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Kh N. Nazarov
Tashkent state technical university named after Islam Karimov, radiofizik2012@mail.ru

T O. Rakhimov
Tashkent state technical university named after Islam Karimov

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Nazarov Kh.N., Rakhimov T.O.

Tashkent state technical university named after Islam Karimov

РОБОТОТЕХНИК ТИЗИМЛАР МЕХАТРОН МОДУЛЛАРИНИНГ ФИЗИК ИШЛАШ ПРИНЦИПЛАРИНИ СИНТЕЗ ҚИЛИШ МЕТОДИНИНГ ФОРМАЛ ЁЗИЛИШИ

Назаров К.Н., Рахимов Т.О.

Ташкентский государственный технический университет имени Ислама Каримова

ФОРМАЛЬНОЕ ОПИСАНИЕ МЕТОДА СИНТЕЗА ФИЗИЧЕСКИХ ПРИНЦИПОВ ДЕЙСТВИЯ МЕХАТРОННЫХ МОДУЛЕЙ РОБОТОТЕХНИЧЕСКИХ СИСТЕМ

Назаров К.Н., Рахимов Т.О.

Ислом Каримов номидаги Тошкент давлат техника университети

Abstract: *The article is focused on a formal description of the method for synthesizing the physical principles of the operation of mechatronic modules of robotic systems. The method of synthesis of the physical principle of action of mechatronic modules is represented by a set of synthesis problems and a synthesis problem solver. At the same time, the structure of the method includes the output physical quantities of mechatronic modules of robotic systems, information about the nature and ranges of variation of the output quantities and other restrictions, input physical quantities or parameters of robotic systems.*
Keywords: mechatronic module, synthesis method, physical principle of operation, synthesis problem solver, model of the physical principle of operation.

Аннотация: *В статье рассмотрено формальное описание метода синтеза физических принципов действия мехатронных модулей робототехнических систем. Метод синтеза физического принципе действия мехатронных модулей представлен совокупностью задач синтеза и решателя задачи синтеза. При этом в структуру метода включены выходные физические величины мехатронных модулей робототехнических систем, сведения о характере и диапазонах изменения выходных величин и других ограничениях, входные физические величины или параметры робототехнических систем.*
Ключевые слова: мехатронный модуль, метод синтеза, физический принцип действия, решатель задачи синтеза, модель физического принципа действия.

Аннотация: *Мақолада робототехник тизимар мехатрон модулларнинг физик ишлаш принципларини синтез қилиш усулиининг формал ёзилиши кўрилган. Мехатрон модулларнинг физик ишлаш принципини синтез қилиш усули синтез масаласини ечувчи ва синтез масалалар тўплами билан ифодаланган. Бунда усулнинг структурасига робототезник тизим мехатрон модулининг чиқиш физик катталиклари, чиқиш катталикларининг диапозонлари, кириш физик катталиклари ёки робототехник тизимнинг параметрлари ҳисобга олинган.*
Таянч сўзлар: мехатрон модул, синтез усули, физик ишлаш принципи, синтез масаласини ечувчи, физик ишлаш принципи модели.

1. Introduction

At present, the issues of the synthesis of the physical principles of action (PPA) of mechatronic modules are relevant in the fields of robotics and mechatronics.

The article pays special attention to the formal description of the method of synthesis of the physical principles of the operation of mechatronic modules of robotic systems. The method of synthesis of the physical principle of mechatronic modules action is represented by a set of synthesis problems and a synthesis problem solver [1]. At the same time, the structure of the method includes the output physical quantities of mechatronic modules of robotic systems, information about the nature and ranges of variation of the output quantities and other restrictions, input physical quantities or parameters of robotic systems, a model of the physical principle of operation, a set of physical and technical effects and the transformation of an input quantity into an output quantity. The structure of the synthesizer is described, i.e. solver of problems of synthesis of mechatronic module [1,2].

The differences between intelligent and non-intellectual methods based on features are determined; redundancy of models of physical and technical effects (PTE) and the possibility of obtaining a new type of qualitative transformation.

2. Research methodology

Any synthesis method (PPD) of mechatronic modules of control systems can be represented by a set of synthesis problems and a synthesis problem solver

$$M = < Z, C >, \quad (1)$$

where problem Z is formally represented by a triple of the form

$$Z = < TR, ID, \rho >, \quad (2)$$

here: TR contains the output physical quantities of mechatronic modules of robotic systems (MMRS), information about the nature and ranges of changes in the output quantities and other restrictions;

ID – initial data, which are the input physical quantities or parameters of the designed MMRS. IDs also reflect information about the nature and range of the input quantities;

ρ – is the solution of the problem Z which is a model of the physical principle of action, which is an ordered set of physical and technical effects (PTE) and techniques, and converts the input value into the output value.

Synthesizer C PPA, or otherwise a solver of synthesis problems, according to [3], is represented as a four

$$C = < M, \Omega, \prod, \gamma > \quad (3)$$

The first two components of the synthesizer C represent the algebra $< M, \Omega >$, and $\prod$ – is the inference rule and γ – are the rules for applying the rule and operations of Ω to the carrier of the algebra M, which contains many names and properties of physical quantities, many names and models of physical and technical effects (PTE) and general laws of the problem area, as well as relations in a variety of physical quantities and PTE. Physicotechnical effects are understood as physical phenomena, effects, laws and techniques that convert some input physical quantities or parameters into output ones. The system of physical and technical effects is characterized by a certain set of quantities and relationships in a set of quantities (in this case, the relationships determine the nature and type of relationship between quantities) and is displayed by the information model [4].

The component Ω of the synthesizer (and algebra) is a system of partial operations in the set M, the composition of which is in accordance with the composition of M (that is, operations on physical quantities, models, or relations);

$\prod$ – partial operations specified in the union of the sets M and Ω, and representing the rules of inference;

γ – is a system of rules for applying $\prod$ and operations Ω to a set M, which is a control structure (strategies: “first in depth”, “first in breadth”, methods of wave, backward wave, and counterpropagating waves, etc.) for the search for the principles of operation of the MMRS. The system of rules γ includes the possibility of increasing and changing the database and knowledge base of the system.

3. Analysis and results

The practical difference between intelligent systems and non-intelligent systems for the synthesis of PPAs is that new knowledge is generated about the former on the basis of existing knowledge of the problem area in the process of work, which will also be used later as knowledge of the problem area. The differences between intelligent and non-intelligent synthesis methods are shown in Table 1.

Table 1.

Differences between intelligent and non-intellectual methods

Signs	Intelligent systems	Non-intelligent systems
Redundancy of PTE Models	each PTE is described once and applied in any of its transformations	each PTE is described as many times as there are transformations
The ability to obtain a new type of quality transformation	there is	has not

The FTE models used in the majority of the existing MMRS for the synthesis of the physical principle of action (PPA) of the MMRS reflect the cause-and-effect relationships of the PTE and, as a rule, in the single-input version of graph models are represented as an arc with its initial and final vertices, or an elementary link of a parametric structural scheme [5].

The initial and final vertices correspond to the input and output physical quantities, parameters. An arc indicates a causal relationship between the input and output quantities.

PTE models are presented in multi-output [6] and single-input versions. The outputs of the models reflect not only the output values, but also their qualitative nature of change, the name and function of the "input-output" dependence. Thus, the compiled models carry information about all the input values of the PTE. Such models correspond to parts of the graph (structures) of the "entry star" type, the tops-sinks of which correspond to the output; values, vertices-sources -input values [7]. Examples of such models of PTE are shown in Fig. 1.

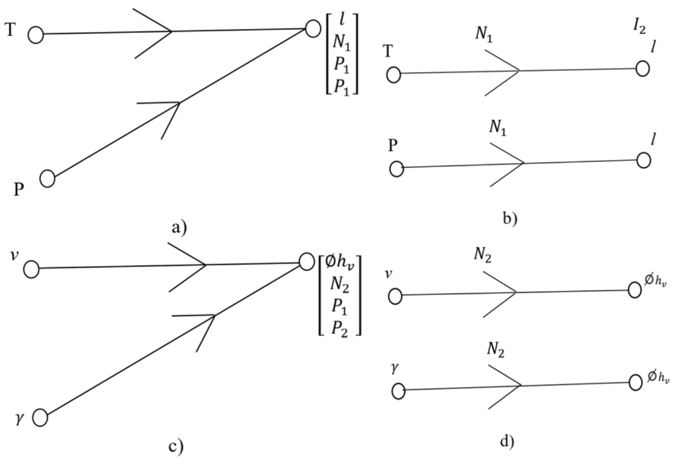

Fig 1. Examples of graph models of FTE: a) model of the effect of thermal expansion; b) model of the Vavilov-Cherenkov effect (radiation); b, d) corresponding single-entry models; N_i and P_j – respectively, the number of the FTE and the number of the property.

The set of PTE models forms a graph of interrelationships of physical quantities (GRPQ) [5]. The systematization of values according to the types (nature) of the chains makes the GRPQ multilayer. Under the layer of the GRPQ we mean a set of quantities of one type of chain. For example, electrical, optical, hydraulic, magnetic, mechanical, etc. In this regard, PTEs are divided into interchain and intrachain. Interchain PTEs are those in which a physical quantity of one nature is converted into a physical quantity of another nature. Accordingly, in intrachain PTEs there is a transformation of quantities of the same physical nature [8]. In most cases, the projection of the intrachain PTE of one layer of the GRPQ onto another layer (other layers) of the PTE of a different physical nature shows the existence of an analogy between the PTE of a different nature.

The paper proposes a formalized model of the PTE in the form of a predicate matrix (PM) [9,10]. This is a tabular representation of a certain predicate expression that describes the essence of PTE. The predicate model of PTE is a matrix of order 3xn (where n is the number of input values), the elements of the first row of which are predicate symbols (or predicate code), the elements of the remaining rows are terms [10,11] (Fig. 2).

Predictive, the symbol in this case represents a type of causal relationship. "Input-output" PTE. The element of the second line PM is the code of the output value of the PTE. The elements of the third line are the codes of the input values of the PTE. Representation in the form of PM allows to synthesize the PPA of MMRS using the resolution method [12] used in artificial intelligence systems.

A1: :

1
4
16

; A2: :

-1
56
22

A3: :

-1
8
98

; A4: :

2
10
2

A3: :

2	2
4	4
-2	8

Fig 2. Examples of PTE models in the form of predicate matrices.

The above models make it easy to formalize the decision-making process when synthesizing new principles of operation of the MMRS.

The list model of the form <output quantity: $-\vee_{i=1}^{n}$ input quantity (i) > it has the structure of the "entry star". For the development of the PTE corresponding to this model, one of its inputs must be excited. In this case, the necessary modes must be supported at other (side) inputs.

Such a PTE model is convenient in that, as the PPA of the MMRS is synthesized, the numbers of the side inputs of the principle of operation corresponding to the unconnected input vertices of the PTE models that form the principle of the MMRS operation are simultaneously accumulated. The described model makes it possible to use the methods of deductive inference for the synthesis of the PPA of the MMRS [13,14].

Methods for searching for the principles of constructing an MMRS are also proposed below. using PTE models in the form of information matrices (IM) [15].

An information matrix, in the simplest case, is a square adjacency matrix of an information graph. Moreover, all diagonal elements of IM are zero, which indicates the absence of loops in the information graph. The rest of the IM elements reflect the numbers of phenomena, formulas and properties of the corresponding arcs of the information graph [16,17].

The list of accepted conventions for properties is given in Table 2. Empty (zero) IM cells show the absence of PTE, which binds the corresponding physical quantities. In fig. 3 [3,4,18]. shows a fragment IM of the combined graph of relationships of physical quantities.

Table 1.

Designation	Property	Designation	Property
P_1	changes	$\overline{P_1}$	constancy
P_2	increase	$\overline{P_2}$	decrease
P_3	radiation	$\overline{P_3}$	absorption
P_4	manifestation	$\overline{P_4}$	disappearance
P_5	rotation right	$\overline{P_5}$	rotation left
P_6	maximum resonance	$\overline{P_6}$	minimum resonance
P_7	modulation	$\overline{P_7}$	demodulation

The first element of the pair is the PTE number. The second element is the property code (P_i).

4. Conclusion

The considered method of synthesizing the physical principle of operation of mechatronic modules is represented by a set of synthesis tasks, while taking into account the output physical quantities of mechatronic modules, information about the nature and ranges of change in output quantities and other restrictions, initial data representing input physical quantities, a model of physical and technical effects, techniques that convert the input to the output.

Differences between intelligent and non-intellectual methods and models of physical and technical effects used in the synthesis of mechatronic modules are presented.

Graph models of interrelationships of physical quantities of electrical, optical, hydraulic, magnetic, mechanical nature, list models using methods of deductive inference for synthesis are proposed.

A formalized model of physical and technical effects in the form of a predicate matrix, is proposed. Methods for finding the principles of constructing mechatronic modules using models of physical and technical effects in the form of information matrices are described. The above models make it easy to formalize the decision-making process. When synthesizing new principles of operation of mechatronic modules of robotic systems.

Inputs \ Outputs	2	4	6	8	10	12
2			$\begin{bmatrix}8\\1\end{bmatrix}$			$\begin{bmatrix}71\\1\end{bmatrix}$
4				$\begin{bmatrix}4\\2\end{bmatrix}$		
6						
8		$\begin{bmatrix}6\\2\end{bmatrix}\begin{bmatrix}21\\-1\end{bmatrix}$	$\begin{bmatrix}19\\1\end{bmatrix}$			$\begin{bmatrix}7\\1\end{bmatrix}\begin{bmatrix}10\\-1\end{bmatrix}$
10		$\begin{bmatrix}3\\1\end{bmatrix}$	$\begin{bmatrix}16\\1\end{bmatrix}$	$\begin{bmatrix}14\\1\end{bmatrix}$		
12		$\begin{bmatrix}24\\1\end{bmatrix}$	$\begin{bmatrix}18\\1\end{bmatrix}$			

Figure: 3. A fragment of the information matrix.

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