Current State and Prospects of Development of the General Theory of Systems[1]

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In the article the approaches to the general theory of systems put by founders of this theory in the sixties of the last century are considered. These approaches are considerably characteristic also of today's submission of the general theory of systems. These approaches can be classified on three conditional groups — mathematical approach to the general theory of systems (M. Mesarovich, Y. Takahara), "physical" approach to the theory of open systems (L. von Bertalanfi, Y. L. Klimontovich) and approach on the basis of functional systems (P. K. Anokhin). The approaches offered by authors to further development of the general theory of systems and its practical application are considered.

Keywords: *general theory of systems, mathematical approach to the general theory of systems, theory of open systems, functional systems, approaches to development of the general theory of systems*

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Современное состояние и перспективы развития общей теории систем

Рассмотрены подходы к общей теории систем, заложенные основателями этой теории в шестидесятые годы прошлого века. Эти подходы в значительной мере характерны и для сегодняшнего представления общей теории систем. Данные подходы можно классифицировать на три условных группы — математический подход к общей теории систем (М. Месарович, Я. Такахара), "физический" подход к теории открытых систем (Л. фон Берталанфи, Ю. Л. Климонтович) и подход на основе функциональных систем (П. К. Анохин). Рассмотрены предлагаемые авторами подходы к дальнейшему развитию общей теории систем и ее практическому применению.

Ключевые слова: *общая теория систем, математический подход к общей теории систем, теория открытых систем, функциональные системы, подходы к развитию общей теории систем*

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Introduction

The classical period of development of modern scientific knowledge lasts more than 300 years, since works of I. Newton which "who for the first time explained with almost divine force of the mind by means of the mathematical method of the movement and a form of planets, a way of comets, inflows and outflows of the ocean. He the first investigated a variety of light beams and feature of flowers, the following from here which to it nobody even suspected. The diligent, penetrating and truthful interpreter of the nature, antiquities and the sacred writing, he glorified in the doctrine the great almighty creator" (an inscription on a grave of sir I. Newton).

The science of the classical period was practically identified with two scientific disciplines. It is, first of all, physics in which the mechanistic principle saying dominated that whole there is a sum of separate parts, and any studied natural object was represented with the mechanism. Such method of a research well worked at linear tasks with two variables and also, on the basis of the 2nd law of thermodynamics, allowed to find a solution for enough difficult isolated objects. However, tasks with unorganized complexity, i.e., those which internal organization could change dynamically depending on influence of external factors hesitated. It is clear, that there was not enough accounting of any other factors. What? The answer is given in [1]: "...only the external agent influencing system S can be such cause".

On the other hand, biologists, researchers of live objects put forward the organismic theory relying on teleology which originates from Aristotle and the doctrine about Kant's expediency. The basic principle of organicism is that live "organisms are organized phenomena" [2]. This organization is a form of the self-organization developing from simple to more difficult and is defined by existence of purposeful behavior due to realization of property of openness (that classics specifically understood as openness and representation of authors of this work in this question, it will be described below). Living system in [2] is defined as hierarchically organized open system keeping itself or developing in the direction of achievement of mobile balance. So, there is a theory of open systems which became subsequently a part of the general theory of systems (GTS) and capable to explain features of living organisms and social groups.

Thus, the contradiction between two conceptual ways of scientific thinking and methods of scientific research, and unfitness of "mechanism" as universal model is available.

The second factor which led to emergence of the theory of systems was desire of researchers to counteract division of science into the mutually isolated specialties. By the way, this problem exists fully still: the number of separate sciences is so high now that often their representatives just objectively cannot understand each other in special questions.

At last, with development of industrial production before science and technology there was a problem of systematic study, design, operation of difficult objects that demanded development of new methodological bases, theories, principles, analysis methods.

Thus, there is a need for creation of new universal models in the form of the general theory of systems as conceptual learning tool and designing of difficult objects and phenomena. The general theory of systems began to develop from 50th years of the last century and is connected, first of all, with a name of the Austrian biologist L. Bertalanfi who as it was stated above, formulated the basic principle of organicism, developed the theory of open living systems, it is considered the founder of the generalized theory of systems (in the form of GTS). Some of bright researchers of living organisms, along with Bertalanfi, can consider the largest Soviet physiologist, the founder of new branches of science about a brain P. K. Anokhin who entered into system approach of a concept of a backbone factor, on its basis — a functional system and developed fundamental issues of the general theory of functional systems [3, 4]. Later also concepts of other authors — W. Ross Ashby, O. Lange, R. Akoff, M. Mesarovich, A. I. Uyemov, A. A. Malinovsky, A. A. Lyapunov, Y. L. Klimontovich, etc. gained fame, each of whem was adapted by the principles of system approach for those fields of fundamental and applied science in which they conducted researches. Here it is necessary to mark out especially U. R. Ashby who was quoted above and also M. Mesarovich [5], who gave the formal description GTS.

The fact that is told above belongs to formation of the general theory of systems. The ideas formulated in works of these researchers gave an impetus to reasonings of authors of article and a basis for further development of ideas of the categorial device GTS.

As for researches of systems within separate sciences and, first of all, philosophy, to them at least two and a half thousand years from Platon and Aristotle. It is possible to look at significantly more retrospective reviews, for example, in [6, 7].

1. Current state of GTS

1.1. About a role of the observer for a concept of a system of the classical theory of a system

The central concept GTS (or system approach) is the concept of what is a system. "System" belongs to number of the terms which are most widely used in various scientific and practical types of activity with obviously not coinciding values: the formalized sign systems studied in logic and mathematics and such systems as a living organism, technical or modern control systems, it is hardly possible to consider as types of the same concept.

Then there is a question if it is about a system, then what can be "physics" of a system? Why in GTS all these types approach under a concept a system? The answer to this question is historical: as follows from the analysis of the factors which led to emergence of system approach as the formulated outlook, the concept of a system arose in the depths of experimental science as way of studying the nature. Such process demands presence of the experimenter/researcher/observer. In [8] the author defines a system as "any essence, conceptual or physical which consists of interdependent parts ... and can show activity, i. e., having behavior (behavioral system)". At the same time, it is such behavioral systems which "are a subject of management from people" and also consists of parts, "each of which finds own behavior". And depends only on the researcher he considers conceptual or physical essence as a system or not. The problem of experimental science is to allocate in, actually, isolated for study from the external environment, a difficult natural object which, is described by many characteristics, those which the experimenter wants and can investigate, describe the relations between characteristics of yRx, and, it is desirable, in the form of formal functional dependences of $y = F(x)$. Thus, here the system is understood as some abstract essence (but not a real natural object) between which elements some relations are entered.

Real objects of live and inanimate nature, a technosphere are systems in the absence of the observer or not? Today in the theory of systems the observer is, actually, the main distinctive sign, and the nature of a system is always speculative, abstract that confirms the definition of a system given by M. Mesarovich [8]: "For this family of sets of $X = \{X_1, X_n\}$ the system (abstract system) is defined as the relation on X, that is $S \subset X_1 \times ... \times X_n$, where "×" designates Cartesian product of sets. Sets $X_1, ..., X_{1n}$ on whom the relation is defined are called objects. Every X_i represents full set of all manifestations of some attribute (or experiments with this attribute) the considered real-life phenomena". This definition is substantial means the specification of a system by definition of the relations connecting values which can accept the X_i attributes of the studied object.

1.2. About a role of criterion function

The following question which still causes a controversy at apologists of system approach in various areas is a question: what separates a system from not a system?

Classics of GTS give various definitions, here, for example, some of them.

1. Bertalanfi: "...the system is a complex of the elements which are in interaction" [2].

2. Stafford Beer suggested to determine systems at the same time by two signs — degrees of complexity of systems and to the nature of their functioning: determined or probabilistic [10].

3. In [11] it is claimed that "a system in the broadest sense everything that can be considered as separate essence can be resolute. For example, the Universe in general is a system. Systems are physical objects, processes and concepts. At the same time the cheese piece, hatred and Markov process taken together do not make a system".

4. M. Mesarovich, as shown above, defines a system by definition of the relations connecting values which can accept X_i attributes of the studied object [12].

So various approaches to definition of a system are connected with absence in definition of a basic factor which can be criterion of to define a concept of a system and its distinctive signs. About it the academician P. N. Anokhin in the work "Fundamental issues of the general theory of functional systems" directly specifies [3]: "Such obligatory situation for all types and the directions of system approach is search and a formulation of a backbone factor. This key problem defines both a concept of a system, and all strategy of its application of research. .... its operational value for formation of a system will be how fully described". Defining a role of a backbone factor in the form of useful result of a system, P. K. Anokhin submits the theory of biosystems and calls such systems functional: "Such imperative factor using all possibilities of a system is the useful result of a system. .... The sufficiency or insufficiency of result defines behavior of a system: in case of its sufficiency the organism passes to formation of other functional system with other useful result representing the next stage in a universal continuum of results " [3].

It should be noted that later M. Mesarovich within the formalism entered above, also enters a concept of the purpose $\alpha(G, T, R)$ for the $S = X \times Y$ system, the having entrance of X and an exit of Y, by means of: introductions a) criterion function of $G(s)$ which defines the required condition of a system; b) function of admissibility $T(u)$ imposing, actually, restriction for a set of values in terms of satisfaction of criterion function; c) the relation of R which estimates degree of approachability of criterion function on a subset of values. Mesarovich's merit is that he not only entered criterion function, but also defined the formal bases for assessment of extent of achievement of the goal on any given input data, i.e., defined category of behavior of a system, effective in terms of achievement of the goal. However, entering criterion function, he did not define its role and the importance as backbone factor as it is noted at P. K. Anokhin.

Thus, after P. K. Anokhin and M. Mesarovich and at the same time in peak to them, one may say, that the system only then is a system when it possesses a backbone factor in the form of criterion function.

There is a question further: and criterion function is defined by someone from the outside or the system can develop criterion function and define the behavior that this purpose to reach?

The answer to this question has world outlook character. Because if to assume that criterion function is a prerogative of the external agent [12], everything in the world can be considered systems [11], then we have to depart from material positions and allow Absolute existence. Then the concept of a system includes objects of both live, and inanimate nature, and the role of the observer takes only the modest place in the course of knowledge and brings only subjectivity. By the way, ancient Greeks (Aristotle, Socrates considering that the way of existence of all real is defined by existence of the purpose) were closest to such thesis. If the system itself is capable to generate to itself criterion function, then it gains a certain subjectivity and then we or we limit a set of systems to wildlife, or, on the basis of [11], we allow existence, conditionally, "souls" at lifeless objects, including a technosphere, i. e., we also pass to idealism positions.

P. K. Anokhin takes into account only technical and biosystems, leaving inanimate nature beyond the scope of reasonings: "Practically for all cars the object is set outside the car and for it only some ability of self-organization in the course of obtaining the result programmed not by it is allowed. The biosystem even of very simple hierarchy itself, on the basis of the internal processes, makes the decision on what result is necessary to its adaptive activity at present" [3].

The following question which has basic value it is understanding that criterion function is that factor which orders "interaction of elements" of Bertalanfi that only way which defines "a self-organizing system" at Ashby, providing transition from "unorganized to organized", i. e. from interaction chaos to a system [13]. In other words, criterion function defines structure of a system, i. e., that structure of elements and those relations between them which are necessary for providing criterion function at present. It is necessary to notice that Mesarovich also defined presence of structure at a system, but defined it from purely formal positions as "result of generalization of the relation describing a system" [12].

1.3. Property of openness of a system

The major sign in terms of understanding of internal essence of a system is qualities of openness/isolation of a system. Classics differently estimated the importance of this question. So, at Ch. Churchman [14] "the generalized system is the closed system remaining closed in all possible environments. In other words, the generalized system is characterized by absolute resistance to changes of the environment". Across Mesarovich the system has this property. At the same time the openness is understood as the fact that in the assumptions which become about properties X_i (and which we check experimentally) some essentially important components are lowered, for example, the smaller number of formal objects X is considered, X_i, than it is necessary. As typical examples of open systems he considers:

1) the systems which are not completely isolated from the environment (a system with external "indignations" or uncertainty);

2) the systems reacting to a pilot study in such a way that it causes significant change in their behavior (the self-adapting and self-organizing systems);

3) systems with which the experimenter interacts bilaterally, i. e., influencing a system, he at the same time is affected from its party.

That is the system here, actually, is isolated from the external environment.

Bertalanfi in [2] emphasizes: "The Self-differentiated systems developing in the direction of more and more high complexity (by reduction of entropy), are possible — for thermodynamic reasons — only as open systems, that is systems into which the substance containing free energy is included in quantity bigger, than it is necessary for compensation of growth of entropy caused by irreversible processes in a system ("introduction of negative entropy")". At the same time in open systems in which there is a substance transfer the input of a negentropy is quite possible. Therefore, similar systems can keep the high level and even to develop towards increase in an order and complexity that really is one of the most important features of vital processes [14].

Closest, according to authors, U. R. Ashby who entered new definition of a system as "cars with an entrance", that is "the system open for information, but closed for transfer of entropy" [1], that explains the reasons of self-organization of a system approached the real situation. Unfortunately, the thought that the open system is open for information, in further representations of classics of GTS was leveled under the influence of thermodynamic reasons which prevailed for that period in science.

Here it is necessary to talk about differences in interpretation of a concept of openness of different areas. Bertalanfi entered a concept of an open system as the system exchanging with the external environment matter and energy (for this reason Bertalanfi approach is called "physical" approach to GTS). In the field of information systems, by definition of IEEE POSIX 1003.0 Committee an open information system is called the system realizing open specifications on interfaces, services and the supported formats of data (this referral was got still by the name of functional standardization). Definition of POSIX gives the chance of realization in information systems of so-called properties of openness — expansibility of scalability, shipping of applications, data and personnel, interoperability of systems.

1.4. Internal management of a system

The fact that the system possesses internal management, was for the first time mentioned by M. Mesarovich at the description it a purposeful system [12] when claimed that if system S possesses the purpose α, then it can make decisions, i. e., it possesses internal management. Such system carries out purposeful process for the benefit of the purpose $\alpha(G, T, R)$ and characterized by such properties as the training (adaptation) directed to reduction of uncertainty of U as self-organization, i. e. process of change of structure of purposeful process. Unfortunately, what represents decision-making process as a basic element of an administrative cycle, was not presented by Mesarovich. Probably, it is explained by those circumstances that, first, only, since 80th years of the last century the theory of making management decisions allowing to receive and analyze qualitative (not quantitative) information is formed. These are such methods as expert estimation, multicriteria analysis, informative analysis of situations, etc. The second factor, significant for implementation of management, is an understanding of essence of information necessary for decision-making. And in this regard only in 1989 after R. L. Akoff's speech at inauguration of society International Society for General Systems Research [16], in information sciences, including such scientific discipline as artificial intelligence, there were ideas of information hierarchy of levels of a maturity of information of DIKW (data, information, knowledge, wisdom) where each level adds certain properties to the previous level. Here in the basis, there is level of data, information adds a context, knowledge defines use mechanism ("as"), and wisdom — terms of use ("when"). Such differentiated approach to "device" of information allows to approach an internal administrative cycle at the conceptual level.

It is also necessary to mention works of one of outstanding scientists of domestic psychology of V. N. Pushkin who formulated the theory of operational thinking [17, 18]. Within this theory it is shown that from the psychological point of view management of behavior of the person is connected with construction in structures of a brain of information model of the outside world within which management process on the basis of perception by the person of information from the outside and already available experience and knowledge is carried out.

1.5. Generalization of basic provisions of GTS

Generalizing the results stated above, it is possible to tell the following.

Uniform, divided if not by everything then most of scientists, the generalized theory of systems did not turn out today, despite essential, approximately general provisions. In each of approaches the emphases are placed on different aspects.

Thus, modern representation of GTS can be classified on three directions — mathematical, "physical" (Bertalanfi, Klimontovich) and the theory of functional systems (Anokhin).

1.5.1. Mathematical approach

The abstract system through the description of properties of its attributes and their values (set-theoretic and linguistic) the Concept of the purpose (criterion function) of a system is considered by formal ways though its importance is mentioned, but does not enter the formal description of a system. Founders of this direction M. Mesarovich and Y. Takahara [5, 9, 12].

1.5.2. "Physical" approach or theory of open systems

The main thing here is an exchange of substance and energy between a system and the external environment. At the same time the reasons of this exchange, methods, ways and instruments of exchange especially are not considered. Also, criterion function is not considered in this context.

Founder of this direction is L. von Bertalanfi [2, 15]. Significant development of this approach in the field of physics belongs to the Russian scientist Y. L. Klimontovich [19].

1.5.3. Theory of functional systems

The founder of this direction is P. K. Anokhin [3, 4]. The main thing here — useful result of functioning of a system. At the same time, it is not absolutely clear — useful result is that it? How this result is connected with criterion function? How at the expense of what and as this useful result is achieved?

2. Prospects of development of the general theory of systems

At once we will notice — in this section the position of authors of this work which is based on work of one of authors [20], experience of authors on design of information systems and researches in computer sciences is stated.

What it would be desirable to tell at once is an expediency of attempt of association of all three GTS directions stated above, but on the basis of some shift of accents and introduction of some new campaigns.

The first is a consideration of criterion function as it was stated above as backbone function. There is no criterion function — there is no system. We cannot know about some objects their criterion functions, but so far we do not know them, we should not consider these objects as systems (it does not mean that we should not look for these criterion functions).

The second — to shift focus of a concept of openness of a system to criterion function — the open system is such system which cannot realize the criterion function without the external environment (the closed system — the return case).

The third — if to accept the first two points, then arises a question as well as what means the system will get from the external environment that it is necessary for it for realization of criterion function. According to authors it is implemented through information exchange between a system and the external environment (DIKW model).

The fourth — depending on strategy (which a system has to be had) the system has to be capable to constantly decomposition criterion function and to make decisions (on the basis of training and development of ontological models of the outside world) on interaction with the external environment for realization of decomposition criterion function. Here it is possible to use practices in the field of the theory of decision-making.

The fifth — for comparison of uniform objects of rather decomposition criterion function the system has to have an opportunity to use the device of multicriteria estimation not to get into position of the Buridanov's donkey.

These are contours of development of the general theory of systems. In each of these directions a huge number of questions for researches seems. Nevertheless, it can set base and a framework for development of the GTS and its possible applications in a large number of areas.

Conclusion

Importance of the general theory of systems for the solution of world outlook problems and practical application of this theory in creation and ensuring reliability of technosphere (first of all in the field of development of information systems, artificial intelligence) it is difficult to overestimate. Development of this theory can give huge jump in these directions. Until we still not really far left in this theory ancient Greeks who defined a system as something, consisting of the parts which are in the relations and communications with each other (structure of a system) and who form a certain value, unity (criterion function). Without development of what was created by founders of the modern theory of systems, we will remain approximately at the same level of constructability of this theory in terms of its practical use, as ancient Greeks.

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