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AUTOMATIC DISCLOSER OF KNOWLEDGE IN THE FIELD OF INVARIANT SYSTEMS STRUCTURES

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Abstract: Automatic knowledge discloser (AKD) is designed in the field of structures of parametric invariant information converting systems. It allows to reveal in automatic mode the fundamental idea (law, structure) containing in potential form the information on the full set of structures of the class investigated, to build hierarchical forecasting knowledge bases, to synthesize natural classifications and complete deductive theories both of linear, and nonlinear structures of invariant converting systems. These possibilities are provided due to the new approach to equivalent transformation and synthesizing of structures; assumed as a basis of the AKD along with the topological approach. The potentialities, fundamentals of constructing and operation of AKD are considered.
Keywords: invariant measuring system, automatic synthesizing of structures

1 INTRODUCTION

The study of different classes of systems with the purpose of revealing their general structures is a characteristic feature of the present stage of progress in many scientific disciplines. The necessity for developing the general mathematical theories allowing by a formal way to gain and represent fundamental and applied knowledge, build forecasting natural classifications and knowledge bases for engineering systems turns out to be quite acute. The field of measurement information conversion is no exception. Constructing the systems of establishing, generative and stipulated knowledge makes it possible to pass the information conversion theory to a new and much higher level, to improve the teaching process etc.

In 1994 the problem of developing a general constructive theory of structures of measurement and information conversion was put forward by V.A. Skomorokhov and the approach to its solution was proposed [1]. The key conception of a general theory is the idea that within the scope of scientific discipline considered there exists some minimum number of fundamental structures (laws, mathematical models), which contain in the potential form the information about all possible particular varieties of structures of the systems of a class considered. The revelation of generative structures and rules for deriving from them all possible consequences also opens out an outlook of constructing the above mentioned natural forecasting classifications and knowledge bases in the field of information conversion systems (ICS). The creation of fundamentals of the general theory has allowed to set up and solve a basically new problem: to design a so-called *automatic knowledge discloser* (AKD), which for the first time creates in an automatic mode the deductive structural theories of given classes of ICS. Such theories submit in the systematized form the fundamental and applied knowledge in the field of conversion structures, both known, and new.

The paper discusses the fundamentals of AKD construction and operation, its potentialities and results obtained with its help.

2 FUNDAMENTALS OF AKD CONSTRUCTION

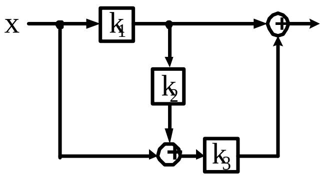
2.1 Design concept

V.A. Skomorokhov proposed in [2] to underpin the theory of information conversion structures and hence the AKD by the philosophical concept of *essence* and to build this theory by studying the paired philosophical category: *essence - phenomenon*. The essence of ICS is unique by definition. It can be cognized, or not, but it always exists. The uniqueness of the concept *essence* allows to build on its basis complete single-valued deductive theories and natural classifications of these ICS by the deduction of all possible consequences from the essence of systems scientifically cognized. All previous classifications and the theories in the field considered started from family–species principle of study, where the separation of systems on families and species was quite subjective. From here, such their deficiencies as absence of generality, completeness and uniqueness result.

2.2 System class considered

AKD is intended for constructing the deductive theories within the limits of a class of parametric invariant ICS. In such systems, the invariance to undesirable parameters of system is ensured only by its structuring under the implementation of specified relations between the values of some system parameters called *identification equations*.

In a class of invariant ICS, two subclasses used to be selected: with *absolute invariance* and with *invariance up to ε.* Figure 1 gives an example of a topological diagram of an ICS, which ensures the absolute invariance to transfer of one of the units with the constraint *a*. or *b*. In Figure 2, topological diagram and relations realizing the *invariance up to* ε are depicted.



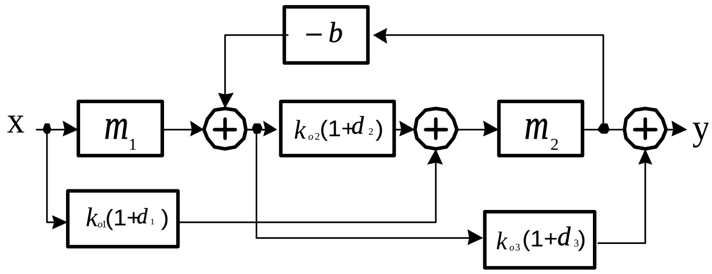


Figure 1. The topological diagram of ICS ensuring absolute invariance at the identification equation *a.* k_1 =-1/β or *b.* k_2 =-1/β.

Figure 2. The topological diagram of the ICS ensuring invariance up to ε at the identification equation *a.* k_{01} β=μ_1 or *b.* k_{03} β=μ_2

2.3 Approaches to ICS design underlying the AKD

Two approaches to designing the ICS structures are known: the topological and the functional (structural) [2].

The topological approach is based on a family–species principle of study. For searching the structures, which have the type of invariance required, 2 kinds of topological approach are used: 1) synthesizing structural alternatives, possible within the limits of initial family's topological diagram of ICS; 2) synthesizing the structure of initial invariant ICS by equivalent transformation.

At the first variety any given physical system is set as initial and its topological diagram, for example in the form of digraph, is constructed. The latter is generalized, i.e. its units (edges) with fixed, (e.g. with single) transfer receive new general notation. For this generalized topological diagram, any coefficient of which now can be variable (controlled), the generalized transfer function is derived. Then, under the determined regulation, all possible combinations of parameters of mathematical units, which ensure a desirable kind of invariance, are found. The number of such combinations also determines the number of invariant ICS structures possible within the limits of the topology specified.

At the second variety the initial is the physical ICS with a desirable kind of invariance. Its structure undergoes all possible equivalent transformations with the purpose of synthesizing new structural alternatives of invariant ICS within the framework of the given class of systems.

The means of equivalent transformations include such topological transformations as N-transformation (graph inversion), I-transformation (inversion of a path in a graph), T-transformation (inversion of a fragment of a graph), substitution methods, etc.

Major merit of the topological approach is its universality. It is suitable for designing ICS both with absolute invariance and with invariance up to ε. The drawbacks of the topological approach when using its first versions considered above are: limitation of synthesis by frameworks of the preset topological diagram, applicability only for *linear* invariant ICS, impossibility of eliciting the generative idea within the framework of an accepted family–species principle of study. The drawbacks of the topological approach under equivalent transformations of the topological diagrams are: the applicability (as a rule) only to linear systems, laboriousness of deriving of identification equations in case of applying most popular I-transformation, and the limitation of possibilities of equivalent transformation by means of pairwise permutations of adjacent elements.

The functional approach is based upon the idea of considering the paired category "essence - phenomenon". The essence of information conversion processes is represented by means of the mathematical laws of information conversion. Eliciting of these mathematical laws (fundamental structures) is also the basic research problem within the framework of the functional approach. As the consequence from these laws (structures) one receives all possible structures of a considered class and builds natural forecasting classifications and knowledge bases.

In contrast to the topological approach, using common structural representation of a ICS, which corresponds to composition of elementary mathematical conversions in it, the functional approach operates with specially constructed structural representations, so-called the functional structures (diagrams) with units, whose functions correspond to the role of these units in providing desirable functional features of ICS. Among these units, there is a unit with the function F_{nd}, to which the system should be invariant; a unit with the function F_d, coincident with the one of desirable invariant ICS, standard units with functions F_s, etc. The means of transformation of structures preset in language of mathematical units, in functional structures is designed.

For an illustration in Figure 3, two functional structures of invariant ICS are presented, which correspond to the topological diagram of invariant ICS introduced in Figure 1, when the relations *a* and *b*. shown under the same figure are fulfilled.

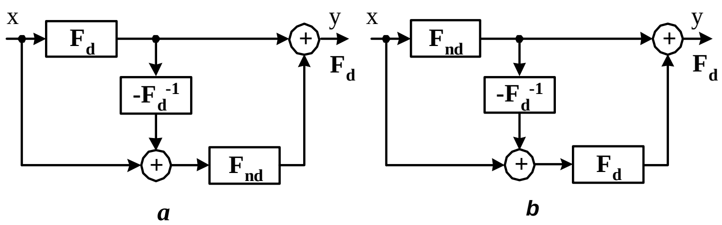


Figure 3. Functional structures of invariant ICS

The representation of invariant ICS structures in the language of function spaces has a series of essential advantages before representation of the structures in the language of elementary mathematical units.

First, the position of functional units (F_d, $F_{nd,}$ F_{nd}^{-1}) of functional structure (Figure 3 *a* and *b*) determine uniquely the structural properties of the system, while under the topological approach the assignment of only a topological diagram is insufficient for such determination - the identification equations need to be specified too. Due to such uniqueness, the functional approach allows to construct explanatory, descriptive structural theory of invariant ICS.

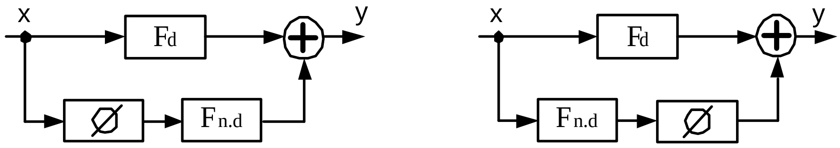
Second, for equivalent transformations of invariant ICS functional structures, the axiomatic body of mathematics of functional space is applicable operating not only with linear, but with nonlinear functional structures as well. This allows to build the *general* structural theories both of nonlinear and linear invariant ICS.

Third, the representation of invariant ICS structures in the language of function spaces has opened an opportunity of formal synthesizing both generative, and stipulated functional structures. Thus, by minimization of the number of components of initial functional structure using the convolution methods it turned out to be possible to synthesize *fundamental* functional structures of invariant ICS containing the information on all structures of systems of a preset class. On the basis of methods of breeding it was possible to derive formally from the synthesized fundamental structures the complete sets of the physically realizable stipulated invariant ICS structures. Thus, for invariant ICS structures described in the language of function spaces, it proved to be possible constructing the general deductive structural theory of nonlinear (linear) invariant ICS.

For the functional structures of invariant ICS depicted in Figure 3 *a* and *b*, generative functional structures invariant ICS are introduced correspondingly on Figure 4 *a* and *b*. Structural properties of these generative structures are different. In particular, while the transfer function of uninvariant unit F_{nd} in structure shown in Figure 4*a* should have no additive error, no limitations should be imposed on F_{nd} in the structure in Figure 4*b*.

And, at last, the laboriousness of equivalent transformations within the framework of the functional approach is drastically reduced, owing to excluding the identification equations from consideration.

So, at the functional approach to synthesizing and equivalent transformations of invariant ICS the source is the law of constructing (generative structure) invariant ICS and this law is represented in language of function spaces as functional structures. Furthermore the means of equivalent transformations used at the topological approach is supplemented by the means based on axioms of a function space.



a ***b***

Figure 4. Generative functional structures of invariant ICS

Nevertheless, despite all listed above advantages of the functional approach, in a basis of the AKD in the field of parametric invariant ICS, both approaches are put: the topological, and the functional. This is because within the framework of the functional approach, the synthesis of fundamental functional structure is possible only for a subclass of ICS with absolute invariance.

2.4 Structure of AKD

The structure of AKD, which reflects the interplay of topological and functional approaches, as well as the interconnection of major blocks inside each approach, is illustrated by Figure 5. The blocks referring to the topological approach are indicated by circles and rounded orthogons, while the ones referring to the functional approach - by rectangular figures. Table 1 gives the destination of each block.

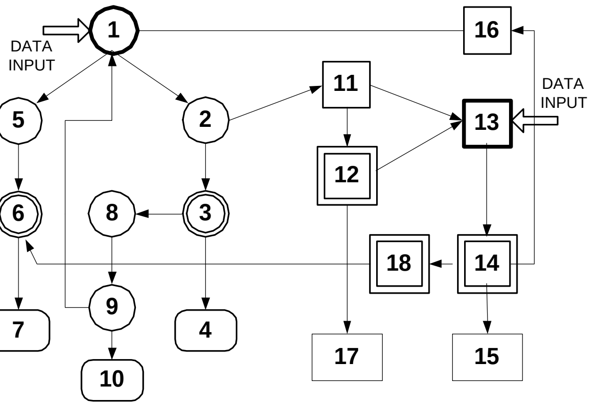


Figure 5. The interconnection diagram of the basic blocks in AKD

3 FUNCTIONS OF AKD

3.1 Synthesizing fundamental knowledge

Synthesizing fundamental functional structures of ICS with absolute invariance is realized in AKD by the following chain of blocks: 1→2→11→13. Block 1 inputs into AKD the topological diagram of ICS (as in Figure 1). On the basis of block 2, identification equations for ICS with absolute invariance are calculated with subsequent synthesizing on their basis invariant ICS structures. The latter are transformed by block 11 to functional structures as in Figure 3. These structures by means of convolution methods (block 13) are minimized and converted to generative structures as in Figure 4, from which the fundamental functional structure of the most general view (Figure 4*b*) is later derived. The fundamental structure (Figure 4*b*) reflects a new, obtained by AKD, structural law of invariant information conversion in ICS with absolute invariance, which can be treated as the law of exclusion during the conversion of a transfer function of non-invariant unit (F_{nd}).

It must be noted, that V.A.Skomorokhov has earlier derived the mathematical law of invariant information conversion in the following form

$$F_d * (F_{nd} * F_{nd}^{-1}) = F_d \,, \qquad (1)$$

starting from the analysis of the axioms of a function space. From (1) under different definitions of abstract operation (∗) (adding, multiplying, superposition) the set of fundamental functional structures of invariant ICS, including the structure shown in Figure 4b, can be derived.

Table 1. List of AKD blocks

Block's label	Designation
1	Input of an initial topological diagram of ICS
2	Synthesizing a structure of ICS with absolute invariance
3	Synthesizing a forecasting knowledge base of structures of ICS with absolute invariance
4	Forming the structural theory of linear ICS with absolute invariance
5	Synthesizing structure of ICS with invariance up to ε
6	Synthesizing a forecasting knowledge base of structures of ICS with invariance up to ε
7	Forming the structural theory of linear ICS with invariance up to ε
8	Synthesizing the generalized generative topological diagram of linear ICS with absolute invariance
9	Synthesizing a forecasting knowledge base of the generalized generative topological diagrams of ICS with absolute invariance
10	Forming a heuristic deductive structural theory of linear ICS with absolute invariance
11	Synthesizing functional structure of invariant ICS with absolute invariance
12	Synthesizing a forecasting knowledge base of functional structures of ICS with absolute invariance
13	Synthesizing fundamental functional structure of ICS with absolute invariance
14	Synthesizing a forecasting knowledge base of functional structures of ICS with absolute invariance
15	Forming the deductive general structural theory of nonlinear (linear) ICS with absolute invariance
16	Synthesizing a forecasting knowledge base of the topological diagrams of invariant ICS
17	Forming the structural theory of ICS with absolute invariance
18	Forming a forecasting knowledge base of structural diagrams of ICS with invariance up to ε

For each particular functional structure of invariant ICS AKD synthesizes in the automatic mode fundamental or generative structure, defining the essence of either class (subclass), or a kind of invariant ICS, correspondingly. This possibility of AKD will be utilized while systematizing invariant ICS structures.

Systematization of invariant ICS structures. AKD solves the problem formally and precisely. It is carried out as follows. Two functional structures considered are entered into AKD. For each of them by means of the block 13, the generative structures of invariant ICS are synthesized, which are compared later. At concurrence of the generative structures a conclusion is made that the source functional structures of invariant ICS refer to the same subclasses (classes) or kinds of invariant ICS and in case of their discrepancy - to different ones.

Constructing the general deductive structural theory of ICS with absolute invariance. From the fundamental functional structure of invariant ICS (Figure 4b) derives formally a complete set of nonlinear (linear) structures of invariant ICS by means of the methods of breeding above mentioned and closed group N-, I- of transformations of a symmetry. The deduction methods are ranked in advance depending on the limitations on the nonlinearity of the function units participating in the equivalent transformations. Primarily, for equivalent transformations the methods are used, which do not impose limitations or impose weaker ones. Due to such ranking, AKD constructs functionally complete network of interconnected nonlinear (linear) structures of invariant ICS beginning with the fundamental structure (Figure 4b).

Synthesizing natural classifications of structures invariant ICS. AKD in automatic operation mode has constructed natural hierarchical classifications of nonlinear (linear) functional structures of ICS with absolute invariance: 1) starting from earlier detected the structural law of invariant information conversion (as in Figure 4*b*); 2) based on the group of symmetry transforms obtained.

3.2 Synthesizing applied knowledge

In the practice of invariant ICS design, it can be important to make available the novelty of designed structures, in particular, when within the framework of a preset ICS class the registered structures exist. These structures can be bypassed by synthesizing the functionally complete set of feasible equivalent (to a prototype) invariant ICS structures and by choosing most suitable.

It is possible to augment the number of patentable structures synthesized by constructing the heuristic deductive theory of invariant ICS within the framework of the topological approach. It can be constructed as follows. The initial topological diagram of invariant ICS, e.g., shown in Figure 1, is generalized by replacing all its units (edges) with single transfer by ones with variable coefficients [2]. From the generalized topological diagram obtained in this way, one derives by means of the topological N-, I-,and T-transforms additional 5 equivalent diagrams. From these 6 generalized topological diagrams of invariant ICS, the AKD has derived more than 50 structural versions of invariant ICS. Naturally, this set is not complete because of initial heuristics.

3.3 Interaction of topological and functional approaches in AKD

As it was noted, the structure of AKD is selected so that it combines the merits of both approaches and countervails their deficiencies.

Thus, within the frame of topological approach, there is an open question of selecting the initial topological diagram of invariant ICS (block 1). At the same time, in the AKD subsystem working within the framework of the functional approach, there is a functionally complete base of topological diagrams of invariant ICS (block 16). It can be used for selecting initial topology in the AKD subsystem, working within the framework of the topological approach. Here, there is a link of the blocks 16 and 1. Entered into the block 1 from the block 16, the topological diagrams can be used also for synthesizing ICS with invariance up to ε (blocks 1→5→6→7), as well for constructing the heuristic deductive theories of ICS with absolute invariance (blocks 1→2→3→8→9→10).

Besides, there is also another path of enlarging the topological diagram base of the ICS with invariance up to ε. It was found, that some combinations of the topological diagrams of ICS with absolute invariance can generate topological diagrams of ICS with invariance up to ε. This property of the combined diagrams of invariant ICS will be exploited in AKD for replenishment of the forecasting knowledge base (block 6) of topological diagrams of ICS with invariance up to ε.

4 CONCLUSION

The AKD as the developer of the deductive structural theories of invariant ICS, can be a basis for creating global base of fundamental and generative knowledge about structures of invariant ICS. The hierarchical knowledge bases for the first time can be constructed not by a classic family – species principle, but by a promising principle based on the study of a paired category “essence-phenomenon” (“the law - particular regularities”), which allows to build complete general deductive theories. AKD due to the generalization algorithms, embedded, is capable to become the generator of fundamental ideas in the field of invariant information conversion. It can essentially promote the progress in measurement and instrumentation by way of discovery and application of alternative and optimal structures for constructing sensors and measuring devices.

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