http://www.moderntechno.de/index.php/meit/article/view/meit36-00-037
DOI: 10.30890/2567-5273.2024-36-00-037

UDC (004.94+004.8)::005

SHALLOW ARTIFICIAL NEURAL NETWORKS FOR ADAPTIVE AND TARGETED MANAGEMENT

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Abstract. *Modern adaptive management is characterized by the need for quick decision-making in a dynamically changing external environment. The importance of machine learning and, in particular, neural networks (NN) in enterprise management is constantly increasing. Neural networks, due to their ability to process large volumes of data, identify patterns and predict results, have become a key tool for increasing the flexibility, efficiency and sustainability of management.*

The relevance of their application is due to global challenges: from digital transformation to economic uncertainty, requiring an intelligent approach to data processing and the development of management decisions.

The article presents the results of research on the is the development of methodology, technology and practical recommendations for the use of especially shallow (at the first stage of the complex of author's research) artificial neural networks in tactical and strategic business management (taking into account national, macroeconomic specificities and industry specifics) for increasing overall efficiency, competitiveness and stability in unstable and even crisis conditions.

Key words: *machine learning, artificial neural network, adaptive & targeted management*

Introduction.

Modern adaptive management requires companies to be highly flexible, accurate and prompt in decision-making [1, 2]. In the conditions of unstable transformation of the global economy, digitalization of business processes (and therefore the growth of data volumes), the accumulation of multicomponent crisis phenomena at the regional and global levels - traditional approaches to management are becoming insufficiently effective [3, 4].

In the conditions of adaptive and targeted management aimed at flexible and sustainable management of organizations, Data Mining plays an important role. After all, it is the methodological, technological and algorithmic solutions of Data Mining that allow managers to effectively analyze data, forecast trends, adapt strategies to changes in the environment and create personalized solutions for different groups of consumers. Taking into account the above, the use of innovative tools of analysis and analytics within the framework of Data Mining is a key factor for increasing the adaptability and efficiency of management decisions in modern conditions of operational, tactical and even strategic management. After all, Data Mining itself involves the use of statistical methods, machine learning to identify new, non-obvious, hidden regularities/patterns and relationships in large data sets [5, 6] to support effective management decision-making.

The authors also reasonably point out that descriptive, predicative and prescriptive modes of economic-mathematical modeling are also a very important tool in modern adaptive management [7, 8]. In connection with the problem of dimensionality of input data, the presence of outliers, anomalies and information noise in input big data - machine learning (ML) has become an important component of modern adaptive economic and mathematical modeling in the field of management. Machine learning is integrated into economic and mathematical modeling, significantly complementing traditional methods of intelligence visualization, OLAP, statistical analysis [9, 10]. Machine learning provides an opportunity to automate the processes of data analysis and analytics, reveal hidden patterns, and generate forecasts with high accuracy and quality [11, 12] (in conditions of large multidimensional structured and semi-structured management data).

Artificial neural networks (ANN) as one of the most effective and modern ML methods - provide an opportunity to analyze large volumes of data, find hidden, complex, multi-component regularities (in conditions of high-dimensional data) and serve as the basis for adopting effective adaptive and at the same time targeted (personalized) management solutions In the conditions of global competition and rapid changes in the market environment, company management needs innovative approaches for forecasting, optimizing processes and increasing efficiency - and precisely ANN, thanks to its ability to learn (and relearn), work with multidimensional (input and even output) data , is an important and relevant tool in solving complex interdisciplinary tasks in modern management.

Thus, artificial neural networks (ANN) as one of the most important and relevant modern methods/algorithms of Data Mining in general (and ML in particular) provide powerful opportunities for analysis, forecasting and automation of complex interdisciplinary and multidimensional processes in management [13]. The relevance of the introduction of neural networks is determined by both technological and economic challenges facing modern companies, enterprises and institutions (especially in crisis conditions).

In other words, in modern adaptive and targeted management, ANNs play the most important role, helping businesses better cope with the challenges of the digital age. They provide greater efficiency, flexibility and accuracy in solving complex management tasks (provided there is a sufficient amount of quality data for their

training).

Analysis of recent research and publications. The main foundations of the classic ANN theory were revealed in their works by such scientists as: Hertz J, Palmer RG, Krogh AS; Fahlman S, Lebiere C; Wasserman PD; Smith M; Lawrence J; Masters T; Bishop CM; Dewdney AK; Gurney K; Haykin SS. highlighting previously unresolved parts of the overall problem.

However, the scientific and practical issues regarding the features/specificities of the methodology and technologies of the use of modern connectionist AI in adaptive and simultaneously targeted business management in conditions of a multifactorial crisis (for example, in the current military, geopolitical, regional and local crisis conditions of Ukraine, etc.).

Formulation of the goals of the article. Therefore, taking into account the above, the main goal of this research is the development of methodology, technology and practical recommendations for the use of especially shallow (at the first stage of the complex of author's research) artificial neural networks in tactical and strategic business management (taking into account national, macroeconomic specificities and industry specifics) for increasing overall efficiency, competitiveness and stability in unstable and even crisis conditions.

Materials and methods. The research materials are: 1) cross-sectoral author's experience, author's practical projects and heuristics accumulated during the implementation of IT projects in management; 2) statistical reports and industry reviews of domestic and foreign authors conducting their scientific and practical research in the field of using AI in modern management; 3) works of domestic and foreign authors conducting their research in the field of symbolic [14] and connectionist [15] corporate AI in business management.

In the process of carrying out the research, the following scientific methods were used: formalization; grouping; analysis and synthesis; systematization; logical generalization of the results.

Main text.

Formulated relevance of using ANN in adaptive management:

1. Growing data volumes and the need to analyze them - modern organizations generate huge amounts of data from various sources: transactions, social networks, IoT systems, CRM and ERP. Neural networks are able to process this data, find patterns and issue practically applicable recommendations.

2. Increasing complexity of business processes - adaptive management requires working with complex multidimensional systems, where traditional analytical tools are often insufficient. ANNs provide a deeper and more accurate analysis of such systems.

3. Rapidly changing market conditions - markets are becoming increasingly dynamic. The ability of ANNs to quickly learn and adapt allows you to make decisions in conditions of uncertainty and minimize the effects of external shocks.

4. Competition and innovation - companies using ANNs have a competitive advantage due to the automation of processes, personalization of services and accurate forecasting of market trends.

5. Integration of artificial intelligence technologies – ANNs are the basis of

many innovative solutions in the field of automation, predictive analytics, robotics and optimization of business processes. Their implementation is becoming the standard for companies striving to stay ahead.

Recommended areas of application of ANNs in adaptive management:

1. Forecasting and decision-making (forecasting demand for products, assessing the effectiveness of marketing strategies) – increase the accuracy of forecasts and minimize risks.

As an example of such functionality, the authors below, in Fig. 1. presented the results of research on the optimal type, architecture and learning algorithms of an artificial neural network for predicting the objective price of real estate (the dataset BostonHousing.sta (with 12 input attributes and one target attribute, 505 rows) and Statistica 7 software were used).

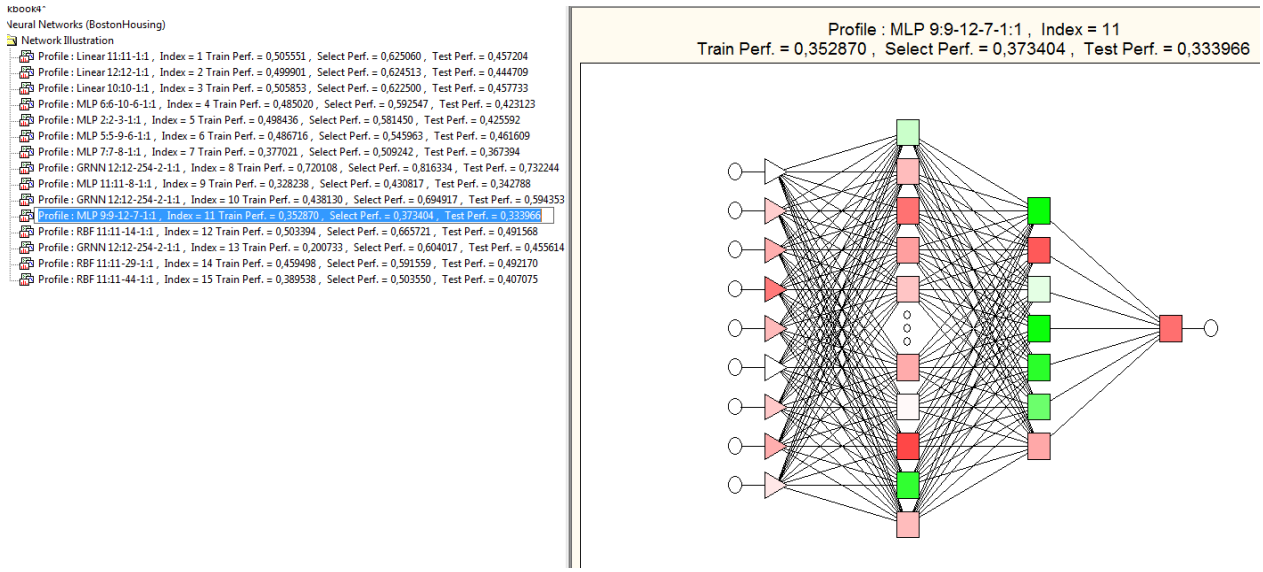

Figure 1 - Results of 15 experiments with optimal type, architecture and learning algorithms of ANN for objective real estate price prediction. The most optimal ANN is the MLP, learning algorithm = BP100, SG20, CG55b, profile = 9:9-12-7-1:1

Source: author's results of experiments and simulations using Statistica 7

2. Automation of business processes (supply chain management, automated distribution of tasks between employees) – optimizes business processes, reduces costs and increases productivity.

3. Personnel management (assessment of employee competencies, forecasting the probability and level of burnout, assessment of the level of wages and social package) – optimizes human resource management.

As an example, the results of the author's research on the architecture and type of an artificial SLOW neural network for the regression problem of predicting the salary of potential employees are shown in Fig. 2. (dataset Employees.sta (with 10 input attributes and one target regression attribute) and Statistica 7 software were used).

4. Analysis of customer behavior (personalization of marketing offers, forecasting customer loyalty) – increases the targeting of offers for customers and, as a result, the level of customer loyalty and retention.

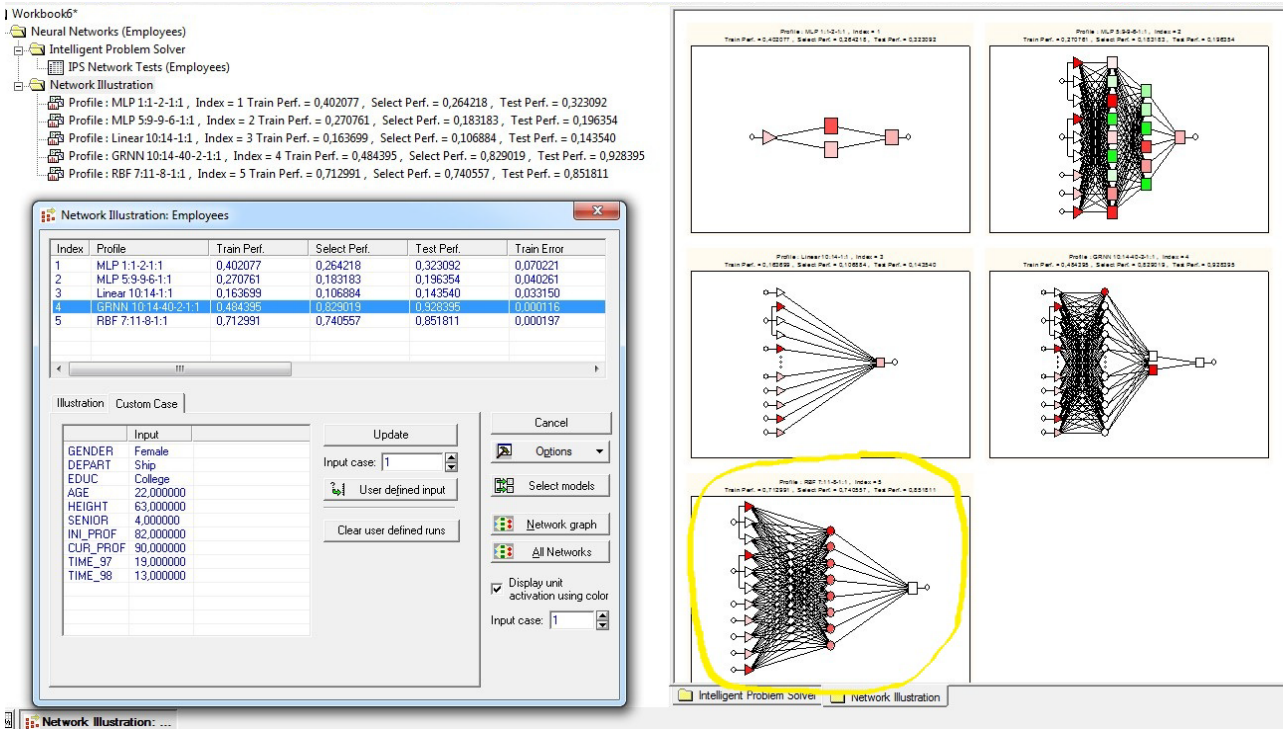

Figure 2 - Results of 5 experiments with type, architecture and learning algorithms of ANNs for the regression problem of predicting the salary level of potential employees. Determined as the most accurate ANN is GRNN, learning algorithm = SS, profile = 10:14-40-2-1:1

Source: author's results of experiments and simulations using Statistica 7

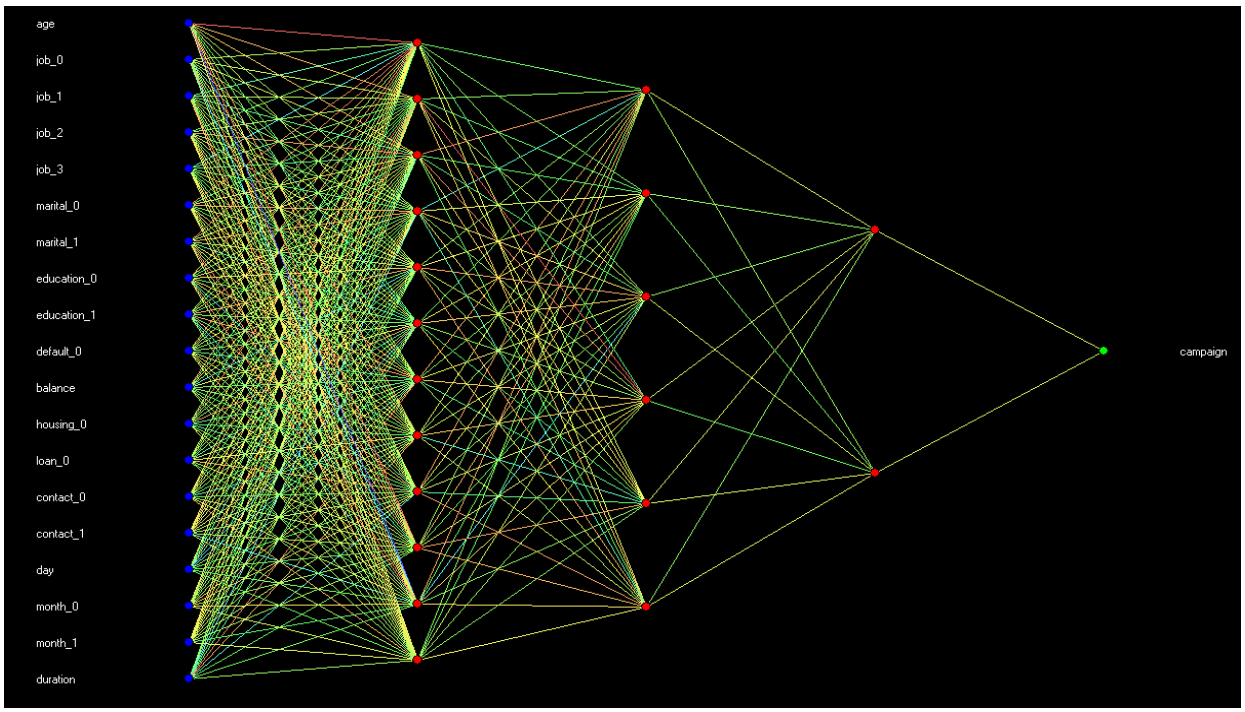

Figure 3 - Example of the configured and trained ANN for binary classification based on 19 input attributes of potential/future clients of a financial company/bank (the following optimal configurations and parameters were experimentally determined: activation function = hypertangent; architecture 18x6x2x1; Back Propagation learning algorithm; learning rate = 0.05; moment = 0 ,8).

Source: author's results of experiments and simulations using Deductor Studio

In particular, as a scientific and practical result of this functionality, the authors developed the classification model of shallow artificial neural network (the multilayer perceptron) for binary classification of potential/future clients of a financial company (or banking institution) (see Fig. 3). This ANN (bank2.txt dataset and Deductor Studio software were used) could be used for potential/new customers of a financial company (bank) to assign one of the two existing marketing loyalty programs.

5. Risk management through the identification of anomalies in operations, cases, employees, clients [16] – reduces the possibility of losses, destruction and increases the overall stability and competitiveness of the company.

In particular, it is advisable to use a shallow ANN of the SOM type to detect unusual/anomalous transactions/cases/characteristics. For example, such unusual/anomalous in the salaries of employees may indicate an external threat /fraud/errors/abuse/inefficiency in the management of labor resources of the corporation. Please, find this author's example in Fig. 4 where detected anomalies circled with a white marker (9 input and 1 output attribute in 15 thousands rows data set; 80% of this data set was used for ANN training and 20% - for ANN testing).

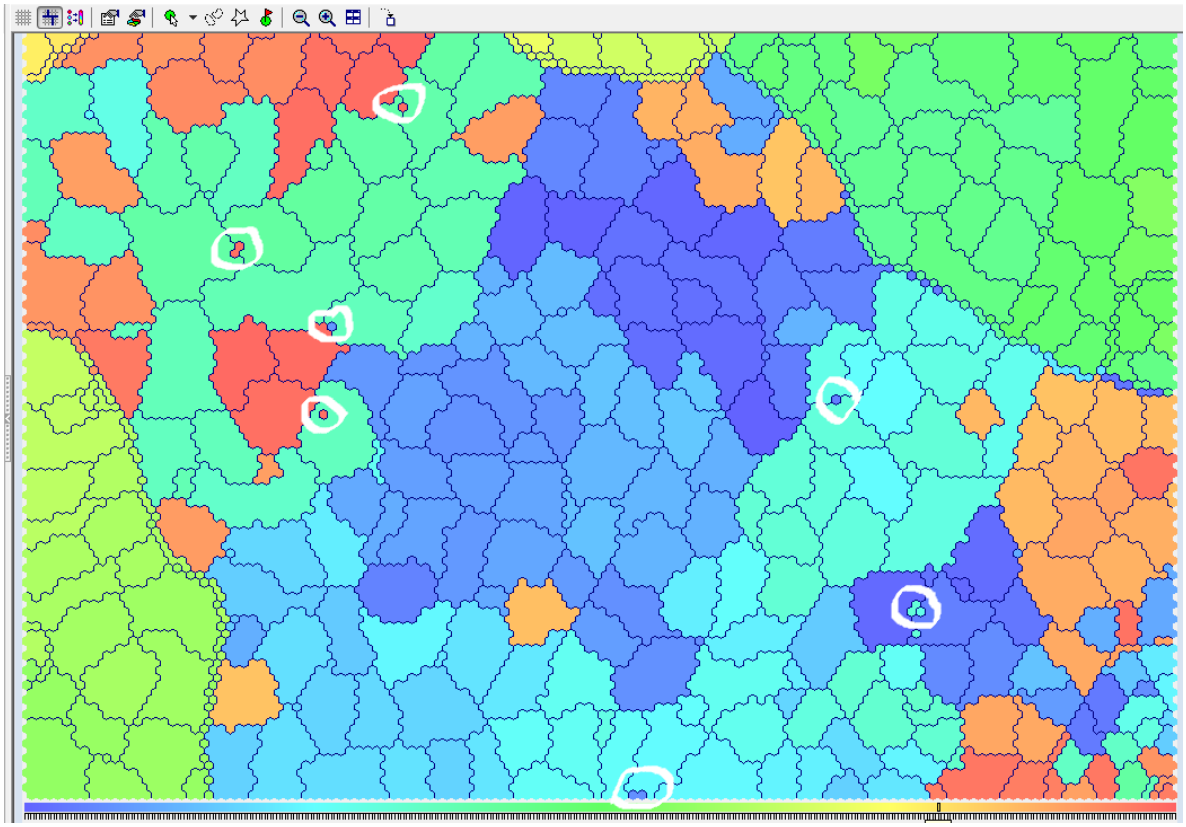

Figure 4 - Visualization of the results of detecting anomalies (marked with a white marker) in Big Data by ANN type SOM Kohhonen using big data set with HR data. The following optimal ANN configuration and parameters were determined experimentally by the authors: 130x130 hexagonal neurons; random initialization; every 10 epochs - mixing of input tuples; the neighborhood function is stepwise; the speed and radius of learning are dynamic and decreasing; the stopping criterion is 50 training epochs or an error of less than 0.05

Source: Configured and Developed by authors using Deductor Studio

Taking into account the Big Data set (15,000 records) used in the above example, the authors consider it appropriate to present the dynamics of the process of unsupervised machine learning of ANN SOM Kohhonen – Fig. 5.

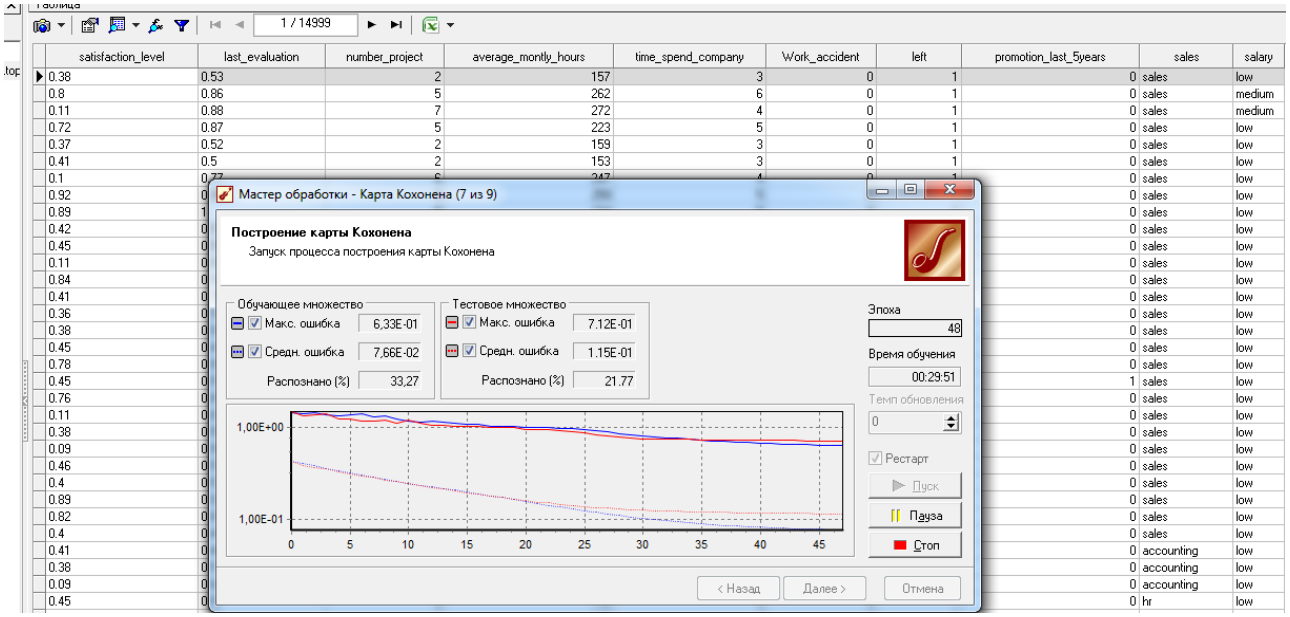

Figure 5 - Visualization of the dynamics of the process of unsupervised ML of ANN type SOM Kohhonen, the results of which are shown in the previous figure

Source: Developed by authors using Deductor Studio

The following types of neural networks are proposed for effective adaptive management:

1. Feedforward Neural Networks (FNNs) - simple architectures where information moves in only one direction: from input to output. Application in management: automation of routine processes; employee performance assessment, etc. Advantages: fast data processing and forecasting.

2. Recurrent Neural Networks (RNNs) - are able to take into account the temporal sequence of data, thanks to feedback between neurons. Application: time series analysis: forecasting sales, costs or demand; monitoring the dynamics of team productivity, etc. Advantages: deep understanding of sequential processes.

3. Convolutional Neural Networks (CNNs) - work effectively with images and spatial data. Application: product quality control in manufacturing; video surveillance analysis in offices and facilities, etc. Advantages: high accuracy in visual analysis of semi-structured and unstructured data.

4. Generative Adversarial Networks (GANs) - consist of two parts (generator and discriminator), which allows generating new data based on existing data. Application: development of new products and design solutions; simulation modeling for management decisions. Advantages: generation of innovative ideas and hypothesis testing.

5. Deep Neural Networks (DNNs) - architectures with a large number of layers that allow solving complex multidimensional problems [17, 18]. Application: supply chain optimization; analysis of complex systems: finance, logistics, personnel. Advantages: high accuracy and the ability to process very large amounts of data.

6. Graph Neural Networks (GNNs) - focused on working with graph data structures (for example, social networks or business processes). Application: customer relationship management; optimization of interactions in the supplier network. Advantages: deep analysis of relationships and interactions.

Determined advantages of using ANN in adaptive management:

1. Deep data analysis: ANNs allow you to identify hidden patterns and regularities that are inaccessible to traditional methods.

2. Adaptability and learning ability: ANNs are able to learn new conditions and remain relevant in the face of changing data.

3. Saving time and resources: process automation reduces manual labor costs and minimizes human errors.

4. Scalability: ANNs work effectively with large volumes of data and can be easily scaled to tasks of varying complexity.

5. Personalization: ANNs provide an individual approach to clients and employees, increasing their satisfaction.

Detected challenges of implementing ANNs in adaptive management identified by the authors:

1. High development and implementation costs: creating an ANN requires significant investments in infrastructure, software, and specialist training.

2. Difficulty interpreting results: ANN models are often perceived as a "black box," which makes it difficult to explain their decisions to management and shareholders.

3. Data quality issues: ANNs require large amounts of clean, structured, and relevant data to be successful.

4. Ethical and legal issues: ANNs must be used in a compliant manner and must take into account data privacy issues.

5. Skilled labor shortage: The high complexity of developing and maintaining ANNs requires expertise in machine learning and data analysis.

Summary and conclusions.

Data Mining is an indispensable tool in modern adaptive and targeted management. Its use allows organizations to respond more effectively to the challenges of the external environment, predict changes and create competitive advantages. The integration of Data Mining technologies into business processes helps to make strategically informed decisions, reduces risks and increases management efficiency. In the future, the significance of Data Mining will only grow, because the role of data in the global economy is becoming more and more important.

Machine learning is an integral part of economic and mathematical modeling, providing modern managers with a powerful tool for making informed decisions. With its ability to analyze large volumes of data, automate routine tasks, and improve predictive accuracy, ML helps optimize business processes, improve customer experience, and reduce risk. Despite the challenges, machine learning is a key success factor in modern management, enabling companies to be more flexible, efficient and competitive in a rapidly changing environment. Its integration into economic and mathematical modeling opens up new opportunities for business development and strategic decision-making.

Artificial neural networks are an important and relevant component of machine learning, which opens up new opportunities for modern management. Their use allows for more effective data analysis, automation of business processes, forecasting of results and increase of competitiveness of organizations. Despite the implementation challenges, the advantages of ANNs far outweigh the disadvantages. In the future, their integration into management systems will become even more widespread, contributing to the development of innovative approaches to decision-making and strategic planning.

The use of artificial neural networks in adaptive management provides companies with unique opportunities to increase efficiency, flexibility and competitiveness. The relevance of ANNs is due to the global trends of digitalization, the growth of the volume of data and the need to quickly respond to changes in the business environment. Despite the existing challenges associated with the implementation and use of ANNs, their advantages far outweigh the costs of all stages of their configuration, collection of large amounts of high-quality input data, training, testing, and implementation.

Thus, the implementation of ANNs in modern management becomes an important step for companies that seek to ensure sustainable development and maintain leading positions in the market. In the long term, ANNs will not only transform management processes, but will also become the basis of a new management paradigm based on data and artificial intelligence.

Discussion.

The authors put forward the following debatable thesis: modern management is faced with a number of challenges: the growth of the volume of data, the high speed of changes in the market, the need for personalized approaches to clients and adaptation to new conditions, including crisis ones [19]. In such conditions, the application of hybrid intelligent methods, in particular hybrid artificial neural networks, becomes strategically important.

Hybrid methods combine the advantages of several technologies, for example, neural networks, machine learning, optimization algorithms, and traditional statistical approaches [20, 21]. This makes it possible to achieve high accuracy of analysis and decision-making in complex dynamic systems [22, 23].

In other words, hybrid intelligent methods, including hybrid artificial neural networks, are a powerful tool for modern adaptive and targeted management. Their use contributes to increasing the efficiency, flexibility and competitiveness of business.

Despite the challenges, the implementation of hybrid methods is necessary for companies and corporations seeking to adapt to rapid changes in the market and customer requirements. The further development of these technologies will become the basis of new approaches to management and will contribute to the construction of intelligent, sustainable and effective business systems, especially in conditions of multifactorial and multilevel crisis [24].

It is this direction of actual scientific and practical research of the authors that will be revealed in detail in the following publications.

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Article sent: 21.12.2024