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Modern Paradigmal Approaches In Modelling Complex Systems

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Abstract: *The article analyzing the philosofic-methodological aspects of modeling of complexity systems. Features, specificity and an originality linear and nonlinear thinking, the linear and nonlinear approach in modern scientific knowledge. The article analyzes fractality is proved to be of the fundamental features of existence.*

Keywords: modeling, complexcity, linear; non-linear; linear thinking, nonlinear thinking, fractal.

Introduction

At the end of the 20th and beginning of the 21st centuries, new methodological approaches to the cognition of reality were formed in world science. One of these philosophical approaches is a complex non-linear approach, widely used in the scientific field. In modern science and practice, complexity, uncertainty, risk are increasing, humanity admits that it has come to the stage of a strictly responsible attitude to its development. Indeed, humanity needs new thinking and new methodological approaches in order to realize, cognize, and carry out activities in an increasingly complex world; scientists of the world are widely investigating the paradigm of complexity. The study of complexity in social, economic, cultural processes and modeling in this process of complexity, its various connections and such properties as uncertainty, chaos, nonlinearity are the most pressing problems for humanity.

The linear development of the system is determined by such states as consistency, equilibrium, stability, the uniqueness of the path of development, the nonlinear development of the system is characterized by nonequilibrium, multivariance, instability, uncertainty, randomness, branching of phenomena, that is, a variety of development paths. The ability to explore such a complex world using a linear approach is limited. This is due to the fact that the occurring phenomena and processes are characterized by growth and decline, oscillation and crisis paths, that is, in the dynamics of the system, randomness and necessity are co-dimensional, the simultaneous existence of both linearity and nonlinearity is characteristic.

The phenomenon of complexity contributes to the emergence of new problems unknown to early mankind and requires the development of a new methodology, new values and, in general, a new philosophical system that can determine the right direction in an uncertain world. The world has properties of complexity, nonlinearity, uncertainty and unpredictability, that is, reality has a complex ontological structure, and traditional schemes and models do not correspond to its cognition and display.

Materials and methods

Complexity research is a multidimensional problem. In this regard, there are various concepts of the analysis of the phenomenon of complexity. In modern philosophy, several research problems have been developed to study complexity. For example, the theory of self-organization (G. Haken), the theory of dissipative structures (I. Prigogine), the paradigm of complexity (E. Moren), the concept of autopoiesis (W. Maturana and F. Varella), an interdisciplinary approach to complexity (E. N. Knyazeva) and a number of other concepts. However, these concepts explore various aspects of the phenomenon of complexity. These concepts are systematically explored in this study.

E.Moren, in explaining the ontological nature of complexity, identifies two of its fundamental aspects. The first aspect is holism, that is, the combination of parts and elements with the formation of a single whole, acquiring new properties. The second aspect of complexity lies in the fact that any complex knowledge, complex phenomenon or structure formation in nature and society is torn apart by deep irreducible contradictions that do not so much destroy the complex as, paradoxically, build it [1, p. 14]. Therefore, E. Moren associates complexity with holism and irreducibility. According to E. Morena, the truth is antagonistic, but manifests itself in the combination of complementary concepts. He calls it dialogics, in contrast to dialectics. For example, a wave-particle in quantum physics or an individual-society in the humanities and social sciences. This principle E. Morin calls the principle of dialogics, according to him, essences incompatible with each other are necessary and complement each other [2, p. 18].

Exploring the complexity of E.N. Knyazeva distinguishes the following properties of complex systems [3]: 1. Complexity is a set of elements of the system, connected by non-trivial, original connections with each other. Complexity is a dynamic network of elements; 2. Complexity is the internal variety of the system, the variety of its elements or subsystems, which makes it flexible, capable of changing its behavior depending on the changing situation; 3. Complexity is the multilevel system; 4. Complex systems are open systems, that is, exchanging matter, energy and / or information with the environment. The boundaries

of a complex system are sometimes difficult to define (the vision of its boundaries depends on the position of the observer); 5. Complex systems are such systems in which emergent phenomena (phenomena, properties) arise; 6. Complex systems have memory, they are characterized by the phenomenon of hysteresis; 7. Complex systems are governed by feedback loops: negative, which ensures the restoration of balance, return to the previous state, and positive, responsible for rapid, self-stimulating growth, during which complexity flourishes.

According to E.N. Knyazeva, complex thinking is thinking about the complexity or complexity of thinking. To understand, cognize the complexity of a complex world, complex systems, we need complex thinking.

The evolution of complexity research is divided into three periods. The position of the classical period of the study of complexity is as follows: complexity reflects the incompleteness of knowledge. Complexity is viewed as epistemological complexity, that is, complexity of display and understanding. In a word, the complexity of the world does not lie in objects and phenomena, in the subject itself (in the head of the researcher).

The next stage in the study of the phenomenon of complexity is the non-classical period; at this stage, another aspect of complexity was discovered, that is, a property associated with the initial state. The incorrectness of Laplace's idea "give me two initial conditions of the peace condition, and I will calculate its future" was determined. In the 19th century, the French mathematician Henri Poincaré first felt this. Henri Poincaré discovered such a property that even a small change in the initial state can lead to an unexpected state of the system. In his work "Science and Method" he writes: "In a changing system, even an absolutely small cause, despite its insignificance, is not left unattended and has a significant impact that we do not see. In this case, it is impossible to predict, we are already in the captivity of random phenomena. ”In this state, a long-term forecast requires a deep mind” [4. p. 54].

At the same time, at this stage, K. Gödel's incompleteness theorem and Heisenberg's uncertainty principle were also developed. In general, at the non-classical stage, the phenomenon of complexity is considered from the following position: At this stage, the development of science leads to the recognition of the concepts of probability, incompleteness of knowledge, uncertainty, randomness, openness, which are properties of a complex world.

At the new third stage of understanding the phenomenon of complexity, characterized by the formation of new scientific directions, in the main, the science of complexity arises as an interdisciplinary approach. It includes the science of nonlinearity, thermodynamics of open systems, synergetic - the theory of dissipative structures, the theory of bifurcations, the theory of fractals and other sciences.

Uncertainty is as an inherent property of complexity. In particular, the fact that epistemological uncertainty is “the limitation of our knowledge” is related to the fact that we do not know the future. That is, epistemological uncertainty is associated with incomplete information about the system. This is due to the fact that “the more complex the system, the more information it has” [5, p. 103]

Complexity has to do with categories of randomness. Indeed, the complexity of objects and phenomena lies in the fact that they cannot be unambiguously foreseen. The reason is that chance reigns supreme. Randomness is defined as “a measure of the lack of our knowledge” [6, p. 415]. The study notes that there are two types of randomness: Subjective randomness and objective randomness. “Subjective randomness is associated with the incompleteness of our knowledge, objective randomness is connected with the nature of matter, that is, its essence” [7, p. 23]. Consequently, subjective randomness is associated with the fact that we cannot foresee the occurrence of objects and phenomena. Objective randomness is associated with being, the inner essence of the object and is not associated with our subjective ideas. From this it follows that randomness has an ontological nature and expresses the essence of a complex world.

Result and discussion

As a result of the study, the following conclusions were made: complexity is a multicomponent property of being. The being of complexity is characterized by such properties as sensitivity to primary conditions (prerequisites), a strange attractor, that is, fractality, self-organization that does not lead to reduction, chaos, nonlinearity, uncertainty.

Another urgent problem of the epistemology of complexity is the question of the style of thinking in the cognition of complexity. In modern epistemology, systemic thinking is investigated as an adequate style of thinking in cognizing complexity.

What is the systemic thinking? For example, A.N. Averyanov considers “systemic thinking as the most developed form of thinking” [8, p. 263]. According to Donella Meadows, “systems thinking is a new method of displaying and learning about the environment”, where attention is drawn to the fact that “everything is connected with everything”, these relationships are non-linear and exhibit a feedback loop, the system is more than a simple collection of it parts.

In our opinion, the systemic thinking is not only parts of the whole, but also the ability to see its synergy, various connections in the system.

An alternative to the systemic thinking is fragmented (analytical) thinking. Fragmentary thinking studies an object and a phenomenon, dividing them into parts, the systemic thinking restores the whole from the parts of the object.

A long time ago, the Chinese philosopher Lao Tzu put forward an idea about the one-sidedness of the fragmentary approach - “as soon as a person begins to divide the world into parts, he ceases to understand not only the influence of divine laws, but together with them human laws”.

As a result, we can draw the following conclusion, the principle of modern epistemology is the simultaneous use of the methods of holism and elementarism. Fragmented thinking is characterized by such methodological methods as reductionism, mechanism.

At the end of the 20th and beginning of the 21st centuries, fundamental changes took place in the methodology of science. The complication of the world means that it has become clear that the traditional methodology of science (for example, reductionist methodology) cannot adequately reflect the knowledge of its laws. Therefore, it became necessary to develop alternative methods for studying the phenomenon of complexity.

In these conditions, it is required to find new rational methods of researching reality. It should be noted that in modern epistemology and methodology of science there are attempts to develop such paradigms as complex dissipative systems (I. Prigogine), complex self-organizing systems (G. Haken), "complex-systems thinking", "science of complexity" (K. Mainzer), "Paradigm of complexity" (E. Moren) [9].

At the same time, in the study of the phenomenon of complexity, "Theory of Complexity", "Theory of Nonlinear Dynamical Systems", "Theory of Catastrophes", "Theory of Bifurcation", "Theory of Chaos", "Theory of Fractals", etc.

The integration of sciences in the cognition of complexity should not be carried out only in the form of expanding links between the sciences, that is, be their mechanical totality. In this case, it will have no methodological significance. The integration process between the sciences should demonstrate the integrity of the structure of science, the emergence property should appear, a new qualitative state of the system should appear.

The advantages of an interdisciplinary approach are that if a separate science (scientific discipline) investigates an object by the method of mono-theoretical thinking, using a unified theoretical scheme, then interdisciplinary science is based on a poly-theoretical, systemic style of thinking, examines the studied subject and phenomenon in a dialogical / polyological way. As a result of the study, it was concluded that the modern picture of the world takes on a very complex form, a very complex methodology is required to display it.

When modeling objects of cognition as a methodological approach, the linear paradigm is based on the classical picture of the world that has dominated science and philosophy since the 18th century, Laplace's determinism. The core of the linear paradigm is Laplace determinism.

In this paradigm, an object is viewed as a strict mechanical structure. According to this, any state of an object can be determined unambiguously.

For example, V.V. Vasilkova argues that classical science is based on the following way of thinking:

- chance is removed from scientific theory, it is considered secondary, has no fundamental significance;
- the properties of the whole are explained by the properties of its parts;
- science is knowledge about stability and balance, disequilibrium and instability are understood as negative and destructive forces;
- the processes occurring in the world are reversible in time, therefore their further fate and future are predictable for a long period of time [10, p. 25-26].

The study made the following conclusions on the methodological standards of the linear modeling paradigm:

- the influence of any process is directly proportional to its result, that is, "the cause is proportional to the effect";
- the idea of the complete determinism of objects and phenomena of the world (Laplace determinism). According to this, the next state of any system can be uniquely determined, predicted;
- strong factors affecting the system are taken into account, but minor, random factors are removed. The consequences of minor impacts are negligible. The linear modeling paradigm is based on linear thinking.

Non-classical (post-non-classical) science is based on a new way of thinking in the knowledge of the world. According to this:

- the subject of science is not only general, repetitive, but also random, individual and unique processes;
-… matter is not inert, it itself is a source of self-movement and has internal activity;
- in the display of the world, determinism does not deny randomness - they come into mutual agreement and complement each other. If at the point of bifurcation randomness and uncertainty dominate, after choosing the path of development, thanks to the power of determinism, the system will be at the stage of highly stable existence;
- development is multivariate and alternative;
- development occurs through (due to) disorder, therefore, one should not be afraid, and also one should not deny the role of fluctuation, chaos in development, chaos is not only destructive, it is at the same time constructive;
- the development of the world occurs according to the laws of nonlinearity, that is, it does not happen cumulatively in stages, the pace and direction of development are not set unambiguously [11, p.30].

The paradigm of nonlinearity is broader than the paradigm of linearity and is adequate to objective reality.

Consequently, the paradigm of nonlinearity opens up wide opportunities for holistic, systemic, poly-paradigmatic study, knowledge of the object of research.

Based on the above, we can give the following definition of nonlinear modeling:

Non-linear modeling is a type of modeling that takes into account non-linearity, non-determinism, random connections of the system, as well as the multi variance of the evolution of the system, and through this is based on knowledge.

The role of the fractal paradigm in modeling complex systems is great. A fractal is an element of a nonlinear picture of the world, it has great conceptual significance in modern scientific knowledge.

The developer of the theory of fractals is the mathematician, Professor Benoit B. Mandelbrot. However, the historical and theoretical foundations of the fractal approach are associated with the Swedish mathematician Helge von Koch, as well as such scientists as D. Peano, G. Kantor, B. Bolzano, K. Weierstrass, F. Hausdorf, A. Renyi and others. For example, Koch calls a curved line a "monster" because it does not conform to the straight and straight shapes of traditional geometry. Such forms are of a pathological (unnatural) nature. Such forms do not correspond to the objects and methods of Euclidean geometry and are forms of a non-linear world. It is known that classical science does not study nonlinear objects.

Until the 70s of the XX century, the fractal approach from a mathematical point of view was first implemented by the mathematician Benoit Mandelbrot. He changed the concept of a mathematical "monster" to the concept of a fractal. Benoit Mandelbrot gave the following definition to the concept of a fractal: "A fractal is a structure consisting of parts that are in a sense similar to the whole" [12, p. sixteen]. According to Mandelbrot, the real landscape is not even, that is, in our world there is nothing even and in the shape of a circle, everything has fractal properties. Consequently, the doctrine of fractal shows that measurements of objects and phenomena are not even, uniform, do not correspond to measurements with whole numbers, but have fractional measurements.

The concept of a fractal expresses disorder, a transitional state of evolving objects, an intermediate state means a state between two stable states.

Fractals are always associated with the concept of chaos. First, both of these concepts are mathematical theories, studying the uneven structures of the real world. Secondly, fractals determine the structure of chaos [13]. Thirdly, fractals are a new language that mainly expresses the form of chaos [14, p. 215-242]. Fourth, a fractal allows you to find a pattern in chaos [15]. Consequently, fractals are part of the chaos.

In classical science, the concept of chaos is considered equivalent to disorder and uncertainty. However, in post-non-classical science it is argued that in chaos there is a certain order, and it obeys a certain pattern. But it is difficult to find this pattern. The purpose of the study of chaos and fractal is to find patterns in an unknown and completely chaotic system. Even in chaos, one can find the interconnection of phenomena. This connection is a fractal. In other words, in every disorderly, uneven, there is also a straight line, stability, order.

Fractals also exist in the social sphere. At the same time, we can say that in human being, the manifestation of fractality exists in a spiritual, psychological, moral form. The ancient Indian epic "Ramayana" says: "In every hair of Rama's body there are many worlds similar to ours." This thought demonstrates the fractal properties of the world, that is, the embodiment of the principle "one in all, all in one".

We can recognize that fractal structures exist in art, literature, music, architecture and visual arts. EV Nikoleva asserts the existence of cultural fractals in the theory of culture.

From the above, we can draw the following conclusion that being is built on the basis of fractality (invariance). This means the manifestation of the fractal pattern of being. The fractal approach is concerned with modeling this pattern.

According to the fractal methodology, the world and a person have fractal properties. This is the repetition of information over and over again at each level of the fractal structure, which is a certain pattern.

As a result, we can conclude that the fractal paradigm is one of the heuristic productive models in the cognition of complexity. That fractal is a definite model of cognition of complexity.

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