Статья опубликована :
Knyazeva, H. and Kurdyumov, S.P. **Nonlinear Synthesis and Co-evolution of Complex Systems // World Futures. 2001. Vol.57. P.239-261.**

Nonlinear Synthesis and Co-evolution of Complex Systems

Helena Knyazeva* and Sergei P. Kurdyumov**

* Institute of Philosophy, Russian Academy of Sciences, Volkhonka St.14, 119 842 Moscow, Russia.
Fax: 007 (095) 200 32 50;
tel.: 007 (095) 203 91 28;
email: knyazeva@iph.ras.ru

** Keldysh Institute of Applied Mathematics, Russian Academy of Sciences, Miusskaya Sq. 4, 125047 Moscow, Russia.
Fax: 007 (095) 972 07 37;
tel.: 007 (095) 250 79 16;
email: kurdyum@applmat.msk.ru

Today a change is imperative in approaching global problems: what is needed is not arm-twisting and power politics, but searching for ways of co-evolution in the complex social and geopolitical systems of the world. The modern theory of self-organization of complex systems provides us with an understanding of the possible forms of coexistence of heterogeneous social and geopolitical structures at different stages of development regarding the different paths of their sustainable co-evolutionary development. The theory argues that the evolutionary channel to the observed increasing complexity is extremely narrow and only certain discrete spectra of relatively stable self-maintained structures are feasible in complex systems. There exists a restricted set of ways of assembling a complex evolutionary whole from diverse parts. The law of nonlinear synthesis of complex structures reads: the integration of structures in more complex ones occurs due to the establishment of a common tempo of their evolution. On the basis of the theory, we can see not only desirable but also attainable futures.

KEYWORDS: anthropic principle, alternative futures, co-evolution, complexity, demographic transition, holistic thinking, nonlinearity, self-organization

1 THE COMPLEX THINKING IN ORDER TO COPE WITH THE COMPLEX WORLD

The modern world staggers us with the tempo of changes and in some countries, including Russia, with the depth of instabilities and crises. Under existing conditions of rapid changes of political and social situation, the shocks and stresses of humans are rather common and usual than exceptional states. To orient ourselves in the changing political and social situations and to adapt ourselves to the cascades of political, ecological, scientific and technical shifts in the world is not at all simple. This leads to the growth of chaotic elements in the social consciousness and culture. It is not clear how to live today and what tomorrow will bring to us. Main guiding lines what to get ready for and what moral rules to stick to in the everyday activities are lost. The dark depths of animal instincts, which are pent-up by culture and the historical traditions, begin to dictate a

primitive policy of survival. This stage of strengthening of uncertainties and chaos is reflected in the modern art, mass culture and philosophy.

The modern communications facilities appreciably reinforce the flows of data messages. Many families of Russian intellectuals hold the book in esteem, follow the old traditions and collect their own rich libraries. But for each member of these families a moment inevitably comes when he realizes that he will never manage to read or even to flick through all the collected literature.

The feeling of unfulfilled intentions, of a sea of unexplored possibilities becomes more and more sharp. This feeling is created by the virtual world as well. Through TV, radio, videotape recordings, computer diskettes, CD-ROMs, Internet, a human being encounters every day and almost automatically crowds of people, gatherings of historical events, enormous arrays of information data. The flows of information stun and hypnotize him, they wash away each other. He doesn't even have enough time to analyze them. The redundancy of information suppresses the personal comprehension and the proper use of the acquired information. The permanent involvement in ever increasing information flows brings about disorder and a confusion into the personal world of the human being. The aspiration for a prosperous life and the obligation to follow some imposed patterns of behavior are being propagated, therefore there is no place for invention and for the flight of creative thought. If the personal protective coverings of a man are weakened, the process of generation of new information and new knowledge is enfeebled as well, since the attainment of an internal calm and the concentration of intellectual activities are necessary for any creative process.

The intensification of information flows in society is an analogue to the strengthening of diffusive, dissipative elements in comparison with an organizational element (the work of nonlinear sources of energy and/or information) in the processes of evolution of complex systems. This leads to a decrease of the rate of growth while some basic system characteristics of the processes remain the same. It appears as if mankind partly returns to the past. The development of society slows down. It looks like the beginning of new Middle Ages. This is one of scenarios of the global demographic transition in the coming decades.

In order to cope with such a complex and unstable world we have to master a complex thinking. E.Morin, President of the Association for the Complex Thinking, underlines the urgent necessity of a reform in thinking and formulates the main principles of complex thinking (Morin, 1990, 1999). The basis for such a thinking is the modern theory of complexity which is under development under a number of different names, viz. nonlinear dynamics, the theory of self-organization, the theory of dissipative structures, fractal geometry, studies in deterministic chaos, the theory of autopoiesis, etc. Following H.Haken, we call this field of scientific research synergetics (Haken, 1978). It is well worth emphasizing that the understanding of the complex world is most likely built up on evolutionary ideas. A general evolutionary outlook on the world is elaborated minutely in the works of E.Laszlo (Laszlo, 1996) .

According to the recent developments of the Moscow School of Synergetics at the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences, synergetics is viewed as the theory of self-organization and co-evolution of complex non-stationary structures emerging in very fast processes, blow-up regimes, in open nonlinear media (systems) (Akhromeeva T.S. et al. 1989; Knyazeva et al., 1994; Kurdyumov et al., 1995, Samarskii et al., 1995). Synergetics is not simply a new research field, it is really an interdisciplinary movement in modern science. It is oriented to the search of general patterns of structure formation, synthesis and decay of complex dissipative structures in open nonlinear systems of any nature. The constructive applications of the synergetic models of complex behavior to the understanding of the human and social evolution are considered also in the recent publication of the German Society for Complex Systems and Nonlinear Dynamics (Mainzer, 1999).

Synergetics can provide us with a *new methodology of world futures studies*. Some basic ideas concerning the possible contribution of synergetics to the futures studies have been put forward in our previous works (Kapitza et al., 1997; Knyazeva, 1999a; Knyazeva, 1999b). One might consider

synergetics as a kind of platform: when standing on it, one could find something certain in the open and uncertain future and could understand not only the principal limits of predictability, but also the possibility to see elements of an infinitely remote future in today's complex evolutionary structures of the world, one would have a certain confidence in our shaky, unsteady, changeable world.

As it was recently pointed out in several papers (Hideg, 2000; Nováky, 2000) presented at the Methodology Seminar in Futures Studies held in June 2000 in Turku (Finland), futures studies are looking now for a new concept and a corresponding philosophy and methods of research. New trends are evolutionary and critical futures studies, i.e. the exploration of the future based on the modern theories of complexity, chaos and general evolution. As E.Laszlo put it, the futures studies must deal with the "cultural-social evolution of culturally mutant homo sapiens" (Laszlo, 1991). "The subject of futures studies is *the evolution of the so-called emergent complexities, which include everything, even Man himself*… By focusing on the nonlinear concept of evolution, *evolutionary futures studies sets as its principle the task of the many-sided exploration of non-linear development, trends of past, present and future*. In the time of evolutionary shift, it wishes to deal with society's future in *a holistic way*, creating the future not by placing the changes of its parts together but by examining the evolutionary dynamics of the whole" (Hideg, 2000, p.2, 4).

Some key features of the *future-oriented thinking* are, in our opinion, as follows:

● consideration of plural possibilities of further development, *alternative futures.* There exists a multitude of possible evolutionary paths for any complex system, however the spectrum of possibilities is not continuous but discrete one;

● orientation not only to a *desirable*, but also to an *attainable future.* One should give up trying to achieve the unachievable and the impossible in principle, i.e. futures that don't conform to the inner potential of a corresponding complex system;

● understanding of a *horizon of our vision of the future*. There are unavoidable uncertainties, chaotic elements, strange attractors what make the future fundamentally noncomputable and open for us. These uncertainties lie in the very fundament of the complex world;

● development of the *holistic thinking*, the understanding of a broad, or even global, *context* of any problem under consideration, i.e. to know how to contextualize the knowledge, as well as the comprehension of general laws of integration, *co-evolution* and interconsistent sustainable development of different complex systems in the world;

● realization of the possibility *to touch an infinitely remote (absolute) future* of complex organization in our present activities.

2 THE DEMOGRAPHIC CRISIS AND THE LAW OF HISTORICAL DEVELOPMENT

S.P.Kapitza has argued in his recent works that the mankind develops as a system and as a indivisible organism already during more than a million years (Kapitza, 1995, 1998). The development of mankind as a single whole may be traced by the change of some parameters. The number of people **N** on the Earth may serve as a key parameter. S.P.Kapitza has collected and analyzed a great scope of demographic and anthropological data. It turned out that the functional dependence of the number of people **N** on time is a hyperbola which has an asymptote somewhere between the years 2010 and 2025.

As a matter of fact, a certain law of historical development of the global system, the mankind, has been discovered and described in a quantitative way. The system develops in the so-called blow-up regime. Various types of blow-up regimes have been studied in mathematics for a long time, the models of blow-up have been applied for the description of different kinds of physical processes. Thus, a spark of reciprocal coincidence could be noticed in the recent results of nonlinear science, synergetics, and the modern data of demography and anthropology.

The processes of development of mankind occur with the tempo of a blow-up regime when, according to the applied model, the number of people on the Earth should reach infinity by the years 2010-2025. It is clear that in reality infinity cannot be reached: entry into a logistic curve occurs; after the drastic increase, the rate of growth of population becomes essentially slower; the world population becomes stabilized. The phenomenon is called a demographic transition. The advanced countries of Europe and North America have already passed this stage of development.

A huge period of human history, more than million of years almost to our time (approximately till 1960-1970), is well described by the law of rapid growth with peaking. Although at present the rate of growth became slightly slower in comparison with the year 1970, it is still extremely high. For the first time in the history of our planet its population redoubled during 40 years: the world population amounted to 3 billions in 1960, it amounted already to 6 billions by the end of 1999. The world population continues to go up and will reach 14 billions by the years 2050-2070.

It is important to note that mankind as an integrated and united system develops irregularly in the course of time. It develops neither according to the law of a geometric series, as it was assumed by Malthus, nor according to an exponent, as many people have believed until now, but according to a hyperbolic law, in the blow-up regime.

3 THE HYPERBOLIC GROWTH IN COMPLEX SYSTEMS. PARALLELS TO THE SPECIAL THEORY OF RELATIVITY

The discovery of the general law of the growth of population on the Earth is supposed to be equivalent in importance to A.Michelson's discovery that the velocity of light is independent of the motion of the Earth. This fundamental fact was taken by A.Einstein as a postulate in constructing the special theory of relativity. New notions of space and time became important constituent parts of the theory. In particular, it was shown that the description of time and of dimensions of objects is different for systems moving with respect to each other with different velocities. These new attributes of physical objects manifest themselves in the most striking way when the difference in velocities of systems approaches the velocity of light. An important feature of the special theory of relativity is the search of invariants, i.e. of quantities that are independent of a relative rate of motion of systems.

Peculiarities of the special theory of relativity are connected with the hyperbolic growth of the mass of a particle when its velocity approaches the velocity of light: $m(v) = m_o / (1 - v^2/c^2)^{1/2}$, where m_o is the rest mass of the particle, v is the velocity of the particle, c is the velocity of light. At bottom of fact, this is a blow-up regime. And what's more, there exists a peaking with velocity in the special theory of relativity, whereas in the case of the growth of world population **N** there exists a peaking with time: $N(t) = 10^8 / (1 - t / t_f)$, where t is time, and t_f is time of peaking, $t_f \approx 2025$.

It is well worth mentioning that in the both cases a singularity in the solution is observed when a characteristic parameter changes within the finite range of quantities, the rate of process is described by the hyperbolic law (blow-up regime). The similarity in the character of laws conveys many things to us. Both of these processes belong to the class of blow-up regimes, and therefore the mathematical model developed for description of one field and all consequences of its application, may be useful for understanding the other field.

Thus, in the first case, when approaching a singularity, i.e. if the velocities are close to be relativistic, the mass of an accelerated particle goes up extremely rapidly (the inertia of motion increases), the distances in the direction of motion reduce, and the flow of time slows down. The problem of going into a world of velocities more than the velocity of light (tachyons etc.), i.e. the problem of passing over the singularity, is under discussion in the special theory of relativity.

If we apply the theory of blow-up regimes to the development of mankind, we come to a conclusion that at present we are passing through this singularity, we are witnesses of the global

demographic transition, we are living near the moment of peaking now. It is worth to study how this demographic transition occurs and what scenarios of further historical development of mankind are. In this connection, we would like to emphasize that we are not at all exterior observers, but participants of the very game. We are in the channels of historical tendencies as if we could observe from within what happens at the blow-up stage and what thermodynamics of strongly non-equilibrium blow-up regimes is.

4 THE THERMODYNAMICS OF THE BLOW-UP PERIOD. VARIOUS SCENARIOS OF PASSING THROUGH THE DEMOGRAPHIC CRISIS

As it follows from the theory of blow-up regimes, a chaotic constituent in the evolution of complex systems gains strength near the moment of peaking. An occasion of the growth of microscopic fluctuations up to macroscopic sizes arises. As a result, the general rate of growth of a complicated structure, which is necessary for the maintenance of its integrity and for its sustainable development, gets broken. Complex structures may fall to pieces, because their fragments (substructures) fall into different tempo-worlds, become to develop with different speeds. Thus, probabilistic, “radioactive” decay of complex structures is one of scenarios of passing through the instability, the moment of peaking.

If we refer to the description of stability (or instability) of trajectories at the developed automodel stage, the applied mathematical model shows that the very law of development may change when the flows of information amount to a certain threshold intensity (the diffusion of information increases in comparison with its production). In such a case the process of growth slows down in a short space of time, as a matter of fact, stepwise (Zmitrenko et al., 1992). Not only the rate of growth of population on the Earth but also the tempo of development of economy, science and culture become slower.

The world population is being dispersed over space, a kind of “global village” is springing up. The traditional society arises anew, the social life is built according certain canons in such a society, people comply with hard rules of behavior. A new philosophy of life takes shape. The global system of mankind is being put in order and harmonized. The living standard in different geopolitical fragments of the global system becomes even. To put it more precisely, the development of parts conforms to the development of the whole system. The law of rapid growth may exert its force once again only after the long passing through the “loop of fading” of processes, after the period of “the going away into the past” and decentralization.

Such stages of deceleration of processes were observed in the history of mankind after the downfall of civilizations and the break-up of great empires. The Middle Ages are indicative of this. The study of this historical epoch can suggest to us, oddly enough, some patterns of the future of the human civilization. Of course, the deceleration of the processes doesn’t signify the immersion in the past, the attained level of development remains, the processes of development becomes more harmonious and stable.

The theory of self-organization of complex system brings us here to a paradoxical conclusion. If such scenario of mankind development will come true, the possibility of connection of the present with the future, not only with the past, will arise.

5 THE FUTURE IS ALREADY HERE. THE POSSIBILITY OF TOUCHUNG AN INFINITELY REMOTE FUTURE

As is well known, those who forget the past are condemned to repeat it. Of course, the lessons from history underlie our current activities. But it turns out that today’s activities are not only

determined by the past, but also are built from the future. The present activities should be oriented – consciously or unconsciously – to one of the possible and feasible (in a given social medium) structure-attractors of development.

It is commonly considered that only the present is more or less accessible for us. The future is attainable only through a complicated and hard work on the forecasting and modeling, whereas the past can be understood through a labor-intensive work on the reconstruction and description as well. An estimation of the past or the future are both inevitably connected with a number of inaccuracies and aberrations in our conceptions and interpretations. The approach based on the theory of complexity is completely different.

The very configuration of available complex evolutionary structures are informative. The analysis of well developed, steady stages of evolution, i.e. of evolutionary structure-attractors, allows us to find out some local areas where the processes go on today as they will go on in the whole structure in the future as well as some other local areas where the processes go on today as they were in the past. This surprising peculiarity follows from the fact that the structure-attractors are described by invariant group solutions in which time and space are not independent, on the contrary, they are closely interrelated. So, if we will learn to "read" spatial configurations of evolutionary structures, we will be able to see in them elements of the ready-made (not obtained by the forecasting, but what will be in reality) future and of the real (free from interpretations) past. It seems as if synergetics would give us a key to the time machine, and with the help of it we could get into the true past and the real, not hypothetical future. However, this key is efficient only in skilful hands. Only those who purchase "synergetic glasses" can become prophets.

According to the synergetic models of the Moscow scientific school, there exist two different and complementary regimes in open nonlinear media: HS-mode and LS-mode with peaking. HS-mode is a mode of "infinitely running out wave" when there is no localization, all structures, heterogeneities are being washed away. LS-mode with peaking is a mode of "converging wave of burning", a mode of localization and intensive growth of processes in a more and more narrow area near the maximum. The changing of these regimes takes place in open media (systems) with strong nonlinearity.

If a complex structure begins to develop in the regime not simply of stabilization but rather of recession and "infinitely propagating wave", i.e. as if in the regime of "rest" and "sleep" of complex organization, then the today's processes in the centre of this structure are an indicator how they will proceed in the whole structure in the future. This regime is however unstable. Under certain conditions, the structure in its centre may touch over a long period of time the infinitely remote from us (absolute) future of mankind (not $t = t_f$ but $t = \infty$) (Knyazeva et al., 1994; Belavin et al., 2000). It seems that a certain harmonization, a revise of current processes with a purpose, with the "future order" takes place. But this is not a fantasy. This is a consequence of analysis of the mathematical models of complex evolutionary behavior. Thus, the applied approach allows us to see real features of the future organization by analyzing the present spatial configuration of complex evolving structures in a certain type of fast evolutionary regimes.

6 THE ANTHROPIC PRINCIPLE. THE SELECTIVITY OF MATHEMATICAL MODELS WHICH ALLOW SPECTRA OF COMPLEX FORMS-ATTRACTORS

It is astonishing that the world we live in is arranged in such a way that it allows the existence of complex forms. The formulation of the anthropic principle connected with the origin of the universe is well known (Barrow and Tipler, 1987). The complexity of the observed universe is determined by an extremely narrow range of sections of primary elementary processes and by values of fundamental constants. If the sections of elementary processes in the epoch of Big Bang

would be, for instance, a little bit larger, the whole universe would burn down during a short period of time. The anthropic principle turns to be the principle of existence of complexity in the world. In order to enable the complex systems to exist and to develop, elementary processes at a microlevel had to occur right from the outset very selectively.

One of the most important results of studies of mathematical models of open nonlinear media is the discovery of a phenomenon of inertia of heat and of localization of processes (for example, the processes of burning) in the form of nonstationary structures developing in blow-up regimes (Akhromeeva et al., 1989; Samarskii et al., 1995; review of the recent works on the mathematical modeling of nonlinear parabolic equations may be found in: Galaktionov, 1999). There are some reasons to put forward a hypothesis of extension of the scope of the anthropic principle to cover the conditions of manifestations of complexity in the phenomena of self-organization. The wording of the hypothesis might be as follows: *complex spectra of structure-attractors, which differ from each other in their sizes and forms, exist only for a narrow, unique class of mathematical models with power nonlinear functions* (Knyazeva and Kurdyumov, 1997). Only in the case of power law, there exists a multitude of forms (*Blow-up regimes*, 1999; Dimova et al., 1998).

Much to our surprise, all the complex formations are built in the world in an extremely selective way, the evolutionary channel to the increasing complexity is very narrow. The evolutionary motion upstairs towards more and more complex formations and structures means the realization of less and less probable events. Such is the nature of our nonlinear world.

It is no more surprising that the possible structures and forms are discrete, quantified in the world. For instance, there is a certain spread between the evolutionary branches representing neighboring biological species. Why are there, for example, only wolves or foxes or horses and camels as certain biological species? Why cannot we observe intermediate creatures? Several intermediate creatures are conceivable, but they are not viable. Even if such a symbiotic creature might be born, it is - from the synergetic point of view - an unstable structure and undergoes very rapid decay. Intermediate evolutionary forms do remain because they evolve to stable states, structure-attractors.

Relatively simple mathematical models contain the complex, i.e. *complex discrete spectra of structure-attractors*. It is shown that complex spectra of nonstationary structures, structures developing in blow-up regimes, can spring up and maintain themselves in a meta-stable way in a restricted class of open nonlinear media. The path of the observed escalating complexity is a path towards media with bigger nonlinearities and new properties, with more and more complex spectra of forms and structures. There are some reasons to consider the world as *a hierarchy of media with different nonlinearities*.

The same notion of selected possibilities of evolution follows from the original synergetic model of order parameters and slaving principle elaborated by H.Haken. There is a principle of circular causality which describes the relationship between the order parameters and the parts that are enslaved by the former: the individual parts of a system generate the order parameters that in turn determine the behavior of the individual parts. It can also be expressed in quite another form, namely: the order parameters represent a consensus finding among the individual parts of a system, to draw an anthropomorphic picture. Thus, the few order parameters and the few possibilities they have in accepting their individual states reflect the fact that in complex systems only few definite structures that so-to-speak are self-consistent with respect to the elements are possible. Or to put it differently, even if some configurations are generated artificially from the outside only few of them are really viable (Haken and Knyazeva, 2000).

We may draw the following conclusion. It was substantiated mathematically and physically that only a specific class of nonlinear power dependence (a certain class of mathematical models) allows the existence of complex spectra of structure-attractors. And so the very model may be used for modeling the processes in complex systems, i.e. for defining:

- an approximate number of structure-attractors for a system under consideration;

● their forms, their spatial and temporal “architecture”;

● the evolutionary hierarchy, the principles of assembling of complex structures from simple ones;

● symmetry breakdown in connection with the integration of structures of “different ages” and the inclusion of the “memory” of the system.

Thus, a new scientific background for the modern view of the open future as well as of the desirable and attainable futures is built in synergetics. As a rule, there is a multitude of alternative paths of development for any complex system. Its developmental path is by no means unique. The future is indeed open and plural, but it is not arbitrary. There is a restricted set of possibilities of further development, a discrete spectrum of evolutionary structure-attractors for any complex system. The spectrum is determined exclusively by own properties of a given complex system. If we choose an arbitrary path of evolution, we have to be aware that this particular path may not be feasible in a given medium. Only a definite set of evolutionary pathways are open, only certain kinds of structures can emerge. Synergetics discovers a kind of *evolutionary laws of prohibition*. In nonlinear situations of instability and of branching of evolutionary paths, man plays a decisive role in choosing a *favorable* and - at the same time – *attainable future* structure, one of a spectrum of possible structure-attractors.

Only restricted sets of pathways of evolution are “allowed” by the inner properties of a complex systems itself. How open is, then, the future? Or, to put it differently, is it possible to make the evolutionary impossible possible? To a certain extent, yes. Spectra of evolutionary paths can transform themselves due to changes in the properties of the corresponding complex systems. Owing to the transformation, new possibilities of further development can be opened. The characteristics of the inner properties of a complex system enter as parameters in the corresponding nonlinear differential equation. If the characteristics change, the set of eigenfunctions of the equation changes too. To express this in a mental image, the field of possible evolutionary paths of a complex system into the future can re-build itself – to this or that extent – depending upon the inner properties of the system.

Some human action are doomed to be unsuccessful. They fail if they are not in line with the inner trends of the complex system development. In that case man has either to look for ways of changing the features of the given open nonlinear system or to give up the attempts “to force” the system to develop in an inappropriate way.

7 THE PRINCIPLES OF NONLINEAR QUANTUM SYNTHESIS OF PARTS INTO A WHOLE

To effectively act in the complex and unstable world one should see the context – near and far – of events under consideration and contextualize the knowledge. A holistic vision should be developed. “Think globally, but act locally!” – this is a slogan of the present time. One should comprehend the ways of integration and interconsistent, harmonic development of different complex structures in the world.

The main principle of holism that “the whole is more that the sum of its parts” may be traced back to ancient philosophical studies. One of the earliest formulations of it may be found in Taoism, in philosophy of Lao Tsu. However, a complete and profound sense of the principle has been revealed only by such theories, as gestalt-psychology, systems theory, and synergetics.

The principle of considering from the whole to the parts is quite unusual for classical science. The latter moves in the course of analysis mostly from separate parts to a whole. From the synergetic point of view, it is order and control parameters that determine the behavior of parts (subsystems) of complex systems. They allow to enormously reduce the complexity of description of a system under consideration.

The classical principle of superposition is not valid in the complex nonlinear world which we live in: the sum of partial solutions is not here a solution of equation. The whole is not equal to the sum of its parts. Generally speaking, it is neither more nor less than the sum of parts. It is qualitatively different in comparison to parts which are integrated in it. Besides, an emerging whole alters parts. The co-evolution of different systems means the transformation of all subsystems by mechanisms of system coordination and correlation between them.

Where do the evolutionary processes in open nonlinear systems run? They run towards the creation of more and more complex structures by means of integration of different parts, which develop with different speeds, in evolutionary entireties. Synergetics allows to formulate some constructive rules of integration and co-evolution of complex structures (Belavin et al., 1997).

The complexity of a structure is connected with the coherence in behavior of its elements (substructures). The coherence is the concordance of the tempos of "life" of substructures/parts thanks to diffusion or/and dissipative processes that are a macroscopic manifestation of chaos. In order to construct a complex organization, it is necessary to coherently unify substructures within it and to synchronize the tempos of their evolution. As a result of the unification, structures fall into one tempo-world, i.e. they acquire one and the same moment of peaking, start to co-exist in one and the same tempo-world.

To create a complex structure it is necessary to know how to unify structures "of different ages", i.e. structures of different stages of evolution and having different rates (tempos) of evolution. It is necessary to know how to include the elements of "memory", the biological memory, DNA, or the memory of culture, cultural traditions. Inasmuch as the structure-attractors which characterize the developed, steady evolutionary stages of structures in nonlinear world are described by the invariant-group solutions, the spatial and temporal properties of structure-processes turn to be tightly bound. The dynamics of development of a complex structure needs a coordinated (with one and the same moment of peaking) development of substructures of "different ages" within it, this leads generally to the breakdown of spatial symmetry. The insertion of "memory" (of elements of the past) signifies the symmetry breakdown in space.

Different but not arbitrary structures can be unified. The degree of connection of structures which are to be integrated and the stages of their development are not arbitrary as well. There are various but not arbitrary ways of unification of structures into integral ones. There is a restricted set of integration ways, ways of construction of a complex evolutionary whole.

The selectivity (the quantum character) of ways of integration of parts into a whole is connected with the imposed requirement of existence in one and the same tempo-world, i.e. of development of all parts with one and the same moment of peaking. This is the physical basis of quantification when integrating complex evolutionary structures. If joinable structures have even slightly different from each other moments of peaking, then, near the moment of peaking (the singularity), they will become incomparable in intensity.

Thus, the synthesis of relatively simple evolutionary structures in an entire complex structure occurs by the establishment of a common tempo of evolution in all unified parts (fragments, simple structures). The intensity of processes in various fragments of the complex structure (for example, for social systems – the level of economic development, quality of life, etc. in different countries) can be diverse. The fact of integration signifies that structures becoming parts of a whole acquire a common rate development.

Furthermore, an integrated complex structure arises only if there is a certain degree of overlapping of simple structures. There must be a certain topology, "architecture" of overlapping. A constructive "sense of proportion " must be observed. If the area of overlapping is not sufficient, then the structures will develop independently, they wont feel each other, they will live in different tempo-worlds. But if the overlapping is too wide, then the structures will flow together very fast, they will straight away "degenerate" in one rapidly developing structure.

One might try to formulate some rules of symmetry breakdown when unifying structures of "different ages" into a whole and to point out an optimum degree of connection (of overlapping of areas of localization) of substructures within a complex structure and the topology of their disposition. It would be reasonable to discover the laws of changing the evolutionary regime and other factors which guarantee the sustainable joint development in one tempo-world.

When integrating structures, the quantities of maxima of intensity of processes should be coordinated in a certain way with their distance from the center. For instance, three structures which have equal maxima of intensity (levels of development) take up positions in the apices of an equilateral triangle in the process of unification. If one of these structures is more developed then the equilateral triangle turns into an isosceles triangle: more intensive process of development of the structure "compensates itself" by its bigger distance from the center of symmetry. When the maxima of intensity increase, the distances between them decrease (the model of "converging waves of burning" is developed and studied by our scientific school). On the contrary, when the maxima decrease, the distances between them increase. Structures with different capacities of intensity may be integrated, if they are situated at different distances from the center and certain rules of their organization are observed.

The factor of unification of complex social structure is a certain analogue of chaos, fluctuations, dissipation, a market in general sense. Chaos, i.e. exchange processes of different kinds, plays a constructive role not only in the moments of choosing a further evolutionary path, but also in the processes of assembling a complex evolutionary whole. Chaos leads to the establishment of coherence of development in all parts (substructures). Chaos serves as a "glue" that binds parts into a united whole.

If a complex structure is organized from more simple structures in a right topological way (if there are a certain degree of interaction of substructures and a certain symmetry of architecture of an originating united structure), an exit to a new, higher level of hierarchical organization occurs, i.e. a step towards a super-organization is taken. Thereby the rate of development of structures which are integrated into a complex one is being picked up. The rapidly developing structures "pull to themselves" by the tempo of life the slowly developing structures. If an evolutionary whole is rightly organized, the whole begins to develop at a rapid pace which is higher than there was a pace of the most rapid developing structure before the unification.

The path of unity and of integration of different parts into entire structures is not steady, permanent and monodirectoral. The evolutionary ascent towards more are more complex forms and structures passes through a number of cycles of decay and integration, of disruption from the whole and inclusion in it, the braking of the processes and their acceleration.

From the theory of self-organization it follows that any open systems with strong nonlinearity are most likely to pulse. They have natural cycles of development: the stages of differentiation of parts alternate with the stages of their integration, scattering alternates with rapprochement, the weakening of bonds changes into their strengthening. The world seems to go towards a universal unity, a superorganism. But it moves forward not monotonously but through certain fluctuations and pulsation. The stages of decay, even if partial, are followed by stages of more and more powerful unifications of structures. This modern scientific notion of complexity reminds us of the eastern images of "rhythms of life" that are peculiar to our world, first of all, of the Chinese symbol Yin-Yang.

The cycles of increase and decrease of the intensity of processes, of decay and unifications of parts indicate regularity of nonlinear processes; the cycles are determined by the very nature of nonlinear processes. Any complex structures at the moment of maximum of accretion, or at the culmination of development (at the moment of peaking of processes), are subjected to the inner instability with respect to small perturbations, they are under the threat of decay.

The history of mankind testifies that the world empires increased in size and became stronger to the maximum extent and in the end they came asunder, sometimes disappeared completely without

leaving a trace. But if the beginning of decay of some geopolitical system is observed, it is reasonable, from the synergetic point of view, to put a question: is the nonlinearity of the system sufficient to turn the evolutionary processes back, to switch them to another regime of the renewal of bonds, the attenuation of processes in the central domain and their stirring at the periphery of the structure? If the nonlinearity isn't sufficient, then the former intensive processes may simply be extinguished and come to naught.

Thus, the fundamental principle of behavior of complex nonlinear systems is the periodical alternation of stages of evolution and involution, the unrolling and the rolling, the explosion of activity, the increase of intensity of processes and their fading, weakening, the converging to the center, the integration and the disintegration, at least the partial decay. There are profound analogies here to the historical testimonies of the downfall of civilizations and the break-up of great world empires, to the cycles of N.D.Kondratieff, the oscillatory regimes of J.K.Galbraith, the ethnogenetic rhythms of L.N.Gumilioff.

At the initial stage of formation of a complex structure, its right topological organization is of great importance. When the process of integration occurs, the structures aren't simply put together, they don't simply become parts of the whole in an unaltered, undistorted form. They become somehow transformed ; they form strata on each other and intersect, and at the same time some of their parts fall out. As the physicists say in such a case, there exists an overlapping with the energy loss. This signifies that the unification leads to the economy of energy, to the diminution of material expenses and human efforts.

The topologically proper organization of structures in an entire evolutionary structure results in an approach to the moment of peaking, the moment of maximum development. The whole develops faster than its integral parts. It is more profitable to develop together, since the joint, co-evolutionary development is connected with a saving of material (in particular, energetic), spiritual and other resources. Every new way of the topologically proper integration of structures, the appearance of successive layers (with bigger exponent of nonlinearity) of hierarchical organization picks up speed of development of the whole as well as its integral parts. Therefore, the evolutionary path to the building of more and more complex organizations of structures in the world is to a certain extent pre-determined. We should lend our ears to Eliot's advice: "We must be still and still moving / Into another intensity / For a further union, a deeper communication" (Eliot, 2000, p.260).

8 NOT ONLY THE DESIRABLE BUT ALSO ATTAINABLE FUTURES

It is important to understand that we are not external observers, but participants of the historical adventure (see: Loye, 1999). We are within the trends of social development. We should not remain passive. We have no right simply to expect what will happen, but should become creators of the desirable futures. Dennis Gabor said that "the future cannot be predicted, but it can be created". This research attitude makes a peculiar sense in synergetics. If we manage to discover spectra of evolutionary aims of complex systems, spectra of structure-attractors of their evolution (it is already done for the simplest natural systems, and nowadays the Russian scholars construct models of economic development of certain regions in Russia under the conditions of instability and economic crisis from these methodological positions /Kapitza et al. 1997/), then the role of humans and their responsibility in choosing the most favorable scenario of development rarely increase.

From the standpoint of synergetics, the changing of emphasis in approaching global problems is required: **not arm-twisting and power policy but the search of ways of co-evolution of complex social and geopolitical systems in the world**. The pursuit of policy by power methods is too dangerous in the modern complex and nonlinearly developing world, where even random bugs in the branching informational and computer nets can bring to a world catastrophe. The more complex a system is, the more functions it performs, the more unstable it is. Therefore, the understanding of

forms of common life of heterogeneous structures which are situated on different levels of development and of the paths of their sustainable co-evolutionary development becomes a constructive alternative of today's policy.

Synergetics shows how it is possible to multiply reduce the required time and the necessary efforts and to generate by means of a resonant influence the desirable and – what is no less important – feasible structures in a given complex system, i.e. certain structures from a discrete spectrum of potentially possible structure-attractors. Besides, it demonstrates how it is possible to achieve the proper and persistent unification of relatively simple evolutionary structures into more complex entities and to accelerate in that way the tempo of their evolution.

The world we live in is nonlinear and open. The world is creative. An unexpected and often charming new appears in it. Synergetics reveals laws underlying the emergent phenomena. The future is multiple and uncertain in our nonlinear world. As one sometimes expresses it now, it is a fuzzy future. The nonlinear world often gives surprises to us. In such a world, the probability of fulfillment of even improbable events increases. That is why our hope for a bright future could be connected not only with our deliberate choice of actions which conform to the inner trends of complex organizations, but also with a lucky chance to attain unattainable. Let us work together to accomplish the unfeasible. Let us hope that even the hopeless can come true.

We all somehow or other think of the future, because we wish to spend there a large or ever larger part of our life. Although we all are interested in our own destiny, not many of us professionally occupy ourselves with futures studies. For the latter, synergetics can be used as a non-traditional and constructive methodological basis.

Synergetics is an optimistic attempt to cope with nonlinear situations and to make use of the methods of effective nonlinear management of complex systems in the states of instability. This is the way of attainment of a desirable and at the same time a realizable future, the future that is coordinated with the own properties of complex systems. The world belong to those who give it the greatest hope.

Acknowledgments:

The research presented in this paper is supported in 1999-2002 by the Russian Foundation of Basic Research (grant # 00-06-80011 for H.Knyazeva, grant # 99-01-01091 for S.P.Kurdyumov as well as grant # 01-06-80204 for both of them) as well as by the Russian Humanitarian Foundation (grant # 99-03-19696 for S.P.Kurdyumov).

References:

Akhromeeva, T.S., Kurdyumov, S.P., Malinetskii, G.G. and Samarskii, A.A., 1989, Nonstationary Dissipative Structures and Diffusion-Induced Chaos in Nonlinear Media, *Physical Reports*, **176**, 186-372.

Barrow, J.D. and Tipler, F.J., 1987, *The Anthropic Cosmological Principle*, Clarendon Press, Oxford.

Belavin, V.A., Knyazeva, H.N., Kurdyumov S.P., 1997, Blow-up and Laws of Co-evolution of Complex Systems, *Phystech Journal*, **3** (1), 107-113.

Belavin, V.A., Kurdyumov S.P., 2000, Blow-up regimes in Demographic Systems. The Scenario of Strengthening of Nonlinearity, *Computational Mathematics and Mathematical Physics*, **40** (2), 238-251.

Blow-up Regimes. Evolution of the Idea. The Laws of Co-evolution of Complex Structures, 1999, Nauka Publishers, Moscow (in Russian)

Dimova, S., Kaschiev, M., Koleva, M., Vasileva D., 1998, Numerical Analysis of Radially Nonsymmetrical Blow-up Solutions of a Nonlinear Parabolic Problem, *Journal of Computational and Applied Mathematics*, **97**, 81-97.

Eliot, T.S., 2000, *Selected Verse*, Raduga Publishers, Moscow.

Galaktionov, V.A., 1999, Dynamical Systems of Inequalities and Nonlinear Parabolic Equations, *Commun. in Partial Differential Equations*, **24** (11 & 12), 2191-2236.

Haken, H., 1978, *Synergetics*, Springer, Berlin.

Haken, H. and Knyazeva, H., 2000, Arbitrariness in Nature: Synergetics and Evolutionary Laws of Prohibition, *Journal for General Philosophy of Sciences*, **31** (1), 57-73.

Hideg, E., 2000, New Paradigms for Studies of Futures, the paper presented at the Methodology Seminar in Futures Studies "The Quest for the Futures", June 13-15 2000, Turku (Finland) (to appear in the Proceedings).

Kapitza, S.P., 1995, Population Dynamics and the Future of the World, *Proceedings of the 44th Pugwash conference on science and world affaires. Towards a war-free world*, World Scientific, Singapore.

Kapitza, S.P., 1998, Population Growth, Sustainable Development and Environment, *World Culture Report, Culture, Creativity and Markets*, UNESCO, Paris.

Kapitza S.P., Kurdyumov, S.P. and Malinetskii, G.G., 1997, *Synergetics and Prognoses of the Future*, Nauka Publishers, Moscow (in Russian).

Knyazeva, H., 1999a, Synergetics and the Images of Future, *Futures*, **31** (3/4), 281-290.

Knyazeva, H., 1999b, The Synergetic Principles of Nonlinear Thinking, *World Futures*, **54** (2),163-181.

Knyazeva, E.N. and Kurdyumov, S.P., 1994, *Evolution and Self-organization Laws in Complex Systems*, Nauka Publishers, Moscow (in Russian).

Knyazeva, E.N. and Kurdyumov, S.P., 1997, The Anthropic Principle in Synergetics, *Voprosy Filosofii*, Moscow, N 3, 62-79 (in Russian)

Kurdyumov, S.P., Malinetskii, G.G., and Potapov, A.B., 1995, Nonstationary Structures, Dynamic Chaos, and Cellular Automata, *International Journal of Fluid Mechanics Research*, **22** (5-6), 75-133.

Laszlo, E., 1991, *The Age of Bifurcation*, Gordon and Breach, New York.

Laszlo, E., 1996, *The Systems View of the World.* Hampton Press, Cresskill (NJ).

Loye, D.(Ed.), 1999, *The Evolutionary Outrider: The Impact of the Human Agent on Evolution*, Praeger, Westport (CT).

Mainzer, K. (Ed.), 1999, *Komplexe Systeme und Nichtlineare Dynamik in Natur und Gesellschaft. Komplexitätsforschung in Deutschland auf dem Weg ins nächste Jahrhundert,* Springer, Heidelberg.

Morin, E., 1990, *Introduction à la pensée complexe*, ESF éditeur, Paris.

Morin, E., 1999, *Seven Complex Lessons in Education for the Future*, UNESCO, Paris.

Nováky, E., 2000, Methodological Renewal in Futures Studies, the paper presented at the Methodology Seminar in Futures Studies "The Quest for the Futures", June 13-15 2000, Turku (Finland) (to appear in the Proceedings).

Samarskii, A.A., Galaktionov, V.A., Kurdyumov, S.P. and Mikhailov, A.P., 1995, *Blow-up in Problems for Quasilinear Parabolic Equations*, Walter de Gruyter, Berlin.

Zmitrenko, N.V., and Kurdyumov S.P., 1992, Time Reversion of Processes in Dissipative Systems, *Modern Physics Letters B*, 6 (1), 49-54.