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Procedia Computer Science 103 (2017) 410 – 415

Procedia Computer Science

XIIth International Symposium «Intelligent Systems», INTELS'16, 5-7 October 2016, Moscow, Russia

The principle of multi-alternativity in intelligent systems. Active neural network models

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Abstract

The article deals with intelligent systems that contain artificial neural networks. After a close comparison of artificial and biological neural networks the authors reveal some fundamental flaws of artificial neural networks. It is shown that the reason for those disadvantages is the constancy of structure or the so called passivity of the neural network. To avoid this problem it is proposed to simulate the information processes in the neural network instead of simulating neurons themselves. The following consideration involves several evolutionary principles of multi-alternativity, such as multilevel approach, diversity and modularity. Those principles find their implementation in facet memory organization that is characterized by the reconfigurable structure and therefore close to its biological prototype. The advantage of the suggested approach is demonstrated by the example of an intellectual system based on an active neural network. The system applied to control an electrical supply network under critical events, such as breaks and overloads. In case of a critical event neural network takes the blocking decision that prevents breakage or accident conditions in the electrical network.

Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"

Keywords: intelligent system; neural network.

1. Introduction

Building intelligent systems on the basis of neural networks is based on a direct analogy between the tasks solved by these systems and motives of higher nervous activity of living organisms.

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Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"
doi:10.1016/j.procs.2017.01.129

Currently, the implementation of the above-mentioned analogy is reduced primarily to the attempts of artificial reproduction of electrochemical processes of biological neural systems through the development of different patterns of excitation and inhibition of elementary neurons and organization of relationships between them.

In the classic form, a neural can be presented by the functional:

$$y_{j_N}(x) = F\left(\sum_{i_N} b_{i_N j_N} \cdot ... \cdot F\left(\sum_{i_2, j_2} b_{i_2 j_2} \times F\left(\sum_{i_1, j_1} b_{i_1 j_1} x_{i_1 j_1} + c_{j_1}\right) + c_{j_2}\right) + ... + c_{j_N}\right), \quad (1)$$

where b, c are the vectors of configurable parameters (weight coefficients); r is the number of the network layer; j_r is the neuron number r in the layer; i_r is the entry number in the neuron; N is the number of layers of the network; x, y are the vectors of input and output variables of the network; $x_{i,j}$ is an element i of the vector x supplied to the neuron j in the layer r; $F(b,c,x)$ is the function of neuronal activation of the sigmoid form.

The formal justification for the use of neural networks in problems of decision-making is the completeness theorem which says that every continuous function on a closed bounded set may be uniformly approximated by functions, computed by the neural networks of type (1), if the activation function $F(b,c,x)$ of a neuron is continuously differentiable twice.

However, in practice these formal grounds for the implementation of artificial properties of biological networks are not enough, and the artificial neural networks of type (1) are inherent in the fundamental inconsistency of their biological prototype.

These inconsistencies are associated primarily with the attempt to reproduce biological processes using a functional with a predetermined constant structure, whose alteration is made only at the low-level parametric: the network is not able to change its structure during training, i.e. it is passive.

The failure of passive neural network to change its structure leads to deficiencies in these networks that are not typical of their biological prototypes[1,2].

The most important of these are:

the problem of retraining, which consists in the growth of a network error when presenting an apriori unknown excessive number of training vectors. In natural neural networks memory elements have a high selectivity, and the nature of memory is cumulative, allowing to keep old information without distortion on the network in almost unlimited volume;

low generalizing properties, establishing the relationship of “private-general” between the recognizable situations, for which the network should have developed a multi-level, hierarchical structure;

the lack of functional autonomy of the elements of artificial neural networks, resulting in a non-linear increase in the number of adjustable parameters to increase the dimension of the tasks, i.e. the manifestation of the “curse of dimensionality” in teaching. In biological neural networks limitations on re-memorize information are not observed.

In order to eliminate these shortcomings, a new approach to the construction of a neural network intelligent control system model is suggested, and it is based on general evolutionary principles of the organization of its functioning – principles of multi-alternative[3-5]:

multilevel principle (hierarchy) implemented by the organization in biological systems of at least two management levels, one of which functions as the tolerance variations of the system state, and the other responds only to critical deviation from this condition;

the principle of diversity of the control algorithms and the separation of functions (multi-mode and switch structures), which is closely associated with the principle of multilevel and reflects the flexibility of the control algorithms in the changing conditions of operation of the system;

the principle of modularity of the structure, which provides a variety of levels and modes of control based on a limited set of elementary modules of the system combinations.

Further it will be shown that a set of defined principles can solve the above-mentioned problem of constructing neural network intelligent systems not as a result of the qualitative complexity of the algorithms, but by increasing in the system the number of its simple ingredients, gradually embedded into the structure of the neural network.