Theory of Knowledge

Systems Thinking in the Twenty-First Century

Elena B. Agoshkova
St. Petersburg State Electrotechnical University

ABSTRACT: Systems thinking is an important factor in solving global problems. The twentieth-century has witnessed the development of a systems paradigm and different spheres of systems knowledge. However, further development of systems thinking necessitates overcoming the contradictions between different schools and unifying them into a single systems conception. With this in mind, systems problems are examined in light of the theory of knowledge. It is suggested that the gnosiological definition of the notion 'system' should be used as a basis for a single approach. An analysis of the concept 'system' leads to a logically well-structured conception of system. It follows from this that, in addition to the general theory of systems and the systems science, a non-formal theory of whole object and non-formal systems logic should form part of the systems thinking. This would set the stage for a categorical structure and a conceptual basis for systems thinking. The development of systems thinking should be regarded as the key challenge in perfecting humanity. The elaboration of a single systems conception within the philosophy of science and the methodology of scientific knowledge should be treated as a basis for meeting this challenge.

Philosophy and science of the 21st century granted humankind one of the most important achievements of human thought - a systems paradigm in knowledge and the systems view of the world. Now the task is that all spheres of human activities be refracted through the prism of the systems viewing of reality, including interstate and state construction, production and consumption, and everyday life of individuals. Let us hope that this new quality of rationality, systems thinking will present the very magic crystal that, being looked through, will help humankind learn to avoid the mistakes that destroy our best undertakings by misleading us from the right track and threaten our very existence.

But in order to do that, a systems paradigm itself should find harmony.

Changes of a Paradigm of Knowledge in the Twentieth Century

The thirties and fifties of the 20th century marked a turning point in science and philosophy. Many outstanding intellectuals realised the mounting crisis. Numerous works contained a formulation of contradictions between the new goals of science and the methods available. It became obvious that the fragmentation of science and the tragic of absence of a common language lacked a perspective.

At the same time, several works, although not declaring a new paradigm, already became the sources that were filling up its stream (E. Husserl, A.S. Lotka, P.K. Anokhin, W. Weaver, N. Wiener and others). In Russia a project of "General Organising Science (Tektology)" was put forward (A.A. Bogdanov, 1913, 1922). But the success to advance an idea that would become a determining paradigm of the 20th century fell on L. von Bertalanffy (1945).

It was suggested to seek the settling of the crisis in the following directions:

(1) It is necessary to change the object of research - to turn to "Lebenswelt", "back to things", to examine "organism", "organised complexity".

(2) One should search for regularities of the complexity at each level of the organisation of objects of reality, without descending to physical origins and striving to reductionism.

(3) It can be expected that regularities in upper levels will possess isomorphism, for the essence of regularities of the complexity is hidden in the character of organisation and not in the nature of elements it's made of.

(4) The unity of approach consists in examining an object's organisation through examining "systems as a composition of interacting elements". This will make a basis for a common language and the integration of scientific disciplines.

Nevertheless, in the recent 50 years the systems problems have gone far beyond the scope of initial ideas and programmes.

Discrepancy of the Initial Position

Already in the initial idea by L. von Bertalanffy there is a contradiction, which has given a momentum toward a deeper self-reflection of systems research and a quest for philosophical bases of the general systems theory (GST). Having advanced a global concept, he perceived a system as a real object, which later on would be called an organised complexity, an integrated whole, etc.

But the theory is not applicable to a real object. It is applicable only to a certain aspect of this object and functions with regard to this aspect. That is why, with the idea of GST, L. von Bertalanffy gave the notion "system" a gnosiological meaning, and with the term "common" spread the notion "system" over ideal, symbolic objects.

This led to the unfolding of systems research over numerous schools and trends differing primarily in two propositions:

(1) Is the notion "system" applicable to a real object, a thing, or an image of an object in knowledge?

(2) Does the definition of the notion "system" include the requirement "to be the whole" (V.N. Sadovsky, 1974, et al.), or the notion "system" can be related to an arbitrary set of elements and relations (B.R. Gaines, 1979, et al.)?

Some philosophers realised that the global character of GST required, first of all, that the problem be posed philosophically as a problem of the theory of knowledge. Then the essence of systems research should be regarded as a task of a most adequate reflection of real objects in perception, as a goal to build up a specific form of knowledge which is capable of reflecting a whole, an object (V.A. Lektorsky, V.N. Sadovsky, 1960).

This task remains actual until present, particularly to the philosophy of science, to find out grounds for building up an initial object system (source system, G.J. Klir, 1985).

It is this position that we shall approach the problem of systems thinking.

Grounds for a Single Systems Conception

The introduction to the systems view of the world (E. Laszlo, 1996) and the development of systems thinking require the integration of all achievements of the systems research over the recent 50 years into a single conception. A thorough analysis shows that the diversity of issues being considered within the systems research belong not only to GST or the systems science, but embrace a wide area of scientific knowledge as human activity. Therefore, a gnosiological understanding of system as a universal and fundamental notion of the theory of knowledge should make a basis. The way to a single systems conception runs through an agreement:

(1) A real object is connected with the notion "system" as a metaphor pointing out to a definite character of a real object.

(2) In its philosophical and scientific understanding, a "system" acts as an abstract object, as a model of a certain aspect of real object, and the meaning of the notion "system" is determined by its function in the theory of knowledge. A system is given on an object (W.R. Ashby, 1956; G.J. Klir, 1985).

(3) The notion "system" is inseparably connected with the notion "wholeness". This requirement has been initially contained in the Greek term "system" and in historical interpretation of this term (N. Webster, 1848, V.I. Dal', 1863), as declared by L. von Bertalanffy (1951) a "doctrine of wholeness"), as a philosophical foundation (V.N. Sadovsky, 1974), as the essence of the systems view of the world (E. Laszlo, 1996).

Essence of the Notion "System" as Viewed by the Theory of Knowledge

Gnosiological Definition of the Notion "System"

The principal gnosiological function of the notion "system" is to find an explanation of the emergence of integral properties of the whole through properties and relations of elements. Hence, the notion "whole" is primary in relation to the notion "system". Consequently, a system is given by not only the assemblage of elements and relations but also by the integral property of the whole object (P.K. Anokhin, 1935, 1973). When developing the notion "object system"(G.J. Klir, 1985), one should speak about "object system with respect to the given integral property (quality) of a whole object" (E.B. Agoshkova, 1986).

Then we can suggest the following gnosiological definition of the notion "system": "system S given on object A with respect to the integral property (quality) Q is the assemblage of certain elements residing in certain relations such that produce the integral property" (E.B. Agoshkova, 1996).

System as a Means of Overcoming the Fundamental Contradiction

It is specific for the systems research that, representing an object as a system, we always reflect the object through a discrete and finite set of elements and relations. At the same time, objects of the real world possess an infinite complexity and an infinite diversity of their properties. A task of the theory of knowledge is to overcome this contradiction and to single out from the infinite complexity of an object such a formation that gives knowledge about this object with attributes of explanation and forecast. It is the notion "system" that scientific knowledge employs for solving this task (B.V. Akhlibininsky, 1989).

System as a Form of Representing a Subject of Scientific Knowledge

From the very beginning science has always operated with a discrete and finite form of representing knowledge about an object, although without using the term of system. The form of law, regularity possesses all features of a system and is nothing else than "a properties' system" (N.F. Ovchinnikov, 1969).

An analysis makes it clear that a system as the assemblage of elements and relations acts as a form of representing a subject of scientific knowledge. Based on the philosophical unity of form and content, the conceptual aspect of the notion "system" consists in producing the integral property of the whole that is of interest for us.

In this sense, the notion "system" acts as a fundamental and universal concept, as a philosophical category. Every regularity, beginning with the theorem of Pythagoras, has been represented as a system.

Procedure of Simplification and the Completeness of Sets of Properties and Relations

Transition from a real object to an object system is a procedure of simplification, which should have a limit. And this limit is determined by the fact that a set making the system should reflect the object as a definite whole, an integrity. Namely, the integral property of the whole relative to which we form a system should be produced by properties and relations of elements.

A criterion of the completeness of representation of an object by a system is self-determination of the set of properties and relations, its capability to produce the integral property of the whole object with a certain determination.

As this takes place, in the course of history of science a different degree of determination has been accepted (from Aristotle's causality through Laplace's absolute determinism to probabilistic determination and its generalisation in the theory of fuzzy sets (Zadeh, L.A., 1973; G.J. Klir, 1985).

The necessity of a complete set of properties and relations is fundamental for the essence of systems research. Regardless of what our cognitive abilities are, this should be a principal objective. To illustrate this, we note that the notion "state" in the theory of dynamic system was introduced right from "the necessity to give complete characteristics of system" (L.A. Zadeh, 1962). At the same time, in the practice of systems research "system" is not infrequently substituted by "non-system". Many ecological and technical projects do not succeed due to incomplete image of real object as a system, and it is here that the contradictory nature of contemporary systems paradigm counts. A proposition that an arbitrary set of properties may form a quasi-system is of great importance for the perception of systems thinking and for the systems view of the world.

Non-Formal Theory of a Whole Object

A distinguishing feature of systems research is the vision of a whole object of reality in rich diversity of its appearances. Nevertheless, a concept of GST advanced by L. von Bertalanffy made an accent on the system as a formal structure indifferent to the specifics of nature of its elements. This approach determined essentially the repeated and successful attempts to abstract from properties and qualities of real objects and to develop a formal apparatus of the systems theory (M.D. Mesarovic, Y. Takahara, 1975; G.J. Klir, 1985).

At the same time, the immense layer of systems research has proved to be devoted to the examination of qualities of objects at all levels of organisation of reality: from constructive geography to living organisms. This gap between GST and the necessity to take account of the "completeness of properties" (E. Husserl, 1937) has been recognised by many scholars (W.R. Ashby, 1964; A. Rapoport, 1957). Obviously, the problem of decomposition of the whole is connected with the diversity of properties and qualities of a real object. Having introduced an integral property of the whole in the above definition of notion "system", we practically reject to abstract from the concreteness of properties and qualities of an object. Moreover, the knowledge of these properties makes a basis for the decomposition of an object and for the forming of a complete set of properties that produce the given integral property.

That is why, in addition to GST and systems science, a non-formal theory of whole object should make part of systems knowledge (E.B. Agoshkova, B.V. Akhlibininsky, B.S. Fleisman, 1992) It can be called systemology. It considers the self-determination of qualities of the whole object, as well as universal, general and specific properties as applied to different levels of the organised complexity and also their hierarchical order. It is this meaning that B.S. Fleisman (1982) gave to systemology. He considered fundamental properties of the complexity and the way they stipulated the increasingly complex behaviour. Feasibility of a purpose and survivability are taken by him as initial in the hierarchy of qualities of real objects.

We should note that the ideas of L. von Bertalanffy resulted from his attempts at elucidating concrete specific properties of the complexity (purposeful behavior, equi-finality, etc.). In his latest works he indicated the necessity to include the theory of information and decision-making into GST. Since real objects are not a system, and a system is formed out of properties of an object, systemology as a science on properties of a whole object is the objective basis for the choice of properties for an "object" system.

Non-Formal Logic of Systems Thinking

Contemporary systems knowledge provides a basis for the development of systems thinking. Therefore, it should involve all components that afford the systems thinking, including non-formal systems logic, which determines categorical structure and conceptual basis for the systems thinking.

Although from the very beginning science has been dealing with systems, non-formal systems logic has not been developed within the framework of non-formal logic of scientific knowledge. This is connected with the fact that in the research on simple systems scholars have been well oriented in the rules of identifying regularities without its obvious systems definition. It was a period of sub-conscious employment of system paradigm. For the comprehension of the very notion "system" started in the second half of the 20th century and has been going on until now.

Conceptual basis for systems research is formed with the terminology borrowed from different spheres of knowledge - from philosophy to mathematics. That is why it is crucial to comprehend the essence which a term obtains when introduced into the conceptual base of systems knowledge. The study of the in-depth meaning of notions (structure, relation, emergence, etc.) has made an essential part of systems problems. Notable is the discussion on an understanding of the notions "purpose" and "teleological" (A. Rosenblueth, N. Wiener, J. Bigelow, 1943) at the time when ideas of the systems theory were just appearing. Now an ultimate comprehension of the notions is to be made through taking account of all the achievements of systems research.

Non-formal logic determines the laws of thinking that are expressed through relations of categories. This is the logic of notions relations, of the production of concepts from concepts. That is why it determines methodology of representing an object as a system and has a direct connection with the problem of emergence and recurrent principle of the elucidation of properties of the whole (B.S. Fleisman, 1982). When concepts of systems knowledge enter into a categorical structure of thinking, they will be used as unconsciously as the categories "cause" and "effect" in everyday practice of searching for "causes of success and consequences of failure".

The development of systems thinking should be regarded as the key challenge in perfecting humanity. The elaboration of a single systems conception within the philosophy of science and the methodology of scientific knowledge should be treated as a basis for meeting this challenge.