Method of dynamic programming on the basis of dekartovozamknuty category with the qualifier of subobjects

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Abstract[1]

Formulation of the problem: when designing an information analytical program system, there arises the problem of representing the domain and its semantic description, expressed by formal models of different levels of the abstract formal system making up the structure.

Purpose: increase the efficiency of processing and transmission of data and knowledge, taking into account the dynamic changes in the formal domain model from the consistency of the structure of the abstract formal system.

Results: the method of transition to quantitative multivariate description of information processes and application of the requirements of ISO / IEC 15288, using the provisions of category theory and set theory as a formal apparatus for describing information objects for the modeling, processing and transfer of data and knowledge. The possibility of constructing a number of identical formal models of algorithms for controlling the integrity of the structure of initial processes is shown, in case of violation of which "external" control is required.

Practical value: the generalized scheme of the data store and knowledge of the analytical information program system is constructed, as an abstract formal structure, considered on the example of the formation of the personnel reserve.

1. Problems of use of formal methods of modeling of processes for design of information analytical program system

Due to the above, at design of information analytical program system (IAPS) the problem of elimination of a semantic gap between idea of subject domain and means of her formal specification is particularly acute. One of traditional ways of reduction of a semantic gap is increase in level of abstract modeling [6]. For example, application of formal language of the theory of categories allows to reveal and describe communications between objects, by means of morphisms, keeping their logical and topological properties in time and in space both in one category [4,5], and between categories [6].

Identification of a set of data with maintaining their semantics in IAPS demands additional formalization and structuring the formed data and knowledge in the form of content, considering at the same time subject-oriented orientation. At the same time, it is possible to use provisions of the theory of categories and the theory of sets as the formal device of the description of information objects for modeling, processing and data transmission and knowledge.

In general, to formulate accurate definition for formal methods of modeling it is problematic. It is caused by the following contradictions:

1. Program compilations, interpretations, modeling methods, on a basis, which they are under construction, are formal.

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2. On the contrary, methods of "formal modeling" apply methods of proofs and reasonings, the mathematical designations accepted in mathematics.

At inspection of subject domain many data and knowledge for which timely processing and transfer to IAPS is necessary are formed. These data are described in a natural language, not assuming expressions by language of traditional mathematics. In this case, it is expedient to use ontologic aspect in the analysis of subject domain and gnoseological – in the analysis of knowledge of this reality.

In case of use of a mathematical apparatus there are considerable difficulties with qualitative data as not real objects, but mathematical descriptions of real objects, that is their abstractions are considered. It allows forming multidimensional display of subject domain in the form of formal algebraic structure or calculation in a look: $\Phi AC = \langle G, R, O \rangle$ where a set of *G* (carrier) with the set of the relations of *R* set on him and a set of operations *O*. In particular, ΦAC with an empty set operation *O* is model, and with an empty set of the relations of *R* – algebra. At the same time, the consistency of model provides the rule of formal logic on a set of *G* where the set of the relations of *R* is a set of predicates of *P*, that is $R \equiv P$.

For further consideration of the mathematical description of real objects and their information processes, we will enter the following designations:

$fi \in F$, i=1,…, n where – it is possible to designate as a set from possible conditions of IAPS;

$qi \in Q$, i=1,…, m, where Q – final number of conditions of a program system;

vi, – the information process intended for design of IAPS at a given time;

V – a set of information processes for creation of IAPS.

Transition of IAPS from one state in another it is shown by $F_o V \to F$ display function *L*,

$$L: F_o V \to F, \quad (1)$$

i.e. *l (fi, vi)* will display the following condition of IAPS after performance of a stage of creation of vi and it can be presented by a formula,

$$fi+1 = l(fi,vi), \quad i=1,...,n. \quad (2)$$

At the same time, it is possible to reveal a set of conditions of IAPS with a recurrent formula, which for each couple of objects of *fi* and *fj* the set of morphisms, Hom (fi, fj) are formed by a class of objects, for each couple (morphisms), for example, of $g_q \in$Hom (fi, fj) and $lq \in Hom\ (fj, fk)$ where their composition by $gq \circ lq \in$ Hom is determined (fj, fk). I.e. conditions of IAPS form category of sets which consists of objects [6,7].

Thus, at formalization of subject domain with use of provisions of the theory of categories, we can describe all relations of objects among themselves; it does not give the chance to claim about functional stability of behaviour of IAPS. At the same time, development of set-theoretic model of business processes of process of the agreement is necessary.

2. Set-theoretic model of process of the agreement

We will consider creation of model of process of the agreement on the example of formation and management of a personnel pool of the enterprise.

The matter is very relevant now, the most demanded is increase in efficiency of processing, transfer and use of data and knowledge for a personnel pool by multilateral consideration in dynamics of changes of all components. This efficiency is important as for the enterprises possessing a personnel pool and for the organizations making investments in formation and maintenance of a personnel pool. Creation of model of functioning of IAPS of management of a personnel pool requires use of provisions of system engineering. There is a problem connected with use of two independent business processes: the organization interested in realization of a personnel pool and recruitment agency (for example, educational institutions).

Using the formalization offered in [1,2,3] ISO/IEC 15288 standards "System engineering" each stage it can be presented in the form of category of processes, at the same time process of the agreement consists of process of acquisition and process of delivery, and causes and effects can be used symmetrically.

We will apply basic provisions of the theory of categories to modeling of this process. We will use the following designations: processes of the agreement of PS processes of acquisition of PS_{pr}, processes of delivery of PS_{po}.

We will allocate processes of the agreement of *PS*, acquisition of PS_{pr} and delivery of PS_{po} to separate category and subcategories which consist of the purposes of process of $PS^1_{pr}=\{pr_1{}^1\}$,, activity of process of $PS^2_{pr}=\{pr_1{}^2,..,pr_8{}^2\}$ and result of $PS^3_{pr}=\{pr_1{}^3,\ldots,pr_7{}^3\}$, is similar for delivery process: is more whole than process of $PS^1_{po}=\{po_1{}^1\}$, activity of process of $PS^2_{po}=\{po_1{}^2,...,po_9{}^2\}$ and result of $PS^3_{po}=\{po_1{}^3,\ldots, po_7{}^3\}$ [11].

As a result of the relation are representable in the form of an ordered set:

$$PS = \langle PS_{pr}, PS_{po} \rangle = \left\langle \left\{ PS^1_{pr}, PS^2_{pr}, PS^3_{pr} \right\}, \left\{ PS^1_{po}, PS^2_{po}, PS^3_{po} \right\} \right\rangle \quad (3)$$

According to information approach of A.A. Denisov [10], at formalization of subject domain, categories of objects and the relation between them are primary. Using above given and the researches presented in [10,11] the model of process of the agreement is representable categories of objects of this subject domain and a set of the relations between them.

3. Method of dynamic programming concerning the theory of topos

Using provisions of the theory of categories, we will consider category of sets by her decomposition satisfying to provisions a top wasp.

For this purpose we will present top wasps as category of sets which has additional properties, for example, of decomposition of categories [12]. By formalization a top wasp, according to the ISO/IEC 15288 standard, applicable process of the agreement, using consecutive application of a ruler or a set of lines of transformations, we receive the chart provided on the figure 1.

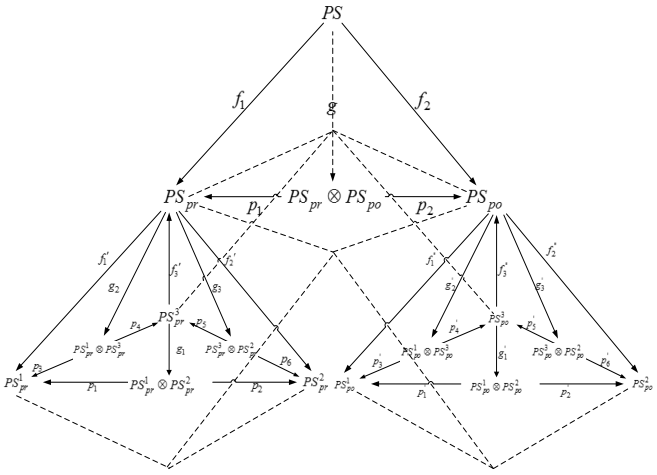

Fig. 1 The categories of process of the agreement presented according to the theory of topos

By consideration of processes of the agreement where process of acquisition of *PSpr*, process of delivery of *PSpo*, each of which on the basis of earlier given conclusions, we will present in the form of categories, interactions of objects can be presented by set of Cartesian products:

$$PS_{pr} \otimes PS_{po} = \langle PS^1_{pr} \otimes PS^2_{pr}, PS^{'1}_{pr} \otimes PS^{'3}_{pr}, PS^{'3}_{pr} \otimes PS^{'2}_{pr}, PS^1_{po} \otimes PS^2_{po}, PS^{'1}_{po} \otimes PS^{'3}_{po}, PS^{'3}_{po} \otimes PS^{'2}_{po} \rangle. \quad (4)$$

Here $\otimes$ – Cartesian product, which reflects interaction of objects by any rule.

It is obvious that process of the agreement in this case can be presented by a formula:

$$PS = \langle (PS_{pr} \otimes PS_{po}), (PS_{po} \otimes PS_{pr}) \rangle \quad (5)$$

Carrying out the given reasonings for process of acquisition of *PSpr* are higher, according to the ISO/IEC 15288 standard, process of acquisition of *PSpr* can be presented by a formula:

$$PS_{pr} = \{\langle (PS^1_{pr} \otimes PS^2_{pr}), (PS^2_{pr} \otimes PS^1_{pr}) \rangle, \langle (PS^1_{pr} \otimes PS^3_{pr}), (PS^3_{pr} \otimes PS^1_{pr}) \rangle, \langle (PS^3_{pr} \otimes PS^2_{pr}), (PS^2_{pr} \otimes PS^3_{pr}) \rangle\}. \quad (6)$$

Similar to process of delivery it can be presented by a formula:

$$PS_{po} = \{\langle (PS^1_{po} \otimes PS^2_{po}), (PS^2_{po} \otimes PS^1_{po}) \rangle, \langle (PS^1_{po} \otimes PS^3_{po}), (PS^3_{po} \otimes PS^1_{po}) \rangle, \langle (PS^3_{po} \otimes PS^2_{po}), (PS^2_{po} \otimes PS^3_{po}) \rangle\}. \quad (7)$$

Thus, interaction between the processes given above presented in the form of categories can be described in the form of a functor based on the Cartesian products given above.

So, on the basis of stated and according to the ISO/IEC 15288 standard, in category *PSpr* any object will be displayed in category *PSpo* objects, the following functor:

$$f \in \mathrm{Hom}(PS_{pr}, PS_{po})$$
$$\{f \in \mathrm{Hom}(PS^1_{pr}, PS^1_{po}),\ f \in \mathrm{Hom}(PS^2_{pr}, PS^2_{po}),$$
$$f \in \mathrm{Hom}(PS^3_{pr}, PS^3_{po})\}$$

In addition, display of objects in category *PSpo* is described:

$$g \in \mathrm{Hom}(PS_{pr}, PS_{po})$$
$$\{g \in \mathrm{Hom}(PS^1_{pr}, PS^1_{po}),\ g \in \mathrm{Hom}(PS^2_{pr}, PS^2_{po}), g \in \mathrm{Hom}(PS^3_{pr}, PS^3_{po})\} \quad (8)$$

In addition, the relation - "Cartesian product" as we will consider it as a new object is similarly described:

$$f \in \mathrm{Hom}(PS_{pr} \otimes PS_{po}, PS_{po}),$$
$$g \in \mathrm{Hom}(PS_{po}, PS_{po} \otimes PS_{pro}), \quad (9)$$
$$f \circ g \in \mathrm{Hom}(PS_{pr} \otimes PS_{po}, PS_{po} \otimes PS_{pro}).$$

We come that the given objects can be described by interaction of functors. In this case we can use Descartes's square where the composition of two processes (fig. 1) given above is direct display of the given process of the agreement to result. The result of process can be considered and as composition of the work of the purposes and deyatelnost, by receiving one more "triangle" where irrespective of an order of performance of the sequence of operations and displays the result will be identical.

We come to the quantitative description of information processes within the ISO/IEC 15288 standard. As a result the given recursion (formula 2) allows to organize finding of an optimal solution of subtasks recursively. Making the sequence of actions given above, finally, we

come to an opportunity to connect among themselves stages of life cycle of IAPS.

Carrying out consistently decomposition or composition of objects in the form of commutative triangles, further to Descartes's squares, receiving as a result the Cartesian polyhedron, we come to self-organization of structure of processes of the agreement.

As a result we obtain many data and knowledge which is expedient for storing in uniform information storage, for reduction of dissociation of data and knowledge by transfer and processing. The received result can be used as an analog of the main recurrence relation of a formal basis of a method of dynamic programming (the principle of optimality of Bellman) since on each step of creation of the specified IAPS some optimum control in the assumption of optimality of all subsequent steps is chosen [9].

4. Information support of the considered subject domain on the basis of storage of data

With use of set-theoretic models of processes of the agreement the scheme IAPS on the basis of storages of these (fig. 2) has been constructed.

IAPS is characterized by the following parameters: use of various database management systems (Oracle, MySQL and тд.), modern means of storage (Data Warehouse), application of expeditious analytical processing (OLTP – Online Transaction Processing, OLAP – On-Line Analytical Processing), means of data mining (Data Mining), etc.

As a result of use of IAPS users (the person the making decisions (PMD), analysts, experts) receive the effective instrument of carrying out selection, the analysis of candidates for a personnel pool and also formation of data on a personnel pool presented in the tabular and graphic style. This IAPS provides the centralized collecting, storage, updating, structurization, systematization, integration, processing and the consolidated analysis of diverse these candidates of a personnel pool.

In IAPS subsystems answer the principles:
– razvivayemost;
– construction blochnost;
– certain independence of separate subsystems and their databases (D);
– corrections of a functional part, etc.
As specification for a DB serves the reference book by these candidates where there is full information on the candidate, the name of the table in which indicators, a code of group to which the indicator belongs are stored the indicator is checked for sub indicators, a code of units of measure of an indicator, frequency of representation of an indicator and the field with the comment for an indicator. The knowledge base contains rules of an algorithm of work of the program, described by means of categories of sets.

Act as external data sources: public authorities (The Ministries of Labour and Social Protection of the population, local city administration and the area, etc.), the interacting organizations (jobcenters of the population, Higher education institutions, Susa, the enterprises, etc.), higher bodies of management (holdings, corporations, etc.).

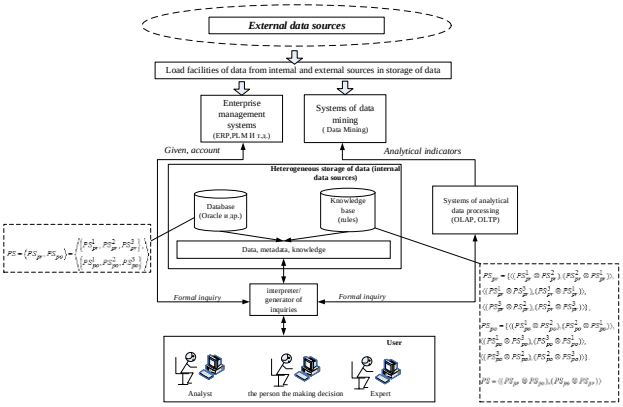

Fig. 2 The generalized scheme of storage of data of information analytical program system

Use of the formal description of information objects in language of the theory of categories, helps to increase a formalizovannost of subject domain, opening new opportunities of identification of problems.

When forming storage of data the separate objects expressed by categories of users, categories of program modules can be considered, the relations between them will be defined by functors. It allows to store data and knowledge in the uniform place. Thus, the problem of dissociation of data and knowledge during the processing and transfer is solved.

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Conclusion

The rule of synthesis of the self-organized structure of process of the agreement based on consecutive decomposition – composition of objects processes in the form of commutative triangles in Descartes's squares and in the Cartesian polyhedron is offered further. We can say that for all elementary structures rules of formal logic, parametrical control of a condition of processes remain. The structure of process of the agreement is synthesized by the scheme given above.

The specified method of transition to the quantitative monovariant description of information processes and applications of requirements of the ISO/IEC 15288 standard allows to connect each stages of life cycle of IAPS, way of introduction of a recursion, finding of an optimal solution of subtasks recursively, making the similar sequence of actions.

References

1. Formalization of the subject area with the use of tools that support the standards / GG Kulikov, VV

Antonov, DV Antonov // Bulletin of the USATU: Nauk. the journal Ufimsk. state. aviats. tech. un-ta UGATU. 2012. Vol. 16. No. 3 (48). Pp. 42-52.

2. Formal domain model based on fuzzy relationships. V. Antonov, G. G. Kulikov // International Journal of Software Products and Systems. Tver. 2011. № 2 (94). Pp. 48-51.
3. Construction of a formal domain model using fuzzy clustering / GG Kulikov, V. V. Antonov, D. Antonov // Herald USATU: scientific. the journal Ufimsk. state. aviats. tech. un-ta. UGATU. 2011. T. 15 number 5. 2011. P. 3-11
4. Chomsky, N. "Language and the problem of knowledge" [Text] // Vestnik MGU: sb.nauch. tr. Moscow, 1996. Issue. 6. P. 157-185
5. The method of designing an adaptive software system based on the methodology of the category formal model of an open domain / V.V. Antonov // Bulletin of the USATU: Nauk. the journal Ufimsk. state. aviats. tech. un-ta UGATU. 2015. Vol. 19. No. 1 (67). Pp. 258-263.
6. Antonov VV Semantic and mathematical language for describing the structure of intellectual system based on fuzzy logic [Text] / Antonov VV, Kulikov GG // International Journal "Software products and systems." Tver. 2011, No. 3 (95). Pp. 33-35.
7. Method of constructing a mathematical model of a domain / VVAntonov, GG Kulikov // Vestnik SSEU: nauch. journal. Samarsk. state. econ. un-ta. 2010. № 5 (67). Pp. 10-14.
8. ISO / IEC / IEEE 15288: 2015 System and software engineering - System lifecycle processes
9. Bellman R., Zade L. Decision-making under vague conditions ", Mir: Sat. sci. tr. Moscow, 1976. pp. 172-215
10. Kulikov G. G., Antonov AA, Shilina MA, Fakhrullina A.R. Structuring the content of the area under consideration for further intellectual analysis. An example of the formation of structured content OPS / G. Mr. Kulikov, Vladimir Antonov, M. A. Shilina, A. R. Fahrullina // Journal of St. Petersburg, "Information and Control Systems" SUAE number 2. 2016 -C. 95-100.
11. Method of subject-oriented classification and system modeling of weakly formalized information flows in industrial automation systems / G.G. Kulikov, V.V. Antonov, D.V. Antonov, F.F. Shingarev // Herald of SUSU. A series of "Computer technologies, management, radio electronics". - 2016. - T. 16, No. 2. - P. 116-130.
12. Goldblatt R. Toposes. Moscow: Mir, 1983