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Original article

Data Mining under the System of Managerial Skills: Shipbuilding Sphere Application

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Abstract

The article discusses such modern methods and tools of artificial intelligence as applied to solving some problems of the Russian shipbuilding market. Researching cases present an example of an algorithm for experimental model of artificial intelligence and its mathematical formalization under environments of forecasting the dynamic development indicators of Russian shipbuilding industry. The article shows that the use of modern data mining methods and tools is in demand from the point of view of solving a wide class of applied problems, such as modeling the economic environment and business activity, trends and tendencies in various markets of developed and developing countries in the context of the cyclical nature of the world economy as a whole. In addition, such methods and tools are characterized by a high demand on the part of society in terms of developing (designing) experimental models for analyzing the evolutionary processes and functioning of complex socio-economic systems, which include high-tech sectors of the Russian industry, determining effective directions for the development of such systems. The article provides an example of an initiative research project that illustrates the formulation of a specific applied economic problem and its possible solution using methods and tools of artificial intelligence.

Keywords: data mining, artificial intelligence, neural networks, managerial skills, shipbuilding industry, applied computation, analysis

The authors declare no conflict of interest.

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Научная статья

Data mining в системе управленческих навыков (в приложении к сфере гражданского судостроения)

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Аннотация
Рассмотрены вопросы, связанные с применением методов искусственного интеллекта и когнитивных технологий в задачах моделирования управляемых динамических систем. Представлен обзор результатов решения некоторых задач когнитивного моделирования. Изучены аспекты построения и исследования когнитивных моделей с применением различных инструментов искусственного интеллекта. Охарактеризованы особенности применения нейронных сетей, эволюционных алгоритмов, объектно-ориентированных языков программирования, многоагентных архитектур в задачах когнитивного моделирования. Дано описание областей применения искусственного интеллекта и когнитивных технологий в задачах моделирования динамических систем. Рассмотрено методическое обеспечение для исследования траекторной динамики систем интеллектного управления. Предложен подход к построению динамических когнитивных карт для моделирования маятниковых систем с применением интеллектуальных технологий. Разработан обобщенный алгоритм стабилизации маятника с применением нечетких когнитивных карт. Рассмотренный подход позволяет синтезировать модели перевернутого маятника с учетом различных физических эффектов и решать ряд задач управления маятниковыми системами. Полученные результаты могут быть использованы при проектировании и совершенствовании управляемых технических систем.

Ключевые слова: дата майнинг, искусственный интеллект, нейронные сети, управленческие навыки, гражданское судостроение, прикладные вычисления и анализ

Авторы заявляют об отсутствии конфликта интересов.

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I. Introduction

Summarizing the results of modern research by authoritative scientists-economists shows that shipbuilding is a complex non-linear dynamic production and economic system, the development of which is a subject to the objective laws of economics as a field of scientific knowledge [1; 2].

Under the digital transformation environments due to high-tech industries, as well as large-scale digitalization of industrial enterprises, the question of the need to use new methods and tools in economic research in development of Russian shipbuilding is on the agenda [3; 4]. *Artificial intelligence (AI)* as an interdisciplinary area of research, along with structuring and in-depth analysis of metadata *(data mining, big data)*, can act as a significant help under the process of solving applied economic problems for all industries and complexes [5; 6].

It seems that modern methods and tools developed within the framework of these areas of scientific research are of interest from the point of view due to solving a wide class of applied problems, such as modeling the economic situation and business activity, trends and tendencies on various markets of developed and developing countries under the context of the cyclical global the economy as a whole.

In addition, modern methods and tools developed within the framework of the above areas of scientific research are characterized by high demand from society in terms of developing (designing) experimental models for analyzing the processes of evolution and functioning due to complex socio-economic systems, which include high-tech sphere of Russian industry, including the determination of effective directions for the development of such systems.

For the purposes of the study, we will give an example of an initiative research project that illustrates the formulation of a specific applied economic problem and its possible solution using artificial intelligence methods and tools.

II. Brief annotation of an initiative research project for the application of data mining under the civil shipbuilding environments

1. Research topic: “*Development of scientific ideas about civil shipbuilding as a non-linear dynamic production and economic system*”.

2. The purpose for research is to develop the theory and methodology of economic and mathematical modeling of processes occurring in civil shipbuilding, as well as to develop (design) an experimental model that allows the management of high-tech shipyards to make a better assessment due to dynamics of economic activity indicators in conjunction with market conditions and forecast.

3. Tasks to be solved in case of research:

to generalize the existing research approaches for displaying socio-economic processes and systems in the form of mathematical models based on the fundamental provisions of nonlinear dynamics as an interdisciplinary field of scientific knowledge;

to analyze modern applied economic and mathematical models that formalize the approaches of nonlinear dynamics to the display of socio-economic processes occurring in sectors and complexes of the economies of developed and developing countries;

to formulate and to substantiate a number of theoretical and methodological provisions that allow developing existing scientific approaches to the construction of economic and mathematical models used in the economic practice of shipyards to improve the process of predicting the dynamics of key indicators in conjunction with market conditions and forecast;

to develop a simulation economic and mathematical model that provides better forecasting of the dynamics of key indicators of the development of shipyards (an artificial intelligence model that constructs a trainable artificial neural network to solve the applied economic problem – the formation of more accurate forecasts for key indicators of the development due to shipyards);

to testt the proposed simulation economic and mathematical model in the conditions of actually functioning shipyards and give an analytical interpretation of the results obtained.

4. The uniqueness (novelty) of the ongoing research project lies in the reconstruction (construction) of a trainable neural network of artificial intelligence correlated with its biological counterparts (the human cerebral cortex, containing about neurons, each of which is connected on average with others neurons, generating about interconnections) to solve an important applied economic problem – more accurate forecasting of key indicators of the development of shipyards.

The degree of complexity of the algorithms for the functioning of a neural network is so high that the implementation of calculations can be provided exclusively by high-performance computing and highly efficient methods of organizing computer calculations (parallel computing and/or other methods adequate to solve the problem posed, used under the applied theory of algorithms).

Successful implementation of research work within the framework of the project requires the use of a unique infrastructure for high-performance computing – the supercomputer complex of Lomonosov Moscow State University, namely the supercomputers “Lomonosov” and “Chebyshev” as unique systems of the highest performance range in Russia and over the world.

5. Expected results of research

The research involves the formulation and solution of an applied problem – the design of a more advanced simulation economic and mathematical model in comparison with existing analogues for predicting key indicators of the development of shipyards – an artificial intelligence model.

It is assumed that the construction of the original model will be based on the synthesis of a new neural network configuration, based on the known types of neural networks of artificial intelligence by increasing the number of network neurons, the density of connections between neurons and the number of layers of neurons in the network, as well as introducing several types of synapses (connections between neurons) for the purpose of increasing the efficiency due to the neural network.

The constructed artificial intelligence model will be in demand under the modern economic practice of civil shipbuilding, as it will allow to obtain more accurate forecasts for dynamics of key indicators due to development of shipyards, thanks to such characteristics as *multifactorial*, *complex geometry*, *multivariance*, and a *high degree to accuracy of calculations*.

III. Mathematical formalization of methods and algorithms for constructing an artificial intelligence model due to solving the applied problem under the civil shipbuilding environments

Mathematical formalization of methods and algorithms for constructing an artificial intelligence model due to solving the applied problem is presented below.

A. Choice of architecture (type) of artificial intelligence neural network

The choice of the architecture of the neural network in accordance with the features and complexity of the set practical economic task with the degree of accuracy (error) specified by the expert.

The choice is made on the basis of already existing neural network architectures, the effectiveness of which has been proven at the theoretical level (mathematically), as well as practically (under the real economic practice of economic entities): *multilayer perceptron*, *Hamming network*, *Word network*, *Hopfield network*, *Kohonen network*, *cognitron*, *neocognitron* [7-13].

If the task set cannot be reduced to any of the known types of artificial intelligence neural networks, it is necessary to carry out a set of works to synthesize a new neural network configuration. Under the process of designing a new neural network architecture, the following basic rules should be followed [14-16]:

network capabilities increase with an increase in the number of network neurons, the density of connections between them and the number of layers;

the introduction of feedbacks (synapses) between neurons, along with an increase in network capabilities, raises the question of the dynamic stability of the network (for the successful operation of such a network, dynamic stability conditions must be met, otherwise the network may not converge to the correct solution, or, having reached the correct value of the output signal at some iteration, after several iterations, get away from such a value);

the complexity of the algorithms for the functioning of the network, the introduction of several types of synapses (connections between neurons) enhances the power of the neural network and at the same time significantly increases the requirements for efficient hardware implementation of calculations (the need for high-performance computing and the choice of effective methods for organizing computer calculations, such as parallel computing , or other methods adequate to the solution of the problem, which are used under the applied theory of algorithms.

B. B. Artificial Intelligence Neural Network Training

An artificial neuron is an integral part of the simulated neural network. The structure of an artificial neuron consists of three types of elements: multipliers (synapses), an adder, and a nonlinear converter. Synapses communicate between artificial neurons, multiply the input signal by a number characterizing the strength of the connection (the weight of the synapse).

The adder performs the addition of signals coming through synaptic connections from other artificial neurons and external input signals. The non-linear converter implements a non-linear function of one argument – the output of the adder. This function is the activation function or transfer function of an artificial neuron. An artificial neuron as a whole implements a scalar function of a vector argument.

Mathematical model of a neuron:

$$s = \sum_{i=1}^{n} w_i x_i + b \ , \qquad (1)$$

$$y = f(s), \qquad (2)$$

where - weight of synapse; $i = 1,..., n$; b - offset value (bias), s - summation result; x_i - input vector component (input signal); y - neuron output; n - number of neuron inputs; f - non-linear transformation (activation function).

The computational element, formalized by the calculation formulas (1) and (2), is considered as a simplified mathematical model of biological neurons [17-19].

The neural network is trained by adjusting the weights of synapses, which formalize the connections between artificial neurons. For a neural network with a complex structure, the number of weights is large and the learning process is a complex, lengthy and time-consuming computational process. For various types of structures of artificial intelligence neural networks, specially developed learning algorithms are used. For the purposes of solving the formulated applied problem, it is supposed to use the *Error Back Propagation Algorithm* [20].

The *Error Back Propagation Algorithm* is an iterative gradient learning algorithm used to minimize the standard deviation of the current from the desired outputs of multilayer neural networks with serial connections. According to the least squares method, the objective function of the neural network error to be minimized is the value:

$$E(w) = \frac{1}{2} \sum_{jk} \left(y_{jk}^{(Q)} - d_{jk} \right)^2 , \qquad (3)$$

where $y_{jk}^{(Q)}$ - real output state of the neuron j of the output layer of the neural network when the k-th image is fed to its inputs; d_{jk} - required output state of the given neuron.

The summation is carried out over all neurons of the output layer and over all images processed by the network. Gradient descent minimization adjusts the weight coefficients as follow:

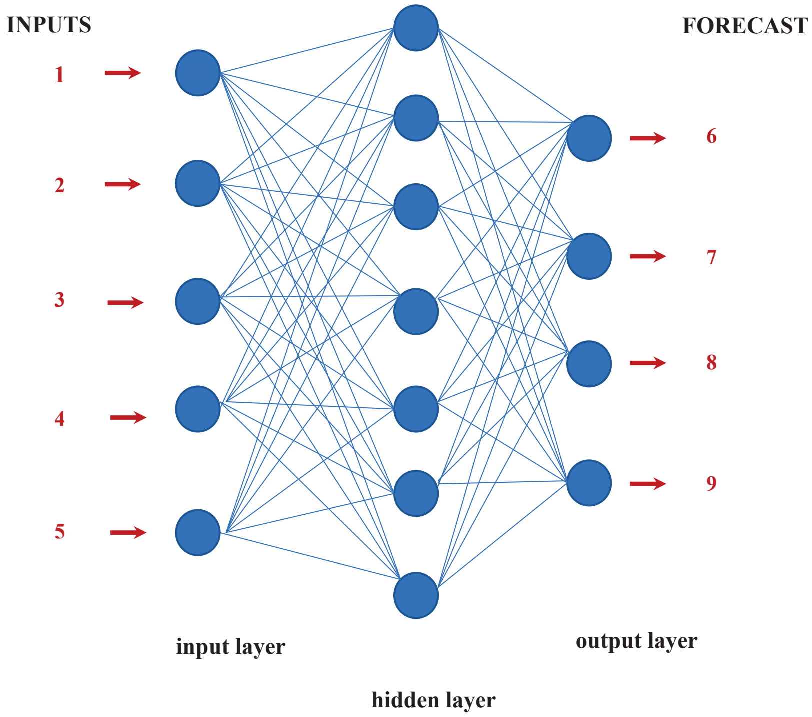
$$\Delta w_{ij}^{(q)} = -\beta \frac{\partial E}{\partial w_{ij}} , \qquad (4)$$

where w_{ij} - weight coefficient of the synaptic connection connecting the i-th neuron of the layer *(q-1)* with j-th neuron of the layer q; β - learning rate factor → $(0 < \beta < 1)$.

IV. Data mining and its application under the civil shipbuilding sphere

The use of data mining and neural network models allows solving a wide class of applied industry problems in Russian civil shipbuilding (Figure 1).

Data mining of prices for materials and equipment, credit load, volatility of exchange rates, labor productivity and the level of depreciation due to fixed assets allows shipyards to form more accurate forecasts of such key indicators of economic activity as output, cash flows, financial performance, internal rate of return for investment projects, providing their production and economic development under the medium and long term planning horizons.



1 – prices for materials & equipment ;
2 – credit load;
3 – depreciation rate for fixed assets;
4 – labor productivity;
5 – exchange rate volatility;
6 – output;
7 – profit (losses);
8 – cash flows;
9 – internal rate of return

F i g. 1. Applied use of neural networks under Russian civil shipbuilding environments Source: compiled by the authors based on a generalization [21-33]

V. Conclusion

The use of methods and tools of artificial intelligence, along with hardware implementation of calculations, a formalized infrastructure for high-performance computing (Lomonosov Moscow State University supercomputer complex), allows to significantly improve management skills and provide a qualitatively new level of formation due to quantitative estimates for the prospective development of Russian shipyards as complex of nonlinear dynamic production and economic systems.

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All authors have read and approved the final manuscript.

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