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INTERWEAVING MATHEMATICS AND HUMANITIES: FRACTALS AS A TOOL FOR ANALYZING SOCIOCULTURAL PHENOMENA

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Abstract:
This article explores the significance of the fractal concept for social sciences and humanities, demonstrating how this mathematical concept has been applied in the analysis of complex sociocultural systems. It highlights the views of various scholars such as E.V. Nikolaeva, V.V. Tarasenko, and others, who have used fractal theory to study recurring cultural patterns, social interactions, and dynamic processes in society. The article shows how fractals help to understand the universality and complexity of natural forms and phenomena, and sheds light on their application in various fields - from biology and geology to physics, art, and architecture. Special attention is paid to the potential of fractal theory as an innovative method of research in social sciences and humanities, offering a new level of understanding and interpretation of social reality.

Keywords: fractal, social sciences and humanities, cultural patterns, social systems, dynamic processes, interdisciplinary analysis, mathematical concepts in humanities, research methodology.

In contemporary science, the idea of a recurring semantic invariant, as a mechanism of meaning formation, is not new and resonates with many researchers in the social sciences and humanities who utilize the mathematical and visual intuition of the fractal. The term "fractal" was introduced by mathematician Benoit Mandelbrot, derived from the Latin participle "fractus," meaning "fragmented" or "irregular in shape" [1, p. 6]. Fractals were initially used to describe natural and mathematical objects with complex and seemingly chaotic structures, such as coastlines, mountains, trees, snowflakes, and the human circulatory system. Generally, a fractal is defined as a structure consisting of parts similar to the whole, possessing scale invariance. In mathematical terms, it is described as an object with a fractional dimension, not describable in our usual whole dimensions. As noted by Russian mathematician and philosopher A.V. Voloshinov, a fractal is not a final form, but a law of formation of this form, a "gene of formation" [2, p. 73]. Mathematicians describe the properties of a fractal through a stable transformation method - an algorithm that may be simple but creates incredibly complex

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structures. In its pure mathematical form, a fractal represents an unfinished and infinite structure, characterized by iterativity and repeating the same pattern.

The importance of fractals in modern science lies in their ability to demonstrate both the universality and complexity of natural forms and phenomena. They allow us to see order in apparent chaos and provide tools for describing complex structures that are difficult or impossible to describe using traditional methods. This concept has a wide application in various fields, from geology and biology to economics and art. Fractal research has opened new perspectives in understanding complex systems. For example, in biology, fractal analysis is used to study structures such as tree leaves, the structure of blood vessels, and even the respiratory tract. In each of these cases, fractal geometry allows for a deeper understanding of the principles of organization and functioning of living organisms. In geology, fractals are used to analyze complex forms of relief, such as mountain ranges, cave systems, and river networks. These studies help scientists better understand erosion processes and other geological processes. In physics, fractal analysis provides unique tools for studying the dynamics of complex chaotic systems, which sometimes cannot be analyzed using traditional physical models. In art and architecture, fractals inspire the creation of works that mimic the complex and repeating patterns of nature; fractal structures are often used to create visually mesmerizing and dynamically changing artworks. Thus, the concept of fractals is a powerful tool for understanding and describing complex structures in various fields of science and art.

All these ideas, based on Benoit Mandelbrot's work "The Fractal Geometry of Nature," emphasize the procedural and dynamic aspects of physical reality, which can form the basis for developing a more adequate methodology for researching procedural phenomena in social sciences and humanities. This expansion of the concept of fractals goes beyond strict mathematics and penetrates the humanitarian sphere, starting from the 1990s the term "fractal" has come to be associated not only with natural or architectural objects but also with sociocultural self-organizing systems. Thus, E.V. Nikolaeva proposed using the concept of a conceptual fractal to describe recurring cultural patterns. She asserts that the conceptual fractal, identified with P. Dauton's "conceptual scheme," expresses similarity at the level of ideas and concepts. This concept allows the reproduction of the same idea, which is common for the sociocultural or philosophical system and its components, including symbols and other social and cultural elements. E.V. Nikolaeva believes that the fractal has become a vivid and operational visualization of the idea of infinite becoming, incompleteness, processuality, and the immanently "programmed" dynamics of all sociocultural phenomena [3]. In this context, fractals allow for the exploration of both static and dynamic aspects of sign systems, offering a new look at their structure and functioning.

V.V. Tarasenko, the creator of the concept of fractal semiotics, considers the fractal as a special procedural language. The fractal possesses an unusual nature for our perception: on one hand, the fractal is a geometric figure, similar to a line, circle, or triangle; on the other hand, the fractal lacks a clear visual image, it does not possess the integrity and clarity characteristic

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of Euclidean geometry forms. Thus, the fractal represents not an image in the traditional sense, but rather a procedural phenomenon, creating a new problem field for fractal semiotics [4].

The idea of the fractal, first proposed in the context of mathematics, proved heuristic for a wide range of modern scientific approaches, extending its influence beyond the natural sciences and deeply penetrating social sciences and humanities. In social psychology, interactionism and the Gestalt approach of D. Newtson and his colleagues [5] use fractal principles to analyze physical interactions of people and perception of space. Approaches such as social constructionism by A. Sandu and S. Poni [6], as well as the theory of sociomateriality by T. Henderson and D. Boye [7], apply fractal ideas to study interactions between social and material elements in society. The theory of nonlinear dynamic systems in social psychology, proposed by R. Vallacher and A. Novak [8], as well as ethnographic studies by M. Agar [9] and developmental psychology by T. Marks-Tarlow [10], also demonstrate the successful use of fractal concepts in their research. These approaches often rely on contemporary "processual" views of reality, gaining popularity in the natural sciences, such as the theory of nonlinear dynamic systems, the theory of autopoiesis, I.R. Prigogine's theory of non-equilibrium systems, the theory of chaos, and others. The use of fractal theory in religious studies research opens new perspectives for the study of the individual consciousness of the believer, which may lead to a profound rethinking of traditional approaches in social sciences [11].

The popularity of the fractal concept is now so great that E.V. Nikolaeva suggests considering it as part of a scientific revolution in the humanities discourse. She admits the transition to a fractal paradigm and a fractal worldview, which could radically change our ways of understanding culture, society, and even reality itself [3]. Thus, the application of the fractal concept becomes a bridge between the exact and socio-humanitarian disciplines, allowing researchers to use mathematical tools for a deeper understanding of cultural and social processes. Fractals offer a new way of analyzing and understanding complex social and cultural structures characterized by nonlinearity and self-similarity. This approach can strengthen and complement existing theories in fields studying dynamic and complexly structured systems, such as social networks, cultural trends, and historical cycles. Fractal theory offers a new perspective for understanding how interactions on a small scale in a specific context can generate complex large-scale structures and patterns. For example, a fractal perspective could be used to analyze historical processes, where recurring events and structures can be seen as reflections of deeper, fundamental social and cultural dynamics. In sociology, fractal analysis can be used to study patterns of population migration, information dissemination in social networks, or even to analyze characteristics of psychological states.

Despite the extensive prospects for using the fractal idea in socio-humanitarian sciences, it is still difficult to talk about a fully formed scientific direction. Currently, we see a number of developing studies that use fractal ideas in various contexts. This is a new look at the procedural aspects of socio-humanitarian phenomena, combining different forms of theorizing and relying on diverse scientific approaches. The emerging commonality of methodology,

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which could be called "fractal theory," represents not a completed and established research methodology, but rather a generalized name for an emerging promising scientific direction in the social sciences and humanities. So far, the number of significant and indicative studies is limited, and a considerable number of methodological questions require further development and deeper theoretical substantiation.

The integration of fractals into social and humanities sciences presents certain challenges. Traditional approaches in these fields often focus on linear models and clearly defined cause-and-effect relationships, while fractal theory introduces the concept of nonlinearity and complexity. This can lead to a conflict between established research methods and new fractal approaches, requiring a revision of some fundamental assumptions and methodologies. Additionally, a key issue is the accuracy and appropriateness of applying mathematical models of fractals to sociocultural phenomena. Social and cultural systems are extremely complex and often subject to the influence of numerous variables, which can complicate accurate modeling of their structure and dynamics using fractal theory. There is a risk of oversimplification or misinterpretation of complex social phenomena if fractal analysis is conducted without proper consideration of contextual factors and the specifics of the object of study. Fractal analysis may not always be applicable to various scales of social phenomena. Some social structures and processes may not exhibit self-similarity or other fractal characteristics at all levels of analysis. Moreover, fractal analysis requires specialized knowledge and methods, which may limit its accessibility and applicability for researchers in the social and humanities sciences who do not have sufficient mathematical education.

Nevertheless, it is evident that the use of fractal theory opens new horizons for research. Fractal theory in the social and humanities sciences is not just a methodological tool but also a way of thinking that allows researchers to penetrate deeper into the essence of procedural and dynamic phenomena characteristic of society and culture. This opens the way to new horizons of understanding and interpreting social reality, making fractal theory an important and promising direction in contemporary social and humanities research.

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