examination methods, the system managed to detect ore deposits worth a million dollars, and none of the nine experts suggested the presence of these deposits. Another interpretive system is HASP / SIAP. It determines the location and types of ships in the Pacific Ocean according to acoustic tracking systems.

Knowledge-based systems can be used as intelligent control systems and make decisions by analyzing data from multiple sources. Such systems already operate at nuclear power plants, control air traffic and exercise medical control. They can also be useful in regulating the financial activities of the enterprise and assist in the development of decisions in critical situations.

In this area, knowledge-based systems are indispensable both in the repair of mechanical and electrical machines and in the elimination of malfunctions and errors in the hardware and software of computers.

Knowledge-based systems can be integrated into computer-based training systems. The system receives information about the activity of an object (for example, a student) and analyzes its behavior. The knowledge base changes in accordance with the behavior of the object. An example of this training is a computer game, the complexity of which increases as the skill level of the player increases. One of the most interesting training expert systems is the EURISCO system developed by D. Lenat, which uses simple heuristics. This system was tested in the game T. Treveveller, simulating military operations. The essence of the game is to determine the composition of the flotilla that can defeat in an unchanging set of rules. The EURISCO system included small ships capable of carrying out a quick attack and one very small high-speed vessel in the flotilla and constantly won for three years, despite the fact that in an effort to prevent this, the rules of the game were changed every year.

Most expert systems include knowledge, the content of which can be attributed to several types simultaneously. For example, a training system may also have the knowledge to perform diagnostics and planning. It determines the abilities of the student in the main areas of the course, and then, taking into account the received data, draws up a curriculum. The control system can be used for monitoring, diagnostics, forecasting and planning. The home security system can monitor the environment, recognize events (for example, a window opens), issue a forecast (a burglar intends to enter the house) and draw up an action plan (call the police).

1. Nilson, N. Principles of Artificial Intelligence / N. Nilson. - M.: Radio i svyaz', 2014. - 373 p.
2. Uoterman, D. Building expert systems / ed. F. Hejes-Rot, D. Uoterman, D. Lenat. - M.: Mir, 2013. - 441 p.
3. Shapiro, S.I. Human Thinking and Computer Processing / S.I. Shapiro. - M.: Sovetskoe radio, 2017. - 288 p.

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Neural network data processing technologies

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Аннотация

Изложены математические и алгоритмические аспекты функционирования искусственных нейронных сетей. Рассмотрены парадигмы обучения нейронных сетей, архитектура и нейросетевые модели.

Ключевые слова: нейросетевые технологии, архитектура нейросетей, нейросетевая модель, обработка информации

Abstract

The mathematical and algorithmic aspects of the functioning of artificial neural networks are described. The paradigms of training neural networks, architecture and neural network models are considered.

Keywords: neural network technologies, neural network architecture, neural network model, information processing

Neural network technologies appeared on the basis of neural networks, i.e. programs that have a structure similar to the brain and imply a complex of information technologies based on the use of artificial neural networks. This direction belongs to one of the directions in the development of artificial intelligence.

Artificial neural networks are software or hardware implemented systems built on the principle of organization and functioning of their biological counterpart - the human nervous system.

The human nervous system consists of neurons. All neurons are interconnected by nerve fibers that transmit electrical impulses.

There are two types of fibers - dendrites and axons.

Dendrites are nerve fibers along which impulses are received. Several dendrites may approach one neuron.

Axons are nerve fibers along which electrical impulses are transmitted. Each neuron has a single axon, which in turn can contact the dendrites of other neurons through synapses.

Synapses are special formations that change the parameters of an impulse.

The magnitude by which synapses change the momentum is called the weight of the synapse. Weights of synapses can vary - this is the process of training a neural network. From this it follows that "training the neural network" is the selection of the correct set of weights. Now the question arises - how can you train the network? In the most general case, there are two approaches that lead to different results: learning with a teacher and learning without a teacher.

Training with a teacher.

Teaching with a teacher is a type of network training in which its weights change so that the network answers are minimally different from the ready-made correct answers.

The essence of this approach is that you give a signal to the input, look at the network response, and then compare it with a ready-made, correct answer. Then, using special algorithms, you change the weights of the connections of the neural network and again give it an input signal. Compare her answer with the correct one and repeat this process until the network begins to respond with acceptable accuracy (the network cannot give unambiguously accurate answers).

If we want the network to recognize faces, we can create a training sample of 1000 photos (input signals) and independently select faces on it (correct answers).

If we want the network to predict price increases / falls, then the training sample should be done based on past data. As input signals, you can take certain days, the general state of the market and other parameters. And the correct answers are the rise and fall of prices in those days.

And so on...

It is worth noting that the teacher, of course, is not necessarily a person. The fact is that sometimes you have to train the network for hours and days, making thousands and tens of thousands of attempts. In 99% of cases, this role is played by the computer, or rather, a special computer program.

Learning without a teacher.

Learning without a teacher is a type of network training in which the network independently classifies input signals. Correct (reference) output signals are not shown.

Teaching without a teacher is used when we do not have the correct answers to the input signals. In this case, the entire training sample consists of a set of input signals.

With this «training», the network begins to distinguish classes of signals fed to the input. In short - the network starts clustering.

For example, you show off a network of sweets, cakes and cakes. You do not regulate the network in any way. You simply submit data on this object to its inputs. Over time, the network will begin to produce three different types of signals, which are responsible for the objects at the input.

In the mathematical description of the neural network, you can determine:

Dendrite - entrance,

Axon - exit,

Neuron - adder for output signals.

The main task is to use the internal function to obtain the pulse power at the output.

Then the mathematical model can be written as follows:

Let $w_1, w_2, \dots, w_n$ be the weights of the dendrites along which the moment a of force $x_1, x_2, \dots, x_n$ are transmitted.

The total output signal will be equal to $d = \sum w_i * x_i$

The output signal of a neuron is determined by the function: $y = f(d)$.

The neuron is fully described by the input signal x , the function of the neuron and the signal y at the output. One of the possible variants of the artificial neuron model is presented in Figure 1.

Figure 1. Artificial neuron model

Thus, an artificial neuron is an elementary transforming element consisting of elements of three types: multipliers (synapses), an adder and a nonlinear converter, and that performs two functions - weighted summation and nonlinear transformation [1].

In order to use neural network technologies, it is necessary to consider several features that the task may or should have in order for the use of neural networks to be justified.

There is no algorithm or unknown principles for solving problems, but a sufficient number of examples have been accumulated; the problem is characterized by large amounts of input information; data is incomplete or redundant, noisy, partially contradictory.

Neural networks for a PC user - a tool that allows you to solve problems based on experience. Neuroimitators are special programs for creating, training, testing and other operations with neural networks. Neuroimitators can be used to process the results of various experiments. The main types of tasks solved using neural networks:

- 1) division into classes or classification, taxonomy or clustering - if without a teacher (network of natural classification);
- 2) prediction of a (real) number or prediction (otherwise called neural network regression);
- 3) pattern recognition;
- 4) optimization;

- 5) forecasting;
- 6) modeling.

Additional tasks:

- 7) forecast («what will happen tomorrow?»);
- 8) conditional forecast («what will happen tomorrow if ..?»);
- 9) determination of the significance of the input parameters. To solve these problems, a mathematical apparatus of artificial neural networks, in particular from sigmoid neurons, has been developed and used.

Architectures and algorithms allow you to train and test neural networks, solve various data processing problems. Figure 2 shows the classification of various neural architectures in connection with a possible area of their application. [2].

Архитектура	Восстановление данных	Фильтрация данных	Сжатие данных	Извлечение ключевых признаков	Анализ данных	Анализ результатов	Оптимизационные задачи
Персептрон				+	+		
Многослойный персептрон	+	+	+	+	+		+
Сети на основе РБФ	+	+		+	+		+
Вероятностные НС				+	+	+	
Регрессионные сети	+	+			+		
Самоорганизующиеся карты признаков				+	+	+	
Квантование векторов обучения	+	+		+	+		+
Сеть Хопфилда	+	+		+	+		+
Ячейчатые сети	+	+	+	+	+		
Адаптивные нейронные фильтры	+	+					
Адаптивная резонансная теория	+				+		
Неокогнитрон		+		+	+		
Динамические НС	+	+	+	+	+		
Семантические НС							
Экспертные системы							+

Figure 2. Neural network architecture

Data processing

An artificial neural network is a set of mathematical neurons interconnected.

A mathematical neuron is an elementary processor, the action of which consists of an input adder, a nonlinear converter, and a branch point at the output. The received signal serves as an input to other neurons or is an output of the network. Typically, a neural network consists of an input layer, the nodes of which correspond to the components of the input vector, one or more hidden layers and the output layer, from which the resulting vector is read (Figure 3). Such networks are called multilayer perceptrons [3, 4].

The operation of a network of this type can be considered as a general continuous nonlinear mapping of the space of input vectors to the space of output vectors. This mapping is completely determined by the network structure and the set of weights of each neuron.

Figure 3. Mathematical neuron. Multilayer perceptron

As a rule, the transfer functions of all neurons in the network are fixed, and the weight is a parameter of the network and can vary. Some neuron inputs are external network inputs, and some outputs are external network outputs.

By submitting any numerical values to the network inputs, you can get a set of numerical values at the network output. The work of a neural network is to convert an input vector to an output vector. The result of this transformation will depend on the network parameters - the weights of the relationships. Almost any task can be solved using the neural network algorithm. The task is usually solved in two stages. At the first stage, the type of network (its architecture) is selected. During the second, network parameters are selected - the weight of the relationships (its training). Choosing a network type is a difficult task, but at the moment there are several dozen effective mathematically proven neural network architectures. The most popular and studied architectures are a multilayer perceptron, Falman cascade correlation network, Volterra network, feedback networks between different neuron layers - recurrence networks (Hopfield network, Hamming network, BAM network, perceptron feedback network, Elman network, RTRN network), competition-based self-organization networks (Kohonen network, neural gas network), correlation-type self-organization networks (PCA network, ICA network), fuzzy neural networks (TSK network, Wang-Mendel network). Before choosing a neural network architecture, it is necessary to determine which models of neurons will be used [5].

Neural network model

A good example of the process of constructing a neural network model can be divided into 5 main stages:

1. Data collection for analysis. Formation of a table of dependent and independent variables.
2. Processing and preparation of data. Formation of training and test samples. Determining the range of parameter changes, data rationing.
3. The choice of the type and architecture of the neural network suitable for solving the problem.
4. Construction and training of a neural network.
5. Testing the model on a test sample. Estimation of the model error, interpretation of the results.

This allows you to significantly speed up the training of neural networks, which is also an additional advantage of their use in the preparation of analytics and the actual issuance of the final forecast.

The ability of the network to make independent decisions based on existing experience makes it the most valuable in the search for unexpressed patterns that are difficult to identify by conventional methods. Classification of networks according to their scope is aimed at

facilitating the choice of architecture when solving a specific problem. Thus, summing up, we can conclude that neural networks are increasingly approaching the imitation of the mind and artificial intelligence. As a result of training, neural networks can be used in the field of forecasting.

1. Neyrosetevye tekhnologii. [Elektronnyy resurs]. Rezhim dostupa: https://studopedia.ru/4_82775_neyrosetevie-tehnologii.html
 2. Uchebnoe posobie po distsipline «Prilozheniya neyronnykh setey», Zhukov L.A., Reshetnikova N.V., Krasnoyarsk 2007. – 51 с.
 3. Bishop C.M. Neural networks for pattern recognition. – Oxford, Clarendone press, 1995.
 4. Hertz J., Krogh A., Palmer R.G. Introduction to the theory of neural computation // Lecture Notes Volume I the Santa FE Institute studies in the sciences of complexity. 1991.
 5. Ispol'zovanie neyrosetevykh tekhnologiy dlya povysheniya energeticheskoy effektivnosti teploekhnologicheskikh ustanovok. V.A. Gorbunov., Ivanovo 2011.- 11 с.
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