

# Neural network theory evolution as an innovative factor of successful and dynamic development of economic systems

## La evolución de la teoría de redes neuronales como un factor innovador de desarrollo exitoso y dinámico de sistemas económicos

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Received: 01/04/2018 • Approved: 20/04/2018

### Contents

- [1. Introduction](#)
- [2. Results](#)
- [3. Discussion](#)
- [4. Conclusion](#)
- [Acknowledgements](#)
- [References](#)

#### ABSTRACT:

The present paper considers a concept of neural networks, as well as their practical application in economics of various countries. In addition, the main stages of the neural network research were analyzed. As a result of the research, the authors proved that initially neural networks were studied in the field of biology and physics, and only at the end of the 20th century, they began to be used in forecasting economic processes. After analyzing the main stages of the neural network research development, the authors came to the conclusion that as a result of the evolution of scientific trends using the neural networks, the tasks that could not previously be solved could now be performed: forecasting and assessing the risk of a forthcoming transaction, forecasting the demand for new products, a comparative analysis of competing companies, detecting and processing video and audio signals. The research applied such general scientific methods as observation, description, and modeling. The authors identified the main advantages and disadvantages of

#### RESUMEN:

El presente trabajo considera un concepto de redes neuronales, así como su aplicación práctica en economía de varios países. Además, se analizaron las principales etapas de la investigación de la red neuronal. Como resultado de la investigación, los autores demostraron que inicialmente se estudiaron las redes neuronales en el campo de la biología y la física, y recién a fines del siglo XX comenzaron a utilizarse en la predicción de procesos económicos. Después de analizar las principales etapas del desarrollo de la investigación de redes neuronales, los autores llegaron a la conclusión de que, como resultado de la evolución de las tendencias científicas utilizando las redes neuronales, las tareas que antes no podían ser resueltas ahora podían realizarse: prever y evaluar el riesgo de una próxima transacción, previsión de la demanda de nuevos productos, un análisis comparativo de compañías competidoras, detección y procesamiento de señales de video y audio. La investigación aplicó métodos científicos generales tales como observación,

neural networks basing on the study of the main neural network application trends in economics, in particular, the application of artificial neural networks in economics of foreign countries. Analyzing the specifics of the neural network application in economics, and also studying their strengths and weaknesses, the authors concluded that the Russian market of neural network solutions was poorly developed due to insufficient research funding. The conclusion follows from the above mentioned that at present the application of neural networks in various spheres of economics is an actual topic for research.

**Keywords:** neural networks, innovations, efficiency of neural networks, neural networks in economics, artificial neural networks

descripción y modelado. Los autores identificaron las principales ventajas y desventajas de las redes neuronales basándose en el estudio de las principales tendencias de aplicación de redes neuronales en economía, en particular, la aplicación de redes neuronales artificiales en economía de países extranjeros. Analizando los aspectos específicos de la aplicación de red neuronal en economía, y también estudiando sus fortalezas y debilidades, los autores concluyeron que el mercado ruso de soluciones de redes neuronales estaba poco desarrollado debido a fondos de investigación insuficientes. La conclusión se desprende de lo mencionado anteriormente que en la actualidad la aplicación de redes neuronales en diversas esferas de la economía es un tema real de investigación.

**Palabras clave:** redes neuronales, innovaciones, eficiencia de redes neuronales, redes neuronales en economía, redes neuronales artificiales

## 1. Introduction

In the management process, the application of neural networks became possible at the beginning of the 20th century; it is based on the properties and regularities of functioning of nerve cells – neurons (Hopfield 1982; McCulloch & Pitts 1943; Hebb 1949). Due to neurons, the entire system of vital activity control is realized; more specifically, such control is performed through their interaction and numerous connections forming a branched network through which electrochemical signals propagate (Rosenblatt 1962; Anderson 1972; Grossberg 1976).

Camillo Golgi and Santiago Ramon y Cajal were the founders of the ongoing research. In 1906, they discovered neurons to the scientific world (Babmindra & Vorobyov 1985). However, initially neural networks were studied only in the field of biology and physics (Widrow & Hoff 1961; Hecht-Nielsen 1987; Kohonen 1972; Kohonen 1982).

The next stage in the development of this science was the invention of *artificial neural networks*, represented in the form of mathematical models and implemented in the form of software products and devices. These models were based on the biological neuron constructing principle. The first developments in the field of production and application of artificial neural networks were carried out by the scientists Warren Sturgis McCulloch and Walter Pitts in 1943 (McCulloch & Pitts 1956). They could provide solutions to issues with no dependence between input and output data, solution algorithms, which made it impossible to use traditional mathematical calculations or expert systems.

The first artificial neural network – perceptron – was invented by Frank Rosenblatt in 1958 to model the activity of the human brain when processing visual data and in learning to recognize objects (Rosenblatt 1958; Rosenblatt 1960; Joseph 1960).

An artificial neural network is a computer system simulating the activity of biological neurons with parallel information processing, the ability to learn and summarize the accumulated knowledge (Tokarev 2016).

At the end of the 20th century, neural networks began to be used in the field of forecasting economic processes. Today, various approaches to the application of neural networks in the management of economic subjects are being studied by scientists such as Tokarev, K.E. (2014, 2016), Guba, K.A., & Dubanov, G.N. (2014), Sokolov, A.F. (2011), Rogachev, A.F., & Kuzmin, V.A. (2013), Rogachev, A.F., & Shubnov, M.G. (2012), Rogachev, A.F., & Shubnov, M.G. (2013), Shatyрко, D.V., Tokarev, K.E., & Kuzmin, V.A. (2015), Astafieva, N.M. (2004), Galushkin, A.I. (2010), Dorogov, A.Yu. (2006), Redko, V.G. (2011), Terekhov, V.A., Efimov, D.V., & Tyukin, I.Yu. (2002), Chervyakov, N.I., Sakhnyuk, P.A., Shaposhnikov, A.V., & Makokha, A.N. (2003), Beer, C. (1993). The founder of the application of neural networks in the field of economic management is the English cyberneticist Stafford Beer, who proposed principles of management based on neurophysiological mechanisms (Vissema 2000).

The idea of creating and modeling the principles of self-organization of economic systems

was developed by A.I. Ivakhnenko, who developed a model for the development of the economy of England, as well as for assessing and forecasting the state of the economies of countries such as the USA, Bulgaria, and Germany (Ivakhnenko & Muller 1985). Shchetinin V.G. also worked in this field; he built a neural network for modeling and solving problems in analyzing the economics of Mordovia and the Penza Region (Schetinin & Kostyunin 1998).

Nevertheless, in the management of economic entities, there is no uniform methodology for the formation of the architecture and parameters of neural networks, which would take into account their specifics. This is due to the specifics of the economic management system, its instability and a wide range of interactions, as well as the range of applications.

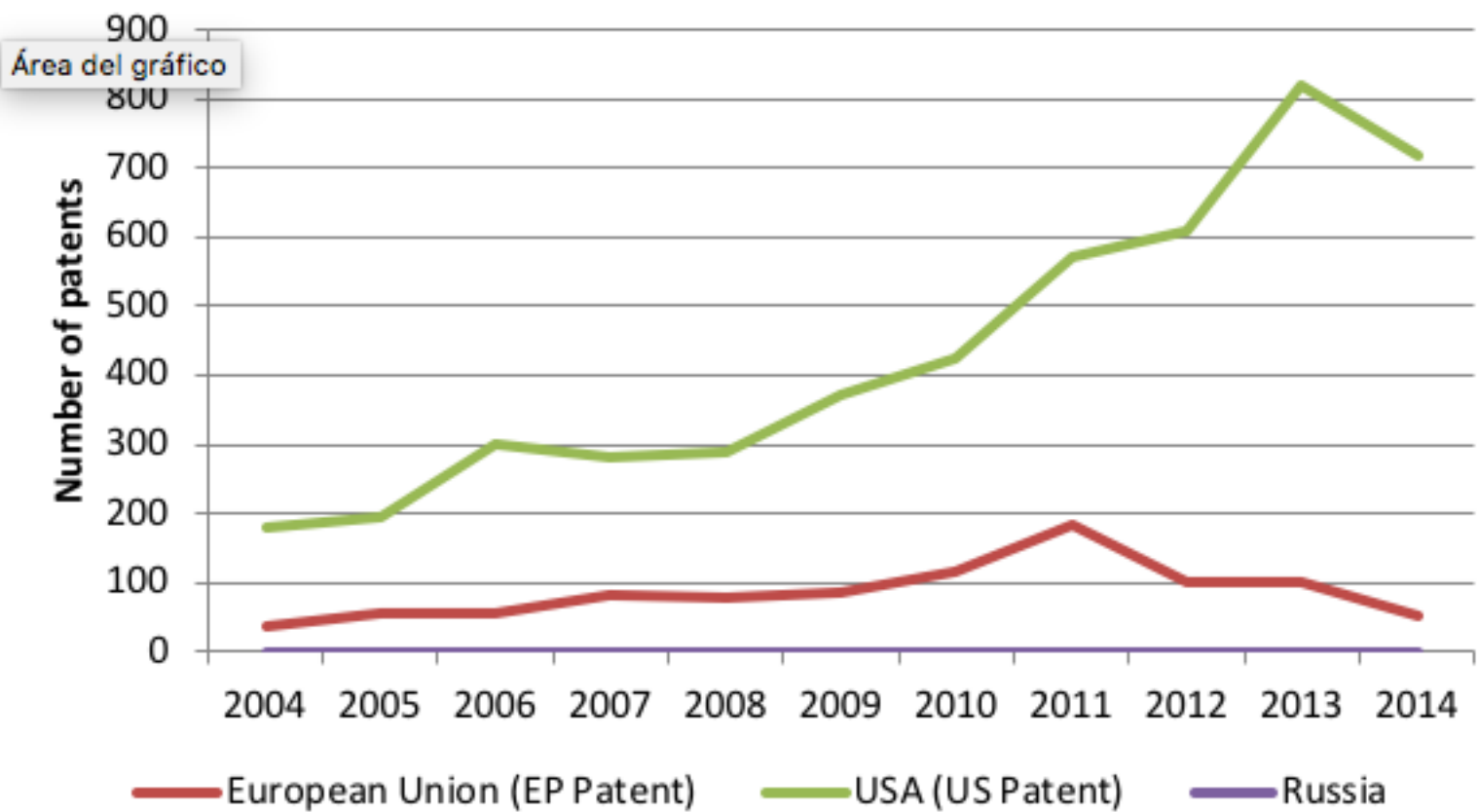
Special software packages are installed in state institutions and commercial enterprises, holdings, credit institutions, financial and insurance companies. Currently, they are used to forecast macroeconomic indicators; forecast calculations of an enterprise's activity; in financial transactions, including exchange and market indices, exchange rates; for analytical studies to make business decisions; valuation of enterprises; for estimating enterprises' work quality.

The application of artificial neural networks in economics has successfully proved itself abroad. Today on the basis of artificial neural networks, the programs have been designed for price forecasts of exchange rates, securities portfolio analysis, securities trading, which are used by stock exchanges in Japan, the United States, and the United Kingdom (Safonenkov 2015). The United Nations apply self-organizing maps (the Kohonen maps) to rank countries by the poverty level (Ostroukhov & Panfilov, n.d.). The positive results of artificial neural networks served as an incentive for the joint work of the London Business School, the University College London, TSB Bank Technology and the Henley Centre for Forecasting for the creation and integration of the Neuroforecasting Club and Neural Networks for Financial Services programs. The services of these programs are used by large financial corporations in Great Britain, France, Germany, Japan, the USA, Canada, and Australia (Tsuprikov 1985), since they are covered by a database and modeled by a network of neurons separately for each geographic location, at the initial stage for further integration in the Control Centre. The well-known financial corporation Citicorp uses them for analysis and short-term forecasting of currency fluctuations (Kosharova 2013).

The application of neural networks for the analysis of the real estate market allowed the Richard Borst company to increase the turnover of capital in some branches by 6% (Tora-Center, n.d.). Microsoft uses neural networks to construct the ratings of their customers, and to create a distribution base for advertising mailings, which reduced advertising costs by 15%. Artificial intelligence is also used to predict the bankruptcy by worldwide large banks, such well-known corporations as General Electric, American Airlines, Coca Cola, Philip Morris, Procter & Gamble, Merrill Lynch, Ford, Reno and many others.

### **Figure 1**

Dynamics of the distribution of patents in the field of neural network development and application among countries for 2004-2014  
(Public Analytical Report on the Direction of Neurotechnology, 2014)



The Russian market of neural network developments is only evolving, despite the negative trend that occurred during the last decade (Figure 1).

Among other causes, the current dynamics can be explained by the lack of targeted public funding for scientific research in the field of neural networks.

Materials and methods. When writing this paper, general scientific methods were used, such as empirical research, theoretical cognition, general logic methods and techniques; as well as methods of system analysis, the method of comparisons and analogies, the method of generalizations, etc.

The authors used the research results outlined in the works of leading Russian and foreign scientists studying neural networks in various branches of science.

The research methodology was based on up-to-date methods of information collection, processing and analysis.

## 2. Results

As a result of the analysis, the authors came to the conclusion that the creation of artificial neural networks made it possible to carry out the assigned tasks, the solution of which had not previously been possible; these tasks could be grouped as follows:

- 1 Modeling for an object of one of its target attributes;
- 2 Modeling of the value of a numerical attribute for an object;
- 3 Dynamic forecasting of the value of a numerical attribute of an object, using time measurements of the values of the same attribute;
- 4 Automatic grouping of objects.

The authors' management system development approach proved its effectiveness when used in large production associations, as well as the economy of the country as a whole.

The authors have grouped the main trends in the application of neural networks in economics, which is presented in Table 1.

**Table 1**

The main trends in application of neural networks in economics (Compiled by the authors)

Branch of economic trend	Mechanism of application
Banking and investment activities	Forecasting the bankruptcy of enterprises, their financial stability and solvency, assessing the risk of insurance of invested funds,

	forecasting the balances on correspondent accounts, drawing up investment projects rating, forecasting the effectiveness of investment projects, calculating customer behavior patterns.
Production activity	Forecasting the production volumes, loading of production capacities, raw material reserves, calculation of optimal prices for products.
Organization of trade	Forecasting the demand, a forecast of prices and analyzing them, calculating optimal prices for products.
Insurance activities	Forecasting the probability of an insured loss, calculation of the most beneficial insurance product, calculation of the insurance premium.
Financial markets	Forecasting the quotations in the foreign exchange market, forecasting the securities rates, real estate valuation, recognition of surges in exchange activity, forecasting the prices for goods and raw materials.
Budget and taxation system	Forecasting gross receipts of taxes and fees, integrated socio-economic development of territories.

The analysis of the data on the development of investment foreign programs shows that governments all over the world pay great attention to projects for the neural technologies research (Table 2), which can be adapted and applied in the economics.

**Table 2**

The largest foreign government investment programs for financing global neural network research projects (Compiled from the materials (Public Analytical Report on the Direction of Neurotechnology, 2014)

<b>Program title</b>	<b>Scope, schedule and financing sources</b>
Connectom	100 million USD, 2005-2015, the USA
Blue Brain	100 million euros, 2006, Switzerland
Human Brain Project	1 billion 190 million euros, 2012-2022, the European Commission of the European Union
BRAIN Initiation	3 billion USD, 300 million USD per year, 2014-2024, the US Government
Big Brain	60 million USD, 2014, Microsoft Corporation
Brainnetome	200 million yuan, 2013, China
Research Plan for Neural Circuits of Emotion and Memory	200 million yuan, 2011-2017, China
Functional Connectome Project	300 million yuan, 2012-2016, China

Scientific developments in the field of neural technologies require significant (million)

amounts of investments, as this type of research is based on the purchase and creation of up-to-date processors and technological equipment. The data presented in Table 2 explain the trend in the development and application of neural networks (Figure 1). As we see, the investment leaders in the world market are the United States and the European Union. The policy of the Chinese government regarding the relevance and effectiveness of investments in the development of neural networks has been formed over the past three years.

Russian enterprises, including large holdings, cannot compete with foreign governments at the level of the investment activity; therefore, the government financing is required. To date, a number of developments, processors for the creation of neural network software are purchased abroad by Russian enterprises. The joint financing of the neural technology scientific research is possible. In the event of the joint financing, the government projects will be implemented to ensure the development of medical technologies, improve information technologies in the field of treasury, budget and tax systems. The research will be conducted through private financing in order to develop software to solve economic problems of a commercial nature.

At present, the following Russian universities are engaged in the creation of new neural software products, including in the field of solving economic issues: Moscow Institute of Physics and Technology (MIPT), Lomonosov Moscow State University (MSU), National Research University Higher School of Economics (HSE), Skolkovo Institute of Science and Technology (Skoltech), etc., as well as such large companies as Mail.Ru Group Holding, Yandex; Tora-Center has a special importance in this list, which has developed software products for more than 700 companies and credit organizations.

Today in Russia, neural networks are used in more than 30 credit organizations and 60 financial companies. At the same time, they are also used to increase the efficiency of government public services, such as the Ministry of Emergency Situations, tax authorities, and the Central Bank of Russia (Tora-Center, n.d.).

The conducted analysis made it possible to identify the main trends and features of the application of neural networks in economics of foreign countries (Table 3).

**Table 3**  
Features of artificial neural network application in economics  
of foreign countries (Compiled by the authors)

<b>Country</b>	<b>Neural network application practice</b>	<b>Main research investment sources</b>	<b>Main issues solved by neural networks</b>
Japan	Credit, financial and commercial institutions, stock exchanges.	Private investment	Forecasting, classification, optimization, associative memory.
USA	Public services, credit, financial and commercial institutions, stock exchanges.	Public and private investment	Forecasting, classification, clustering, optimization, associative memory.
Great Britain	Credit, financial and commercial institutions, stock exchanges.	Private investment	Forecasting, classification, clustering, optimization, associative memory.
France	Credit, financial and commercial institutions, stock exchanges.	Private investment	Forecasting, classification, clustering, optimization, associative memory.

China	Public services, credit, financial and commercial institutions.	Public and private investment	Forecasting, classification, clustering.
Canada	Public services, credit, financial and commercial institutions, stock exchanges.	Public and private investment	Forecasting, classification, clustering, optimization, associative memory.
Russia	Public services, credit and commercial institutions.	Public investment	Forecasting, classification, clustering.

### 3. Discussion

The following main advantages of neural networks can be identified explaining the increase in the activity of their use in economics:

- 1 Easy to use and operate;
- 2 Compatibility with a variety of software and databases;
- 3 Ability to self-learning and self-setting when editing individual parameters;
- 4 Ability to perform their functions in the absence of some data, the presence of distorted and inconsistent information;
- 5 Accounting for the impact of external factors (interference) on the cluster data system (Kokh & Prosalova 2017);
- 6 Ability to operate with a large number of variables while not reducing the accuracy of calculations when they increase;
- 7 An increase in the speed of data processing by increasing the volume of internal information.

In addition to these advantages, neural networks have a number of disadvantages:

- 1 Lack of standard calculation mechanisms for specific tasks. When setting up a new specific task, it is necessary to independently develop a calculation model for the neural network and form the basis for its learning.
- 2 The formalization complexity of processes, the neural network. The processes occurring during the operation of the neural network are quite complex for understanding, both for ordinary users and for developers, so it often remains the so-called "black box".
- 3 The formation complexity of an information base for learning. Before the neural network operates, it needs to be trained on specific patterns. The instability conditions typical for the economic system do not allow accumulating a sufficiently large database over a long period of time.

Nevertheless, it is necessary to highlight the unique property of neural networks, their ability to take into account and model the change in economic processes, as well as the behavior of society, something that cannot be calculated using mathematical models.

This property of neural networks determines the effectiveness of their use in predicting the activity of a cluster. The cluster management is a process of organizing, controlling and stimulating the system activity that is influenced both by internal and external factors. The fact that the cluster consists of a large number of participants, which differ both in the field of activity and in their organizational and legal form, exacerbates the special impact. As a result, the probability of losing control and disorganizing the centralized management system increases.

### 4. Conclusion

Based on the above research, the authors proposed the definition of an *artificial neural network applied in economic activity* as a computer system that simulated changes in economic processes, as well as the behavior of society, and had the ability to learn and summarize the accumulated knowledge.

It should be noted that the application of neural networks in all areas of human activity is moving at an increasing pace. At the initial stage, the neural networks were considered only in such narrow spheres as physics and biology; while at the present stage, the neural networks introduction occurs practically in all scientific fields. This is due to the fact that the neural network application makes it possible to analyze the input information, and also to find patterns in it, to make predictions. Thus, the neural networks represent a new and very promising computational technology, which gives completely new approaches to the study of various issues in the economic field.

## Acknowledgements

The authors are grateful to Viktor Nikolaevich Likhovidov, Associate Professor of the Department of Applied Mathematics, Mechanics, Management and Software at the Far Eastern Federal University, and Yury Vladimirovich Rozhkov, Ph.D. in Economics, Professor of the Khabarovsk State University of Economics and Law, for valuable advice in planning the present research and recommendations for the design of the paper.

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