Neural Forecasting System of Regional Cooperative Systems
Innovative Activity Results

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Abstract. The analysis of changes in the external and internal environment of organisations, requirements for ensuring long-term sustainability and competitiveness in modern conditions suggests the need to develop instrumental support for decision-making support processes in the implementation of innovative projects of cooperative formations. Significant expenditures of financial and time resources allow to determine the priority problem – the insufficient development of systems for reducing uncertainty in interaction with the processes of scientific and industrial cooperation, which determine the disproportions of the resulting economic indicators of the functioning of innovative activity in the region. The proposed solution is an implemented multiplatform software for neuro-cluster analysis of multiformat data, which is based on fuzzy data prediction algorithms based on a nonlinear autoregressive exogenous model. An important feature of the implemented software is an algorithm for optimising the processing of predicted data, based on distributed processing of big data using Microsoft Server operating system.

1. Introduction
The need to proceed to innovative development principles, which is defined as the main one in the current technological order and was previously implemented only in some enterprises, is now no longer in doubt and is widely used in all enterprises that want to be competitive and operate effectively. The focus on innovation is noted in the industry development strategies of European countries, the United States, China and the Russian Federation. A special role in the effective implementation of innovative processes is assigned to the cooperative interaction of economic subjects. Inter-firm relations are considered as a strategic resource of modern enterprises, since their use contributes to the receipt of economic benefits and other synergistic effects by the subjects, as well as to the optimal achievement of the set goals. As part of innovation processes joint implementation, it is assumed that industrial enterprises, research and educational organizations, small enterprises and state authorities will interact, which in turn has a direct impact on the innovative development of the entire region.

The information necessary for making informed decisions on innovation processes management implemented by regional scientific and industrial complexes at the regional level due to the significant size of the production component, the heterogeneity of such formations, as well as the features of production and innovation and related processes has the following qualitative features: a wide range and specificity of individual indicators that reflect the results of a particular activity or process, inaccurate interpretation of sources and methods of information transmission; heterogeneity and relevance of
information. These features determine the urgent need for the development of existing tools for managing innovative processes implemented within the framework of the network of interaction between science and industry in the aspect of territorial development. In particular, the proposed evaluation system should provide the possibility of predictive determination of the output economic indicators distortions, in this regard, it is planned to integrate a nonlinear autoregressive neural network into the implemented system.

The primary feature of the proposed system will be the possibility of interpolating fuzzy data as indicators of evaluating the innovative development through the introduction of fuzzy logic, which will allow in the future to use the versatility of the system in the study of multi-format data. A secondary feature of the implemented system is the possibility of distributed processing of big data due to the implementation of parallel analysis algorithms in cluster operating systems for calculating predictive inter-organisational factors. Consequently special attention was paid to multiplatformity - the implemented modules of the system will use the Python language for data processing; for data processing from the client side on the Microsoft Windows operating system, it is assumed that the interface will be implemented on the WPF platform, the C Sharp programming language.

2. Main algorithm
A modern innovation system, whether it is an enterprise that produces high-tech products, or a research and production complex, is a combination of a large number of managed subsystems and business subjects connected by a significant number of complex horizontal and vertical hierarchical relationships with parametrically uncertain influence of various parts of the system on each other and on the system as a whole. The result of this is that it is impossible to quantify some of the relationships of the participants in the innovation process within a separately selected system. In addition, it should take into account the intensive dynamics of interrelations typical for the production of intellectual capital and the presence of economic entities interests that often contradict each other. The information necessary for making noted decisions on the management of network interaction in the implementation of the innovation process at the strategic level due to the significant size, heterogeneity of innovative cooperative associations, as well as the peculiarities of the production and innovation process has the following qualitative features: inaccurate interpretation of sources and methods of information transmission; heterogeneity and weak relevance of information obtained not on the basis of objective measurements; non-formalized, often verbal type of information messages. These features prevent the use of traditional methods of managing economic systems, such as budgeting, cost management, trend analysis, etc. Because of this, it becomes relevant to use methods of managing innovation structures based on the apparatus of fuzzy logic, which contributes to a more complete reflection of the uncertainties and inaccuracies of managed socio-economic systems, which will contribute to the early acceptance and implementation of control actions in the economic innovation space. As a rule, it is advisable to integrate fuzzy algorithms into an information and analytical decision support system. On the other hand, the forecasting of economic indicators using traditional methods of compiling mathematical models is not so accurate. We can say that the integration of neural networks of learning with the teacher will significantly reduce technical and human resource costs.

Based on the noted specifics of the research area, the main software and hardware requirements for the implemented software were determined. As a hardware component, a device based on the AMD-64 architecture and a compatible video card with support for NVIDIA CUDA technology are used. The Python programming language is used as a software-dependent component. The Python programming language is used as a software-dependent component of the main data processing module. The C# programming language is used to process information from clients.

The algorithm presented in figure 1 is based on the principle of modular execution of operations, which allows in the future to perform parallel neuro-cluster processing of groups of factors that characterise interorganizational interaction during the implementation of the innovation process. Among other things, predictive data processing modules are responsible for identifying the input parameters of a neural network, as well as data processing methods defined by the module “intelligent identification
of an organisational unit”. This module allows you to determine the size and type of the organisation under consideration based on primitive factors.

Figure 1. Modular implementation of a neural prediction system.

2.1. Identification of primary conditions module

Based on the analysis of the main factors of inter-organisational interaction between Russian and foreign authors [1 - 7], a hierarchical system for evaluating the results of innovation activities in the framework of its joint implementation was determined. Among the main groups of factors, it is possible to distinguish the following: characteristics of interaction members; structural factors; situational factors.

Taking into account the fact that in addition to the factors under consideration, there are additional important parameters, the overall structure was brought into a separate database structure [8]. Each factor group was assigned to the corresponding database table. Among other things, the ER chart includes separate tables on favorable and negative outcomes, separated at different time intervals, and tables on similar economic entities with an identical data set.

Based on the fact that the above structure fully corresponds to the implementation of processing a single application instance, the approach of deploying all data on a single drive is not relevant. In this regard, the database structure has been improved to the possibility of interaction based on cluster data processing technologies.

Implementation of cluster processing is based on the use of the Windows Server 2021 operating system. Data processing capacity is distributed using multiple nodes and a single network resource. Among other things, this approach provides software functionality in the event of a failure of one or more hardware devices. To implement the described approach, the deployment of the “Cluster Failover Manager” snap-in was performed. The following parameters were set as the main parameters:

- iSCSI Storage - Static Local IP Address (iSCSI);
- PC-WDC1 - PC-WDC3 - static local IP addresses: iSCSI, cluster IP address; static external IP address;
- Failover cluster access point (cluster resource) – external static IP address.
The isolation of three machines used in a cluster is expressed by the number of factor groups used. To implement the described algorithm, the computer devices WDC No.1 - WDC No.3 were included in the same Active Directory domain user group (figure 2) [9].

As you can see in figure 2, the devices are connected using two network interfaces in an aggregated channel for the transfer of production and cluster traffic. In this case, the main quorum is the configuration of the witness resource - the disk drive as the mount point of the directory to provide access to the file system [10].

To implement the cluster network management system, the SSH server module was integrated into the Windows Server operating system, on the basis of which the method of encapsulating an active connexion through an SSH tunnel is implemented. To organize tunnelling, a virtual interface was created using the “NIC Teaming” component, which is part of the server manager. Subsequently, the organisation of tunnelling of the network segment is determined by the command “ssh-R 127.0.0.1: 5900: 163.221.245.26: 5900 root@localhost”.

As a result of system development, the database server was placed in the fault-tolerant storage section, which made it possible to use all available resources for processing big data in the future. Among other things, the structure shown in figure 2 allows Remote App services to access the system through an external gateway [11].

2.2. Predicting factors in variable time intervals
The proposed tool for evaluating the innovation process implementation in the framework of inter-organizational interaction allows the end user not only to use various predictive functionality, but also due to the technologies of neural network data processing will make it possible to increase the accuracy at the stage of forecasting the values of factors in long-term time intervals [12].

To implement the system under consideration, a deep learning neural network process was integrated into the intelligent forecasting module, based on the use of a dynamic network with neural feedback – the Nonlinear autoregressive exogenous model (NARX). The main advantage highlighted in NARX is the ability to interact with closed and open circuits, which affects the performance of the module in the absence of feedback. The algorithmic implementation of the output layers of NARX is represented by the vector \( o_t \) equation (1), determined on the basis of specifying the input vectors as features obtained by analysing the input parameters from the ER diagram in equation (2). The considered vector \( o_t \) in the NARX network passes the regression stage, regardless of the input vector. The prediction of
parameters in the considered neural network is carried out according to equation (2), and directly depends on the time interval used.

\[ o_f = f(y(t-1), y(t-2), \ldots y(t-n_y), u(t-1), u(t-n_u)) \]  

\[ q_{d,h} = \beta_h q_{m-1,d} + \beta_h q_{m-2,d} + \beta_h q_{m-3,d} + \beta_h q_{m-1,min} + \beta_h q_{m-5,z} + \sum_{i=1}^{5} \beta_h q_{i,d} + e_{d,h}, \]  

were \( q_{d,h} \), \( min = \min = \min_{m=1, \ldots} \{ q_{m-1, d} \} \) -- reference to the minimum value of the factor under consideration, related to the previous values of the factor for the previous months; \( Z \) -- logarithm of the predicted values for a certain time period (exogenous variable); \( d_i \) -- accounting for the change in the coefficient for the selected period; \( e_{d,h} \) -- distributed normal variables.

Thus, the introduction of a recurrent neural network and a fuzzy pattern processing module will allow us to obtain predicted states of the considered features-factors.

3. Conclusion

With the development of technological, industrial and socio-economic conditions, the socio-economic entities themselves, the forms of their organization and management are also transformed. There are new, complicated ways of organizing development, which include forms of integration and inter-organizational interaction in the implementation of innovative processes, among others. This form takes into account a significant range of weakly structured factors and trends in changes in the external and internal environment that caused it: the formation of technologically and socially new needs, the growing demand for maximizing the total social, social and environmental benefits from such interaction, the increasing role of social values in the production of goods and services, etc. These aspects, as well as the high dynamism and uncertainty of modern changes in the environment, together with mainly qualitative descriptive and subjective parameters in the assessment of integration formations, are important in predicting and evaluating the results of innovation, creating corporate value, interacting with partners, customers and the external environment.

Thus, the proposed tool for assessing the implementation of innovative processes will make it possible to increase the efficiency of management entities functioning on regional level by making management decisions based on the principles of optimality and balance. The proposed approach will allow to support decision-making at all stages of the innovation process in the region, to quickly monitor the dynamics of the internal and external environment without significant costs for modifying the models and algorithms used. The proposed system has a number of advantages, which are expressed in the simplicity and clarity of information presentation, the ability to combine completely different indicators, from various aspects that characterize the innovation process into one integral one, and the versatility of application.

The described developed approach of cluster data processing using Microsoft Windows Server 2021 will allow not only to place the database server in iSCSI storage, but also to use the Remote Desktop Protocol-RemoteApp functionality, which in the future will make it possible to initialize the application launch on the client side through an external gateway, while processing the predicted data on the cluster. Using the platform-based C# programming language .NET made it possible to create a universal application for interacting with customers through a user-friendly interface.

4. References

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**Acknowledgments**

The research was carried out with the financial support of the “Council for grants of the President of the Russian Federation for state support of young Russian scientists – candidates of science” according to the project MK-4087.2021.2.