T. I. DOMBROVAN

SYNERGETICS: A NEW PERSPECTIVE IN INTERDISCIPLINARY RESEARCH

To Prof. Valeriya Andreevna Kukharenko,
who has always been open-minded and supportive of new ideas

Introduction. The term '*synergetics*' (from Greek 'coherent action') was suggested by the German physicist Hermann Haken in the mid-1970s to name a science of complexity, dealing with principles of emergence, self-organisation and self-regulation of complex systems of various ontologies – either man-made (artificial) or natural (self-organised).

A precursor of synergetics was cybernetics – an interdisciplinary theory of control and communication in the animal and the machine. The word is of Greek origin as well, meaning 'governance', or 'government'. Cybernetics focused on negative-feedback-based complex systems of causal-chain circularity, i.e. automatic systems capable of restoring their stability within a desired range regardless of any disturbances. It is within cybernetics that the notion of '*homeostasis*', meaning invariability and balance of states, came to be applied not only to living beings, but also to technological systems. This notion is seen as one of the most important aspects of a system, necessary for maintaining the stability and functioning of the latter.

Unlike cybernetics which studies relatively balanced, stable and homeostatic systems, synergetics focuses its attention on hysteretic, i.e. evolving, positive-feedback-based complex systems. What, then, is understood by 'complex systems'?

The common description of a complex system as having numerous components connected to one another is insufficient for research purposes. "A modern definition is based on the concept of *algebraic complexity*" (emphasis added) [37, 4], i.e. it includes a sequence of data describing both the interconnected network and cooperativity of the system's elements and their complex behaviour.

Robert C. Bishop considers it more informative to characterise complex systems phenomenologically. In the list of the most important features he includes such characteristics as broken symmetry, hierarchy, irreversibility, integrity, intricate behaviour, stability and a few others [31, 111–112].

A complex system calls for new ways of scientific analysis, as well as a new framework of categories. Synergetics suggests integrity of methods elaborated in various disciplines and a variety of models to represent the complexity of organic and inorganic systems. **The aim of the present article** is to draw researchers' attention to heuristic potency of synergetics and promising applications of its categories and methods in various scientific studies.

On an Interdisciplinary Character of Synergetics. A disciplinary approach to the study of an object implies the usage of notions and categories, as well as a methodology of analysis, elaborated within a particular discipline.

An interdisciplinary approach is realised in at least two directions. Firstly, it presupposes expansion of the set of categories and methods of analysis at the expense of those from other disciplines. We call it a centrifugal vector of interdisciplinarity (see Fig.1).

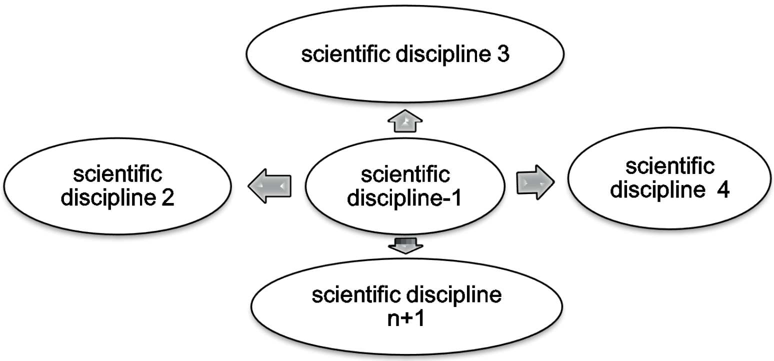

Fig. 1. Interdisciplinary investigations: a centrifugal vector

Secondly, an interdisciplinary approach is a cooperative study of an object when it is placed into the sphere of scientific reflection of researchers working in different fields of science and/or belonging to different academic schools of thought. It is a synthesis of methods and concepts of two or more disciplines. Let's refer to it as a centripetal vector of interdisciplinarity (see Fig.2).

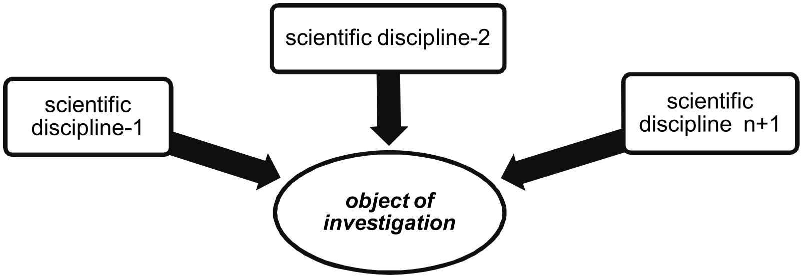

Fig. 2 Interdisciplinary investigations: a centripetal vector

The interdisciplinary methodology is a horizontal, associative network of links, integrating experience, modes of thinking and methods of particular scientific fields. The disciplinary methodology is vertically structured, digging into the depths of the object of investigation, and more or less limited by the boundaries of its own discipline.

From a historical point of view, the interdisciplinarity is not novel, and we cannot but agree with Andrew Barry that it would be incorrect to think that, in the past, knowledge production has primarily taken place within autonomous unified disciplines but that it no longer does so [30, 23]. Similarly, it would be a mistake to contrast the homogeneity and closure of disciplines with the heterogeneity and openness of interdisciplinarity, for disciplines themselves are often remarkably heterogeneous or internally divided [ibidem, p. 26].

A disciplinary approach is often seen as prior to the interdisciplinary one. In Vladimir Arshinov's words , "a disciplinary approach is supposed to solve a definite task, appearing in a historical context of the object development, with the help of the already established methods. *Exact opposite* is an interdisciplinary approach <…> it is a principally different, holistic way of categorisation of the reality, where polymorphism of languages and analogy are dominant, not a cause" [2, 75] (emphasis is added). In our opinion, however, the concepts of ‘disciplinarity’ and ‘interdisciplinarity’ are not “exact opposite”, but complementary. An interdisciplinary approach reinforces an explanatory potency of research, enriching a certain scientific discipline with new concepts and modes of thinking, and takes a researcher across the boundaries to a meta-level of analysis.

Interdisciplinarity is considered a step to synthesis of knowledge obtained in various spheres of human activity, a specific reaction to hyper-specialisation as a process leading to a dramatic increase in fragmentation of knowledge when researchers working in adjacent fields are ignorant of their colleagues’ achievements, and that is why many discoveries are ‘re-discovered’ in neighbouring spheres [19, 73; 21, 27].

It is worth noting that contemporary science is at such a stage of development when, in fact, there can hardly be found a phenomenon that would be an object of research within only one, autonomous discipline. Both man, nature, society, and even language are no more monodisciplinary objects of analysis. Moreover, interdisciplinary projects seem much more fruitful due to the possibility to widen a researcher’s world outlook, as well as to improve his/her investigational skills, and finally to form a holistic view of the reality.

Synergetics is a rather young interdisciplinary mainstream, still at a tender age. It integrates a variety of sciences dealing with open, dynamic, self-organising complex systems, developing non-linearly in different environments. Interdisciplinarity of synergetics is in the synthesis of methods and research techniques elaborated and implemented in natural sciences. It is a holistic perception of the world in which everything is interconnected and it never stops changing.

Applications of Synergetics. The methodology and conceptual network of synergetics can be employed in various spheres of scientific activity studying complex evolving systems. In the words of H. Knyazeva, any theory which is used to obtain new knowledge becomes a method, or, as it were, our companion (from Greek μετα ‘complicity, cooperation’ + οδος ‘way, road’) on the thorny paths of scientific study [19, 83].

Our review of special literature has shown that synergetic principles set up a heuristic scheme for complex systems modelling both in sciences and in humanities to solve technological, ecological, social, political and other problems. The first results have already been obtained of the successful application of synergetics in:

- *Technology:* creation of new materials.
- *Mathematical history:* mathematical modelling of historic events in order to develop algorithms and methods of description of historical alternatives, as well as to state possible ways of further development of various situations.
- *Mathematical sociology and social management:* studying and modelling social phenomena, such as residential dynamics, emergence of self-organising cities, social instability, or collective opinion formation [40; 41].
- *Psychology*: A net model of the fractal world makes for mathematical modelling in psychology. Researchers have described non-linearity and cyclical patterns of thinking processes, as well as the net-like structure of the human brain. Psychologists see a synergetic character of the evolution of the individual and collective conscience and consider the theory of attractors and the catastrophe theory valid for description of psychic processes [11; 33 – 36].
- *Brain studies*: The application of synergetics to the analysis of the neuron network of the cerebral cortex gave birth to a new interdisciplinary approach, namely neurosynergetics. Recent research in neurophysiology and neurosynergetics has uncovered self-organisation of the neuron network. It has been proved that the human brain presents a non-linear complex system whose dynamics are predetermined by a variety of attractors responsible for perception, learning, thinking and other functions of the brain. [12; 15 – 17; 34; 36].
- *Medical diagnostics*: The application of recent achievements of the dynamic systems theory and non-linear dynamics for the mathematical modelling of functioning and diagnostics of health conditions of animate systems is regarded as a novel and promising approach of interdisciplinary studies, involving and uniting the efforts of physicists, biologists, mathematicians and medical workers. As V. Anishchenko puts it, in the nearest future the cardio-vascular system

of a human will be adequately described by a mathematical model with the parameters corresponding to the physiological condition; and in order to cure this or that illness it will be sufficient to influence the corresponding parameter [1, 203-204].

- *Education*: The so-called synergetic principles of organisation of the educational process are being developed. Investigation into the factors increasing efficiency of the educational process in high and higher schools indicates that an interactive chaotic environment triggers the development of creative thinking [4 –7; 24; 28].
- *Linguistic synergetics*, which considers language as an open self-organizing complex system and deals with principles of language change and development. It is a new stage in the investigation of language as an open self-regulating system. The main task of linguistic synergetics is to reveal, describe and explain the mechanism of the inner dynamic structure of a language using research principles of synergetics as a paradigm of complexity [8 – 10; 13; 14; 23; 25; 26; 32].
- *Arts and culture studies*: On the whole, culture and arts can be represented as dynamic self-organising systems that are able to alter their structure due to their own openness and interaction with other systems of the environment. It means that the universal principles of self-organising complex systems development can be projected onto the sphere of culture studies on the whole and the creative process in particular.
- *Meteorology*: Researchers see the validity of the synergetic models in modelling climatic changeability, as for climatic and/or weather pattern studies the interaction of numerous factors should be considered (the so-called co-operative effect), which can adequately be described in categories and notions of synergetics.
- *Prognostics*: Synergetic strategies open a world of new opportunities to foresee and even govern the future of the planet. Making demographic prognoses involves taking into account the development of economy, science, and technology, as well as consideration of social, ecological and political problems of the contemporary world. It calls for an interdisciplinary approach to analyse vast information flows, to work on a great number of factors-

parameters (variables and constants) simultaneously.

Synergetics has offered powerful research equipment for science and the humanities. It is seen as a conceptual-methodological basis for interdisciplinary synthesis of knowledge, a sort of bridge between various spheres of scientific activity.

Successful application of the concepts and methods of the synergetic approach to the description of biological, physical, historic, social, and even economic phenomena has revealed similarity, if not universality, of principles of evolution of complex systems. As a result, synergetics has made it possible to launch a wide variety of interdisciplinary interrelationships, among them mathematical physics, mathematical history, social government, neurosynergetics, meteorology, geodynamics, prognostics, to name a few. The new disciplines, in their turn, require specialists with a profound knowledge of complex systems methodology. Otherwise, as Cliff Hooker points out, people whose education does not include relevant competency in complex systems are excluded from science, policy, and large-scale business, or they find themselves increasingly dependent on those who have such competency [*39,* 6].

Nowadays, the necessity of integration of different sciences calls for no argument and most scholars agree that the future of science lies within interdisciplinary research of complex systems [see, e.g. 17, 8; 29, 235; *38; 39].* In the words of George Malinetsky, the 21st century is bound to become a century of a re-establishment of holism and a deep understanding of common problems [22, 42]. It is interdisciplinary orientation that helps scientists think globally, i.e. beyond the borders of particular disciplines.

Scientists strongly believe that the application of principles of co-evolution of complex systems, as well as principles of non-linear development of open dissipative environments, will result in the formation of a new efficient approach to the solutions to global problems facing mankind and contemporary science [Белавин].

Needless to say, the common feature of all synergetic systems is their uniqueness: the Universe, our life on planet Earth, the languages and cultures of the peoples of the world, ecosystems, and so on are unprecedented and one-off. Consequently, man's responsibility for his actions (most of which are irreversible) increases. We cannot but agree with George Malinetsky who says: “We must think, foresee and plan our actions in this only world where we live and in this only life at our disposal. It is a challenge to many sciences” [20, 21].

All things considered, synergetics helps us understand the principles of complex systems, predetermining our present day and our tomorrow. Synergetics also sheds new light on one of the fundamental issues of philosophy, namely the problem of the correlation of the part and the whole. This problem seems to be connected with the issue of the co-evolution of integral parts of a given system. It is well known that the whole is not a mere sum of its components. Water, ice and vapour are three forms of existence of one and the same substance. Other examples – diamond and graphite – have the same components but different physical and chemical characteristics. The ‘mystery’ can easily be explained by the specific network of relationships among the system components.

It was within the synergetic paradigm that scientists paid attention to another phenomenon: an open dynamic complex system consists, as a rule, of parts that are at different stages of their development. This is true with a language system, too. Take, for example, a word-stock of any living language, and you will find new words and expressions alongside obsolete ones.

Conclusions. Synergetics is seen as a specific theoretical and methodological platform, systematising numerous fragments of knowledge about the external world obtained by science and integrating them into a comprehensive image of the world. A synergetic view of the world represents the latter as capable of self-organising from parts into unity. This calls to mind a hologram, in which the whole can be restored from any of its fragment. The holographic model of the world is supported by a philosophical understanding of the wholeness of the physical matter and may be regarded as a next stage in the never-ending evolution of the Universe. The Universe constitutes a total dynamic superstructure of limitless variety of criss-crossed powerful mega-systems developing in a non-linear way and changing according to their own inner laws and purposes.

Nowadays, the methodology of science undergoes significant changes, concerning, first of all, the paradigm shift – from 'destructive analysis' to 'constructive synthesis'. A unified theory of complex systems is being born.

We would like to finish this article with the words of Hermann Haken: "Synergetics is very much an open-ended field in which we have made only the very first steps. In the past one or two decades it has been shown that the behaviour of numerous systems is governed by the general laws of synergetics, and I am convinced that many more examples will be found in the future. On the other hand we must be aware of the possibility that still more laws and possibly still more general laws can be found. <...> this programme is not yet finished but leaves space for future research" [37, 14].

REFERENCES

1. Анищенко В.С. Знакомство с нелинейной динамикой.– М.: Изд-во ЛКИ, 2008. – 224 с.
2. Аршинов В.И., Буданов В.Г. Когнитивные основания синергетики // Синергетическая парадигма. Нелинейное мышление в науке и искусстве. – М.: П-Традиция, 2002. – С. 67–109.
3. Белавин В.А., Курдюмов С.П., Князева Е.Н. Режимы с обострением и законы коэволюции сложных систем. Available at: http://spkurdyumov.narod.ru/Belavin.htm
4. Буданов В.Г. Методологические принципы синергетики // Новое в синергетике. – М.: Наука, 2006. – С. 312-322.
5. Буданов В.Г. О методологии синергетики // Вопр. философии. – 2006. – № 5. – С. 79–94.
6. Буданов В.Гс . Методология синергетики в постнеклассической науке и в образовании. – Ин-т философии РАН, М.: Изд-во ЛКИ/УРСС, 2007. – 232 с.
7. Буланчиков В.А., Серков Л.А. Синергетическое моделирование образовательных процессов. – Екатеринбург, 2007. – 232 с.
8. Герман И.А. Лингвосинергетика: Монография. – Барнаул: Изд-во ААЭП, 2000. – 168 с.
9. Домброван Т.И. Лингвосинергетика: Язык как синергетическая система. – Saarbrucken: Lambert Academic Publishing, 2014. – 308 с.
10. Домброван Т.И.Синергетическая модель развития английского языка. – Одесса,: КП ОГТ, 2014. – 400 с.
11. Донченко Е.А. Фрактальная психология. – Киев: Знания, 2005. – 323 с.
12. Дрейманис А.П. Нейросинергетика и процесс творческого мышления // Научно-техническое творчество. Проблемы эврилогии. – Рига: ИФП, 1987. – С.152–154.
13. Єнікєєва С.М. Системність і розвиток словотвору сучасної англійської

мови. – Запоріжжя: ЗНУ, 2006. – 303 с.

14. Кійко Ю.Є. Німецько-українські паралелі в інформаційних медіажанрах: фрактальний підхід. – Чернівці: ВД Родовід, 2016. – 392 с.
15. Князева Е.Н., Курдюмов С.П. Законы эволюции и самоорганизации сложных систем. – М.: Наука, 1994. – 236 с.
16. Князева Е.Н., Курдюмов С.П. Интуиция как самодостраивание // Вопросы философии. – 1994. – № 2. – С. 110-122.
17. Князева Е.Н., Курдюмов С.П. Основания синергетики: Синергетическое мировидение. – М.: КД «ЛИБРОКОМ», 2010. – 256 с.
18. Князева Е.Н., Курдюмов С.П. Основания синергетики: Человек, конструирующий себя и свое будущее. – М.: КД «ЛИБРОКОМ», 2011. – 264 с.
19. Князева Е.Н., Курдюмов С.П. Синергетика: Нелинейность времени и ландшафты коэволюции.– М.: КомКнига, 2011. – 272 с.
20. Малинецкий Г.Г. Чудо самоорганизованной критичности. Вступ. статья к кн.: Бак П. Как работает природа: Теория самоорганизованной критичности. – М.: УРСС, 2013. – С. 13-46.
21. Малинецкий Г.Г., Потапов А.Б. Современные проблемы нелинейной динамики. – М.: КомКнига/ URSS, 2005. – 368 с.
22. Малинецкий Г.Г., Потапов А.Б. Нелинейная динамика и хаос. – М.: КД Либроком, 2011.
23. Москальчук Г.Г. Структура текста как синергетический процесс. – М.: УРСС, 2010.
24. Олександренко К.В. Психологічні чинники розвитку професійної комунікативної діяльності майбутніх фахівців міжнародних відносин. – Хмельницький: Поділля, 2012. – 372 с.
25. Пиотровский Р.Г. Лингвистическая синергетика: исходные положения, первые результаты, перспективы. – СПб.: Филол. фак-т С.-Петерб. гос. ун-та, 2006. – 160 с.
26. Пихтовникова Л.С. Лингвосинергетика: основы и очерк направлений. Монография. – Х.: ХНУ им. В.Н. Каразина, 2012. – 180 с.
27. Пригожин И.Р., Стенгерс И. Порядок из хаоса. Новый диалог человека с природой. – М.: Прогресс, 1986. – 431 с.; М.: Едиториал УРСС, 2003. – 312 с.
28. Розин В.М. Социально-гуманитарные науки и проблема специфики синергетики как научной дисциплины // Философские науки. – 2004. – № 2.– С.85–102.
29. Чернавский Д.С. Синергетика и информация (динамическая теория информации). – Изд. 3-е, доп. – М.: Книжный дом «ЛИБРОКОМ», 2009. – 304 с.
30. Barry, Andrew, Georgina Born and Gisa Weszkalnys. Logics of interdisciplinarity // Economy and Society, 37(1). 2008. – pp. 20-49.
31. Bishop, Robert C. Metaphysical and epistemological issues in complex systems. – In: *Hooker, Cliff (ed.) Philosophy of Complex Systems. Amsterdam, etc.: Elsevier B.V., 2011. – pp. 106-136.*
32. Dombrovan, Tetiana. An Introduction to Linguistic Synergetics. – UK: Cambridge

Scholars Publishing, 2018. – 152 p.

33. Haken, Hermann. Synergetics. An Introduction. – Berlin: Springer-Verlag, 1977.
34. Haken, Hermann. (ed.) Pattern Formation by Dynamic Systems and Pattern Recognition. (Springer Series in Synergetics) – Berlin: Springer-Verlag, 1979. – 305 p.
35. Haken, Hermann. Synergetics of Cognition. – Berlin: Springer-Verlag, 1990.
36. Haken, Hermann. Principles of Brain Functioning. A Synergetic Approach to Brain Activity, Behavior and Cognition. (Springer Series in Synergetics). – Berlin: Springer-Verlag, 1996.
37. Haken, Hermann. Information and Self-organisation: A Macroscopic Approach to Complex Systems. 2nd enlarged ed. (Springer Series in Synergetics). – Berlin: Springer-Verlag, 2000. – 226 p.
38. *Hooker, Cliff (ed.) Philosophy of Complex Systems [Handbook of the Philosophy of Science. Vol. 10]. Amsterdam; Boston, Heidelberg, London, etc.: Elsevier B.V., 2011. – 931 p.*
39. *Hooker, Cliff. Introduction to Philosophy of Complex Systems: A. In: Hooker, Cliff (ed.), 2011. – pp. 3-90.*
40. Portugali J., Benenson I. and Omer I. Sociospatial residential dynamics: stability and instability within a self-organizing city // Geographical Analysis.1994. Vol. 26. No. 4. pp. 321–340
41. Weidlich W. Synergetic modelling concepts for sociodynamics with application to collective political opinion formation // Journal of Mathematical Sociology. 1994. Vol. 18. No. 4. – pp. 267-291.