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COMPUTER MODELS OF ARTIFICIAL INTELLIGENCE SYSTEMS BASED ON NEURAL NETWORKS

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Abstract. The possibilities of artificial neural networks as a basis for creating artificial intelligence systems are considered. The main advantage of artificial neural networks is their ability to learn, generalize, and identify hidden dependencies in the source data. The peculiarities, classification, and methods of training artificial neural networks and the tasks successfully solved using these networks are presented. The stages of solving various problems using artificial neural networks are considered. The features of fuzzy neural networks, deep neural networks, and convolutional neural networks are considered in detail.

The following examples of intelligent systems developed on the basis of artificial neural networks are considered: a system for approximating functions from noisy data, a system for classifying large amounts of data, an automatic control system, a cryptographic system, and an image recognition system.

Computer models of these systems have been developed, implemented as computer programs. The results of the work of the considered intelligent systems are presented in a visual graphical form.

Key words: artificial intelligence, artificial neural networks, fuzzy neural networks, deep neural networks, convolutional neural networks, computer models, function approximation, classification, automatic control, cryptographic system, image recognition

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Introduction

The use of artificial neural networks (ANN) is the most effective approach to creating artificial intelligence systems. The main advantage of ANNs is their ability to learn, generalize and identify hidden dependencies between inaccurate, incomplete, or partially distorted (noisy) data [1–5].

As an ANN, we can imagine a system consisting of simple processors representing artificial neurons exchanging data.

The ANN scheme with training and error calculation blocks is shown in fig. 1.

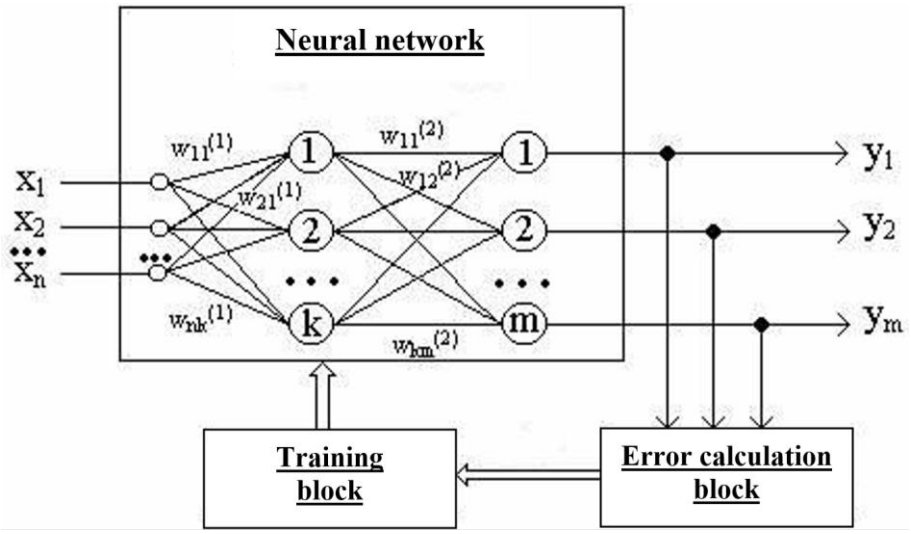


Fig. 1. **Neural network with learning and error calculation blocks**

The reverse error propagation method is often used to train the ANN. This method involves the use of a learning process in which the error value calculated for a certain neuron is propagated back to all the neurons whose output signals were incoming for this neuron.

Let us formulate the problem statement, the results of which are presented in this article. It is necessary to consider the capabilities of ANN, which make it possible to develop artificial intelligent systems (AIS) capable of solving complex tasks, including the tasks of approximating functions from noisy data, classifying large amounts of data, automatic control, cryptography and image recognition.

The topic of the article is relevant, as the creation of intelligent systems is an urgent area. The scientific novelty of the research lies in the creation of computer models of intelligent systems based on ANN, implemented in the form of computer programs.

Fuzzy neural networks

Fuzzy neural networks are systems based on fuzzy logic. The fuzzy ANN diagram is shown in fig. 2.

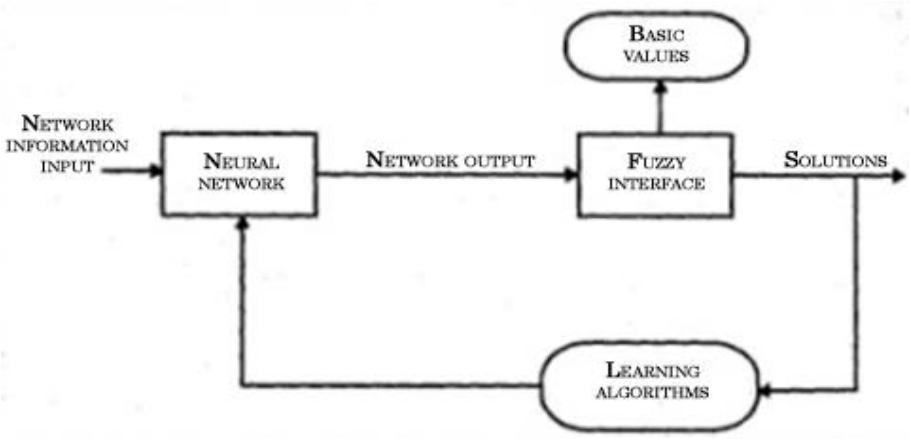


Fig. 2. **Neuro-fuzzy system**

In this neuro-fuzzy system, a multilevel neural network triggers the interface mechanism of fuzzy logic. A fuzzy neural network is a network with a fuzzy transfer function of the first layer of the network.

Deep neural networks

A deep neural network allows you to model complex nonlinear relationships due to the fact that they create various compositional models in the process. In each composite model, the object is modeled as a hierarchical multilevel system consisting of primitives.

Modern methods of deep learning of neural networks consist in finding the minimum of a certain continuous error function. Reinforced learning involves stimulating actions that lead to successful results. Deep reinforcement learning uses Markov decision-making processes, which is supported by a probabilistic approach based on Bayes' hypothesis theorem.

Convolutional neural networks

In a convolutional neural network (CNN), a convolution operation is performed in the convolutional layers of the network, and the network is trained using the error backpropagation method.

CNN is used to create systems used for image recognition. In such systems, the filtering coefficient and the proportion of active image pixels taken into account in the recognition process are determined during image recognition. This allows adaptive adjustment of neural network parameters.

Intelligent systems based on neural networks

Approximation of functions based on noisy data

In order to approximate the functions, INN training uses functions of the form:

$$Y = Cos^3(X);\ Y = Sin(X);\ Y = Sin(X)*Cos(X).$$

In each training cycle, an array of 20*20 values (400 values in total) was processed, and in 20 training cycles 400*20 = 8000 values were processed. The results of the approximation of the function Y = Sin(X) are shown in fig. 3, 4.

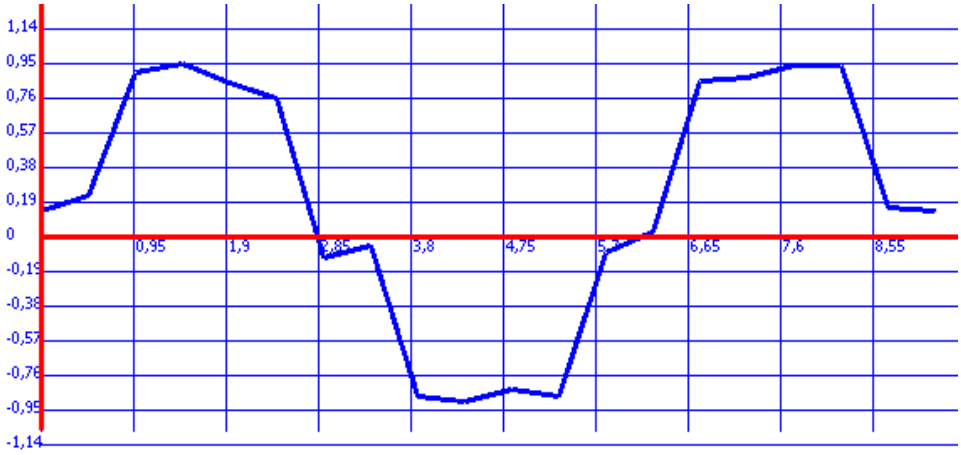


Fig. 3. **Noisy dependence Y=Sin(X)**

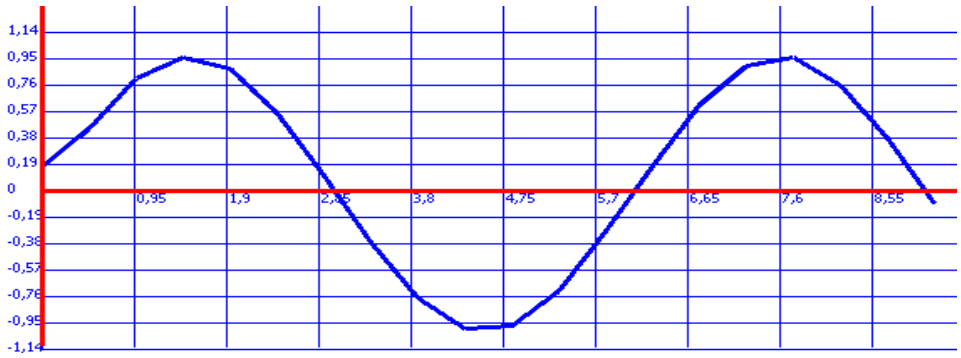
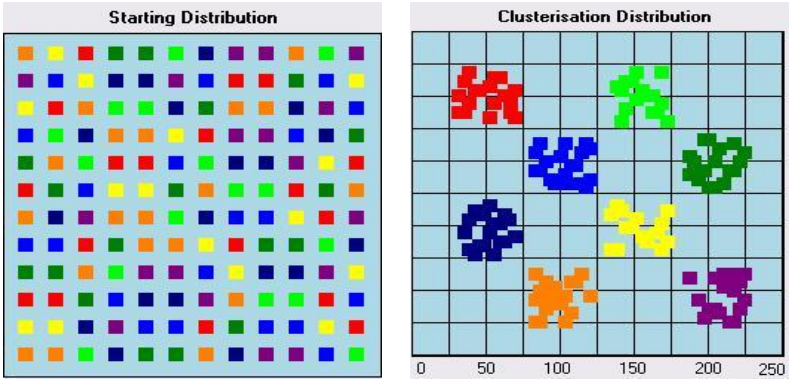


Fig. 4. **Reconstituted dependence after 20 cycles of training**

To conduct computational experiments on the approximation of functions, a computer model was created, and implemented later as a computer program [6].

Classification of large amounts of data

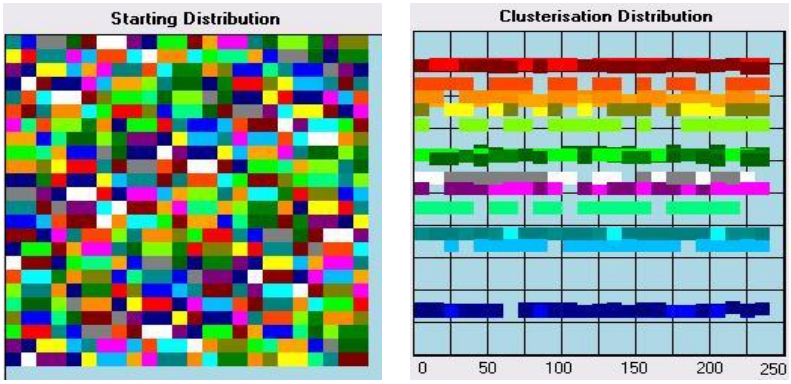
Let's consider the possibilities of self-learning neural networks for classifying large amounts of data. From 144 to 576 graphic objects were used as data, which were classified according to various criteria, the number of which varied from 8 to 24. An example of the classification of 144 graphic objects according to eight criteria for the case of a square configuration of cluster regions is shown in fig. 5.



a) **b)**

Fig. 5. **a – initial data; b – classification into clusters**

An example of the classification of 576 objects according to 24 criteria is shown in fig. 6.



a) **b)**

Fig. 6. **a – initial data; b – classification into clusters**

To conduct computational experiments on the classification of large amounts of data, a computer model was created, and implemented later as a computer program [7].

Automatic control system

Consider a cooling system with an automatic control system (ACS). Such a system includes a fuzzy neural network that allows adaptive control of the cooling system. Figure 7 shows the results of neuro-fuzzy control.

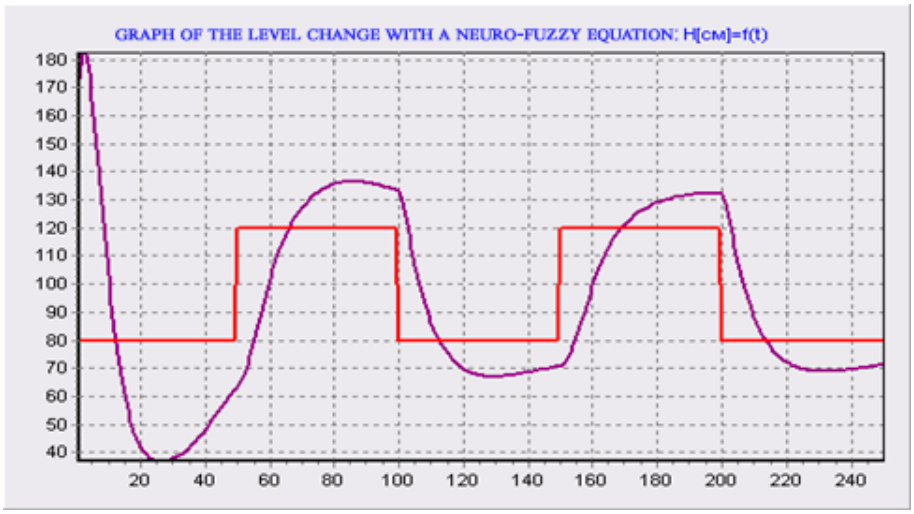


Fig. 7. **A transitional process for adaptive neuro-fuzzy control**

To conduct computational experiments with the adaptive neuro-fuzzy control system, a computer model was created, and implemented later as a computer program [8].

Cryptographic system

Let us consider a cryptographic system consisting of an artificial unidirectional neural network without feedback loops. The process of encrypting information in such a system is characterized by the fact that the dependence of the number of iterations on the size of the encryption key (bits), which represents the coefficients of the network, is shown in fig. 8.

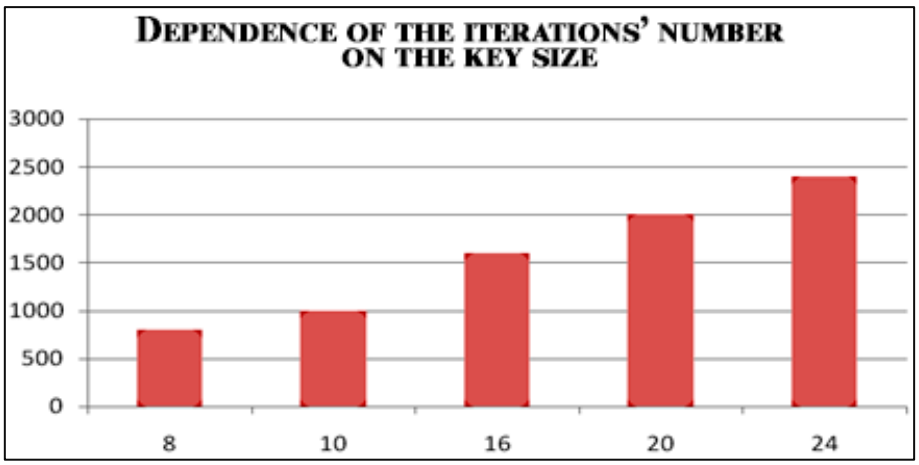
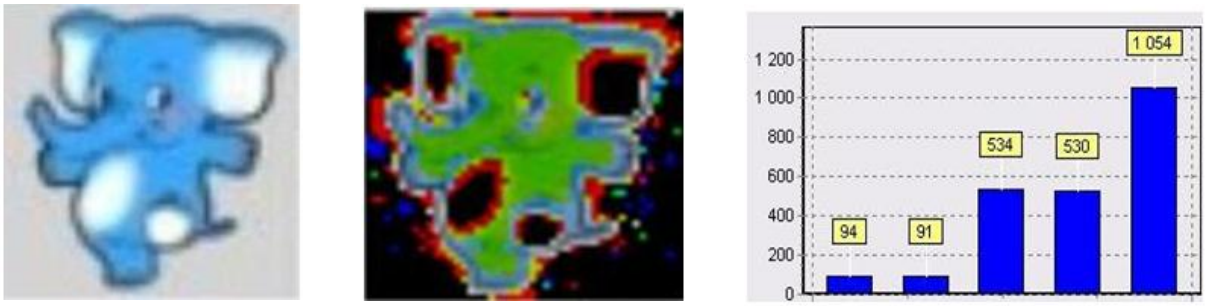


Fig. 8. **Dependence of the number of iterations on the key size**

To conduct computational experiments on data encryption, a computer model was created, and implemented later as a computer program [9].

Image Recognition system

Let us consider the possibilities of an ANN implementing an image recognition system. In the computer model of the image recognition system, the neural network parameters are adjusted adaptively, for which the filtering coefficient and the proportion of active image pixels taken into account in the recognition process, as they are determined during image recognition. Figure 9 shows the original image, the result of filtering, and the brightness diagram of the pixels in the image.



a) **b)** **c)**

Fig. 9. **a – initial image; b – filtered result;**
c – image pixel brightness chart

To conduct computational experiments with an image recognition system based on an ANN, a computer model was created, and implemented later as a computer program [10].

Conclusion

The ANN can serve as a basis for the creation of an AIS.

The ability to identify hidden dependencies in the source data, generalize, and learn is the main advantage of an ANN.

A system for approximating functions based on noisy data, a system for classifying large amounts of data, an automatic control system, a cryptographic system, and an image recognition system are considered as examples of intelligent systems developed on the basis of ANN.

These systems are implemented as computer programs. The results of the work of the considered intelligent systems are presented in a visual graphical form.

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