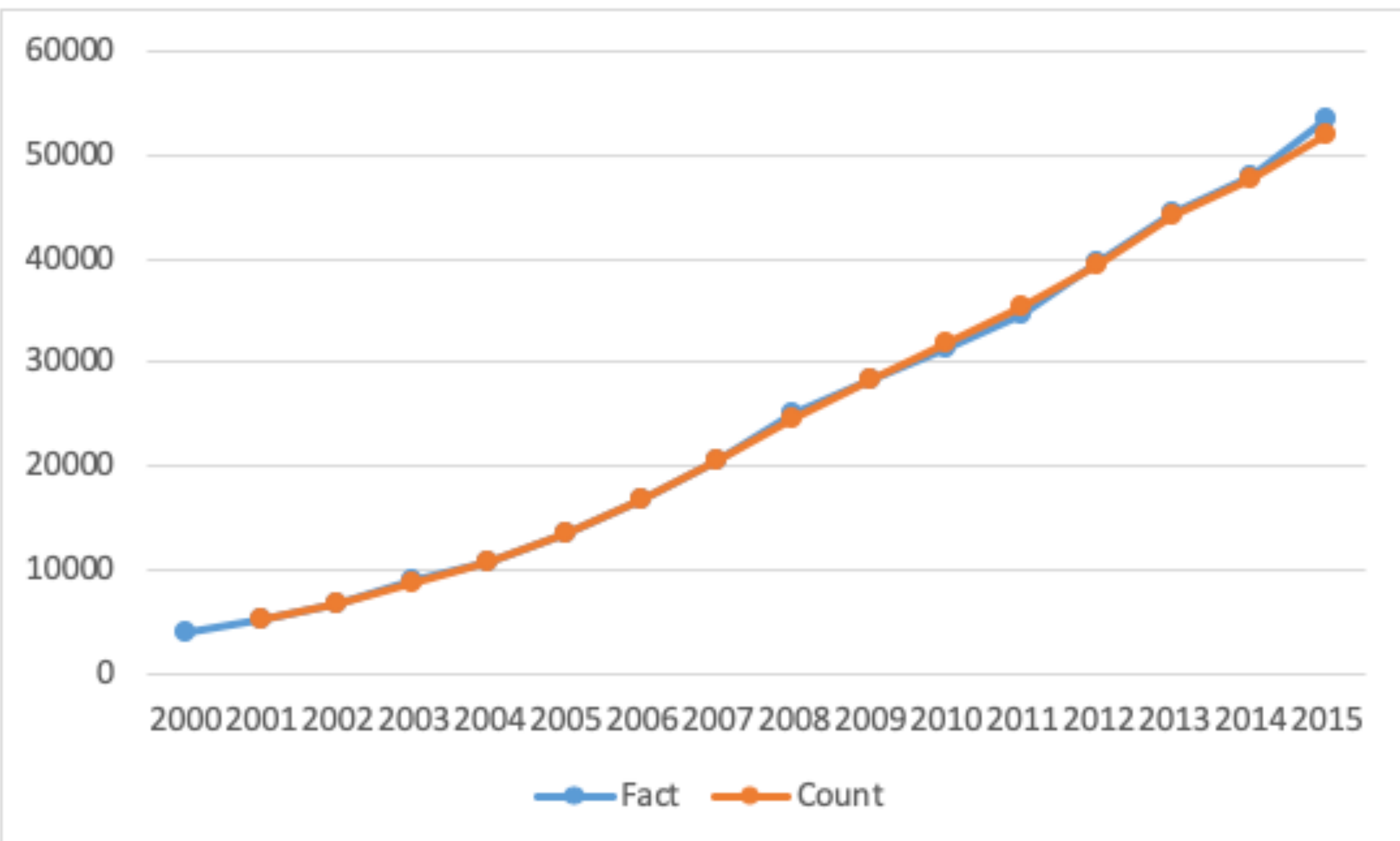
The system Horizon is used in the educational process in analysis and forecasting socio-economic indicators of the Russian Federation. Within the framework of the system, models for the blocks of indicators: scenario, macroeconomic, investment and social sphere of the Russian Federation were implemented. A system of regression equations was built for 70 indicators from the blocks mentioned. The results of the verification of this model are shown in the Table 2.

Table 2
Regression equation verification results

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Quality assessment criteria</th></tr>
<tr><th>High</th><th>Middle</th><th>Low</th></tr>
<tr><td rowspan="2">Accuracy assessment criteria</td><td>High</td><td>47</td><td>4</td><td>6</td></tr>
<tr><td>Low</td><td>4</td><td>6</td><td>3</td></tr>
</table>

The table shows that 47 equations allowed to obtain the predicted values of acceptable accuracy and quality. An example of plotting for the indicator "Cash expenses and savings of the population" is presented in Figure 1. For this indicator the regression equation has reliable predicted values and a high level of accuracy and quality (the coefficient of determination is 0.99; the Durbin-Watson coefficient 2, 2; Fisher statistics - 10.2).

Figure 1
A graph of the indicator "Cash costs and savings of the population"



However, for 23 regression models gained poor results. For these models, using the developed Horizon system, artificial neural networks were built, having a multi-layer perceptron architecture with one hidden layer. Perceptron has improved the accuracy and quality of forecasts of 7 indicators. The result of verification is shown in the Table 3.

Table 3

The result of verification of models of neural networks

Indicator	Regression		Artificial neural network	
	R2	MAPE	R2	MAPE
Property income	0,99	25%	0,91	7%
Income from business 1	0,94	21%	0,89	5%
Buying currency	0,95	27%	0,87	8%
The average amount of pensions granted	0,99	18%	0,91	7,50%
Gross accumulation	0,60	15%	0,81	9%
Net exports of goods and services	0,61	9%	0,89	7,50%
Organizations leading the training of doctoral students	0,67	10%	0,92	8%

A graphical comparison of the regression and neural network models is presented in Figures 2 and 3.

Figure 2
A chart for regression for the indicator "Organizations training doctoral students"

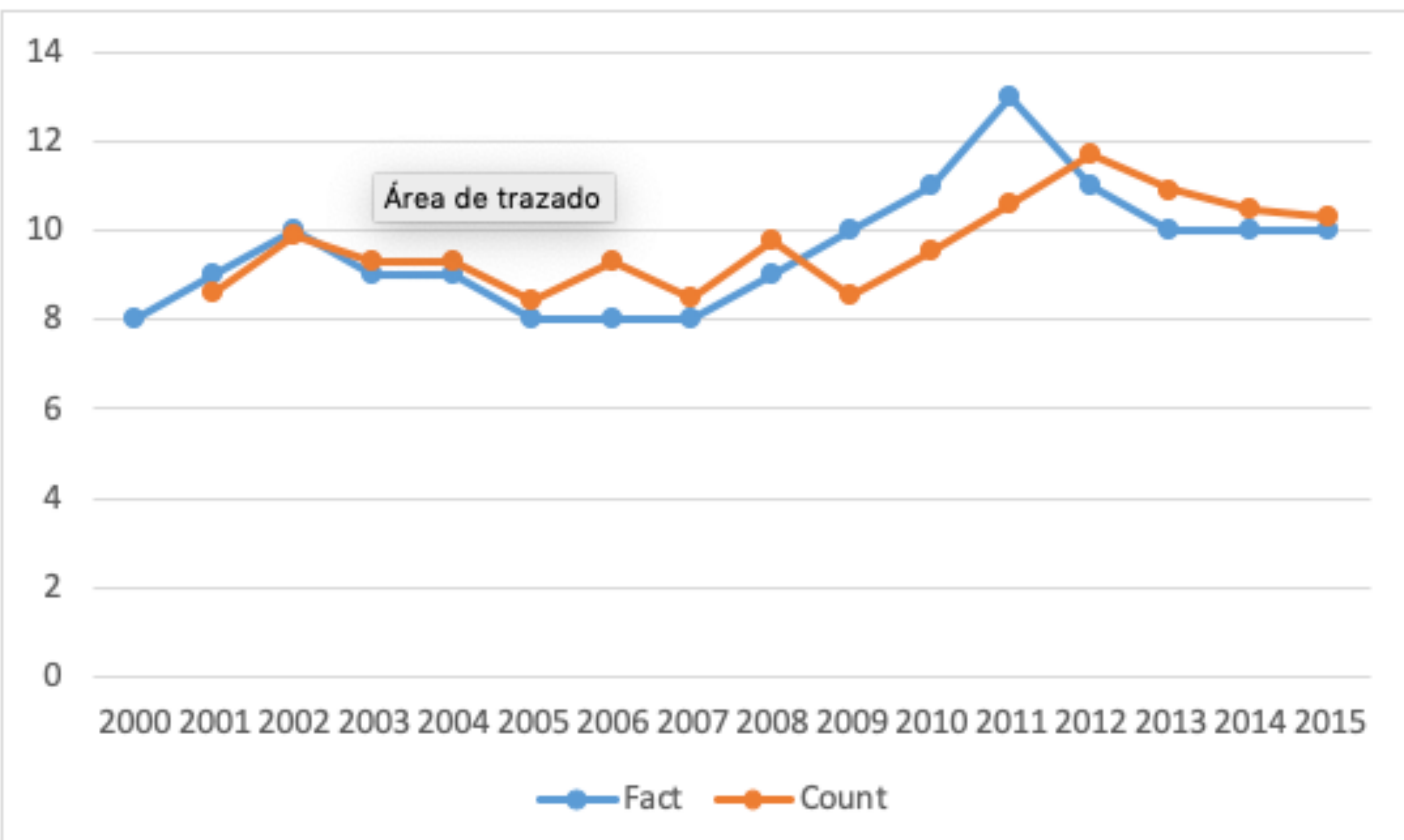
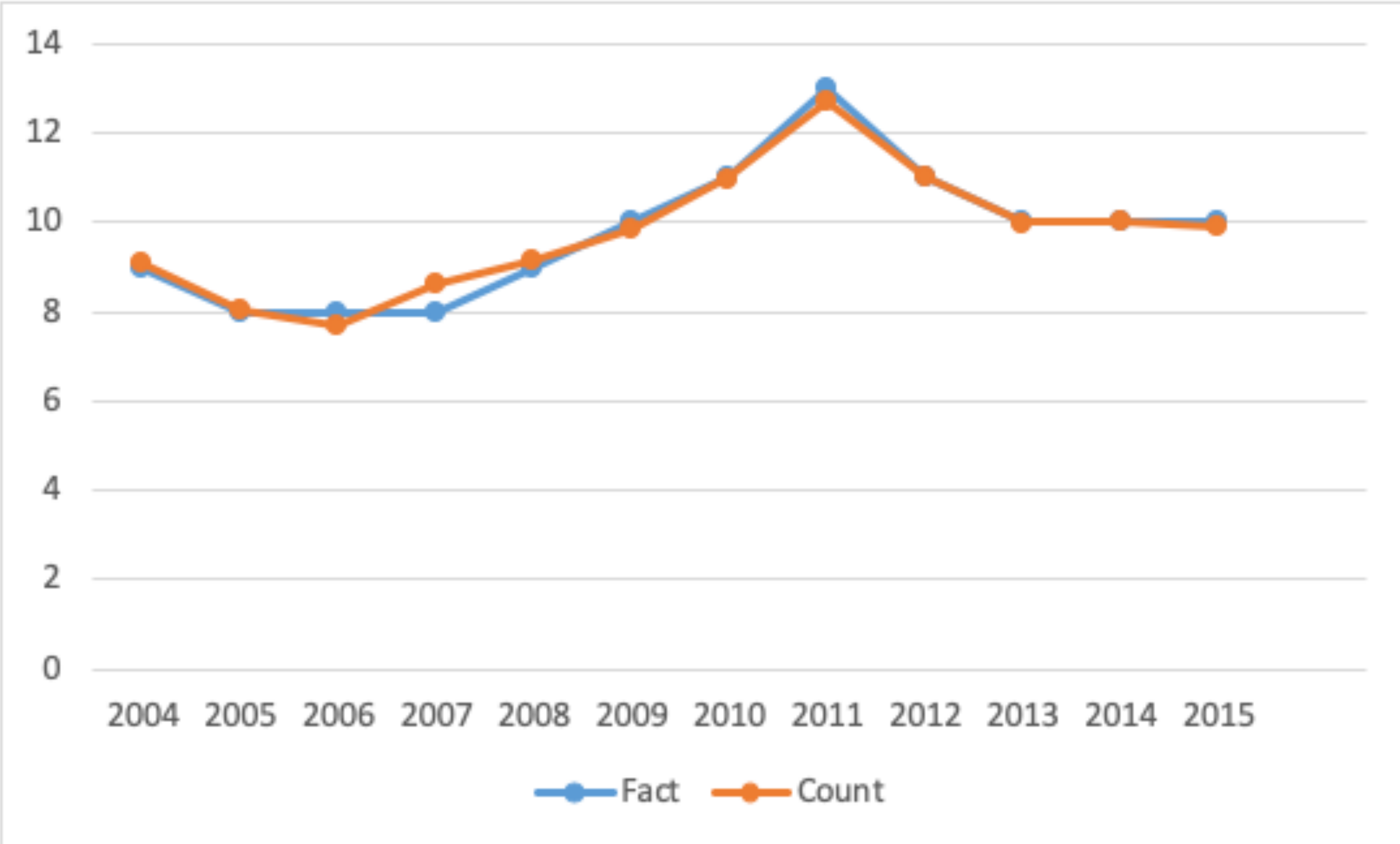


Figure 3
A chart for the neural network for the indicator "Organizations training doctoral students"



Currently, an authentication module that allows the user to register and get space on the server for building models has been developed. The system enables uploading txt, csv, xls, xlsx files to the system. Due to the use of the .NET Core platform, the system has the ability to load data from external systems using API (application programming interface) technology. In the Horizon system it is possible to build a system of regression equations, as well to create artificial neural networks with the architecture of a multi-layer perceptron (certificates for registration of intellectual property are obtained). Some visualization is possible within the system, however, the visualization module is in the process of development, and therefore the system provides for the possibility of uploading data to MS Excel format. The developed system allows to verify the obtained models. The list of built-in models is planned to be expanded by introducing additional methods of machine learning.

5. Discussion

As a result of the research, hybrid forecasting models were developed within the framework of the Horizon system for 70 indicators. With the use of the neural network, 7 indicators were improved, which supports the practicability of using this approach. Four system modules were implemented to allow registration, access to resources for building a model, data uploading, assessing data quality, as well as building models of interconnected regression models and artificial neural networks.

In the process of developing a system the technology of agile development was used. This technology is convenient, as it allows to quickly adapt to changes in the formulation of tasks, quickly solve problems arising during the development process, and more precisely observe the deadlines set.

The process of developing the Horizon system has a number of limitations, including:

1. The small size of the development team, which reduces the number of possible time resources and slows down the pace of development

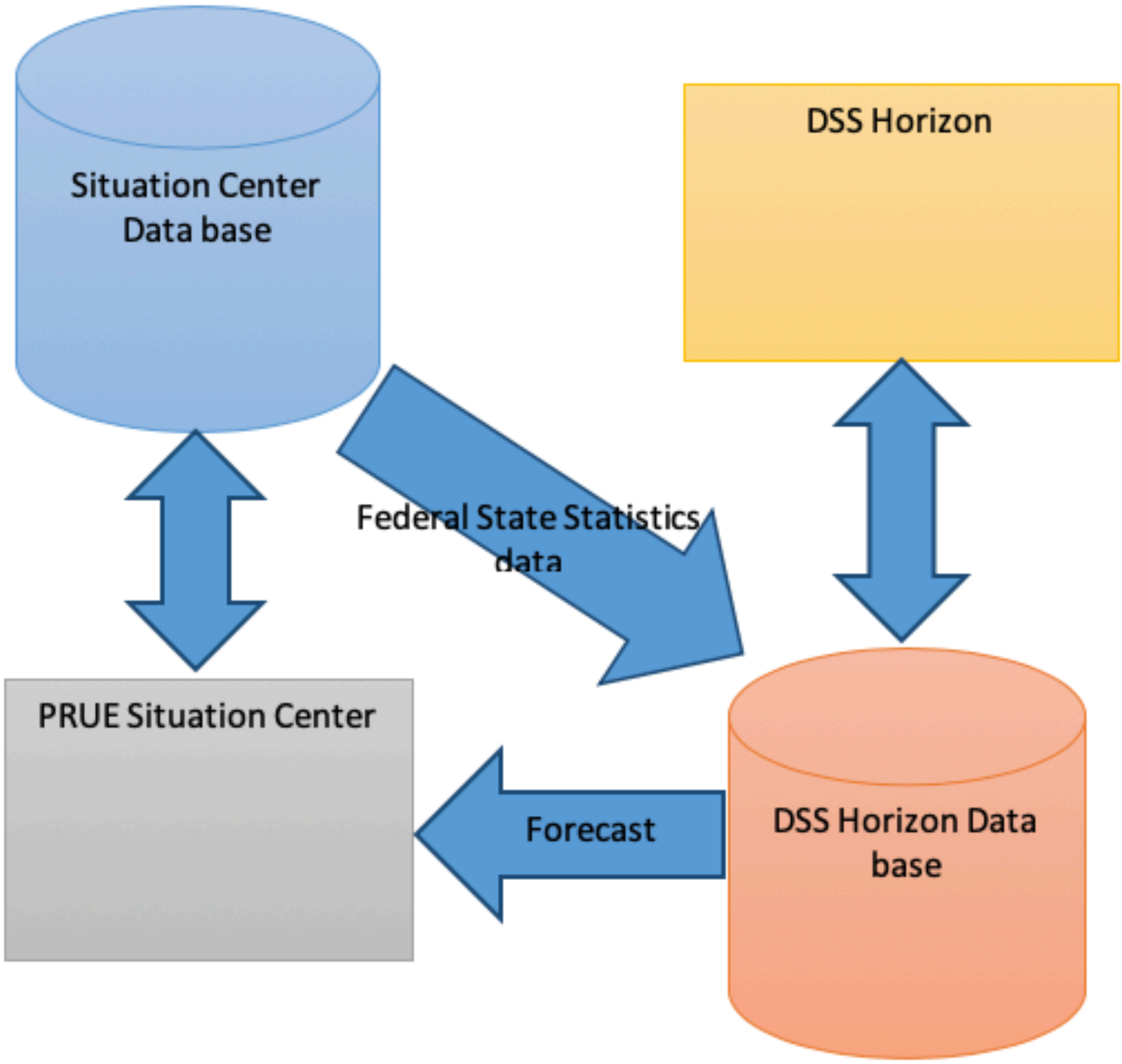
2. Lack of resources by the server

3. Limitation of project financing.

An adaptive network is currently being developed by the authors on the basis of a fuzzy inference system, the main goal of which is the selection of a suitable prediction model for downloaded data. Additional methods of machine learning will be included in the system which will improve the accuracy and quality of prediction models.

In PRUE a Situation Center is operating, one of the main objectives of the Center is the implementation of expert-analytical and consulting work on the current areas of social and economic development of Russia and the regions of the Russian Federation (Kitova et al., 2017). The developed decision support system will be able to integrate with the software of the center, as well as with its database (Figure 4).

Figure 4
Integration with the situation center of the PRUE



6. Conclusions

Developed decision support system Horizon allows to predict the indicators of socio-economic status of the Russian Federation and the regions on the basis of a hybrid model. It includes a regression model and a number of intellectual predictive models.

This system allows modeling the future value of the indicators, based on the scenario conditions set by an expert.

The development of the system uses modern development technologies that allow making the system cross-platform. The scrum technology used allows to to more quickly respond to changes in problem statements and solve the problems identified.

The designed adaptive network module based on the fuzzy inference system will make the system more adaptive and self-learning, which will allow the experts to conduct research without having deep knowledge in the field of programming and machine learning.

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