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HIERARCHICAL LOGICAL DESCRIPTION AND NEURAL RECOGNITION OF COMPLEX PATTERNS

Tatiana Kosovskaya, Adil Timofeev

Abstract: Authors suggested earlier hierarchical method for definition of class description at pattern recognition problems solution. In this paper development and use of such hierarchical descriptions for parallel representation of complex patterns on the base of multi-core computers or neural networks is proposed.

Keywords: complex patterns, logical class description, neural network.

Introduction

In papers [1–4] the authors suggested logic-axiomatic approach to solution of a series of pattern recognition problems. In papers [1, 2] in the framework of this approach hierarchical method of definition for class description, intended firstly for reducing of complexity of described problems, has been proposed.

In current work it is proposed to use such hierarchical descriptions for classes (DC) for their parallel representation on the base of neural networks. Neural representation of logic descriptions of classes and resolution rules provides mass parallelism and high speed at complex pattern recognition.

For building of logic DC it has been proposed to use the following methods and technologies:

- word (linguistic) class description from special study, scientific or reference literature [2–4];
- direct description of learning set in terms of defined predicates [4];
- logic-frequency method [3, 4];

- test tables [5];
- diophantine neural networks [6–8];
- multi-agent technologies of solution making by neural networks group [9].

1. Problem set for complex pattern logic recognition

Let on parts (fragments) x which are included in plants of arbitrary nature ω from the set Ω, the set of predicates, characterizing features and relations between elements of fragment x of the plant $\omega \in \Omega$, is defined.
Let be defined expansion of the set Ω on M (uncrossing or probably crossing) classes (patterns) of the kind

$$\Omega = U_{k=1}^{M} \Omega_k .$$

Description S(ω) of the plant ω is called the set of atomic formulas of the kind $p_i(x)$ or $\neg p_i(x)$, true for x, written for all possible parts (fragments) x of the plant ω.
Description of the class (OK) Ω_k is called such logic formula $A_k(\omega)$, that

1. $A_k(\omega)$ contains as atomic ones only the formulas of the kind $p_i(x)$, where $x \subseteq \omega$;
2. $A_k(\omega)$ does not contain quantors;
3. if the formula $A_k(\omega)$ is true, then $\omega \in \Omega_k$

DC may be written always in the kind of logic formula

$$\mathop{\mathbf{V}}_{j=1}^{J_k} \&_{i \in I_k^j} \&_{x \subseteq \omega_{i,j}} p_i^{\alpha_{ijx}}(x), \tag{1}$$

where J_k – natural number, $I_k^j \subseteq \{1,\dots,n\}, \omega_{i,j} \subseteq \omega, \alpha_{ijx}$ – logic constants. Expression p^{α} is used as cancellation for writing of p or $\neg p$ in dependence of that whether α be the constant of И (1) or Л (0) accordingly.
By the help of built logic DC it is proposed tosolve the following problems of recognition for simple or complex patterns:
1. Identification problem. It is necessary to determine, whether the plant ω or its part x belongs to the class Ω or its part belongs to the class Ω_k.
This problem in the works [3, 4] is reduced to proof of formula derivation ability

$$\exists y (y \subseteq \omega \,\&\, A_k(y)) \tag{2}$$

from description of recognized plant S(ω).
2. Classification problem. It is necessary to find all such numbers of the classes k, that $\omega \in \Omega_k$.
This problem in the works [3, 4] is reduced to proof of formula derivation ability

$$\mathop{\mathbf{V}}_{j=1}^{M} A_k(\omega) \tag{3}$$

from description of recognized plant S(ω) with notification of all such numbers k, for which according disjunctive memberis true on ω.
3. Complex object analysis problem. It is necessary to find and classify all parts x of the plant ω, for which $x \in \Omega$.
This problem in the works [3, 4] is reduced to proof of formula derivation ability

$$\mathop{\mathbf{V}}_{j=1}^{M} \exists x (x \subseteq \omega \,\&\, A_k(y)) \tag{4}$$

from description of recognized complex plant S(ω) with notification (localization) and identification of all parts of complex plant ω, that may be classified, i.e to determine belonging to one or another class every selected fragment.

Number of steps for algorithm work, building derivation of mentioned formulas, especially in the case of solution of problem for complex plant analysis, may be sufficiently great. For reducing of steps number of solution for recognition problems in [2] more economical hierarchical description of classes, permitting unparallelizing at realization on multi-core computers and neural networks, has been proposed.

2. Hierarchical logic class description

There is a description of plants, which structure permits select their simpler parts, i.e. fragments, and give description of plant in terns of properties of these parts (fragments) and relations between them. Particularly it may be done by selection of "frequently" found sub-formulas of the formulas $A_k(\omega)$ of "small complexity". In this case the system of equivalences of the kind

$$p_i^l(x) \leftrightarrow P_i^l(x), \tag{5}$$

is formed where p_i^l – predicates of *l*-th level, P_i^l – sub-formulas of the formula $A_k(\omega)$.

More promptly, let say that the system of initial predicates $p_1,\dots,p_n$ determines properties and relations of first level and write sometimes p_i^1 instead of p_i.

Let fix integer positive numbers *r* and N. They will characterize such fuzzy conception as "small complexity" of sub-formula (number of variables in sub-formula is less than *r*) and "frequently" (number of enterings, with precision to variables names, of given sub-formula in already available one is more than N).

Let select all frequently found sub-formulas of small complexity of the formulas $A_k(\omega)$ and designate them $P_i^2(x)$ (where *x* – list of variables, entering in sub-formula).

Let designate predicates, defined by these sub-formulas by mean of $p_i^2(i=1,\dots,n_2)$ and let name them parts of predicates of second level. These predicates are determined by the correlations

$$p_i^2(x) \leftrightarrow P_i^2(x) \tag{6}$$

Let designate formulas, obtained from $A_k(\omega)$ by means of substitution of all enterings of formulas of the kind $P_i^2(x)$ on atomic formulas $p_i^2(x)$ (at $x \subseteq \omega$) through $A_k^2(\omega)$. Such formulas may be described as logic DC in terms of first and second level.

Procedure of selecting of frequently found (typical) sub-formulas of small complexity may be repeated with the formulas $A_k^2(\omega)$.

Let be component predicates of 1-st, 2-nd, ..., *l*-1-th levels.

Let select all frequently found (typical) sub-formulas of small complexity of the formulas $A_k^{l-1}(\omega)$ and let designate them $P_i^2(x)$. Here *x* – list of variables, entering in sub-formula).

Let designate predicates, defined by these sub-formulas by means of $p_i^l(i=1,\dots,n_l)$ and let name them component (complex) predicates of *l*-th level.

These predicated are determined by the correlations

$$p_i^l(x) \leftrightarrow P_i^l(x) \tag{7}$$

Formulas, obtained from $A_k^{l-1}(\omega)$ by means of substitution of all enterings of the formulas of the kind $P_i^l(x)$ on atomic formulas $p_i^l(x)$, are designated through $A_k^l(\omega)$. Such formulas may be considered as logic descriptions of classes in terms of predicates of 1-st, 2-nd, ..., *l*-th levels.

To stop creation of component (complex) predicates of next level is possible in every moment but no later than current situation, when whether lengths of all formulas $A_k^l(\omega)$ are less than *r*, or among these formulas it is not found *N* sub-formulas of the same kind. This is rule of stopping of proposed initial-converged algorithm of hierarchical DC.

In result of building of component (complex) predicates and multi-level logic DC initial system of DC may be written by the means of equivalent multi-level logic system of DC of the kind

$$\begin{array}{ccc} & A_k^L(\omega), & \\ p_1^2(\omega) & \Leftrightarrow & P_1^2(\omega), \\ & \vdots & \\ p_{n_2}^2(\omega) & \Leftrightarrow & P_{n_2}^2(\omega), \\ & \vdots & \\ p_i^l(\omega) & \Leftrightarrow & P_i^l(\omega), \\ & \vdots & \\ p_{n_L}^L(\omega) & \Leftrightarrow & P_{n_L}^L(\omega). \end{array} \qquad (8)$$

It is possible to show that at sufficiently successful choice of parameters *r* and N time of work of algorithms solving different problems of recognition will be decreased [1].

3. Neural representation of hierarchical class description

At building of neural networks for unparalleling of representation of logic DC and recognition of complex patterns solution of values of predicates of one or another level may be done by corresponding neural level or core of multi-core computer. For example, at use of only predicates of first (initial) and second (synthesized) levels architecture of multi-level neural network will be such as it is presented in the fig.1.

Thus, in the first layer (sensor neurons) all possible values of initial predicates of recognized plant are calculated. In the second layer all possible values of second level predicates are calculated. In the third level formulas, defining logic DC, are checked.

In process of recognition of patterns complex plant or its fragment will be given to that class with number *k* for which the formula $A_k^2(\omega)$ is true.

It is necessary to mind that process of logic recognition for complex patterns on neural network may be organized by such means that to remember those fragments of initial plant ω, for which even if one of the formulas defining belonging to a class, will be true. By this mean problem of full logic analysis of complex plant may be solved automatically.

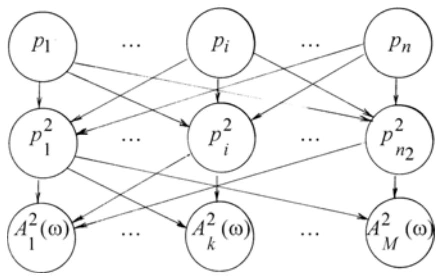

Fig.1. Architecture of multi-level neural network

Conclusion

Thus, for complex patterns (complex patterns and scenes, mixed signals etc.) methods for hierarchical description of classes (patterns) and evaluation of their effectiveness in problems of logis analysis and pattern recognition have been proposed. Informational technology for neural or multi-core representation of hierarchical descriptions of classes (patterns), providing mass parallelism at data processing and significant acceleration of processes for solution making in the process of pattern recognition has been described.

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ADAPTIVE WAVELET-NEURO-FUZZY NETWORK IN THE FORECASTING AND EMULATION TASKS

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Abstract: The architecture of adaptive wavelet-neuro-fuzzy-network and its learning algorithm for the solving of nonstationary processes forecasting and emulation tasks are proposed. The learning algorithm is optimal on rate of convergence and allows tuning both the synaptic weights and dilations and translations parameters of wavelet activation functions. The simulation of developed wavelet-neuro-fuzzy network architecture and its learning algorithm justifies the effectiveness of proposed approach.

Keywords: wavelet, adaptive wavelet-neuro-fuzzy network, recurrent learning algorithm, forecasting, emulation.

ACM Classification Keywords: I.2.6 Learning – Connectionism and neural nets