Dualism for CAD-system creation based on natural-intellectual representation

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Abstract. When developing difficultly deterministic software solutions of automated systems, control over the algorithmization and structurization of the task should lie outside the control of the formal interconnection of operators and data. The design of software systems should be controlled from the external control area both over the algorithmization and structuring, and over the autonomous independent consideration of the element. The fact of the possibility of arbitrary coordination of the structural elements of the software system is called the dual representation. The integrative role between independent design elements is assigned to the natural – intellectual interface, which is able to provide a dualism of perception of the elements of the information space both as structurally related and as independent.

1. Introduction

During creation of any software product, the connectivity of the automatic and informal components of the development environment plays a decisive role. Such complexes are appropriately called automated systems for designing and Lifecycle Management of a software system. In them, the system-forming core is always assigned to the informally acting "human factor». The use of automated systems frees the developer from the coordination of details, allowing him to specifically focus on the creative aspects of the design process [1]. Simultaneously with this attitude, there is a clear representation of automated systems as systems of "accumulation of computational knowledge about machine methods of control theory" [2].

That is, based on the concept of automation, we can assume that the universe of the life cycle of an automated system must include elements of creatively meaningful control. Confirmation to it is an opportunity to provide responsibility for the quality of the results and their estimated reliability. As clearly emphasized in [3]: "the problem of the reliability of the results of solving problems lies between the real world and theoretical knowledge, and the mediator between them is a man." Indeed, the contradiction between the formal and qualitative representation of the real problem leads to a decrease in the content characteristics of the software product throughout its life cycle. This process leads to a decrease in the reliability of operation and deterioration of the comfort of the interface between the human and software sides of the automated process.
2. Previous Work

Of particular importance is the sense of order, consistency, ranking, alternation, etc. in the software part development of the automated systems for making quality decisions. I. Prigogine noted that the discovery of order in nature gives rise to a sense of intellectual confidence [4]. Such a rule is closely coordinated in the human mind with the need to control the manageability of the information content of the project and, therefore, with its successful completion. The importance of supporting the controllability of information content at one time gave rise to the emergence of such well-known software and hardware solutions such as data encapsulation and polymorphism [5].

When forming the development plan of a complex CAD it is important to consider a set of obstacles in a way of successful implementation of the project. First of all, two aspects are important: knowledge management and decision-making.

In [6], a knowledge graph was proposed for the structural storage of new ideas arising in the process of solving geophysical problems. The knowledge graph provides a structural method for storing a person's existing knowledge, the relationships between which are expressed graphically.

A significant problem in the implementation of integrated automated systems is a risk factor in the decision to refuse or continue the project. An analysis of factors influencing the risk of a project in a multi cultural aspect is given in [7]. The achievement of the required goals in the creation of complex CAD is associated with the formation of motivational strategies of developers, which was presented in [8]. This article emphasizes the importance of motives in making decisions about the development of the project. In [9], the necessity of using the psychological theory of dual processes as a decrease in programming errors is shown. When mentioning the theory of dual processes, it is necessary to single out one of the main papers [10] on this topic.

3. Problem definition

To develop a robust CAD algorithm, it is important to investigate two main problems: the creation of separate (autonomous) algorithmic solutions, as well as the formation of clear and controlled links between the functional elements of the algorithm. It is important to consider each of these problems in terms of perception of a set of information items of an algorithm, its local parts and results. When developing hard-to-determine software solutions for automated systems, the allocation of procedural and structural links should not be uniquely correlated with the formal requirements for the project, as well as with the established tradition of CAD analysis and design.

The factor of arbitrary coordination of the structural elements of the program system is called the dual representation. The organizing link between the declared independent elements can only be a natural – intelligent interface that is able to provide a duality of perception of the elements of the information space. And the perception of such objects should take place simultaneously both for structurally related elements and for independent ones.

The semantic goal of creating such a duality of perception is that when making a local decision, do not focus on existing, visible, definite connections between the parameters of the task. On the contrary, it is required to consider each of those facts that even tentatively can influence the result. This is possible only in the case of maximum separation of information elements from each other. Considering them outside the network of interdependencies, the designer gets the prospect of changing the order of their use in the structure of the system. Creating the conditions for generating new connections helps simplify the search for new ways and combinations of local solutions. This is achieved through a sense of control over an arbitrary change in the content and structure of the information space of software solutions for the life cycle of automated systems.

4. Methods

4.1. Intellectualization of the information space

It is possible to illustrate the factor of the dual representation of elements of the information space of the system as follows. Figure 1 shows the traditional way of perception and control on its basis over the
structural dependence between the algorithmic elements AE1 and AE2. A naturally intelligent interface keeps track of the existing connection between the specified elements. The control results here will be the general parameters for the whole complex of elements AE1 and AE2, as well as the relationship between them.

![Figure 1. The traditional model of control over the elements of the algorithm.](image1)

The order of the naturally intelligent dual representation is shown in Figure 2. The perception of the complex of the elements AE1 and AE2 splits into its individual components. Here, the autonomous algorithmic elements AAE1 and AAE2 are virtual images of the elements AE1 and AE2, which should be perceived outside the direct connection with each other, as well as outside the connection parameters in the structure of the algorithm. At the same time, the control of links within the structure of the algorithm, which corresponds to the traditional algorithmization approach, is preserved.

![Figure 2. The dual representation model of the elements of the algorithm.](image2)

Thus, the dual representation of the elements will allow observation over the information space at once in two planes: the traditional structural-algorithmic and autonomous-chaotic. In this case, any element under study will be able to perform the role outside its pre-limiting structure or meaningful value. To the point that even categorical boundaries can be overcome. The function can be perceived as a static value, and the data structure – as a functional element. The proposed strategy has a number of
advantages. First, non-contiguous elements can be evaluated together. Secondly, there is the opportunity to build a new parallel or complementary with the introduction out of the project elements or parts.

4.2. Experiment

Verification of the proposed dual representation method requires experimental confirmation of its success. The positive result of the application of this method can ensure, firstly, the separation of the elements of the designed structure from each other. Secondly, the study of the properties of element relationships within the context of a software solution. The experiment should be based on the introduction into the studied ordered set of algorithm elements of a certain complement whose behavior is conditionally known.

When carrying out an experiment we expect to receive confirmation of the fact on need of any coordination of structure members of an algorithm that will give us advantage of comfortable consideration of all range of information space of design.

The dual representation method affirms the primacy of informal and natural descriptions and designations, as they are easier to perceive and use. Some researchers understood this as follows: “although the steps we follow in formalizing the strategy may appear mechanical, it is not an automatic procedure... [it] requires a great deal of real world knowledge and intuitive understanding of the problem” [11]. The main purpose of the method is to generate, diffuse and implement new ideas, as well as to evaluate the potential of some elements of the system structure in comparison with others.

Consider the structure of the algorithm for reading data with their subsequent conversion, and then placing the transformed file primitives into a database (DB). The structure of this algorithm is rather trivial (Fig. 3). However, it does not often happen that the developer focuses on non-adjacent elements of the structure of the algorithm. In other words, the direct link “File” <-> “DB” (Fig. 3) does not exist, and it, accordingly, drops out of the consideration of the designer. In contrast, the strategy of the dual representation method declares an arbitrary relationship between the elements having the ability to exist. Then a separate analysis of possible pair relations takes on the meaning, for example: “File” <-> “DB”, “File” <-> “Converter”, “File <-> Losses”.

![Figure 3. Simplified structure of the data converter algorithm.](image)

The analysis of the “File” <-> “DB” pair outside the algorithmic interaction scheme makes it possible to get the idea of designing an additional element “Write to file”. In the structure of the algorithm (shown in Figure 3), the “File <-> Converter <-> DB” complex is analytically perceived in the mind as the following sequence: reading a file, converting reading information, placing data into a database. The traditional perception of the algorithm allows you to detect and implement an algorithmic element that is outside the analytical channel of the algorithm structure.

Thus, the strategy of the dual representation method of information elements helps to find an important additional functional element, by forming an associative set to the name “File”. It is important to note that the function “Writing” proposed as an additional element of the algorithm, looks like a kind of “mirror” reflection to the traditional meaning of the designation “File” as “Reading” in the “File <-> Converter <-> DB” complex.
The meaning of the function “Writing” in addition to visual, can be extended associatively. As a result, there is an idea to implement the function of data quality control "DB". The appearance of this algorithmic element is dictated by the need to establish a correspondence between the primitives of the data file and the corresponding elements of the "Database". Such a correspondence will ensure the coordination of the original data D and twice converted data D': when reading with subsequent conversion, as well as when writing (or converting and further writing) data to a file (Fig.4).

![Figure 4. Information model for the coordination of the original and converted data.](image)

Now it is possible to compare directly D and D'. Determination of the need to make corrections to the "Converter" is carried out by the result of the comparison. Firstly, it enables processing of single isolated information, that is, data primitives. Secondly, it allows to take into account the result of the algorithm at an early stage of its creation, and not during debugging and testing.

In both cases, taking into account the separate data of the information space will allow the developer to focus on the internal properties of the studied functionality. Such an autonomous element is deprived of the properties of interdependence. Instead, the designer’s consciousness turns out to be in much more favorable conditions, due to the acquisition of the possibility of forming any arbitrary ideas and means of their realization. In addition, we get the opportunity to improve the system by informally relating the elements of the algorithm to each other. This will make it possible to introduce additions and inserts into the project, as well as to replace some elements with others, clarifying the solution. The dual-representation method seeks to generate patterns of "pure thinking", outside the formal scope of abstraction, in order to: "striving to think of any certainty, to connect it with the ideality of thinking" [12].

As a result of the modification of individual elements of the design space, the structure of the algorithm changes. In the process of the dual representation, the structure will look like the one shown in Figure 5.

![Figure 5. The structure of the data converter algorithm using the dual representation method.](image)

Obviously, by the result of diffusion of perception of properties, we easily get a very productive structure of the algorithm, in which not only analytically and technically justified actions, but also additional operations are potentially possible. Such additions, firstly, make the algorithm much more
fully functionally, and secondly, allow for debugging and testing solutions until the project is completed and, thirdly, they take into account the results of the algorithm execution during its implementation.

Summing up, we pay attention to the sequence of perception change when using the double representation method:
1) Initial (traditional) perception of the structure;
2) Splitting of perception based on the semantics of the observed object: file-read-write;
3) Expansion of perception based on the introduction of new links between existing elements;
4) Expansion of perception based on intuitive-sensory assumptions about the introduction of supplements.

4.3. Experimental objects
On the way of the dual representation, each element can be assigned the status of an experimental one, since initially, at the moment of its introduction into the context of the structure, such an element is not planned. Consequently, the process of its design will be spontaneous. Such an element is much more manageable. The cognitive and structural element in development provides a dual vision and description of the problem and solution. As formal connections of the algorithm ensure its correct operation, the cognitive aspect allows to expand the space of creative observation of the project and to find an unexpected solution.

At the same time, the perception of the designer will be concentrated not only on the analytical and formal requirements for him. On the contrary, each of the elements of the information space of the algorithm design can be perceived as a product of creativity, association, evaluation, assumptions, intuition, etc. Such structures of the algorithm can sometimes take very bizarre forms, the reason being that they are generated on the basis of creative rather than formal synthesis criteria. The creative criteria are ease of entry, ease of selection of the option, the feeling of the flexibility of restructuring. That is, the dual representation method ensures the natural-intellectual commonness of the design information space and the integrity of its perception. In addition, the method has value from the point of view of managing the development of automated systems, since it involves control at the level of understanding of what is happening in the automation of design processes.

5. Discussion
Elements outside the algorithmic adjacency are not thought out together. The illusion of their independence from others is created, therefore, there is a reason for the emergence of an erroneous decision. In the early stages of algorithm development, it is especially important to get the result of its operation as soon as possible. The result is necessary for correlation with algorithmic elements for their correction. By introducing additional elements into the development process - descriptions or pairs, execution results, and even debugging information - you can significantly increase the actual understanding of the algorithm. The decision on the development or correction of the algorithm by the dual representation method is easier and more reliable, since it is based on the psychological theory of dual processes [10].

6. Conclusion
Among today's tasks, the dual representation method can be successfully applied not only in the development of CAD, but also in the creation of recognition algorithms, robotics and control of unmanned flying vehicles. Eventually, use of the method of the dual representation will allow to investigate in a complex a perspective of a task and ways of its solution. Thanks to cognitive aspect, the presented method is capable to increase the level of perception of tasks of the formal technical analysis and development of a CAD.

Dual representation as a kind of diffusion of multiple perception of the diversity of the information space will contribute to the following opportunities:
- see the new version of the algorithmic extension;
- simplify changes to the structure of the system;
- observe simultaneously several variants of algorithmization, and, as a result, to ensure that decisions are made on the choice of the best of them informally, based on the creative criteria of the really best structure variant.

But the most important – the natural-intellectual dual representation will provide support for the individual characteristics of the problem being solved, as well as taking into account the personal preferences of the designer. In solving complex, difficult to determine problems of development of software modules automated systems, this is its most valuable quality.

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