
WHAT IS SYNERGETICS?

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New science of complexity, ie, synergetics, is in the process of becoming widely appreciated now. Synergetics deals with cognition and explanation of complex structures, principles of their self-organization, generation of order from chaos, evolution and co-evolution. Synergetics as an interdisciplinary research field has far-going applications to understanding of humanbeing and development of social systems.

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Synergetics, starting from everyday life

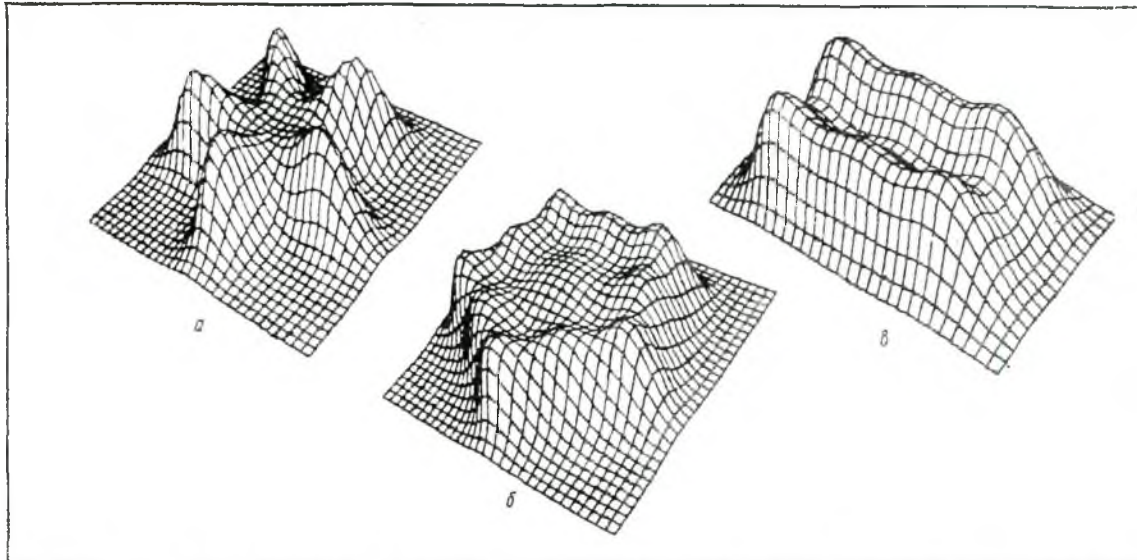
I often happen to be in one of the overcrowded metro stations of Moscow. Each time I see a quite peculiar picture. Because of a rather disadvantageous planning of this station, two crowds are constantly confronting each other: of those who enter the station and want to catch a train arriving every 2 or 3 minutes, and of those who go upstairs to leave the station. What happens then? Each crowd spontaneously dissipates into two or three streams which flow through those

of opposite crowd with a certain angle forming all together a complicated picture.

This picture often comes to my mind when thinking of synergetics. In a fascinating way it displays almost all the basic features of synergetic phenomena.

The key feature is *self-organization*. It is neither an organization as somebody's intentional act from above, nor is it an initial chaos. Without openly communicating to each other and seeing only several backs in front, the crowds spontaneously

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The visual presentation of several complex structures in open dissipative medium investigated in computer experiments at the Keldysh Institute in Moscow.

reorder themselves into streams of "human particles".

The phenomenon at the metro station can thus be considered as an *open system* with a strong inflow of energy. The passengers hurry to get here or there, and the increase of overcrowding after the arrival of the next train could be seen as an analogy of energy inflow. Be it only a limited number of the same people in the hall having no appointment, they would undertake a random walk around and perhaps even a pleasant talk instead. That is, there is a certain *threshold* of number of people; only if number of people exceeds the threshold quantity, a process of self-organization can take place.

But if, on the other hand, the inflow of passengers would rise further and the mutual pressure would increase, the orderly streams could dissolve into an overpressed

multitude of "human bodies" requiring regulations by the police.

These "human particles" act *cooperatively*, or *coherently*. And this is not mainly due to their mental abilities. They adapt to each other just like real material particles can do. As a result, a unified stream arises which averages the impulses of the strongest and the weakest members of the crowd to a certain generally acceptable and effective movement.

Sometimes a direction and a path of one of the streams may suddenly change. Because of somebody's momentary indecisiveness or an appeared gap in the opposite stream, a single most energetic path-finder may decide to push through another way. These are typical *fluctuations* (micro-deviations) and *bifurcations* (branching of possible ways) to which fluctuations may lead.

The streams of passengers make a *sustainable structure*. Yesterday I was pushed by a particular lady, today by another one, but their trajectories remain the same. Our brave path-finder has taken another train long ago, but the stream still follow his steps. People change, the structure is being maintained. To be more precise in our case, we have here two confronting dynamic structures (originating from two crowds) which form a stable *pattern* of their interaction.

Indeed, the streams are not rigid and can fluctuate, but there are paths which they objectively and persistently tend to. The streams can change their directions by somebody's occasional move, but still their *number and general structure* are not absolutely random. They can switch over to a certain *discrete spectrum of paths* (attractors). It is determined by a design of the metro station. If its configuration and size differ, the patterns are different too.

People flow through a structure, generating and sustaining it, and are subordinated to it at the same time. This is called the *slaving principle* in synergetics. You may wish it go your own way through the crowd, but to get quicker and to save your energy, you have to follow the stream. As to human systems, a *purposive communication* could be introduced. People may wish not to act as material bodies and manage themselves in a more sophisticated way, which interferes with the original spontaneous self-organization and adds a higher degree of complexity to the system.

Finally, it is synergetics that reveals some

essential similarities between animate and inanimate systems. It shows that structures themselves may display features of self-preservation and purposive (quasi-conscious) activity as separate from those of their elements. It could thus happen that new barriers, installed to do away with the constant turmoil in the station, once in a night disappear in a mysterious way.

Something of the history of synergetics

Synergetics as a field of scientific research has existed for over thirty years already. The term "synergetics" was introduced by the German scholar, Prof H Haken. It is widely used, but still not generally accepted. Instead, "theory of self-organization" is used as a more traditional term. In the last year, two other terms "studies in complexity" and "theory of chaos" became widely circulated. Sometimes they are used as identical with the former two, and sometimes only partly overlap with them.

Synergetics can be considered as a modern stage of development within the traditions of cybernetics (N Wiener, W R Ashby) and system-structural analysis (attempts to elaborate the general theory of systems). However, many elements of the latter have undergone further essential reformation. While cybernetics investigates the functioning of complex systems using an abstract model of *black box*, synergetics studies some physical mechanisms of the complex structures formation, ie, it tries to look into the "black box". While cybernetics elaborates algorithms and

methods of control of systems, synergetics investigates the processes of *self-controlling* and *self-organization* of complex systems in the world.

Various scientific schools

The focus of synergetic research programme is to reveal some general laws of self-organization and evolution which are common to processes of quite different nature: physical, chemical, biological, psychological, social. As such synergetics contains an open trend towards universalization and directly borders on philosophy whose aim is to deal with the ultimate features and laws of reality. General line of synergetic research consists mostly of two elements: from a concrete, but fundamental model of processes to interdisciplinary generalizations and back to concrete subject with its rectified theoretical understanding. Accordingly, synergetics functions as applied synergetics and synergetics proper.

The whole history of development of the theory of self-organization shows that significant theoretical generalizations appeared from rather narrow, but fundamental scientific results. The nonequilibrium thermodynamics and the theory of dissipative structures developed by the Brussels School of the Nobel Prize winner (1977) I Prigogine had its background in investigation of processes in physical chemistry.

The development of the theory of coopera-

tive behaviour, made by H Haken and called by himself synergetics proper, originated from the investigations of the coherent radiation of lasers. Lasers became a paradigmatic example of synergetics. H Haken is an editor of a Springer series of books on synergetics (already more than 60 volumes) presenting a whole spectrum of synergetic developments in the world.

As one of other examples of natural science starting point of for further generalizations up to a worldview, one can mention the investigation of nonlinear auto-waves as early as in 1930s by the Russian School of L I Mandelshtam and A Andronov.

Some astonishing results have been obtained recently by the Moscow Synergetic School at the Keldysh Institute of Applied Mathematics (Russian Academy of Sciences) led by S P Kurdyumov with whom I have been collaborating for more then 10 years. The basic model is here a certain class of nonlinear equations describing evolutionary processes of burning in very fast, so-called blow-up, regimes in dissipative media. The model implies a profound sense. Some general features of the complex systems behaviour are being revealed, namely, mechanisms of localization processes (structures formation) in open dissipative media; spectra of structure-attractors as the most stable formations which evolutionary processes in such media go to; methods of resonant excitation of structure-attractors; way of a complex whole construction from parts (structures) developing with different speeds.

It's worth mentioning some other trends in



Prof S P Kurdyumov, Director of the Keldysh
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the studies of complexity, chaos and self-organization. E Laszlo, President of the International Society for the Systems Sciences and a Member of the Club of Rome, is involved in finding ways of a transdisciplinary unified theory construction. The American scholar B Mandelbrot elaborates the so-called theory of deterministic chaos, various scenarios of transition to chaos and back. The Chilean biologists H Maturana and F Varela introduced the notion of autopoiesis which, in their opinion, describes a fundamental ability of living beings to permanently maintain their organization and to develop. F Varela is

working now in Paris and develops the theory of autopoiesis and its application to the human brain activities. The other scholar working in Paris, E Morin, a founder of Association of Complex Thinking (Association de la Pensee Complexe) has undertaken profound analyses of the very language of complexity and chaos. There are many other researchers fruitfully working in the fields. All these trends are coloured in specifications of the original disciplines, eg, mathematics, physics, chemistry or biology.

New science of complexity

"Complexity" is one of the key notions specifying investigations in the field of synergetics. The theory deals with such questions as :

1. how does a complex structure arise, ie, the problem of becoming;
2. what are trends of development of a complex structure, the problem of aims of development;
3. how can a complex evolutionary whole be constructed, the problem of relation of parts to a whole.

Synergetics reveals the creative role of chaos in the process of origin of complex structures and their evolution. Chaos and fluctuations on micro-level play an essential role in determining actual trends, "aims" of processes at a macro-level. Chaos manifests itself as a mechanism underlying an exit to one of evolutionary structure-attractors. The macro-organization evolves from a disorder, a chaos on micro-level. Dissipative

processes — which are a macroscopic revelation of micro-chaos-act in the same way as a sculptor's chisel shapes a statue from a block of marble.

One of the most essential questions is that of the trends of evolution: where do evolutionary processes go to? How does history flow on? The future states of complex systems escape our control and prediction. The future is open, not unequivocal. But at the same time, the spectra of "purposes" of development are available in open nonlinear systems. If we chose an arbitrary way of evolution, we have to be aware that the way may be not feasible in a given system. Only a definite set of evolutionary ways, evolutionary structure-attractors can develop. Figuratively speaking, there is "a tacit knowledge" of the system itself. The spectra are determined exclusively by the inner properties of open nonlinear systems. Thus, the future is open in the form of spectra of pre-determined possibilities.

Complexity is closely connected with speed (tempo) of evolution. A complex structure is an integration of structures of "different ages", ie, structures at different evolutionary stages of development. The principles of integration of such structures of "different ages" into an evolutionary whole structure are being revealed in synergetics. The integration of relatively simple structures into a more complex one occurs through the establishment of a common tempo of development in all unified parts (fragments, simple structures). Structures of "different ages" start to co-exist in one and the same 'tempo-world'. The term 'tempo-world' proposed here signifies 'a world having a

certain rate (tempo) of development'. Rate of development is the most important characteristic in the process of assembling of a complex evolutionary whole.

From strict science to the philosophy of life

Synergetics goes beyond the framework of strict mathematical models and narrow applications. Scholars are trying now to apply synergetics not only to new fields of natural sciences, but also to the humanities. There are some attempts to use synergetic models in understanding human artistic and scientific creativity, cognition, health, education, communication, humankind development, etc. Although it is very difficult to use synergetic models here in a quantitative way, a general qualitative synergetic view allows us to reveal some unusual features of the human individual and his collective life.

Synergetics is optimistic in its essence. In the modern situation of accelerated and unstable development of the world, synergetics brings us new hopes. It is an optimistic attempt to understand the principles of co-evolution of the complex social systems, to reveal causes of evolutionary crises, instability and chaos and to master the methods of nonlinear management of complex systems in unstable states. How to manage a complex system without harsh management is the major problem. How can we push the system in a favourable (for the subject) evolutionary path with a small resonant influence? How can we provide a self-maintaining and sustainable develop-

ment? Synergetics can serve as a heuristic instrument in search of answers to the questions.

The synergetic approach to a human being is a new approach to individual and collective health (socio-therapy). Healing acquires a metaphorical image of "self-opening", "returning to self". It is a kind of "synergetic adventure" of a human being when the latent attitudes (structures-attractors) to a favourable and healthy future are being revealed in the humans. It is discovering some self-maintaining paths and inner forces to follow them. From a synergetic point of view it is possible to discuss the following questions: Is it healthy to be chaotic? What are the causes of the efficiency of weak influences, such as, homeopathic or acupunctural? Is it possible to be psychically healthy and to have simultaneously a somatic disease?

The synergetic approach to education, synergetics of education, can be characterized as a gestalt-education. The procedure of education, a way of connection between a teacher and a pupil, is not a transfer of knowledge from one head to another. It is neither an enlightenment nor rendering of some already discovered truths. This is a nonlinear situation of an open dialogue with an intermediate feedback, a joint educational adventure. This is falling — in course of solving some problems — into one and the same self-concordant tempo-world. The latter means that due to common activity the teacher and the pupil begin to develop with the same rate.

The educational procedure consists simply in awakening of the forces and abilities of

a given pupil and in stimulating progress on his or her own paths of development. The gestalt-education is an initiating education, reopening of ourselves, collaboration with ourselves and with other people. It is a way to discover the reality as well as to search paths into the future.

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References

- T S Achromeeva, S P Kurdyumov, G G Malinetskii and A A Samarskii, *Physical Reports*, 176, 186-372, 1989.
- H Haken, *Synergetics*, Berlin : Springer-Verlag, 1977.
- H Haken, *Principles of Brain Functioning. A Synergetic Approach to Brain Activity, Behavior and Cognition*, Berlin: Springer-Verlag, 1996.
- H N Knyazeva and S P Kurdyumov, *Evolution and Self-organization Laws in Complex Systems*, Moscow: Nauka (in Russian), 1994.
- E Laszlo, *The Interconnected Universe*, New York : World Scientific, 1995.
- B Mandelbrot, *The Fractal Geometry of Nature*, San Francisco: Freeman, 1986.
- H R Maturana and F Varela, *The Tree of Knowledge. The Biological Roots of Human Understanding*, Boston and London: New Science Library, 1988.
- E Morin, *Method, Towards a Study of Humankind*, Vol. 1. *The Nature of Nature*, New York : Peter Lang, 1992.
- I Prigogine, *From Being to Becoming* San Francisco: Freeman, 1980.
- I Prigogine and I Stengers, *Order out of Chaos Man's New Dialogue with Nature*, New York : Bantam Books, 1984.
- A A Samarskii, V A Galaktionov, S P Kurdyumov and A P Mikhailov, *Blow-up in Problems for Quasilinear Parabolic Equations*, Berlin: Walter de Gruyter-Verlag, 1995.