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Prerequisites for the use of neural networks in the synthesis of structures in mechanical engineering

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Abstract. *The article presents the prerequisites for the development of algorithmization of the synthesis of structural elements in the process of design and technological solutions in mechanical engineering on the basis of classical methods using a neural network. The paper considers the existing methods of searching for engineering solutions and presents an analysis of the application of neural networks. The article proposes a solution to the problem of optimizing the synthesis of functional units of mechanical engineering structures, which will reduce the time of their design and provide a technical solution of algorithmic calculations with elements of intuition and experience engineers.*
Keywords. synthesis; analysis; technical solution; designing; invention; engineering; optimization; neural network.

The rapid development of technology stimulates scientific and technological progress to new discoveries, which in turn create new challenges for improving and creating more adapted design and technological solutions in mechanical engineering [1].

Thus, there is a need to solve the problem of designing new, more adapted, and universal technical objects associated with the conceptual design of complex structural elements that require analysis and evaluation of a large number of possible alternatives. For these reasons, the task of creating (optimizing) new (existing) methods is to find technical solutions, which will effectively solve the problem of synthesis of new, more efficient and flexible technical solutions with the use of modern technologies.

Numerous authors on design and technical creativity discuss in detail the methods and rules for finding ideas for solving engineering problems. They allow the increasing efficiency of both the individual creative work of the designer and the efficiency of the creative activity of the team of developers [1].

Each method has both advantages and disadvantages and is carefully selected before the task. However, with the development of technology, the search for more efficient methods of generating new solutions becomes quite relevant to date. Therefore, the use of machine learning in the problems of technical creativity will make the synthesized design algorithmic calculations with elements inherent in the engineer, components of intuition and experience, which often become the main and determining.

To date, the introduction of new technologies in various industries is not complete without the use of machine learning. In most studies, upon a detailed examination, one can find classical problem statements for neural networks.

So, we can talk about the rapid development of the formal theory of neural networks. A huge number of algorithms for the functioning and training of neural networks have been developed, work is underway to create algorithms for optimizing their structure in order to increase speed, quality of results, and reduce training time. Neural network technologies have found application in economics, medicine, industry, and many other fields of science and technology; they are capable of solving almost any problems associated with modeling, forecasting, and optimization [2].

The lion's share of research in the field of neural network technologies falls on the task of mechanical engineering. In this area, there is a tendency to move to production modules with a high level of automation, and this requires more and more intelligent self-regulating and self-adjusting machines that would be able to handle a wide range of parts, assemble and commission various

devices, evaluate product quality with minimal monitoring and assistance from the human operator [3].

Currently, the most common application of neural networks is in the tasks of pattern recognition, optimization, prediction, classification, automatic control and more.

Reducing the time for the creation of design and technological solutions in mechanical engineering can be achieved only by automating all stages of design, which is ensured by the use of modern powerful CAD / CAE systems. Automation of the early stages of design is provided by structural synthesis. The most common in computer design is combinatorial-logical synthesis methods, one of which is morphological analysis [4]. Visualization of the results of structural synthesis is performed using parametric synthesis and structural synthesis. In the process of synthesis of the structure, many possible options for the implementation of structural elements to create or improve the system are generated. This includes the stages of synthesis of the principle of action, structure and parameters of the designed object. The functional diagram of the synthesis step is shown in Fig. 1.

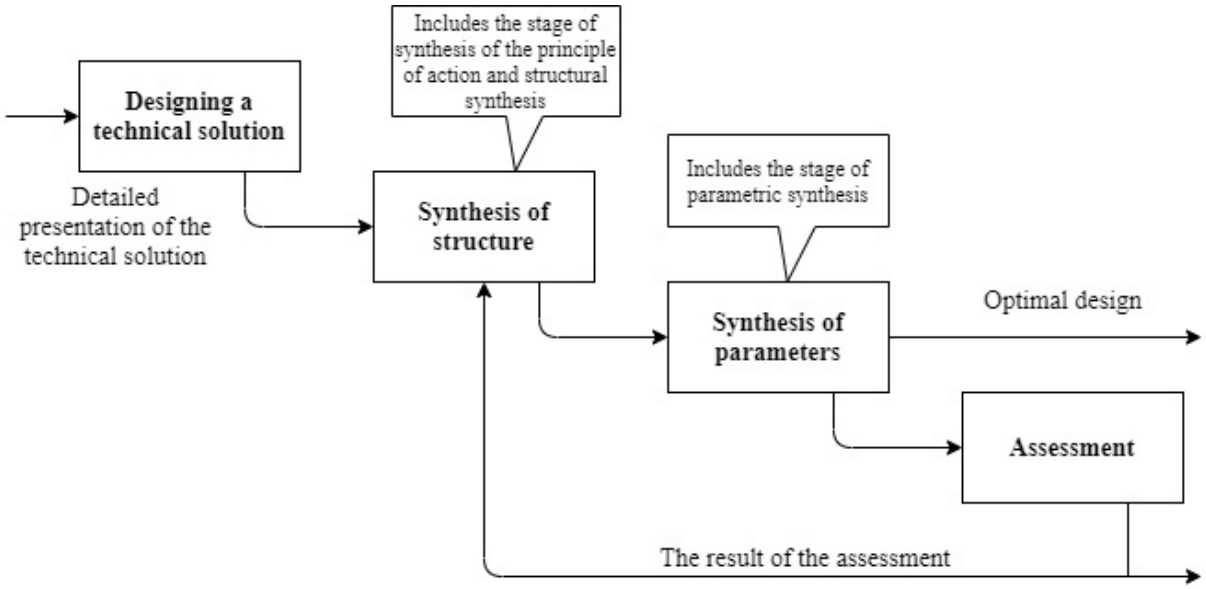

Fig. 1. Functional diagram of the synthesis step

After that, a search is carried out for possible solutions to the problem in accordance with the selected method of morphological synthesis, which consists in the sequential selection of many options for implementing the system using operations to evaluate the effectiveness and compatibility of the subsystems of the investigated technical solution.

Since this problem statement is not classical for the neural network (unlike the problems of clustering, classification, approximation, pattern recognition, etc.), as a result, it leads to a number of problems associated with the choice of architecture, input preparation, determination of optimal neural network learning algorithms, etc. Addressing these issues is complicated by the lack of standards in this area. Therefore, before setting the problem of technical solution synthesis, it is advisable to get acquainted with the classical application of neural networks and methods of their training, which will further avoid problems associated with the peculiarities of their training and operation.

Let us consider in more detail the structure and principle of operation of the neural network. A typical hierarchical structural diagram of neural network is shown in Fig. 2.

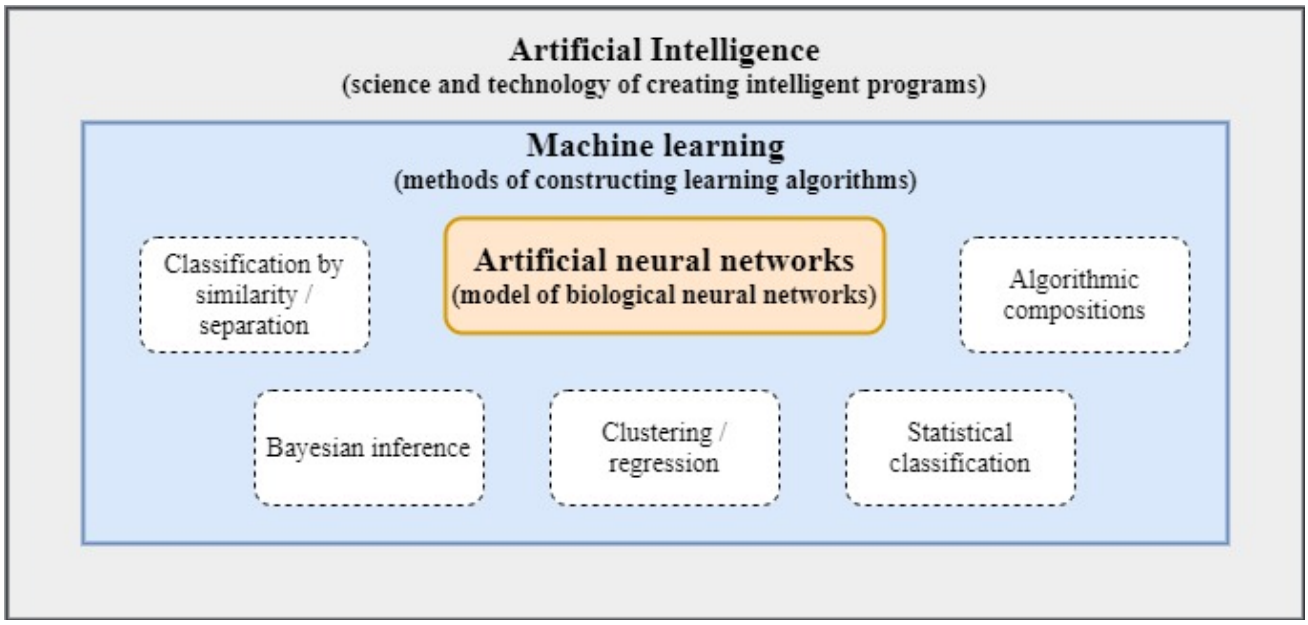

Fig. 2. Hierarchical structural diagram of a neural network

An artificial neuron is a simplified model of a biological neuron (Fig. 3), the structure of which receives a signal, converts it (approximately as real neurons do), and transmits it to other neurons (which do the same) [1].

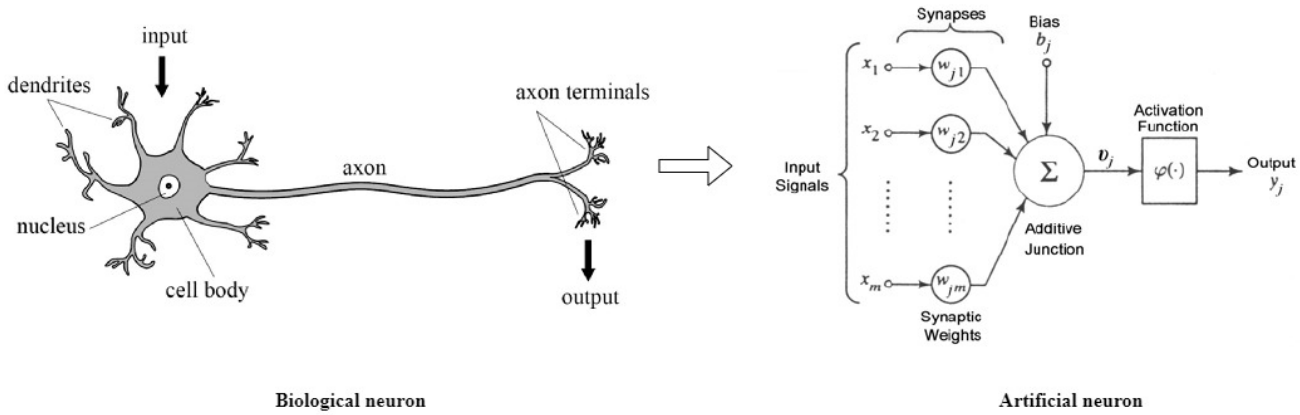

Fig.3. Simplified comparative model of artificial and biological neuron

In the depicted neuron model, a threshold element (threshold value) is also included, which is indicated by the symbol Θ_j. This value reflects an increase or decrease in the input signal supplied to the activation function.

The mathematical model of a neuron is described by relations (1):

$$\begin{cases} y = f(s) \\ S = \sum_{i=1}^{n} w_i \cdot x_i + \theta \end{cases} \quad (1)$$

where y - the output signal of the neuron, f - a nonlinear converter (activation function), S - the summation result, x_i - the component of the input vector (input signal), ω_i - the synapse weight, Θ is the offset value, n is the number of neuron inputs.

Thus, the neuron is completely described by its weights w_i and the activation function $f(s)$, where the speed depends on the choice and method of learning the neural network. Having received a set of numbers (vector) x_i as inputs, the neuron produces a certain number y at the output.

To optimize the work to reduce the sample of alternatives and select the most suitable options for prototype designs, a simplified structural and functional model for the synthesis of structural and technological solutions in mechanical engineering (Fig. 4) based on a morphological approach using systems analysis and machine learning elements.

We propose to use neural networks:

- at the design stage for the synthesis of design and technological solutions;
- to optimize the choice of the best alternatives from all synthesized according to the specified criteria;
- to analyze and evaluate the created design and technological solutions in order to identify shortcomings and further improvement.

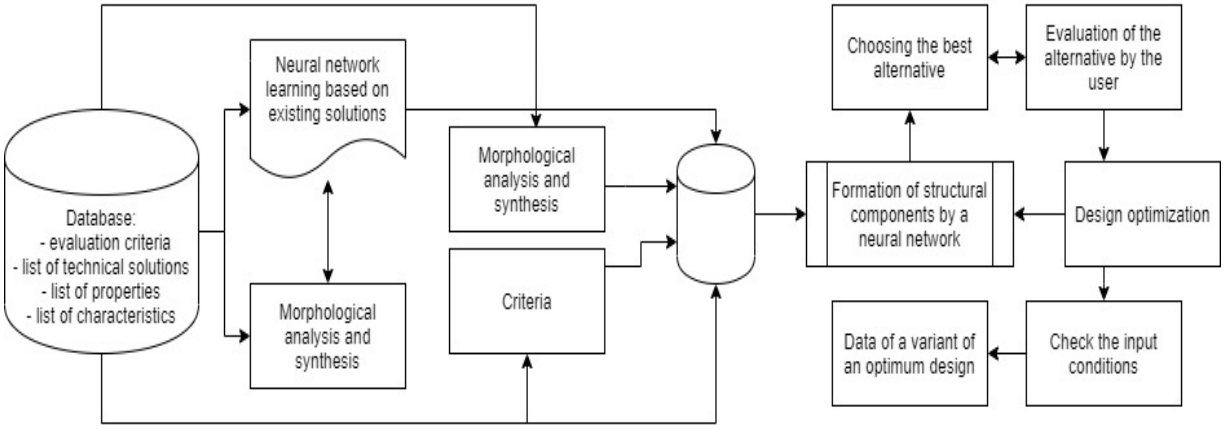

Fig.4. Simplified structural and functional model for the synthesis of structural and technological solutions in mechanical engineering

To date, the introduction of new technologies in various industries is not complete without the use of machine learning. Neural networks are a fairly new and promising computing technology that opens up many possibilities and approaches in the synthesis and design of new technical solutions, including in mechanical engineering.

Therefore, the use of neural networks to optimize the synthesis of new technical solutions in mechanical engineering is a very urgent task, expanding the technical level of the developed functional units, while reducing their design time, in turn, will allow algorithmic calculations with elements of intuition and experience components to be introduced into the technical solution.

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Передумови застосування нейронної мережі при синтезі конструкцій в машинобудуванні

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Анотація: *У статті представлені передумови розвитку алгоритмізації синтезу конструктивних елементів у процесі проектування проектних та технологічних рішень в машинобудуванні на основі класичних методів з використанням нейронної мережі. У роботі розглядаються існуючі методи пошуку інженерних рішень та представлений аналіз застосування нейронних мереж. У статті пропонується вирішити проблему оптимізації синтезу функціональних підрозділів машинобудівних конструкцій, що скоротить час їх проектування та забезпечить технічне рішення алгоритмічних розрахунків з елементами інтуїції та досвіду досвідчених інженерів.*
Ключові слова. синтез; аналіз; технічне рішення; проектування; винахідництво; машинобудування; оптимізація; нейронна мережа.