Automation of individual areas of activity through the integration of neural networks

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Abstract. At present, a large number of developments in the field of neural networks are being carried out. All of the researchers are trying to use in their solutions and software products the algorithms of neural networks for maximum and automation without a clue of understanding they work. This circumstance can lead to erroneous data. The article is intended to consider the principles of the operation of neural networks in automated systems.

1. Introduction
The level of automation of individual industries has reached its peak and can only be increased by the introduction of neural networks. A pressing issue in Russia is the further automation of mining and oil-producing enterprises [1, 2]. In particular, the search for solutions is being carried out in the direction of automating tasks performed by operator-operators of various technological processes. Examples can be completely different. This process is the process of wetting the surface, carried out by an aerosol cannon based on a vehicle [3], when the driver carries out the choice of the optimal route, and control the truck, and control special equipment on board. An example is the process of manufacturing powders [4] and other processes. An example from the field of the oil complex is the acoustic emission monitoring system for pipeline integrity. In this case, the task of intellectual interpretation of the results of the analysis of correlograms is performed using neural networks [5].

2. Methods and materials
Before moving on to the topic of automation of any area of human activity with the help of a neural network, it is necessary to understand how neural networks work in general and how to apply them. The application should begin with how the neural network is used on the example of the classification problem.

1. We determine the statement of the problem, for example, classification. Let us choose a simple classification using the example of a binary logical operation with sets “&” (And). The result will be 1 (true) only when both input parameters are 1 (true).
2. Choose the architecture of our neural network. The first input layer consists of 2 neurons (2 neurons, because the binary logical operation takes two values to the input). The second layer can be immediately made output with one neuron (1 neuron, because the classification task gives the categorical answer “YES”, “NO”), because the task is linear and does not require complex architecture.

3. Select the activation function. Let it be sigmoid $f(x) = \frac{1}{1 + \exp(-x)}$.

3. Results

It turns out a single-layer perceptron.

However, even the logical “&” problem cannot be solved with such an architecture. It is necessary to add one bias neuron (they are also called bias).

What is a displacement neuron for?

Displacement neuron makes the neural network more flexible. When creating a neural network without a displacement neuron, this will require a more significant number of neurons in any of the layers, which will affect the learning speed and the process of solving the problem itself.

The final optimal form for solving the logical & problem:

The result of this single-layer perceptron will be the answer YES or NO. If greater than 0.8, then the answer is 1, i.e. YES, less than 0.2, then – 0, i.e. NO, in any other case, we assume that the neural network does not know the correct answer.
Figure 2. The final network architecture for solving binary logical operations “AND”, “OR”, “FOLLOWING.”

This section will not discuss how the weights (w1, w2, b) were obtained (they can be obtained using the backpropagation method of the error or in another way, backpropagation). Let them already be there and properly configured. A configured neural network is as follows:

Figure 3. A single-layer perceptron for solving the logical problem “CONJUNCTION.”
Consider the truth table "CONJUNCTION":

| i1 | i2 | i1&i2 |
|----|----|-------|
| 0  | 0  | 0     |
| 0  | 1  | 0     |
| 1  | 0  | 0     |
| 1  | 1  | 1     |

**Figure 4.** The truth table "CONJUNCTION".

We plot the function $f(i1, i2)$ equal to

$$f(i1, i2) = \frac{1}{1+e^{-(i1w1+i2w2+b1)}}$$

where $w1 = w2 = 8.6$, $b1 = -13.2$

**Figure 5.** Graph of the plane “CONJUNCTIONS” with correctly selected parameters.

Consider Figure 5: for each point $x$, $y$ is the input data, and $z$ is the result of the operation, respectively, only the point D with the input (1,1) on the applicate axis has a value of 1, all other points are 0. Also, if we take into account that the architecture of the neural network is a single-layer perceptron, then if we project a 3-dimensional graph onto a plane, we get an offset sigmoid (Fig. 1).

Precisely the same architecture can solve the tasks of other logical operations:

- Disjunction;
Figure 6. A single-layer perceptron with correctly selected parameters capable of solving the “DISJUNCTION” problem.

• Following:

Figure 7. A single-layer perceptron with correctly selected parameters, capable of solving the "FOLLOW" task.

Such an architecture solves all these three logical operations (AND / OR / FOLLOWING) because they are simple. If we construct points in the two-dimensional space of each logical operation, then they can be separated by a straight line of the form $y = kx + b$.

• Logical "AND":
Figure 8. A straight line graph separating the correct answer from the incorrect in the logical operation “CONJUNCTION.”

- Logical "OR":

Figure 9. A straight-line graph is separating the correct answer from the incorrect in the logical operation "DISJUNCTION."

- Logical "FOLLOW":
Figure 10. A straight line graph that separates the correct answer from the incorrect in the logical operation "FOLLOWING."

For solving such problems as “XOR” or “EQUIVALENCE”, it is necessary to add a hidden layer of 2 hidden neurons and one displacement neuron (Fig. 11).

Figure 11. The optimal structure of a multilayer perceptron for solving the XOR and EQUIVALENCE problems.

A universal formula for these three simple tasks is below. The formula for solving the logical problems “AND”, “OR”, “FOLLOWING”, where it is necessary to select the correct parameters $w_1$, $w_2$, $b_1$. 
In conclusion, summarize:

![Multilayer perceptron structure and value formation at the output neuron](image)

**Figure 12.** Multilayer perceptron structure and value formation at the output neuron

Having the corresponding weights $w_1$-$w_6$, $b_1$-$b_3$ for similar problems, we could substitute them in the equation and use:

$$\frac{1}{1 + e^{-\left(l_1 w_1 + l_2 w_2 + b_1\right)}}$$

$$\frac{1}{1 + e^{-\left(h_1 w_5 + h_2 w_6 + b_1\right)}}$$

$$\frac{1}{1 + e^{-\left(h_2 w_5 + h_3 w_6 + b_3\right)}}$$
Figure 13. An example of correctly selected parameters for the XOR solution.

Figure 14. A graph of a function with correctly selected parameters for solving the "XOR" task.
4. Conclusion
Today, neural networks are used for working in relatively narrow areas, but the dynamics of their integration into human life is quite high. The use of neural networks will form the prerequisites for the automation of most processes of manual labour, determine new requirements for specialists in the fields of economics, medicine, technology, and other branches of science.
Along with this, it is interesting to consider the operation algorithms of these networks under the conditions of the functioning of a natural-industrial system [6].

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