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Mathematical modelling of intellectual self-organizing automatic control system: action planning research

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Abstract

Mathematical modelling procedure is an integral part of complex system development process. Intellectual self-organizing automatic control systems are intended for functioning in conditions of changing the environment, controlled plant parameters, along with control purposes. Information incompleteness causes declarative statement of control task, i.e. without action sequence for its solution. As consequence, the major component of intellectual self-organizing automatic control systems is the action planning subsystem. Declarative tasks are solved by using artificial intelligence methods. However, existing methods of action planning represent the procedures demanding greater use of computing resources. Therefore efficiency of intellectual self-organizing automatic control systems in many respects is defined by productivity of action planning subsystem. Artificial neural planning networks are applied to increase efficiency as the mechanism of action planning in intellectual self-organizing automatic control systems. Mathematical modelling of intellectual self-organizing automatic control systems requires software realization of artificial neural planning networks. In this article we review the results of our study on the properties of artificial neural planning networks.

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Keywords: Intellectual self-organizing systems; artificial neural planning networks

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1. Introduction

Computer aided design often uses declaratively defined tasks. For solving these tasks, artificial intelligence methods are conventionally used. However, existing methods of action planning represent the procedures demanding greater use of computing resources. It is known, that multilevel systems of representation and processing of knowledge are the most effective [2]. They allow reducing expenses of time and resources by decomposition of search space. On the other hand, parallel processing allows reducing time of solving tasks. These include neurocomputer systems [3].

Computer aided control system design GAMMA-3 [4] possesses opportunities of solving tasks both in procedural and non-procedural (declarative) statement. Artificial neural planning networks (ANPN) are applied to increase efficiency as the mechanism of action planning in intellectual self-organizing automatic control systems. In this article we review the results of our study on the properties of artificial neural planning networks. The most important property of those is convergence of solutions. Also, when knowledge of control problem area is presented as axiomatic theories of formalized task automatic solutions of the automatic control [6], resolvability examining is necessary. Axiomatic theories of automatic decisions of the formalized control tasks are used as the form of knowledge representation of automatic control [6]. As consequence, resolvability examining of decisions theory is necessary.

2. Material and methods

2.1. Investigating decision convergence of artificial neural planning network

In the structure of artificial neural planning networks (ANPN), the artificial neural archival network (ANAN) is used as the memory device for storage of the decisions obtained in the artificial neural deciding network (ANDN). Hence, it does not render influence on convergence of decision process stability of a task in artificial neural planning network as a whole. Therefore, the main attention will be paid to the investigation of properties of *artificial neural deciding network* (ANDN).

Let us denote the following variables: $S^i(\mathrm{z}) = \left\langle \varphi_\mathrm{z}; \mathrm{d}^i; \mathrm{o}^i; \mathrm{p}^i \right\rangle$ is a state of ANDN on i-th decision step of a z-task; $\varphi_\mathrm{z} = \left\langle \mathrm{d_z}, \mathrm{r_z}, \mathrm{t_z}, \mathrm{c_z} \right\rangle$ is a statement of z-task; $\mathrm{d_z}$ is a source data of z-task; $\mathrm{r_z}$ is a desirable result of z-task; $\mathrm{t_z}$ is a z-task requirements to solution; $\mathrm{c_z}$ is a z-task applicability conditions; $\mathrm{d}^k =< \mathrm{d_R}, \mathrm{d_T}, \mathrm{d_C} >$ is a state of ANDN data-layer neurons (further referred to as "data-neurons"), which include desirable results, requirements to the results, and conditions of applicability), at the k-step; o^k is a state of ANDN operations-layer neurons (operations-neurons) at the k-step; p^k is current plan of the task decision plan, constructed after the k-step; $o: C(o) \to D(o) \Rightarrow R(o) \leftarrow T(o)$ is the format of own decision theory axiom record; o is name of the action (operation) described by an axiom; $C(o)$ is function for returning applicability conditions of an axiom o; $D(o)$ is function for returning source data of an axiom o; $R(o)$ is a function returning required results of an axiom o; $T(o)$ is a function returning requirements to results of an axiom o; *card A* is a set A quantity of elements (cardinal number); $\varnothing$ is an empty set; $w_{\mathrm{dz}}(\mathrm{z}): \mathrm{d_z}, \mathrm{r_z}, \mathrm{t_z}, \mathrm{c_z} \quad \mathrm{d_R}, \mathrm{d_T}, \mathrm{d_C}$, ($\mathrm{d_R} \cong -\mathrm{d_z} + \mathrm{r_z}, \mathrm{d_T} \cong \mathrm{t_z}, \mathrm{d_C} \cong \mathrm{c_z}$) is the operator, establishing data-neuron states according to z-task attributes; $w_{\mathrm{do}}: \mathrm{o} \quad \mathrm{d}$, ($\text{д}_\mathrm{R} \cong -R(o) + D(o) + T(o) + C(o)$, $\mathrm{d_T} \cong T(o)$, $\mathrm{d_C} \cong -T(o)$) is the operator, establishing data-neurons state according an operations-neurons states; $w_{\mathrm{do}}: \mathrm{o} \quad \mathrm{d}$, ($\mathrm{d_R} \cong -R(o) + D(o) + T(o) + C(o), \mathrm{d_T} \cong T(o), \mathrm{d_C} \cong -T(o)$) is the operator establish data-neurons state according an operations-neurons states; $w_{\mathrm{od}}: \mathrm{d} \quad \mathrm{o}$, ($\mathrm{o} \cong \{o_i \mid R(o_i) \subseteq \mathrm{d_R}, T(o_i) \supseteq \mathrm{d_T}, C(o_i) \supseteq \mathrm{d_C}\}$) is the operator establish operations-neurons state according an data-neurons states; $S_\mathrm{z}^0 = \left\{ s \mid s(\mathrm{z}) = \left\langle \varphi_\mathrm{z}; [0]; [0]; [0] \right\rangle \right\}$ is initial state set of ANDN to z-task, where symbols "$[0]$" designate zero vectors accordingly dimension; $S_\mathrm{z}^\mathrm{z} = \{ s \mid s(\mathrm{z}) = \left\langle \varphi_\mathrm{z}; \mathrm{d_z}; \mathrm{o_z}; \mathrm{p_z} \right\rangle \}$ is the final ANDN-states achieved upon termination of the z-task decision.

Among final ANDN-states we shall allocate set of target states $S_\mathrm{z}^\mathrm{T} = \{ s \mid s(\mathrm{z}) = \left\langle \varphi_\mathrm{z}; [0]; [0]; \mathrm{p_z} \right\rangle \} \subset S_\mathrm{z}^\mathrm{z}$, which achievement testifies to successful construction of the plan π_z of a z-task decision. Achievement of final states of the kind $s(\mathrm{z}) = \left\langle \varphi_\mathrm{z}; \mathrm{d_z}; \mathrm{o_z}; \mathrm{p_z} \right\rangle \notin S_\mathrm{z}^\mathrm{T}$, $\mathrm{d_z} \neq [0], \mathrm{o_z} \neq [0]$, not being target, testifies to absence of the z-task decision. Convergence of process of search of the decision, with respect to a planning artificial neural network, as a matter of fact, means resolvability.