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DEVELOPMENT OF A DECISION SUPPORT SYSTEM USING ARTIFICIAL NEURAL NETWORK AND GENETIC ALGORITHM

Abstract. Relevance. Nowadays artificial intelligence technologies are developing rapidly making it possible to automate the most routine component of data processing. AI is based on the computing architecture of a neural network which applies modeling of biological processes that occur in human brains. To improve the structure of neural network for a decision support system and determine its key parameters, such as the number of inputs, the quantity of layers and neurons within each of them, and choosing a training method, this study suggests to use evolutionary methods. **The purpose of this research** is to investigate the principle of operation of an artificial neural network, whose parameters and structure are determined using genetic algorithm, and to design a decision support system on the basis of the developed model. **Research results.** Taking into consideration that genetic algorithms software implementation requires a good random number generator and that the basis for the correct functioning of a neural network is the training sample that describes the presented task, it was decided to use the source database of learning materials which can provide parameter values for this purpose. Along with databases, important parts of the developed system are new phenotypes generation block, the block for evaluating them and the neural network training block. The process of a neural network training is preceded by determining a set of training samples and adding noise to them, since the output signals of a well-trained neural network should be insensitive to variations of input values within certain acceptable limits in order to implement monotonic data display. The main criterion when choosing the optimal network architecture is its ability to generalize different types of tasks. **Conclusions.** Defining parameters of artificial neural network using genetic algorithm allows to simplify the design of its structure and to develop a decision support system on its basis. Experimental results prove that after the training phase is complete the processed data is divided into clusters that correspond to either solution.

Keywords: artificial neural network; decision support system; genetic algorithm; artificial intelligence; clustering; evolutionary methods.

Introduction

Rapid advancement of artificial intelligence technologies in recent years has fundamentally changed the approach to many types of activities. AI tools make it possible to automate the most routine component of digital tasks and data processing. AI is based on the computing architecture of a neural network which applies modeling of biological processes that occur in the brains of humans and animals. Such a network, created within a computer program, is capable of self-learning, performing specific tasks, correcting errors, etc. The concept of an artificial neural network was originally proposed by American scientists Warren McCulloch and Walter Pitts in 1943. Their model of the complex neural connections of the human brain represented a network of vacuum tubes. Over the years expanding technological capabilities of computer engineering led to the creation of more complex mathematical algorithms based on machine learning. It was a new approach to solving decision-making problems as well as modeling, identification and signal processing. Today problems of classification and image recognition, forecasting and control of dynamic processes are solved using AI. To improve the structure of neural network and determine its key parameters, such as the number of inputs, the quantity of layers and neurons within each of them, choosing a training method, etc., this study suggests to use evolutionary methods, specifically the genetic algorithm.

Review of Recent Studies and Publications. Over the past few years research focus has shifted from a simple increase of the number of artificial neural network layers towards understanding their scalability, security and logical capabilities. Scaling laws investigation [1] has become a major scientific breakthrough and proved that model performance is a function of both number of parameters and training data size. A designed compute-optimal model named Chinchilla dramatically improved efficiency of the training process and allowed to predict its performance beforehand. It revealed that most of neural network models had been undertrained earlier, setting a new standard for large models training.

The study of large language models, presented by OpenAI company [2], proposed to configure neural network models using approach of reinforcement learning from human feedback. Therefore, models upgraded significantly giving more useful, safer and better response to following complex user instructions, which became the basis for all modern chatbots including ChatGPT and Claude.

An attempt of adapting neural networks to solve difficult tasks was made in paper [3] on the basis of Chain-of-Thought. It enables models to solve multi-step logic, mathematics and coding problems due to intermediate reasoning steps generated before the final answer is found.

Creating photorealistic images using artificial neural network received a boost in the study [4]. It is focused on diffusion models that enable to remove noise gradually from a random set of information, particularly visual data. A step towards Artificial General Intelligence was made in paper [5], where single neural network architecture is used to handle various inputs/outputs variables (text, images, control signals). As a result, it can perform hundreds of different tasks and reduces the need for maintaining specialized models.

Massive increase in capacity of a neural network with only a fractional increase in computational cost was presented in [6], which allowed to create huge network models. Instead of activating the entire network, the developed model routes queries to specific sub-networks.

Authors of [7] carried out training to perform an internal "thought process" of neural network before its responding. This approach improves performance on complex reasoning tasks and makes it possible for the model to correct itself.

Therefore, the improvement of neural network architectures and data processing models based on them became a foundation for today's significant progress of artificial intelligence technologies.

The purpose of this research is to investigate the principle of operation of an artificial neural network, whose parameters and structure are determined using genetic algorithm, and to design a decision support system on the basis of the developed model.

Main part

Artificial neural network consists of the elements called neurons which have the similar structure and summarize received signals. If the total sum exceeds threshold level, an output signal is produced, otherwise neuron does not respond to input signals. Therefore, transfer function of the neuron can be expressed as:

$$f_{tr} = \begin{cases} 0, \ for \ \sum_i x_i \le \gamma; \\ 1, \ for \ \sum_i x_i > \gamma, \end{cases} \quad (1)$$

where x_i – input signals of the neuron; γ – threshold value. Hence, output of a binary neuron is determined according to the equation:

$$F = f_{tr}\left(\sum_i x_i w_i, \gamma\right), \quad (2)$$

where w_i – input weights. Fig. 1 descibes operating principle of binary neurons with *n* inputs and one output.

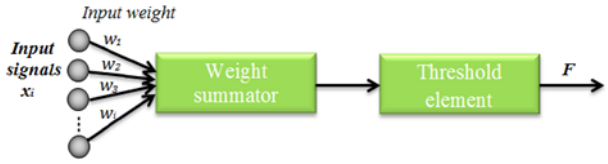

Fig. 1. Model of a binary neuron with n inputs and one output

At the beginning of the learning process neurons have equal or randomly distributed weights of input contacts with a summator. To resolve more complicated problems, several neurons can be combined into neural network. Learning of an artificial neural network means that identified data in the form of combination of signals x_i come to the input of the system. Each of the signals is binary and can take one out of two values – either 0 or 1. Reference signal F_0 is given to the output of a neuron. It defines what should appear at the output of trained neuron. In the case neuron returns the signal different from reference one, the process of machine learning begins.

Nowadays, there are a large number of neural network architectures and methods for training them. Combination of a multilayer perceptron and a backpropagation algorithm is one of the most widespread approaches. This technique is based on gradient estimation, and its disadvantages are the significant time required for calculations and the fact that it is not always possible to obtain accurate results. Another way to train neural networks is using probabilistic methods, in particular the principle of stochastic modeling. Metropolis-Hastings algorithm, simulated annealing, Gibbs sampling can be distinguished among them. Stochastic neural network learning procedure is developed in Bayesian networks, restricted Boltzmann machine, Helmholtz machine, deep belief network. A separate class of neural network training strategies is the search for the weight of synaptic connections and the network structure organization which can be performed using genetic algorithms.

First of all, it is necessary to note that genetic algorithms software implementation requires a good random number generator, since this approach is largely determined by probabilistic selection. Besides, the basis for the correct functioning of a neural network is the training sample that describes the presented task. A standard version of the source database of learning materials can provide parameter values for this purpose. Architecture of decision support system that uses a genetic algorithm to find the best neural network structure for the problem being solved is shown in Fig. 2.

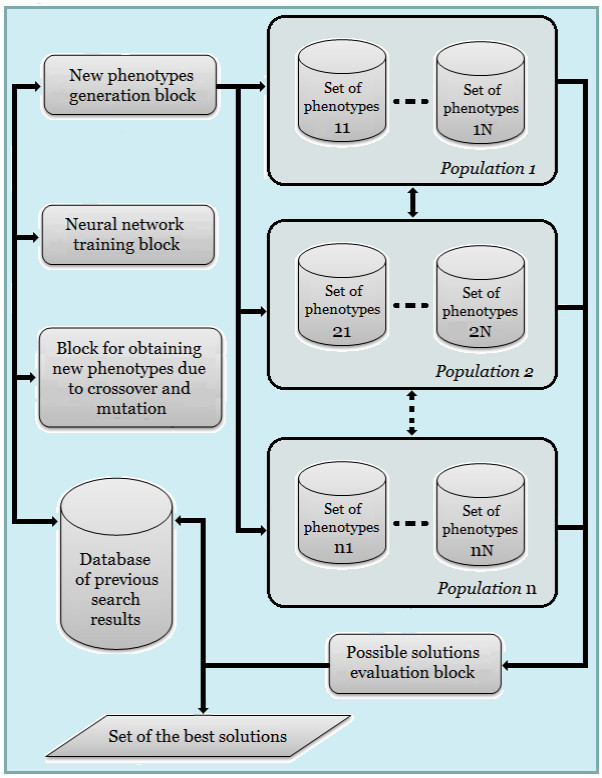

Fig. 2. Decision support system architecture based on genetic algorithm and neural network

Presented system implies the use of databases in its topology, which are mostly dedicated to store necessary data about the results of previous successful and unsuccessful decisions. Therefore, the time required to determine an appropriate neural network structure during further operation of the algorithm can be reduced. The database also stores protocols of all neural network parameters search results and the solutions of previous tasks. Along with databases, important parts of the developed system are new phenotypes generation block, the block for evaluating them and the neural network training block. In addition to direct testing of the new population, the evaluation block also uses a specific

algorithm to determine individuals for the next generation. Selection can be implemented using the roulette wheel or the tournament principle [8]. This subsystem should be independent of other blocks of the considered topology. New phenotypes generation block operates both at the stage of forming the initial set of possible solutions and for further obtaining subsequent populations. Applying databases in the presented scheme allows to determine starting position during phenotypes generating, so that the final solution of the problem can be discovered faster [9]. Meanwhile the random nature of the required parameters search using genetic algorithm remains unchanged.

Neural network training process takes place in a separate subsystem – the neural network training block, which receives a common chromosome with parameters for the network designer and recommendations for the training process from the database according to the previous runs. These recommendations contain information about the method and speed of learning, its sequence, etc., and at the output of the subsystem matrices of synaptic connection weight values are determined. The objective function of the problem of determining a neural network structure can be considered the formula that evaluates the quality of neural network training:

$$Q = \sum_{j=1}^{m}\left(\sum_{i=1}^{k}\left|F_i^j - F_{0i}^j\right| \Big/ (k \cdot m)\right),, \qquad (3)$$

where F – real output value; F_0 – required output value; m – number of examples in the validation selection; k – number of neural network outputs.

The dynamic architecture of a neural network assumes that neuron layers are consistently generated until the given level of accuracy is achieved. The final decision on which network scheme to choose is made only after a full study of different possible types of its structure. It is followed with reducing error in solving the problem to an admitted value. The process of a neural network training is preceded by determining a set of training samples and adding noise to them, since the output signals of a well-trained neural network should be insensitive to variations of input values within certain acceptable limits in order to implement monotonic data display. The main criterion when choosing the optimal network architecture is its ability to generalize different types of tasks.

To develop a decision support system on the basis of neural network, it is necessary to identify a specific set of outcomes regarding certain decision and solve the clustering problem. Unlike classification, which involves distribution of input space vectors between several classes defined by the user, clustering performs research of the input set of vectors in order to identify and divide them among several groups according to characteristics that determine proximity between the elements of the set. Clustering is carried out automatically, clusters are not set by the initial conditions of the problem, they are formed assuming similarity of feature vectors. The features of the studied objects should be encoded in numeric form and normed using an appropriate algorithm. After preprocessing, N-dimensional feature space is obtained including grouped vectors. The dimensionality of the space N depends on the number of parameters that determine each decision. During the neural network training, the number of feature vectors of the training sample must be greater than the specified number of clusters C, and when the number of vectors exceeds the $N \cdot C$ product, the clustering process provides satisfactory result. In case of linear cluster discreteness, received clusters of inputs can be separated with lines (for $N = 2$) or planes (for $N = 3$). If they are separated with a line or a surface of more complex shape, there is a nonlinear cluster discreteness. If the clusters overlap, there is probabilistic discreteness, which means that a feature vector can be attributed to one or another cluster with a certain probability. Since most of the neural network architectures are unusable for solving problems with probabilistic discreteness, the problem is restricted to condition that decision support system is based on clusters which are linearly separable or nonlinearly separable, or can be reduced to them due to data preprocessing.

Neural network simulation was carried out via Deep Learning Toolbox application, which is part of the Matlab software package. The result of the neural network operation is presented as a graph in two-dimensional space of input features (Fig. 3).

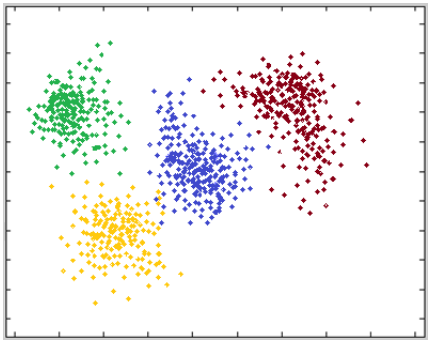

Fig. 3. Visualization for clustering using trained network

For a three-dimensional space of parameters, the graphic image is also three-dimensional, and for higher dimensional vectors, it is practically impossible to visualize the results. In this case, the multidimensional feature space can be reduced to a space of lower dimension using reflection.

Conclusions

Nowadays neural networks are no longer constrained and insufficient methods for solving complex, highly specialized problems. Featuring artificial intelligence advancement, they have become widespread in common applications for data organization, time reduction and decision making. Development of a decision support system on the basis of artificial neural network is carried out using evolutionary methods to create its structure. Parameters of the neural network are determined proceeding from the genetic algorithm results. Such an approach simplifies neural network design and allows to carry out cluster analysis of data sets. Experimental results prove that after the training phase is complete the processed data is divided into clusters that correspond to either solution.

Conflicts of interest. The author declare that he has no conflicts of interest in relation to the current study,

including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

Use of artificial intelligence. The authors confirm that they did not use artificial intelligence technologies when creating the current work.

REFERENCES

1. Hoffmann J., Borgeaud S., Mensch A., Buchatskaya E. et al. (2022). Training Compute-Optimal Large Language Models. In Proceedings of the 36th International Conference on Neural Information Processing Systems (NIPS '22). Curran Associates Inc., Red Hook, NY, USA, Article 2176. – P. 30016–30030. DOI: https://doi.org/10.48550/arXiv.2203.15556
2. Ouyang L., Wu J., Jiang X., Almeida D. et al. (2022). Training language models to follow instructions with human feedback. OpenAI. Journal «Advances in neural information processing systems». Vol. 35. – P. 27730-27744. DOI: https://doi.org/10.48550/arXiv.2203.02155
3. Wei J., Wang X., Schuurmans D., Bosma M. et al. (2022). Chain of Thought Prompting Elicits Reasoning in Large Language Models. In Proceedings of the 36th International Conference on Neural Information Processing Systems (NIPS '22). Curran Associates Inc., Red Hook, NY, USA, Article 1800. – P. 24824–24837. DOI: https://doi.org/10.48550/arXiv.2201.11903
4. Sauer A., Boesel F., Dockhorn T., Blattmann A. et al. (2024). Fast High-Resolution Image Synthesis with Latent Adversarial Diffusion Distillation. In SIGGRAPH Asia 2024 Conference Papers (SA '24). Association for Computing Machinery, New York, NY, USA, Article 106. – P. 1–11. DOI: https://doi.org/10.1145/3680528.3687625
5. Reed S., Żołna K., Parisotto E., Gomez S. et al. (2022). A Generalist Agent. Transactions on Machine Learning Research. – 42 p. DOI: https://doi.org/10.48550/arXiv.2205.06175
6. Fedus W., Zoph B., Shazeer N. (2022). Switch Transformers: Scaling to Trillion Parameter Models with Simple and Efficient Sparsity. Journal of Machine Learning Research. Vol. 23, No. 1, Article 120. – P. 5232–5270. DOI: https://doi.org/10.48550/arXiv.2101.03961
7. Zelikman E., Harik G., Shao Y., Jayasiri V. et al. (2024). Quiet-star: Language models can teach themselves to think before speaking. First Conference on Language Modeling. arXiv preprint arXiv:2403.09629. – 26 p. DOI: https://doi.org/10.48550/arXiv.2403.09629
8. Рибак О. (2021). Застосування еволюційних методів оптимізації для вибору режимів шліфування. Технічні науки та технології. Чернігів: НУ «Чернігівська політехніка». № 4(26). – С. 97-105. DOI: https://doi.org/10.25140/2411-5363-2021-4(26)-97-105
9. Bayer H.G., Schwefel H.P., Wegener I. (2002). How to analyse evolutionary algorithms. Theoretical Computer Science, 2002, Vol. 287, Is. 1. – P. 101−130. DOI: https://doi.org/10.1016/S0304-3975(02)00137-8

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Розробка системи підтримки прийняття рішень за допомогою штучної нейронної мережі та генетичного алгоритму

О. В. Рибак

Анотація. Актуальність. На сьогоднішній день технології штучного інтелекту зазнали бурхливого розвитку, що дає можливість автоматизувати рутинну частину обробки даних. ШІ заснований на обчислювальній архітектурі нейронної мережі, яка застосовує моделювання біологічних процесів, що відбуваються в людському мозку. З метою вдосконалення структури нейронної мережі для системи підтримки прийняття рішень та вибору її ключових параметрів, зокрема визначення числа входів, кількості шарів та нейронів у кожному з них, методу навчання тощо у даному дослідженні пропонується використовувати еволюційні методи. **Метою статті** є дослідження принципу функціонування штучної нейронної мережі, параметри і структура якої визначаються за допомогою генетичного алгоритму, і розробка системи підтримки прийняття рішень на основі створеної моделі. **Результати дослідження.** Враховуючи те, що генетичні алгоритми багато в чому спираються на ймовірнісний вибір, при їхній програмній реалізації необхідно використовувати якісний генератор випадкових чисел. Також основою правильного функціонування нейронної мережі є навчальна вибірка, що описує представлену задачу, відтак для зберігання значень параметрів застосовується база даних. Окрім баз даних, важливою частиною розробленої системи є блок генерації нових особин, блок їхньої оцінки і блок навчання неронної мережі. Процесу навчання нейронної мережі передує визначення набору навчальних вибірок та додавання до них шуму, оскільки вихідні сигнали добре навченої нейронної мережі повинні бути нечутливими до варіацій вхідних величин, що знаходяться у певних допустимих межах, задля реалізації монотонного відображення даних. Головним критерієм при виборі оптимальної архітектури нейронної мережі виявляється її здатність до узагальнення різних типів задач. **Висновки.** Визначення параметрів штучної нейронної мережі за допомогою генетичного алгоритму дозволяє спростити процес проєктування її структури, а також розробити на її основі систему підтримки прийняття рішень. Експериментальні результати доводять, що після завершення етапу навчання мережі оброблені дані поділяються на кластери, які співвідносяться з тим чи іншим варіантом вирішення задачі.

Ключові слова: штучна нейронна мережа; система підтримки прийняття рішень; генетичний алгоритм; штучний інтелект; кластеризація; еволюційні методи.