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INTELLIGENT INFORMATION PROCESSING SYSTEMS BASED ON NEURAL NETWORK TECHNOLOGY

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Abstract. The use of fuzzy logic in management tasks was primarily due to the increasing complexity of existing tasks. Fuzzy logic and management based on it are close to the principles of human thought. Fuzzy logic essentially provides effective means of displaying uncertainties and inaccuracies in the real world. The availability of mathematical means to reflect the fuzziness of the source information makes it possible to build a model of adequate reality.

Key words: schematic diagrams, metal-dielectric-semiconductor, analysis, synthesis.

Introduction.

Neural network management models are based on fuzzy logic. The basic mathematical apparatus of fuzzy logic was introduced by Lotfi A. Zade in 1965.

In mathematical representation of the fuzzy set we see a universal set $F$ Variable $x$ is an element $E$, and $R$ some properties. The usual (clear) subset $A$ of the universal set $E$ whose elements satisfy the property $R$ is defined as a set of ordered pairs

$$A = \{ \mu_A(x)/x \}$$

where $\mu_A(x)$ - is a characteristic function of an accessory that takes the value 1 if $x$ satisfies the properties $R$, and 0 in the opposite case. The fuzzy sub-set differs from the usual one in that for elements $x$ of $E$ there is no unambiguous yes=no answer to the property $R$. In this regard, the fuzzy subset $A$ of the universal set $E$ is defined by a similar set of ordered pairs in which the formula takes on a value in some ordered set $M$, for example $[0;1]$.

Function accessory [8] indicates the degree of accessory of an element $x$ subset $A$. Multiplicity $M$ is called a set of accessories. If $A = \{0, 1\}$, then a fuzzy subset of $A$ may be considered as a regular or a clear set.

As examples of fuzzy entries, the following expressions can be cited:

Let $E = \{x_1, x_2, x_3, x_4, x_5\}, M = [0,1]; A$ is a fuzzy set, for which

$$\mu_A(x_1) = 0.3; \mu_A(x_2) = 0.3; \mu_A(x_3) = 1; \mu_A(x_4) = 0.5; \mu_A(x_5) = 0.9.$$ 

A subset can then be presented as a:

$$A = \{0.3/x_1; 0/x_2; 0/x_3; 0.5/x_4; 0.9/x_5\},$$

Or

$$A = \{0.3 + 0 + 0 + 0.5 + 0.9\}$$

Or

$$A = \{0.3 + 0 + 0 + 0.5 + 0.9\}$$

<table>
<thead>
<tr>
<th>$x_1$</th>
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**Main characteristics of fuzzy sets**

Let \( M = [0, 1] \) and \( A \) be a fuzzy set with elements from the universal \( E \) set and the \( M \) set of accessories.

The value \((\mu_A(x))\) is called the height of an indistinct set \( A \). An indistinct set \( A \) is normal if its height is 1, i.e. upper boundary.

Its function as an accessory is equal \( \sup_{x \in E} (\mu_A(x)) = 1 \).

When \( \sup_{x \in E} (\mu_A(x)) = 1 \) is fuzzy, the set is called subnormal. The fuzzy set is empty if \( \forall x \in E \mu_A(x) = 0 \) is not an empty boy set and can be normalized by a formula:

\[
\mu_A(x) = \frac{\mu_A(x)}{\sup_{x \in E} \mu_A(x)}
\]

A ambiguous set is unimodal if \( \mu_A(x) = 1 \) only on one \( x \) of \( E \).

Carrier of the Fuzzy Set \( A \) is the usual subset property \( \mu_A(x) > 0 \), i.e. Carrier \( A = \{x \in E, \mu_A(x) > 0\} \).

Elements \( x \in E \) for which \( \mu_A(x) = 0.5 \) are called transition points of set \( A \).

Operations on fuzzy sets

**Switching off.** Let \( A \) and \( B \) be fuzzy on the universal set \( E \). They say \( A \) is contained in \( B \) if \( \forall x \in E, \mu_A(x) \leq \mu_B(x) \).

**Equality.** \( A \) and \( B \) are equal, если \( \forall x \in E, \mu_A(x) = 1 \Leftrightarrow \mu_B(x) \).

**Supplement.** Let \( M = [0, 1] \), \( A \) and \( B \) be a fuzzy set given on.

\( A \) and \( B \) complement each other if \( \forall x \in E, \mu_A(x) = 1 \Leftrightarrow \mu_B(x) \).

Obviously, if the addition is defined for \( M = [0, 1] \), it can be defined for any ordered \( M \).

**Intersection.** \( A \cap B \) is the largest fuzzy subset contained in both \( A \) and \( B \) at the same time.

**Association.** "\( A \cup B \)" is the smallest fuzzy subset that includes both \( A \) and \( B \). With an accessory function.

**Difference.** \( A \Leftrightarrow B = A \cup B \) with accessory function:

\[
\mu_{A-B}(x) = \mu_{A\cap B} - (x) = \min(\mu_A(x), \mu_B(x))
\]

**Dividend amount**

\[
A \oplus B = (A \Leftrightarrow B) \cup (B \Leftrightarrow A)
\]

With accessory function:

\[
\mu_{A-B}(x) = \max(\min(\mu_A(x), 1 \Leftrightarrow \mu_B(x))) \cdot \min(1 \Leftrightarrow \mu_A(x), \mu_B(x)).
\]

For fuzzy sets, you can build a visual representation. Let's consider a rectangular system of coordinates, on the axis of which the value \( \mu A \) is laid down, on the abscissa axis there are elements of the \( E \) set in random order.

Graphical interpretation of logical operations: a - fuzzy set \( A \); b - fuzzy set \( B \); b - \( A \cap B \); f - \( A \cup B \).

Neural Networks (NN) refers to computational structures that simulate simple biological processes commonly associated with human brain processes (8). Adaptable and trainable, they are parallel systems capable of learning by analyzing positive and negative effects. An elemental converter in these networks is an artificial neuron, or simply a neuron called so by analogy with a biological prototype.
Currently, a large number of neural-like element models and neural networks have been proposed and studied, some of which are discussed in this chapter.

The term "neural networks" was formed in the 40s of the 20th centuries among researchers who studied the principles of organization and functioning of biological neural networks. The main results obtained in this area are related to the names of American researchers W. McCulloch, D. Hebb, F. Rosenblatt, M. Minskiy, J. Hopfield and others.

**Methods.**

In the context of the use of neural networks for the purpose of intellectualization of measurement technology, tasks of image classification, clustering of approximation, prediction, optimization, organization of memory addressed by content and management in general are being carried out.

A *classification* of images consists of specifying whether an input image (e.g. a speech signal or a handwritten symbol) represented by a feature vector belongs to one or more predefined classes. Known applications include letter recognition, speech recognition, electrocardiogram signal classification and blood cell classification.

**Clustering.** This task corresponds to the categorization of images. When solving the clustering task, which is also known as classification of images "without a teacher", there is no teaching sample with class labels.

The clustering algorithm is based on the similarity of images and places close images in 1 cluster. Known clustering applications for knowledge extraction, data compression and non-sequential data properties.

**Approximation of function.** Suppose that there is a learning sample \([(x_1, y_1), (x_2, y_2), ..., (x_n, y_n)]\) (input-exit data pairs), which is generated by an unknown noise distorted function \(F(x)\). The approximation task is to make an estimate of the unknown function \(F(x)\) in finding the estimate. The approximation of the function is necessary when solving numerous engineering and scientific modelling tasks.

**Prediction (forecast).** Let the back \(n\) of the discrete reports \(\{y(t_1), y(t_2), ..., y(t_k)\}\) at consecutive times \(t_1, t_2, ..., t_k\). The task is to predict the value of \(y(t_{k+1})\) at some future time \(t_{k+1}\). The task of predicting is important in a measurement because it makes it possible to determine the events corresponding to failures in the functioning of the measuring device or system, as well as other cases where the accuracy of the measured value is reduced.
**Optimization.** Numerous problems in mathematics, statistics, technology, science, medicine and economics can be regarded as optimization problems. The objective of the optimization algorithm is to find a solution that satisfies the system limitation and maximizes or minimizes the target function.

**Organization of memory addressed by content.** In the von Neumann calculation model, memory can only be accessed by means of an address which is not written down from the content of the memory. Moreover, if there is an error in the calculation of the address, completely different information can be found there. The associative memory, or the memory addressed to me by content, is available by specifying the content. The content of the memory can even be called up by partial input or distorted content. Associative memory is extremely desirable when creating multimedia information databases.

**Management.** Let's consider a dynamic system defined by the aggregate, \( \{u(t), y(t)\} \) where \( u(t) \) is the input control and \( y(t) \) is the output of the system at time \( t \). In systems with a reference model, the purpose of control is to calculate such an input impact \( u(t) \), where the system follows the desired trajectory dictated by the reference model. An example of this is optimal engine management.

The neuron is an integral part of the neural network.

The neuron is made up of multipliers (synapses), an adder and a non-linear converter. Synapses carry out the communication between neurons and multiply the input signal by the number characterizing the communication strength, the weight of the synapse.

The summator adds up the synoptic elm signals from other neurons and the external output signals. A non-linear transducer implements a non-linear function of one argument, the adder output. This function is called an "activation function" or "transfer function" neural. In general, the neuron implements the scalar function of a vector argument. The mathematical model of the neuron is described by the following relations:

\[
    s = \sum_{i=1}^{n} w_i x_i + b
\]

Where the \( w_i \)-weight of the synapse \( (i=1, 2, ..., n) \), \( b \)- offset value, \( s \)- summation result: \( x_i \) component of the input vector (input signal) \( (i=1, 2, ..., n) \), \( n \)- number of neuron inputs.

**Fig. 2. Artificial neuron structure.**
Fig. 3. Examples of activation functions: a - single jump function; b - linear threshold (hysteresis); v - sigmoid (hyperbolic tangent); g - sigmoid (logistic).

In general, the output signal, weight factors and their offset value can take actual values. Output(y) is determined by the output of the activation function and can be either valid or whole. In many practical tasks, only a few fixed values can be taken during moves, weights and offsets.

Synoptic links with positive Weights are called excitatory links with negative Weights - inhibiting. Thus, the neuron is fully described by its $W_i$ weights and the transfer function $f(s)$. Having received a set of numbers (vector) $X_i$ as inputs, the neuron outputs a certain number $y$ at the output.

The described computational element can be considered a simplified mathematical model of biological neuron cells, which make up the nervous system of humans and animals.

In order to emphasize the difference between biological and mathematical neurons, the latter sometimes refer to neurons as similar elements or formal neurons.

A non-linear inverter responds to the output signal(s) with an output signal $f(s)$, which represents the neuron output $y$.

Conclusion.

One of the most common is the non-linear saturation function, the so-called logistic function or sigmoid (i.e. the S-function). Neuron sets, when combined, form artificial neural networks. As a rule, the transfer(activation) functions of all neurons in a network are fixed and weights are network parameters and can change.

Reference


