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M.A. Poliakov, S.A. Subbotin, I.A. Andrias

CONTROL SYSTEM CONTROL UNIT FSM SEMANTIC MODELS

The semantic models for the representation of control machines in the knowledge bases of control devices of control systems are considered. The principles of setting the names of elements of sets of states, inputs and outputs of the automaton, as well as methods for describing the functions of automata in terms of these names are described. Examples of semantic models of control machines are given.
Key words: finite state machine, semantic model, knowledge base of finite state machines, control system.

Introduction. The prospects for constructing cognitive control systems make relevant the issues of knowledge representation about control machines in the knowledge base of a control system. Classic automaton converters are defined as a tuple [1, 2]

$$A=< S, X, Y, s_0, \delta, >, \tag{1}$$

where S is a finite nonempty set (of states); X is a finite nonempty set of inputs (input alphabet); Y is a finite nonempty set of outputs (output alphabet); s_0- initial condition; δ - transition function; $\lambda : S \times X \rightarrow Y$, $\lambda : S \rightarrow Y$ are the functions of the outputs of the Miles and Moore machines, respectively.

More complex behavior of finite automata is described in the Harel formalisms [3], state diagrams of the UML language [4], and automata with non-binary elements of sets [5]. The finite state machine proposed in [5] is defined as a tuple

$$A=< S, X, Y, s_0, C, c_0, F>, \tag{2}$$

where C is the set of controls; c_0 - initial management; F is the set of functions of the automaton in its states. The element f_i of the set F for the i-th state is defined through the functions of this state

$$f_i = <\mu_i, \lambda_i, \sigma_i>, \tag{3}$$

where $\mu_i, \lambda_i, \sigma_i$ are the activation, output, and structure functions, respectively.

The set of controls *C* characterizes the ability of the machine to adapt, that is, change its structure and functions on the initiative of other machines. This ability is relevant in the cognitive control system [6], the main elements of which are a multi-level knowledge base, subsystems of cognition, cognition and activity. Automata are used in the subsystem of activity, where they are organized into a hierarchical control structure.

Research problem statement. When designing and documenting a finite state machine, its elements are given names. For example, the status "WAIT", "ACCELERATION"; inputs "START", "PARAMETER MORE THAN THE NORM"; outputs "INCLUDE OVEN", "INITIATE STRATEGY N", etc.

Despite the widespread use of finite state machines in control systems, there are no unambiguous recommendations on the semantics of the names of elements of automata in the literature. For example, in [7] it is recommended that the name of the state characterizes "a situation or a period of time when something happens in the system", and the name of the event "should explain what exactly happened". The essence of the state of an automaton in [2] is defined as "all that an automaton knows about the past in terms of its future behavior". Moreover, information about the past is not differentiated; the very concept of "past machine" is not defined. Is it a sequence of states or inputs or outputs, or all together? Do the type of machine and the relationships in the control system between the control object and the control machine affect the semantics of the names?

Partially answers to the questions posed are given in [8], where it was proposed to describe the name of the state in the form of a complex of statements and definitions characterizing the pre-history, post-history and the current choice of actions of the automaton. But, in this work, the results of subsequent studies on the structure of finite automata are not reflected, for example, the results obtained in [5, 9].

The lack of recommendations on the presentation of the semantics of a finite state machine in the names of its elements complicates their design and processing of knowledge about the machine in order to adapt it in the process of the control system. The theoretical justification of the process of constructing a semantic model of a control automaton is an actual unsolved scientific and technical problem.

The aim of the work is to expand the knowledge base for the selection of effective goals, scenarios for their achievement and behaviors during the execution of the script by including the knowledge contained in the names of the elements of finite automata.

Semantic model of a finite state machine. By a semantic model of a finite automaton we mean a set of statements characterizing the semantic relations between the definitions of elements of automata contained in the names of these elements.

The knowledge contained in the semantic model can be processed by the same means that are used in the processing of knowledge about the control object. This is a consequence of the principle of homogeneity of knowledge in a cognitive system [10] - an analogue of the well-known von Neumann principle of homogeneity of memory for computing systems. Such tools are logical inference systems, in the form of PROLOG programs [2].

We will distinguish between two processes of using the semantic model of a finite automaton: identifying unknown elements of the designed automaton and searching for incompleteness and inconsistencies in the elements of the semantic model that are already formed. (Hereinafter referred to as the design and testing process); changing the structure of the control machine presented in the knowledge base of the control system of its semantic model (hereinafter - the adaptation process). Moreover, this change occurs during operation of the control machine.

A feature of information processes in the management system is the presence of ring causality. Its essence lies in the fact that the control device and the control object are connected in a loop. Therefore, to build a semantic model of a control automaton, it is necessary to have models of the control object.

For example, if about the control object, it is known that it is a physical system, and exposure to it will lead to a rise in temperature, then in the semantic model of the control automaton there may be statements like “ENABLING THE HEATING OUTPUT” There is a REASON for INCREASING

THE TEMPERATURE AT THE ENTRANCE ”, so and “INSUFFICIENT INPUT TEMPERATURE IS THE REASON FOR THE“ HEATING ”OUTPUT TURNING ON”.

In some cases, when constructing a semantic model of a control automaton, it is also advisable to take into account environmental models and models of unobservable parameters of the control object.

To enter the state machine, you can offer the following names:

1. The name of the measured or estimated output of the control object or its model and the current assessment of the compliance of the measured (estimated) value with some standards, ranges or conditions. For example, “POWER SUPPLY VOLTAGES IN NORM”, “TEMPERATURE IN THE EPICENTER OF OVER ONE MILLION DEGREES”.

2. Characterization of the current value of the input of the machine, as a result, a consequence of the impact(s) in the past on some input(s) of the control object. For example, “HIGH TEMPERATURE DUE TO OVERHEATING THE OBJECT”.

3. Description of the current value of the input of the machine, as the cause of future impacts on the input(s) of the control object. For example, “CURRENT TEMPERATURE TO INCREASE BY HEATING THE OBJECT”.

4. The name of the command transferred to the machine for execution by a higher machine, arc system or operator. For example, “GO TO EMERGENCY MODE”.

5. The characteristic of the input as the relationship between the current S_i and the future S_j active state of the control automaton. For example, “X_k IS THE REASON FOR TRANSITION FROM S_i TO S_j”, “X_k IS INCIDENTAL TO THE TOPS OF S_i AND S_j”.

The names of the outputs of the machine are due to their information connections in the control device of the control system. In a single machine, which is described by tuple (1), the outputs are connected to the inputs (directly or through output operating machines) of the control object, as well as through input operating machines with their own inputs.

If the automata form a hierarchy in which the parametric and structural adaptations of the elements of the control device are performed [11],

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new information links of the outputs with the control inputs of the slave operating and control automata appear. With that said, we list the types of output names:

1. The name of the input of the control object or actuator connected to this input. For example, “TURN ON THE PUMP”, “COOL”.

2. Characterization of the current value of the output of the machine, as a result, a consequence of changes in the output of the control object or its model. For example, “COMPENSATION OF THE SUPPLY OF THE SUPPLY VOLTAGE”.

3. Description of the current value of the output of the machine, as a reason, the forecast of future changes at the outputs of the control object. For example, "LEADS TO INCREASE THE OUTPUT POWER OF THE OBJECT."

4. The name of the command transmitted by the machine for execution to subordinate operating and control machines. For example, “SET A NEW POLL FREQUENCY”.

5. Characteristics of the output as a relation to the current state of the machine (for the Moore machine) or characteristic of the output as a relationship to the input signal (for the Mili machine), For example, “THE FURNACE IS ON IN THE STATE OF THE AUTOMATIC“ HEATING ””, “Y_k - CONSEQUENCE OF THE ENTRANCE OF THE ENTRANCE X_i DURING THE AUTOMATION OF THE AUTOMATIC STATE IN THE STATE OF S_i. ”

The state of the automaton sums up the past sequences of inputs, controls the process of forming the outputs, is a filter of future inputs, participates in the process of transferring activity to another state. Therefore, the names of states play an important role in the semantic model of an automaton. They can be formulated in the following ways:

We clarify that Fig. 1 describes one of the control options in the system at the level of behavior. With a more general view of the system, it is necessary to consider other levels of the system located higher and lower in the hierarchy of management. As well as other options for control machines at the level of behavior. For example, an automaton for heating an object according to a given law of temperature change (another variant of behavior); scripting machine on which the type of behavior is selected (higher level). At the lower levels of the hierarchy, signal processing, control of electric currents and heat flows takes place. Knowledge of the state and parameters of these processes may also be of interest to higher levels of government.

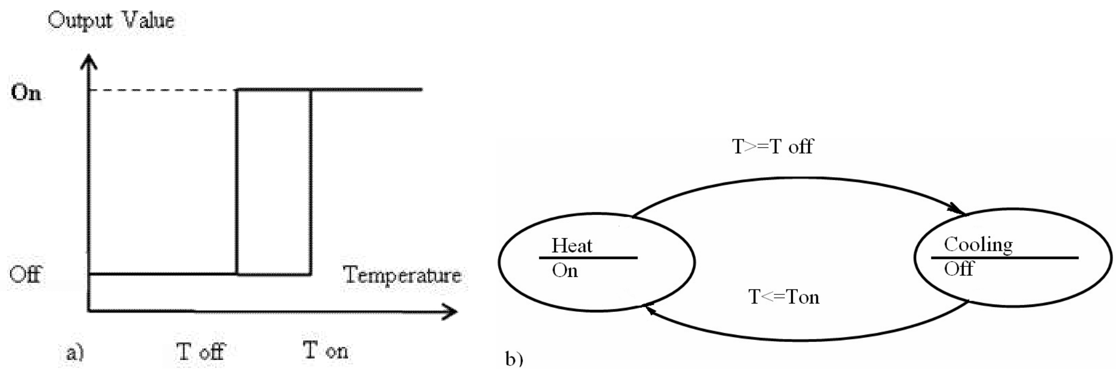

Figure 1 - Control device: a) - transfer characteristic of the relay controller; b) - graph of the temperature control automaton

In fig. 2 shows a modified graph of the automaton with additional arcs, such as “state - name of the action - input of the control object” and “output of the control object - name of the reaction - input of the state”.

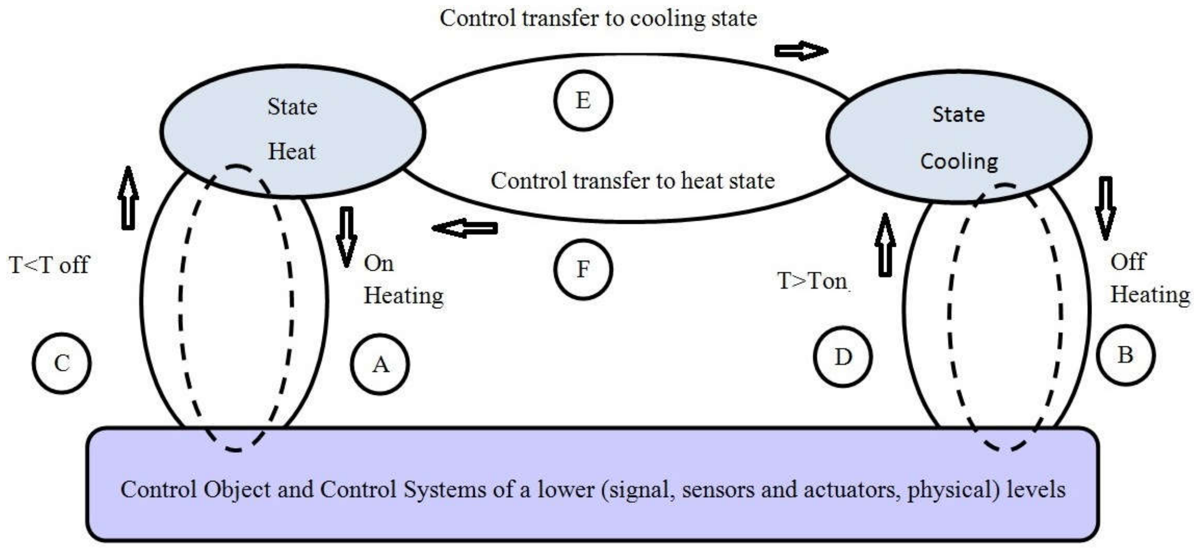

Figure 2 - Control system with the contours of causal relationships

The arc corresponding to the transition from one state to another is not related to the activity and values of the outputs of the control object, and the boundary between the object and the control device is drawn between the signal level and the level of behavior.

In the column of Fig. 2 there are six arcs that correspond to the names of the elements and are denoted by the letters *A, B, C, D, E*, and *F*. The names shown in Fig. 2 correspond to the "current choice" variant described above. Depending on the chosen system of cause and effect relationships, some of the notation *A* - *F* are independent, and the rest are dependent variables of the semantic model of the control system. Arcs, states, and the control object form the contours of actions and action control. The knowledge contained in the names of any two elements in the circuit can be connected by cause and effect relationships. The direction of this connection is determined by the direction of the circuit. For example, suppose in the action loop, "object - *E* - heating state - *A* - object", the clockwise direction of the bypass is accepted. Then "A is a consequence of E" or in another notation "IF *E* THEN *A*". When going around the contour counterclockwise, we have "*E* is a consequence of *A*".

The formal description of the semantic model of the SMS control machine is a tuple system:

$SMS = \langle S_a, S_c \rangle; S_i = \langle N_i, CD_i, KB_i \rangle; N_{ij} = \langle N_p, N_{pr}, N_f \rangle;$

KB_{ij}: *IF* CD_i *THEN* $N_{ik} \Leftarrow N_{im}$,

where S_a, S_c is the set of activity and control loops, respectively; S_i is the set included in the sets S_a, or S_c; N_{ij} - a complex of names of the *j*-th element in the *i*-th circuit; CD_i - the direction of causality in the *i*-th circuit; KB_i - knowledge base of the *i*-th circuit; N_p, N_{pr}, N_f, - the set of names of the *j*-th element in the *i*-th circuit in the style of pre - history, current selection and post - history, respectively; KB_{ij} is the knowledge base element of the *j*-th element in the *i*-th circuit. The expression $N_{ik} \Leftarrow N_{im}$ describes the fact that N_{im} is a consequence of N_{ik}, where N_{ik}, N_{im}, is knowledge in the form of names for the elements *k* and *m* in the *i*-th circuit.

To analyze the structure of knowledge represented in the semantic model of the system, methods of inference can be applied. The description of the structure of the semantic model of the SMS system (Fig. 2) in the language PROLOG has the form:

SMS (A, B, C, D, E, F) <= Heating (A, C, E, F), Cooling (B, D, E, F), Object (A, B, C, D).

Fragments of the specifications of the subsystems of the object, the states of Cooling and Heating:

Object (0, 1, 0, 1).

Heating (0, 1, 1, 0).

Cooling (1, 0, 1, 0).

Object (1, 0, 1, 0).

Heating (1, 0, 0, 1).

Cooling (0, 0, 0, 1).

In these specifications, “0” if the corresponding statement is false and “1” is true. The purpose of the PROLOGUE for this program may be, for example, the following:

? SMS (A, B, 1, 0, 0, 1).

(What are the outputs A and B, if C is true, D is false, and the control is in the “Heating” state.). Answer: A = 1, B = 0.

Thus, the semantics, the meaning of the processes of activity in the control system is expressed through the meaning of the names of the elements of the system and the cause-effect relationships between them in the control loops. Each element can have several names. These names describe the pre-, post- history and current selection of the element's activity in the circuit.

Conclusions. Distinctive properties of modern and promising control systems is the hierarchical structure of the control device, the use of knowledge both in the process of controlling the object and in the course of adaptation, the choice of goals for the functioning and self-development of the control device.

A semantic model is proposed that describes knowledge about the structure of control machines. It uses a set of names of elements of automata and causal relationships between them on the basis of control loops formed on the basis of the control automaton graph and the control object. The knowledge contained in the model can be analyzed by means of logical inference and formalized as a PROLOGUE program.

Joint processing of knowledge about the control structure, the dynamics of external influences, the parameters of the control object and the state of the elements of control devices is the basis of the processes of adaptation and self-development of control systems. In subsequent works, it is supposed to describe the application of the semantic model of the automaton of the control device in these processes.

ЛИТЕРАТУРА / ЛІТЕРАТУРА

1. Глушков В.М. Синтез цифровых автоматов.—М.:ГИФМЛ, 1962. — 476 с.
2. Карпов, Ю. Г. Теория автоматов. [Текст]. – СПб., Питер, 2002. – 224 с.
3. Harel D. Statecharts: a Visual Formalism for Complex Systems. Sci. Comput. Prog. 8, 1987, p. 231-274.
4. Буч Г., Рамбо Д., Джекобсон А. – Язык UML. Руководство пользователя: пер. с англ. – М: ДМК Пресс, 2001. – 432 с.: ил.
5. Поляков М. А. Конечные автоматы с небинарными элементами множеств. /М. А. Поляков, И. А. Андриас. //Системні технології. Регіональний міжвузівський збірник наукових праць, №2(121), Дніпро, 2019. - С.85-94.
6. Поляков М. А. Теоретико-множественные модели функциональных структур систем когнитивного управления. // Системні технології. Регіональний міжвузівський збірник наукових праць, №3(110), Дніпро, 2017. - С. 16–23.
7. Гома Х. UML проектирование систем реального времени, распределенных и параллельных приложений. – М.:ДМК, 2002 – 704с.
8. Поляков М.А. «Семантика состояний автоматов систем логического управления», с. 200 - 201, «Дні науки – 2008: зб. тез-доповідей : в 3т.» / Класичний приватний університет, 23-24 жовтня 2008; ред. кол. В.М. Огаренко та ін. – Запоріжжя : КПУ, 2008. – Т.2 – С. -208.
9. M. Poliakov: Implementing Automaton Behavior with Fuzzy Controllers”. David Luengo, Sergey Subbotin, Peter Arras, Yevgeniy Bodyanskiy, Karsten Henke, Ivan Izonin, Vitaly G. Levashenko, Volodymyr Lytvynenko, Anzhelika Parkhomenko, Andreas Pester, Natalya Shakhovska, Alexei Sharpanskykh, Galyna Tabunshchyk, Carsten Wolff, Heinz-Dietrich Wuttke, Elena Zaitseva: Proceedings of the Second International Workshop on Computer Modeling and Intelligent Systems (CMIS-2019), Zaporizhzhia, Ukraine, April 15-19, 2019. CEUR Workshop Proceedings 2353, CEUR-WS.org 2019 p.183-192
10. Поляков М.А., Применение принципов фон Неймана в архитектуре

информационно-управляющих систем. Автоматизація: проблеми, ідеї, рішення: матеріали міжнар. наук. - техн. конф. Севастополь, 9-13 вересня 2013 р. / М-во освіти і науки України; Севастоп. нац. техн. ун-т; наук. ред. В.Я. Копп - Севастополь:, СевНТУ, 2013. – 240 с.

11. Poliakov, M. Set-theoretical FSM models activity subsystem for Cognitive Control Systems. /M. Poliakov, O. Subbotin, O. Poliakov. [Text] //In Proceeding of the 15th International Conference "The Experience of Designing and Application of CAD Systems" (CADSM), (26 February - 2 March, 2019, Polyana-Svalyava (Zakarpattya), Ukraine). P. 1/1 – 1/4/.

REFERENCES

1. Glushkov V.M. Sintez tsifrovykh avtomatov. — M.: GIFML, 1962. — 476 p.
2. Karpov Y.U. G. Teoriya avtomatov. [Tekst]. – SPb., Piter, 2002. – 224 p.
3. Harel D. Statecharts: a Visual Formalism for Complex Systems. Sci. Comput. Prog. 8, 1987, p. 231-274.
4. Butch G, Rambo D., Jacobson A. - UML. User Guide: Per. from English - M: DMK Press, 2001. - 432 p.: Ill.
5. Poliakov M. A. Finite automata with non-binary elements of sets. / M.A. Poliakov, I. A. Andrias. // System technology. Regional Ministry of Health Sciences, No. 2 (121), Dnipro, 2019.-C.85-94.
6. Poliakov M.A. Teoretiko-mnozhestvennyye modeli funktsional'nykh struktur sistem kognitivnogo upravleniya System technology. Regional Ministry of Health Sciences.- №3(110),Dnípro, 2017.P.16–23.
7. Goma H. UML design of real-time systems, distributed and parallel applications. - M.: DMK, 2002 – 704p..
8. Poliakov M.A. Semantika sostoyaniy avtomatov sistem logicheskogo upravleniya. (Logical control systems automata states semantics), p. 200 - 201, «Days of Science - 2008: Coll. abstracts: in 3 vols. »/ Classic Private University, October 23-24, 2008; ed. qty. V.M. Ogarenko and others. - Zaporizhzhya: KPU, 2008. - Vol.2.-208 p..
9. M. Poliakov: Implementing Automaton Behavior with Fuzzy Controllers". David Luengo, Sergey Subbotin, Peter Arras, Yevgeniy Bodyanskiy, Karsten Henke, Ivan Izonin, Vitaly G. Levashenko, Volodymyr Lytvynenko, Anzhelika Parkhomenko, Andreas Pester, Natalya Shakhovska, Alexei Sharpanskykh,

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Galyna Tabunshchyk, Carsten Wolff, Heinz-Dietrich Wuttke, Elena Zaitseva: Proceedings of the Second International Workshop on Computer Modeling and Intelligent Systems (CMIS-2019), Zaporizhzhia, Ukraine, April 15-19, 2019. CEUR Workshop Proceedings 2353, CEUR-WS.org 2019 p.183-192

10. Poliakov M.A. Primeneniye printsipov fon Neymana v arkhitekture informatsionnykh sistem upravleniya (Application of von Neumann principles in the architecture of information management systems). Automation: problems, ideas, solutions: materials and materials. sciences. - tech. conf. Sevastopol, 9-13 spring 2013 p. / Ministry of Education and Science of Ukraine; Sevastop. nat. tech. un-t; Sciences. ed. V.Ya. Kopp - Sevastopol :, SevNTU, 2013. - 240 p.

11.Poliakov M. Set-theoretical FSM models activity subsystem for Cognitive Control Systems. /M. Poliakov, O. Subbotin, O. Poliakov. [Text] //In Proceeding of the 15th International Conference "The Experience of Designing and Application of CAD Systems" (CADSM), (26 February - 2 March, 2019, Polyana-Svalyava (Zakarpattya), Ukraine). P. 1/1 – 1/4.

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Семантичні моделі автоматів управляючих устроїв систем управління

Розглянуто семантичні моделі для подання керуючих автоматів в базах знань керуючих пристроїв систем управління. Описано принципи завдання назв елементів множин станів, входів і виходів автомата, а також способи опису та аналізу функцій автоматів в термінах цих назв. Наведені приклади семантичних моделей керуючих автоматів.

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Поляков Михаил Алексеевич - профессор кафедры электрических и электронных аппаратов национального университета «Запорожская политехника».

Субботин Сергей Александрович - профессор, заведующий кафедрой программных средств национального университета «Запорожская политехника».

Андриас Ирина Аркадиевна - доцент кафедры электропривода и автоматизации национального университета «Запорожская политехника».

Поляков Михайло Олексійович - професор кафедри електричних та електронних апаратів національного університету «Запорізька політехніка».
Субботин Сергій Олександрович - професор, завідувач кафедрою програмних засобів національного університету «Запорізька політехніка».
Андріас Ірина Аркадієвн - доцент кафедри електроприводу та автоматизації національного університету «Запорізька політехніка».

Poliakov Mykhailo Oleksiyovych - professor of the electrical and electronic devices Department of National University «Zaporizhzhia Politechnic».
Subbotin Sergii Alexandrovich - professor, head of the department of software of the National University "Zaporizhia Polytechnic".
Andrias Irina Arkadievna - assistant professor of the electric drive and automation Department of National University «Zaporizhzhia Politechnic».

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