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USING KOHONEN NEURAL NETWORKS AND FUZZY NEURAL NETWORKS IN INTELLIGENT ANALYSIS OF IoT SENSOR INFORMATION

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ABSTRACT

The article presents methods for using Kohonen neural networks and fuzzy neural networks in intelligent analysis of information from IoT sensors. A detailed data analysis process based on a neural network is shown. The types of intelligent data analysis based on neural networks are considered. The advantages and disadvantages of popular neural networks in data mining are also given.

Keywords: *data mining, rule extraction algorithm, neural network method, evaluation rules, Kohonen networks, neural network models.*

ИСПОЛЬЗОВАНИЕ НЕЙРОННЫХ СЕТЕЙ КОХОНЕНА И НЕЧЕТКИХ НЕЙРОННЫХ СЕТЕЙ В ИНТЕЛЛЕКТУАЛЬНОМ АНАЛИЗЕ ИНФОРМАЦИИ С ДАТЧИКОВ IoT

Аннотация. *В статье представлены методы использования нейронных сетей Кохонена и нечетких нейронных сетей в интеллектуальном анализе информации с датчиков Интернета вещей. Показан подробный процесс анализа информации, основанный на нейронной сети. Рассмотрены типы интеллектуального анализа данных, основанного на нейронных сетях. Также приведены преимущества и недостатки популярных нейронных сетей в data mining.*

Ключевые слова: *интеллектуальный анализ данных, алгоритм извлечения правил, метод нейронных сетей, правила оценки, сети Кохонена, модели нейронных сетей.*

INTRODUCTION

Data is the new oil. We are now entering a new era of innovative modern information technology, where the Internet of Things is on an unstoppable explosive growth and the importance of information and data is becoming more and more noticeable. IoT sensors are hardware devices that detect changes in the environment and collect data. The sensor itself is useless, but it plays a vital role when we deploy it in the IoT ecosystem. IoT sensors serve to collect data, communicate and share it with the connected devices throughout the network. All this collected data allows the devices to work autonomously, thus making the entire ecosystem “smarter” every day.

The development of database technology and database management systems contributes to the growth of the volume of data stored in the database. This data contains a lot of important information that has a great potential for profit. In view of this, many companies use data mining technology, which allows processing massive databases and extracting useful information from them. The goal of data mining is to identify latent rules and patterns in data sets. For a long time, the main tool for data mining was traditional mathematical statistics, but it is often unable to solve real-life problems. Mathematical statistics is mainly useful for testing pre-formulated hypotheses (verification-driven data mining).

Initially, the use of neural networks in data mining caused skepticism due to the disadvantages inherent in neural networks: complex structure, poor interpretability and long training time. However, their advantages, such as high tolerance for noisy data and low error rate, continuous improvement and optimization of various network training algorithms, rule extraction algorithm, network simplification algorithm, make neural networks an increasingly promising direction in data mining. The areas of application of neural networks are extensive - automation of pattern recognition processes, forecasting, adaptive control, creation of expert systems, organization of associative memory, processing of analog and digital signals, synthesis and identification of electronic circuits and systems. Thus, it can be said that the use of

neural networks in data mining technology is a relevant area that is constantly developing, along the path of eliminating shortcomings [1,2].

RESEARCH OBJECT AND METHODS

Neural Network Method in Data Mining. As a rule, the following existing methods of data mining are distinguished: neural networks, decision trees, genetic algorithms, fuzzy logic, limited enumeration algorithms, evolutionary programming, reasoning systems based on similar cases, rule induction, analysis with selective action, logical regression, association and sequence detection algorithms, data visualization, combined methods. Most analytical methods in data mining technology are well-known mathematical algorithms and methods. What is new in their application is their adaptation to solve certain specific problems, which is possible due to the emerging technical capabilities and software. The majority of data mining methods were developed within the framework of artificial intelligence theory.

The neural network method is used for classification, clustering, forecasting and pattern recognition. The neural network model can be divided into three types: 1) Backpropagation networks: one of the most common architectures, mainly used in areas such as forecasting and pattern recognition; 2) Feedback networks: such as the discrete Hopfield model, mainly used for computing optimization and associative memory; 3) Self-organizing networks: include adaptive resonance theory (ART) models and Kohonen models, mainly used for cluster analysis.

Currently, feedforward neural networks are used in data mining analysis. Artificial neural networks are an actively developing field of science, but some theories have not yet been fully formed, such as convergence, stability, local minimum, and parameter adjustment. For the feedforward network, common problems are that training is slow, it can get into a local minimum, and it is difficult to determine the training parameters. In view of these problems, many have switched to the method of combining artificial neural networks with genetic algorithms and have achieved better results. One of the main advantages of neural networks is that

they can, at least theoretically, approximate any continuous function, which allows the researcher not to make any pre-existing hypotheses about the model. The significant disadvantages of neural networks include the fact that the final solution depends on the initial settings of the network and is almost impossible to interpret in traditional analytical terms [3,4].

Neural Network Based Data Analysis Process

The data mining process can be represented by three main phases: data preparation, data analysis, expression and interpretation of results. Details are shown in Fig.1. Neural network based data mining consists of: data preparation, rule extraction and rule evaluation, i.e. three stages, as shown in Fig.2. Data Preparation. The data preparation process must identify and process the data to be mined to make it suitable for specific mining methods. Data preparation is the first important step in data mining and plays a crucial role in it.

As a rule, data preparation includes four processes: 1. Data Cleaning. Data cleaning should fill in vacant data values, remove noisy data and correct inconsistencies in the data. 2. Data Selection. Data selection should determine the layout of the data to be used in the analysis. 3. Data Preprocessing. Data preprocessing is an extension of the data cleaning process that has been selected. 4. Data Expression. Data expression should transform the preprocessed data into a form that can be accepted by the neural network-based data analysis algorithm.

Neural network-based data analysis can only work with numeric data, which means that it is necessary to transform character data into numeric data. The simplest way is to create a correspondence table between character data and numeric data. Another, more complex approach is to adopt hash functions to create unique numeric data corresponding to a given row. Although there are many data types in a relational database, they can basically be reduced to character, discrete numeric, and continuous numeric data, i.e., three logical data types. For example, the word "Apple" in Figure 3 can be converted into the corresponding discrete numeric data using a character table

or a hash function. The discrete numeric data can then be quantified into continuous numeric data and can also be encrypted.

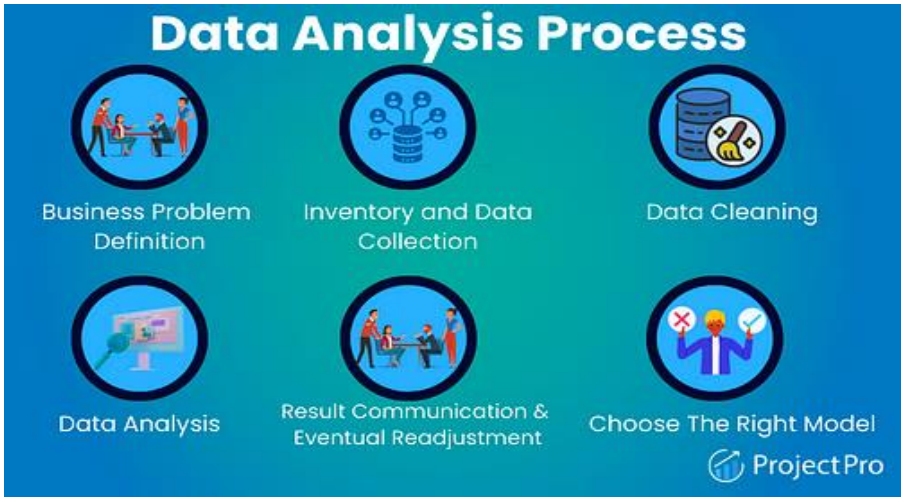

Fig. 1. General data analysis process

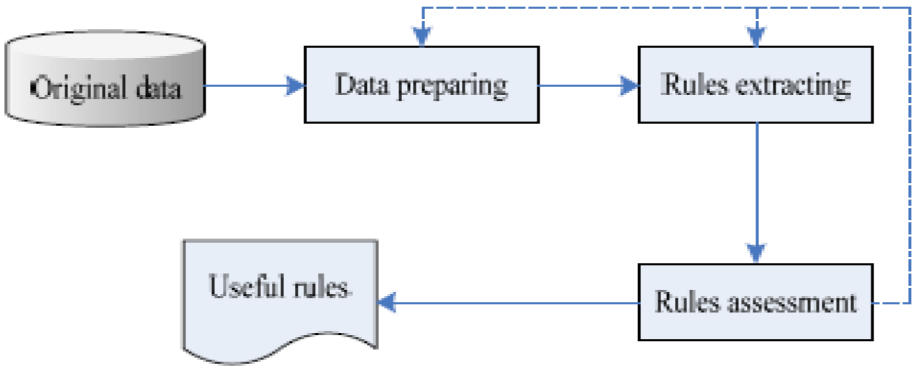

Fig. 2. Neural Network Based Data Analysis Process

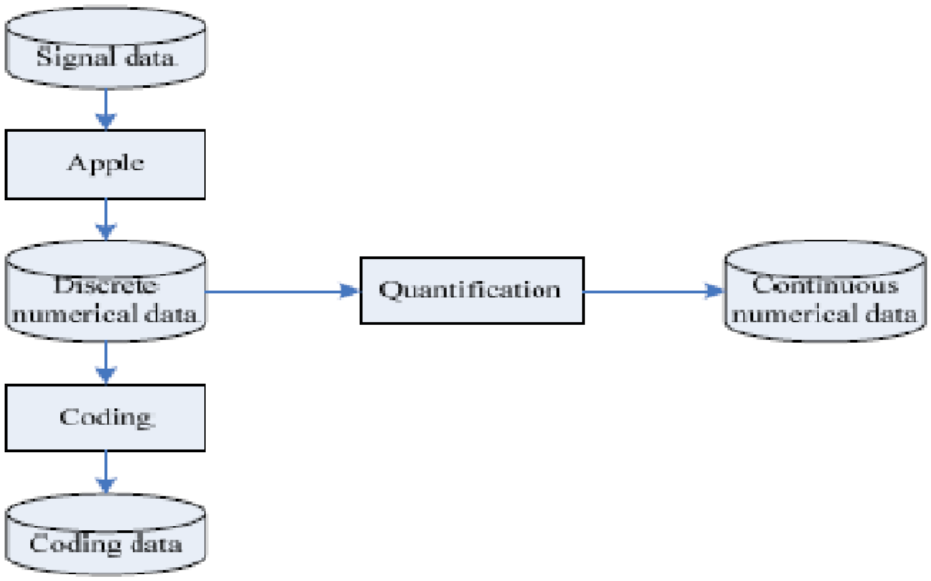

Fig. 3. Data expression and transformation in neural network data mining

Rule extraction. There are many methods for extracting rules, among which the most commonly used are LRE (Limited Relative Error) method, black box method, fuzzy rule extraction method, recursive network rule extraction method, binary input output rule extraction algorithm (BIO-RE), partial rule extraction algorithm (Partial-RE) and full rule extraction algorithm (Full-RE). Evaluation rules. Although the purpose of the evaluation rules depends on the specific application, in general, they can be evaluated according to the following objectives: find the optimal sequence of rule extraction. By doing this, we will get the best results in a certain set of data; check the accuracy of the extracted rules; determine the amount of knowledge in the neural network that has not been extracted; determine the contradictions between the extracted rules and the trained neural network [5-7].

RESEARCH RESULTS AND THEIR DISCUSSION

Types of data mining based on neural networks. There are many types of data mining based on neural networks, but two of them are the most popular. They are based on self-organizing neural networks and fuzzy networks. Data mining based on a self-organizing neural network. The self-organizing process is a learning process without a teacher. In this type of learning, the training set consists of the values of the input variables, and the learning process does not compare the outputs of neurons with the desired values. We can say that such a network learns to understand the structure of the data. The idea of the Kohonen network belongs to the Finnish scientist Toivo Kohonen. The principle of operation of these networks is to introduce information about the location of a neuron into the learning rule, that is, neuron placement maps are created.

Kohonen self-organizing maps are used for modeling, forecasting, finding patterns in large data sets, identifying sets of independent features and compressing information. Data mining based on a fuzzy neural network. Fuzzy neural networks are based on the idea of using an existing data sample to determine the parameters of membership functions, conclusions are made based on the apparatus of fuzzy logic,

and neural network training algorithms are used to find the parameters of membership functions. Such systems can use previously known information, learn, acquire new knowledge, predict time series, and classify images. But one of the main advantages is the visibility of such a network for the user.

The main difference between Kohonen networks and other types of neural networks is their clarity and ease of use. These networks allow you to simplify the multidimensional structure; they can be considered one of the methods for projecting a multidimensional space into a space with a lower dimensionality. Another fundamental difference between Kohonen networks and other neural network models is unsupervised or uncontrolled learning, which allows you to specify only the values of the input variables. The most important advantage of a neuro-fuzzy network is the ability to build a single network to calculate several output values from several inputs, as well as the ability to logically describe processes and manually adjust membership functions. However, fuzzy neural networks compare favorably with other types in that they have absorbed all the advantages of fuzzy sets. Thus, by combining fuzzy sets and neural networks, we obtained universal systems that compensate for the shortcomings of neural networks.

CONCLUSION

The main advantage of using neural networks is the ability to solve various non-formalized problems. At the same time, you can very easily model various situations by feeding various data to the network input and evaluating the result produced by the network. In the course of using neural networks, a significant drawback was noted: the complexity of understanding the process of obtaining a result by the network. The first step to eliminating this problem is the development of a new technology that allows generating a description of the process of solving a problem by a neural network. Using the results of experimental data describing the subject area, it will be possible to obtain an explicit algorithm for solving the problem. From the considered types of data analysis based on neural networks, it can be said that

neural networks, fuzzy logic systems are an indispensable tool for intelligent search and knowledge extraction, since they have the ability to identify significant features and hidden patterns in the analyzed economic indicators.

REFERENCES

1. Ni, X. (2008). Research of Data Mining Based on Neural Networks. *World Academy of Science, Engineering and Technology.* № 39. pp. 381-384.

2. Muradova, A.A., & Begmatov, Sh.A. Methods for managing the reliability and quality of IoT sensors. *Multidisciplinary Scientific Journal Golden Brain*, Volume 2, Issue 4, 2024, pp. 49-58.

3. Luo, Zheng, L., & Xueqian, Z. (2020). Detection Model of Malicious Domain Names Based on Evolutionary Thinking Algorithm Optimized S-Kohonen Neural Networks. *Information Network Security,* 20 (06):82-89.

4. Su, Y., Qiu, Z., Li, G., Lu, Sh., & Chen, M. (2024). A Review of 2D Single-Person Pose Estimation Basedon Deep Learning. *Computer Engineering and Applications,* № 7, pp. 1-21.

5. Majumdar, A. (2011). Adaptive neuro-fuzzy systems in yarn modelling. *Soft Computing in Textile Engineering.* pp.159-177.doi.org/10.1533/9780857090812.2.159

6. Muradova, A.A. (2023). Reliability and security of the Internet of things. *Multidisciplinary Scientific Journal SCHOLAR*, Vol.1,27, pp. 109-117.

7. Muradova, A.A., & Zaynobiddinov, Sh.Z. (2024). Analysis of delivery models in cloud architecture. *Multidisciplinary Scientific Journal, Research and education*, ISSN: 2181-3191, Vol.3, pp. 4-10.