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NEURAL NETWORK APPROACH TO COGNITIVE MODELING

✉**Labinsky Alexander Yu.**
Saint-Petersburg university of State fire service of EMERCOM of Russia, Saint-Petersburg, Russia
✉***labynsciy@yandex.ru***

Abstract. Some features of cognitive modeling are presented, including the prerequisites for a cognitive approach to solving complex problems. Cognitive modeling involves the use of various artificial neural networks, including convolutional neural networks. The classification of artificial neural networks according to various characteristics is given. The features of self-organizing neural networks and networks using deep learning methods are considered.

The artificial neural network, which is a three-layer unidirectional direct propagation network, the interface of a computer program used to approximate functions using the specified neural network, as well as the solution of the image recognition problem using an artificial convolutional neural network, in which the neural network parameters are adjusted for each recognizable image fragment in order to adaptively filter the image, are considered in detail.

The analysis of images in video surveillance systems in order to detect fires allows them to be detected at an early stage and, thus, prevent the fire propogation.

Keywords: adaptive image filtering, artificial neural network, cognitive map, cognitive modeling, computer model, computer program, convolutional neural network, image recognition

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Introduction

Cognitive modeling is used to determine the most effective management decisions based on an assessment of the mutual influence of various factors in uncertain situations [1].

The prerequisites for using a cognitive approach to analyzing complex situations are the following features:

– the multidimensional nature of the processes taking place in such situations;

– lack of sufficient information about the dynamics of the process under study;

– variability of the nature of the process under study over time.

Cognitive modeling is usually carried out by using computers. It is necessary to note the effective use of artificial neural networks (ANN) both for creating cognitive maps, image and written text recognition, setting parameters of automatic control systems, solving differential equations, forecasting and approximating functions, as well as for classification [1–3, 4]. ANN are created as a virtual model (CM), implemented on a computer.

KM is an algorithm or computer program that solves a system of logical, algebraic or differential equations in order to simulate the behavior of the studied system, with which it is possible to conduct computer experiments.

A cognitive map (latin *cognitio* – knowledge, cognition) is an image of a spatial environment. Cognitive maps can be formed as maps of varying degrees of generality and organization. Among the various maps, a path map is usually distinguished as a sequential representation of the connections between objects along a certain route and a survey map as a simultaneously represented spatial arrangement of objects [2].

Let's formulate the statement of the problem, the results of which are presented in this article. It is necessary to consider cognitive modeling, which allows the development of artificial intelligent systems (AIS) which work similarly to artificial intelligence and capable of solving

complex tasks, including the task of image recognition, which allows detecting fires at an early stage. The topic of the article is relevant, since the importance of preventing fire propogation is beyond doubt.

The novelty of the research reflects the personal contribution of the author and is based on developed CM, that has implemented image recognition and approximation functions via ANN usage.

Consider the various veiws on ANN. From the machine learning point of view, ANN is a special case of pattern recognition methods, discriminant analysis and clustering methods [5]. From a mathematical point of view, neural network training is a multiparametric nonlinear optimization problem. Based on the concepts of cybernetics, ANN is used in adaptive control tasks. Thus, ANN is a mathematical model that includes a software or hardware implementation. This model is based on the principle of organization and functioning of biological neural networks, that is, networks of nerve cells of a living organism [5].

The features and capabilities of ANN are described in detail in the works [6–9].

The ANN model is shown in fig. 1.

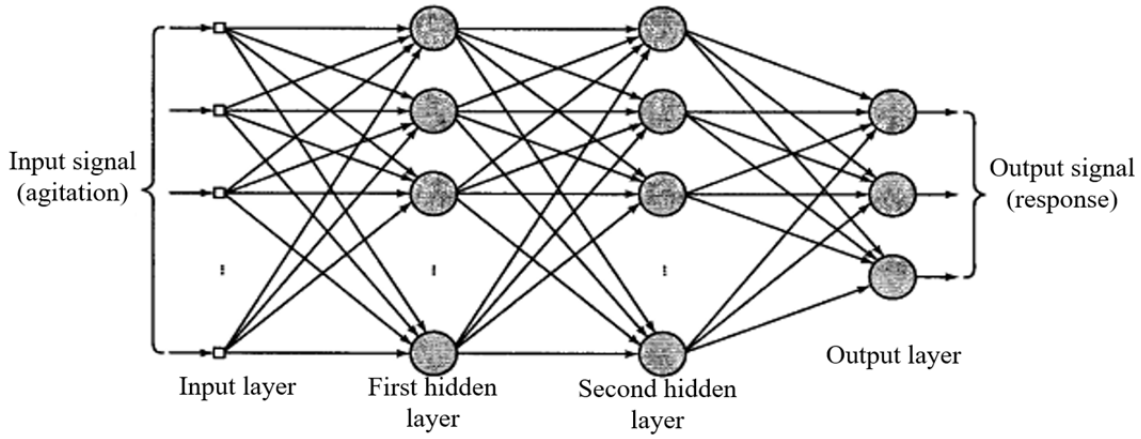

Fig. 1. **ANN model**

The ability to learn is the main advantage of neural networks over traditional algorithms. The ANN scheme with learning and error calculation blocks is shown in fig. 2.

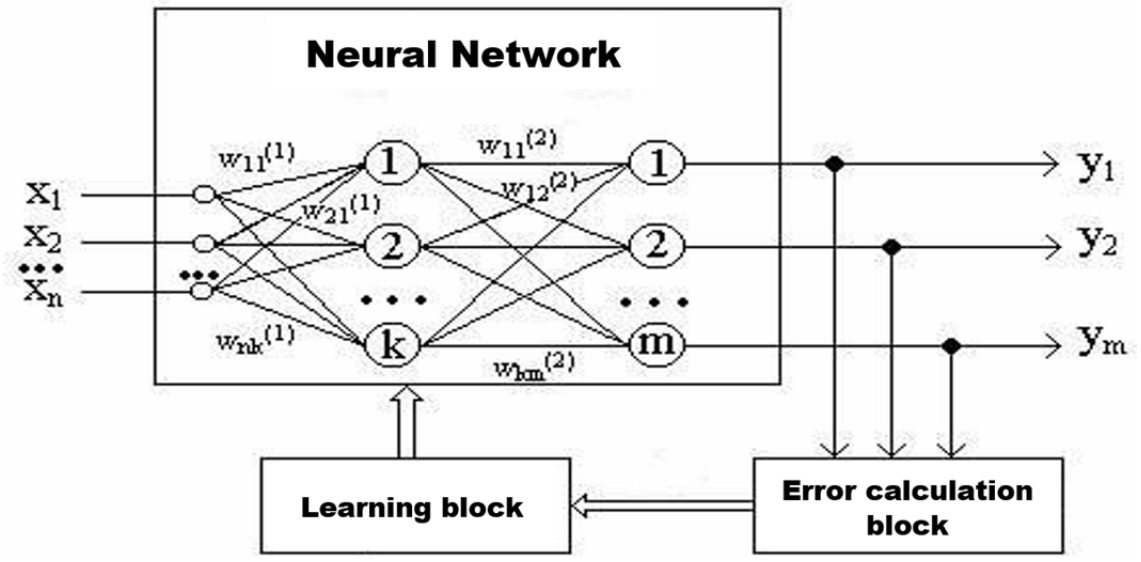

Fig. 2. **Neural network with learning and error calculation blocks**

Let's consider the learning process of ANN. It consists of Browsing a training sample of data, the order of which can be random or sequential, and the browsing is performed at least once. The data sample is divided into two parts: the training sample and the test data. The test data is used to determine the modeling error and to test the quality of the ANN training.

The various ANNs are classified according to the following criteria.

1. The Type of training:

− Learning without a teacher – the output solution space is unknown;

− learning with a teacher – the output solution space is known;

− Reinforcement learning – a system of assigning fines and rewards is used.

2. Type of neuron connections:

– direct propagation networks – all connections between neurons are directed from the ANN input to the ANN output;

– recurrent networks – there is a connection between neurons from the output to the input of the network.

Kohonen's self-organizing maps are used to solve data visualization and clustering problems. They are ANN with no teacher training.

ANN that utilize «deep learning» are used to recognize human speech, automated translation from one language to another, and solving object recognition problems. «Deep learning» implies the use of huge arrays of source data in the ANN learning process.

Digittal model of neural network

A three-layer direct propagation ANN is used to approximate the functions. fig. 3 shows a scheme of a unidirectional three–layer ANN, in which the input distribution layer contains 20 neurons, the hidden layer contains 20 neurons and the output layer contains one neuron [4].

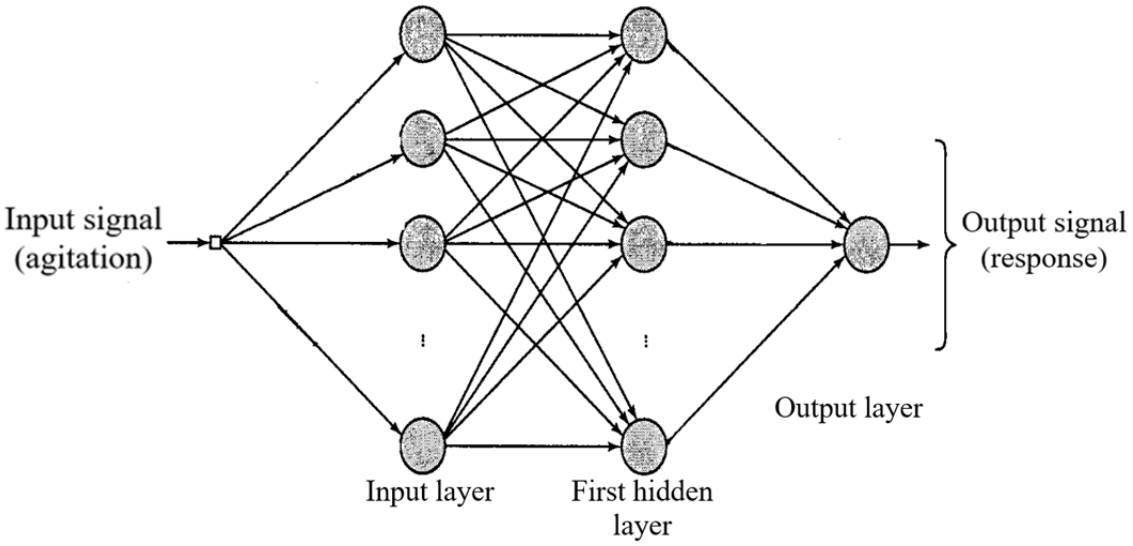

Fig. 3. **Three-layer ANN model**

At each training cycle, the components of the input vector of the learning sample of the source data are sequentially fed to the ANN input. The resulting output values are then compared with the values of the output data vector. Next, the value of the average quadratic error is calculated and the coupling coefficients (synaptic weights) of neurons are adjusted.

The interface of a computer program implementing a three-layer ANN [4] is shown in fig. 4.

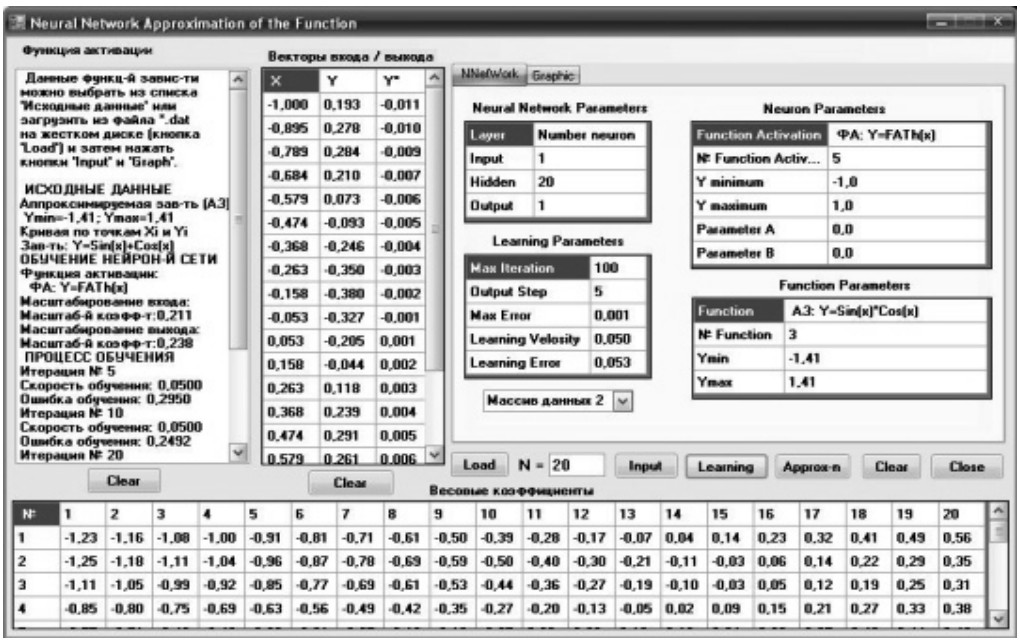

Fig. 4. **The interface of a computer program implementing a three-layer ANN**

Image recognition

Solving the task of image recognition allows for detection fires at their early stage and, thus, leads to prevention of fire propogation by analyzing images in video surveillance systems. One resolution, proposed in [3] is the use of ANN.

Classical neural networks are not used for image recognition. They have two significant disadvantages:

– the size of the input data vector is too large for them, which requires a large number of neurons in the intermediate layers;

– it takes a lot of computing resources to train a classical neural network and calculate the values of the output vector of the network.

Convolutional Neural Networks lack the disadvantages described above. They have a special architecture in which convolutional layers (C-layers) and subdiscretizing layers (S-layers) alternate in them, and fully connected layers (F-layers) are present at the network output [10].

Such a direct propagation ANN with one hidden layer, equipped with two-dimensional filters (convolutional layers C-layers) can be used for image recognition. Convolutional layers contain coefficient matrices (convolution matrices). The elements of such a matrix are calculated for each characteristic image size. The image processing takes place in the following sequence. First, each fragment of the image is incrementally multiplied by the elements of the convolution matrix. The result is then written to a similar position of the output image. Further, the output signal of the network is determined by processing the output image [4].

In the created adaptive image recognition system, the ANN parameters were adjusted for each recognized image by calculating the proportion of active pixels in the image. This allowed adaptive adjustment of the filtration coefficients in the convolution matrix [4].

Figure 5 shows the interface of the adaptive color image recognition program with a size of 50*50 pixels, equipped with two-dimensional filters (convolutional layers C-layers) [4].

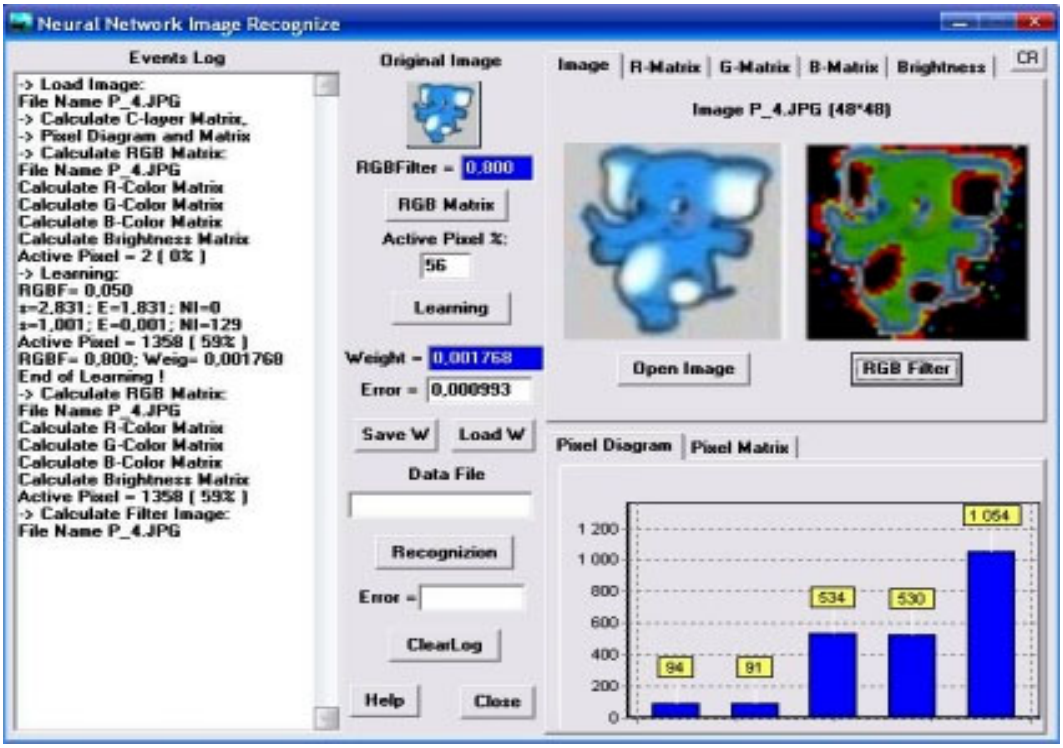

Fig. 5. **The interface of the image recognition program**

An example of adaptive filtering of a fragment of a color image is shown in fig. 6.

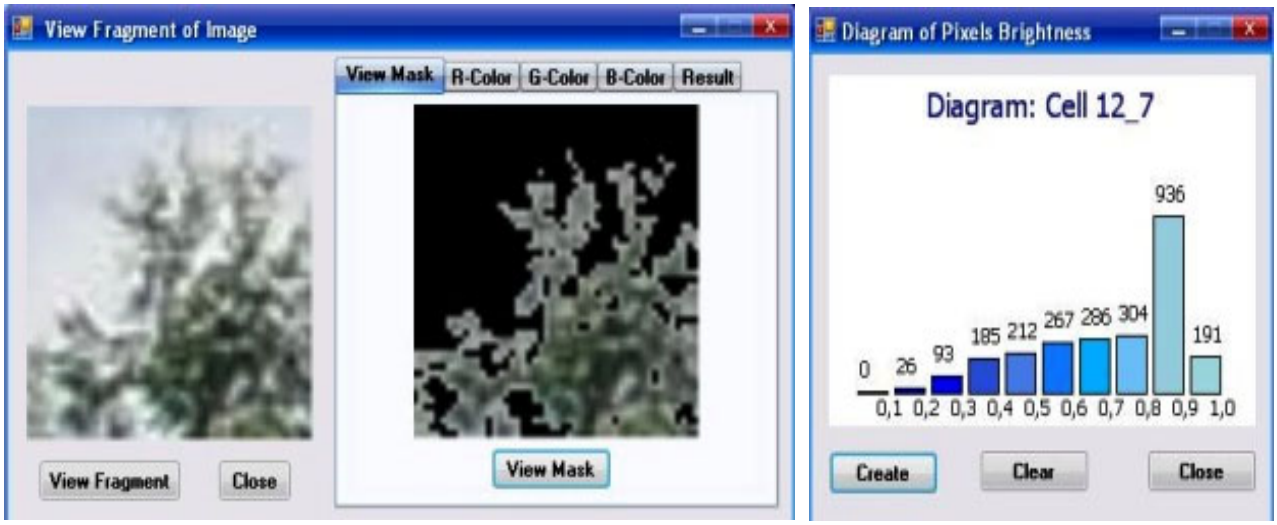

Fig. 6. **On the right is a brightness diagram of an image fragment, in the center is a filtered fragment, on the left is an enlarged image fragment**

The convolutional ANN, used to recognize a color image with a size of 50*50 pixels, is able to adaptively adjust its parameters taking into account the features of the image topology.

Analysis of fire presence

Image analysis in video surveillance systems for the purpose of fire detection can be carried out within the framework of two approaches [3]:

– analysis of the shape of detected objects – smoke and fire;

– analysis of the color of the fire associated with the temperature of the flame.

To implement the first approach, it is necessary to use an ANN with learning, in which the presented data sample contains examples of fire and smoke shapes.

To implement the second approach, it is necessary to take into account that each flame color can be assigned a flame temperature value, as shown in fig. 7.

Colour	Name	t° C
	Bright white	1250–1300
	Bright yellow	1150–1250
	Dark yellow	1050–1150
	Orange	900–1050
	Bright red	830–900
	Bright cherry red	800–830
	Cherry red	770–800
	Dark cherry red	730–800
	Dark red	650–730
	Brown red	580–650
	Dark brown	530–580

Fig. 7. **Flame colour and temperature**

Conclusion

The neural network approach to cognitive modeling makes it possible to detect fires at an early stage and, thus, prevent fire propogation by developing AIS with the properties of artificial intelligence.

The AIS uses a convolutional ANN, the parameters of which are adjusted for each recognized image by calculating the proportion of active pixels in the image. This allows adaptive adjustment of the filtration coefficients in the convolution matrix, taking into account the features of the image topology.

After the necessary refinement, the ANN in question can be used to detect fires at an early stage.

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Infromation about authors:
Labinsky Alexander Yu., associate professor of the applied mathematics and information technology chair of Saint-Petersburg university of State fire service of EMERCOM of Russia (196105, Saint-Petersburg, Moskovskiy ave., 149), Phd in technical sciences, associate professor e-mail: labynsciy@yandex.ru, https://orcid.org/0000-0001-2735-4189, SPIN: 8338-4230