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Organisation of Fuzzy Cognitive Maps Considering Real Parameters of Simulated Systems

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This article explores cognitive modeling development aimed at expanding the scope of its application. The methods of organising cognitive structures that allow a combination of the processing of conceptual parameters and real parameters of simulated systems in a single model are considered. The implementation of these complex models, defined as mixed computational-cognitive maps (MCCC) is proposed based on appropriately alarmed neural networks. Neural networks for MCCC are formed based on specialised models of neurons - dynamic neurons with state memory.

Key words: *Cognitive modeling, neural networks, fuzzification-defuzzification, concepts, cause-effect relationships, dynamic neuron with state memory.*

Introduction

One of the most promising areas of research for complex, difficult to formalise systems (objects/processes) is cognitive modeling (Ginis and Kolodenkova, 2017) (Bozhenyuk and Ginis, 2013). At the same time, the need to increase modeling processes efficiency and expand areas of applied application necessitate the development of this mechanism. In this article, the following are considered as the most relevant areas of development:

a) combining within the framework of a single model of cognitive (virtual) parameters based on expert estimates and real (measured) parameters;
b) using a neural network mechanism for processing cognitive structures.

Methodology

In the traditional view, the parameters determined in the process of modeling the cognitive system (and represented by the values of the concepts of cognitive maps - QC) (Paklin, 2003) are some estimated values that are formed based on knowledge developed by experts. Such parameters reflect some qualitative statistics and, as a rule, are not directly related to the real indicators of the simulated object. Cognitive assessments are introduced precisely because they are used in difficultly formalised situations in which it is impossible or difficult to conduct an analysis based on processing the measured characteristics of the system using traditional formal methods. This is due both to the problems of measuring all the parameters that characterise the system, and to the problems of constructing formal computational procedures.

The impossibility of using real indicators for a complete analysis of systems nevertheless does not exclude the feasibility of taking them into account in the framework of the cognitive model. Obviously, if it is possible to build a complete formal model based on real variable indicators, then there is no need to use cognitive models. However, even in difficult formalised cases, as a rule, it is possible to construct partial (fragmentary) formal models. The use of such fragments as part of a general cognitive model will allow, firstly, to carry out the adjustment and tuning of cognitive structures and, secondly, to use them directly in the process of solving problems on cognitive models. Cognitive models combined with formal, calculated ones will be denoted as mixed calculative-cognitive cards (MCCC).

In accordance with the traditional concepts of cognitive models, MCCC are formed as a graph structure, the vertices of which are concepts - factors of the situation, and weighted arcs reflect cause-effect relationships established between the concepts (Kovriga and Maksimov, 2005). Within the framework of MCCC, in addition to the values of concepts, which are the only type of variables in traditional cognitive models, additional variables are introduced that reflect the real characteristics of the object and are defined as functional variables of MCCC. These variables, on the one hand, are used to calculate the values of concepts, and on the other hand, to adjust cognitive models.

Thus, the main variables — the state values of concepts, and the additional — functional variables are distinguished as part of the MCCC. Properties of variables are defined as follows.

a) Nature of assessment:
- cognitive parameters;
- real (functional) parameters.

b) Presentation format:
- phased;
- dephased.

c) Functional role:
- input;
- controlling / managing;

- intermediate;
- weekends.

Cognitive parameters are used as evaluative objects in MCCC in the same way as in traditional models (Abramova and Kovriga, 2008). This article proposes the development of the traditional representation of cognitive structures through the use of a mechanism that provides the formation of the concept potential's two components: cognitive and formally calculated. The cognitive component is determined on the basis of traditional network interactions of the cognitive map. The formal component is determined on the basis of real parameters and available mechanisms for its calculation.

Each of the cognitive and real parameters, depending on the modeling tasks solved at MCCC, can be represented in both phased and dephased formats (Kolesnikov et al., 2014). So, for example, characterising the situation with the material and technical supply of the production workshop, you can use the indicators: "Expert assessment of the level of material and technical support of the workshop" and "Percentage of positions provided with materials from the current plan of the workshop". The first presentation is formed on the basis of expert opinions and may consist of qualitative assessments: "excellent", "good", "satisfactory", etc. The second parameter can be associated with specific numerical characteristics to be measured. The percentage of unsecured positions is selected from the production and economic documentation (Mate, 1993). For processes of physicalisation / hyphenation, the following table can be specified:

Expert assessment of the level of material and technical support of the workshop (phased assessment)	**Percentage of Secured Positions** (dephased estimate)
Fine	100-92%
Good	82-91%
Satisfactorily	73-81%
poorly	< 73%

Here, the left side of the table describes the cognitive representation, the right side describes the real (functional) one.

The capabilities of cognitive-functional modeling make it possible to formulate and solve new problems. As one of these tasks, we indicate the problem associated with the analysis of the studied object reaction to the input and control actions, as well as the assessment of alternative control actions. For example, as inputs for the model of the production workshop, one can specify the following: the above-mentioned assessment of the logistics level, as well as the condition of the equipment, staffing, portfolio of orders, etc. Estimates can be either cognitive (for example: assessing the equipment state) or real (availability coefficient of equipment). As inputs can be used:

- cognitive: observance of planned discipline (formed in the traditional way (Sternin, 2005));
- real: percentage of tasks completed in a timely manner.

The formal MCCC model proposed in the article will be defined as:

a) a topology reflecting the cause-effect relationships of objects;

b) a model of the concept as an elementary processor - information processor within the framework of MCCC.

The topological model MCCC is based on the graph representation (Kulinich, 2010) and is described as follows:

$$T = \{C, L, P, A = \{A_{DF}, A_P\}\}$$

Here: $C = \{C_1, \dots, C_i, \dots, C_I\}$ – many concepts that are identified with the vertices of the graph model;

L is the set of weighted arcs that reflect the influence of concepts (cause-effect relationships). The weight of the arc reflects the degree of influence of the concept corresponding to the original vertex of the arc;

P is the set of model variables;

A - many functional procedures that reflect the relationship between the various parameters of the model.

In this case, many procedures are divided into A_{DF} - transformative fuzzification / defuzzification procedures and A_P - applied procedures, in which quantitative relationships between variables are reflected.

This leads to modifications of the traditional representation of the concept model as follows:

$c_i = \{id_i, S_i, P_i, A_i\}$.

Here: id_i – identifier (concept number), which, on the one hand, determines the number of the vertex corresponding to the concept in the topological model, and on the other hand, identifies the semantic meaning of the concept (number in the concept descriptor);

S_i – the value of the concept state (which in the future we will define as the general potential of the concept);

$P_i \subset P$ – a subset of the parameters associated with the i-th concept;

$A_i \subset A$ – a subset of the functional procedures used to calculate the state value of the concept and the values of the variables associated with the concept.

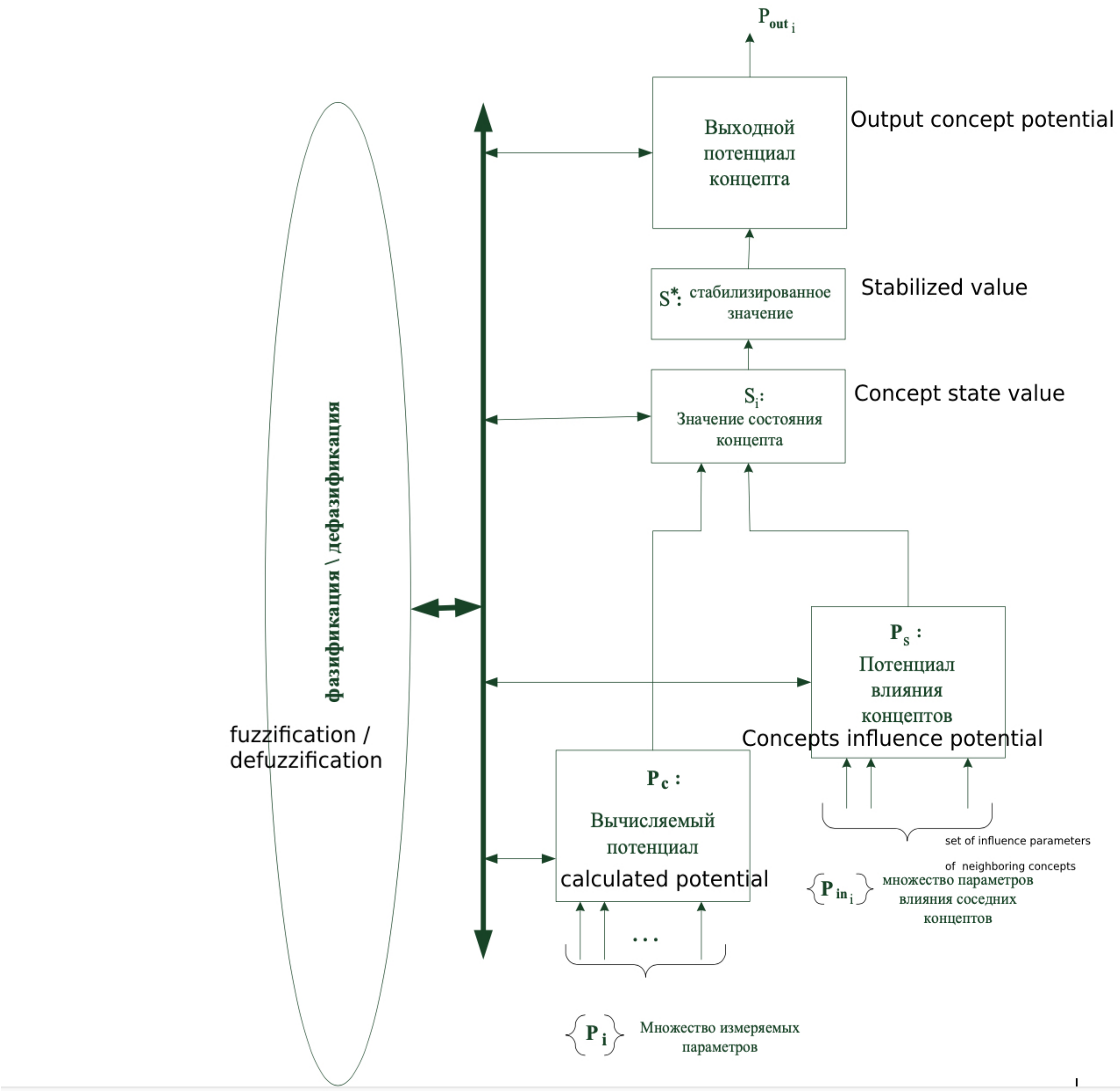
An illustration of the proposed concept model is shown in Figure 1.

Possible Diagram for MCCC Concept Model Implementation

In accordance with the above structure, the following scheme for implementing the MCCC concept model is proposed:

1. Definition of the calculated measurement potential of the i-th concept, considering the influence of the measured parameters on the concept state value $Pc_i = a_i(P_i)$.
   Here $a_i \in A$ is a module for calculating the measured parameters.
2. Definition of cognitive potential (potential influence of related concepts) Pc. The definition of cognitive potential is carried out on a graph model similar to the calculation of the value of the state of a concept in traditional models of cognitive maps.

Figure 1. Proposed concept model.



3. Determining the value S of the state of the concept. The value of the concept S is defined as a function of two components:

$S_i=f_i\{(Pc)_i, Ps_i\}$, where f_i – function for defining a concept, in the simplest case it can be defined as:
$S_i=(a_i^c *(Pc)_i+a_i^s*Ps_i)/2$ – where a_i^c, a_i^s – assigned coefficients of influence of measured and cognitive parameters.
To stabilise the value of the total potential of the concept (limiting the uncontrolled growth of the value), restrictive relations:

$$S^*_i = \begin{cases} S_i & \text{where } S^{\min}_i \leq S_i \leq S^{\max}_i; \\ S^{\min}_i & \text{where } S_i \prec S^{\min}_i; \\ S^{\max}_i & \text{where } S_i \succ S^{\max}_i. \end{cases}$$

4. Output potential detection $P_{outi} = F_{out}(S_i)$,

where F_{out} output potential detection function.
In the simplest case, one can take $P_{outi} = k*F_{out}(S_i)$,
where k – coefficient assigned by the designer.

Conclusion

To implement the MCCC models formed by such images, it is planned to develop a special model of a neural network, and to use a modification of a dynamic neuron with a state memory DNSM as neural elements (Guzik et al., 2017).

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