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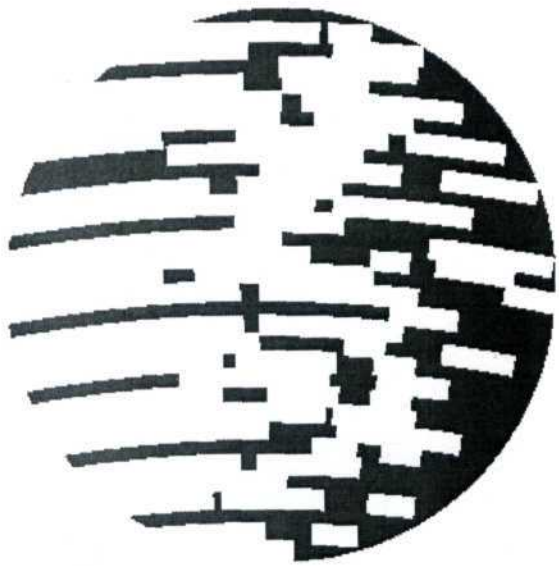

Our self-organizing world:

from disruption to reparation

15-17 October 2014

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- Modelling the marine environment: Integrating the DPSIR framework with Holling's panarchy theory.

4. Design and Control of Self-organising Systems
   - Design and simulation of a logistics distribution network applying the Viable System Model (VSM)
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   - Construction of Complexity: What is Allowed from the Evolutionary Point of View
   - A complexity science approach to resilience in the operation of networked infrastructure systems
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5. Democracy, Citizenship and Civil Society Self-organisation
   - Colombia: designing systemic local democracy to active citizenship
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   - Citizen training and university. The experience "Paz y Region" Program
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   - 'Model M' 2013 – allow me to dream and realize my dream! Practical training for employment of young bachelors'

6. Computer modelling, power and the management of complexity
   - Coping with social systems: agent reflexivity in computational models
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Construction of Complexity: What is Allowed from the Evolutionary Point of View

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Abstract

The modern theory of complexity is one of the most promising tools to comprehend an uncertain, full of sudden changes, and complex world we live in. Due to the rapid development of this theory, considerable changes occur in the whole conceptual net, with the help of which we understand the world and build our own managerial activity. Complexity as a concept is closely connected with the notions of non-linearity, instability and meta-stability, transformation (integration and decay) of structures, evolutionary holism, emergence, innovation, cycles of evolution, etc. The effective risk management and forecasting activities should be based on our understanding what is feasible in dissipative media, how a complex system can be constructed and how to maintain its meta-stable state and its sustainable development. Our efforts have to correspond to own, inner trends of evolution of natural and social media, i.e. to what is allowed and what might be constructed in them from the evolutionary point of view.

Key words: alternative futures, co-evolution, complexity, constructivism, emergence, nonlinearity, management, self-organization, space and time, tempo-worlds.

Challenges of the Complex World

A task of paramount importance nowadays is to learn how to construct a complex system, how to control its emergent properties and how to predict alternatives of its future development. The modern theory of complex adaptive systems (CAS) allows us to assert that properties of a complex system, be it a natural entity, a human personality or a group of them as a social actor, and a medium in which it functions determine each other. Complexity, emergence and activity of a complex system and of its medium are mutual properties which are being under permanent construction in their interactive coupling. The system is formed by its medium and builds its own medium which, it its turn, exerts a reverse influence on the system and transforms it. Methods of control over innovations in complex systems and appearance of holistic features in them are of great significance as well. They include skills of management of complex irreversible time and of controlling emergent properties of hierarchically organized systems and their media. In order to be effective, governing influences should be diversified, situational and constructive.

There are *general laws* and *rules* of development of complex systems. They show rather *trends* which are observed sufficiently often and with high probability under fixed conditions, but are not obligatory. They help us to gain an understanding of complex phenomena and processes and give them a profound scientific explanation. They allow us to make foresights and to reveal vectors of further development of complex systems. Of course, it is impossible to make accurate forecasts; however, such general laws allow us to make certain general conclusions concerting, for example, the strengthening of instability of development and the increase of probability of decay of a complex system, the amplification of the process of concentration of resources, the reinforcement of stratification in society, etc. They help us to elaborate reasonable managerial solutions. Management of the future, construction of sustainable and dynamically developing complex organizations, control over emergence and risk management are topical technologies of management of the modern time.

When trying to reveal general laws of evolution and self-organization of complex systems and to elaborate some patterns of complex nonlinear thinking, I rest upon unique and little known (for the Western scientific community) results of computational experiments and mathematical modeling of course of processes in complex dissipative systems, of situations of instability and of scenarios of passing though a crisis, which are obtained during last decades by the Moscow scientific school of complex systems research with the center at the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (RAS) (Knyazeva & Kurdyumov 2001).

Complexity as a Natural Phenomenon

The general laws of self-organization and evolution of complex systems look like laws of evolutionary prohibitions (Haken and Knyazeva 2000). When constructing a complex system, it is allowed everything what is not prohibited. What are general characteristics of complex systems?

- complexity is a multitude of elements which are connected by non-trivial, original bounds with each other. Complexity is a dynamical net of elements (elements are connected according to a certain rules);
- complex systems are unique and inimitable ones. There are no two identical men, cities, biological individuals, organs and even stars or typhoons;

- complex systems are regulated by loops of feedback: *negative feedback* which secure the recovery of an equilibrium, the return to a former state and *positive feedback* which is responsible for a fast, avalanche-like growth, in the course of which complexity blossoms;

- each complex system has its own *characteristic scales of time and space*. The scale of time is determined by speed of a main process connecting elements into a whole, while the scale of space depends on a radius of interactions within the system. Space and time within the system are connected with each other. In the process of evolution, the acceleration of the course of system time is observed. This is expressed in the reduction of characteristic time intervals in which global system events occur, for instance, the duration of cycles is reduced;

- a complex system doesn't possess a property of *ergodicity* and never demonstrates all its properties on the observed trajectory. From this it follows *weak predictability* of behavior of the system. Because of complex hierarchical functional and topological organization, nested structure of complex systems, permanent change of a given system under the influences of external medium, it is in principle impossible to determine all the functions of complex system and to predict its behavior in the future. The future of a complex system is open; there are only horizons of vision of the future (Prigogine 1997);

- at the certain stages of evolution, a complex system can demonstrate a *butterfly effect*, i.e. strong sensitivity to small, insignificant perturbations those consequences tell upon the trajectory of development of the system in the future. A complex system is poised on the edge of chaos. As a rule, such behavior is observed close to points of bifurcation or in the area of turbulence of a strange attractor. A horizon of vision of the future is extremely small here; behavior of a given system is practically unpredictable;

Huge material concerning the study of complex systems is accumulated by now. When generalizing it and basing on my own experience of exploration of complex systems, I would emphasize the following main laws of self-organization of complex systems which should be understood as characteristic trends of their evolution and principles of their construction and design.

a) In the process of evolution, the complication of structure and organization of a system occurs, the complication of interactions within it and with environment takes place. All the structural and functional complexity appears as a result of the processes of competition.

b) Evolution occurs on the boundary of order and chaos, succession and changeability, regularity and chance.

c) The process of evolution often runs in the regime of blow-up and is characterized by compression of spatial and temporal scales. The regime of blow-up describes a main trend.

d) Evolution of complex system has cyclical character. The periods of stormy development alternate with periods of decline, crisis. In the next cycle of evolution, new leaders appear, new more complex organized (in aspects of architecture and function) structures are observed; thereby complexity increases in a discrete steps, with jumps.

f) Cycles are not equivalent; they have a tendency to reduction and occur around the main trend growing in explosive regime. This gives a notion of evolution as development on ascending spiral, and cycles are convolutions.

g) In the process of evolution, the spatial discontinuity increases, the processes of concentration are reinforced; a bigger and bigger exfoliation of system occurs.

h) Significant stages of evolution are finished by critical points, points of singularity; when passing through such points, a system enters a qualitatively new phase of evolution.

Laws of Construction of a Complex Evolutionary Whole from Parts

The path of evolution in nonliving and living nature is a path of increase of complexity. How can more and more complex structures emerge from separate parts which may be in fact complex structures themselves? What are general laws of integration of structures in the course of evolution of nature and mankind? To put it in other words, what are laws of co-evolution? The modern theory of complexity has managed to discover such laws.

The theory shows that complexity of a structure is connected with its coherence. By coherence, we understand the concordance of tempos of life of structures by means of diffusive (dissipate) processes that are a macroscopic manifestation of chaos. In order to build a complex organization, it is necessary to coherently joint subsystems within it, to synchronize tempos of their evolution. As a result of the unification, structures fall into one tempo-world, so they acquire one and the same moment of peaking; they start to co-exist in the same tempo-world.

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To construct 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 the 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 co-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 by integration of 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 the social medium – a level of economic development, quality of life, provision with information, etc. in different countries) can be diverse. The fact of integration signifies that structures becoming parts of a whole acquire a common rate development.

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 will not feel each other, they will live in different tempo-worlds. However, 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 may attempt to formulate rules of symmetry breakdown, when uniting structures of "different ages" into a whole and to indicate an optimum degree of connection (of overlapping of areas of localization) of substructures within a complex structure, a proper topology of their location, laws of switching of regimes and other factors, ensuring sustainable concordant development in one and the same tempo-world.

When integrating structures, a magnitude of maxima of intensity of processes occurring in them must be in an appropriate way matched with their distance from a center. Three structures having equal maxima of intensity (levels of development), when integrating, settle themselves in apexes of an equilateral triangle. If one of these structures is more developed, the equilateral triangle turns into an isosceles one: bigger intensity of burning is "compensated" by its bigger distance from a center of symmetry. But there is no continuity in such a mechanism of "compensation", i.e. a majority of intermediate states is unstable and only selected, definite configurations of structures are metastable. The compensation of a magnitude of a maximum by its bigger distance from the center of symmetry of a complex structure "works" in a discrete, quantized field of possibilities of integration.

When maxima of intensity increase, a distance between them decreases ((the model of "converging waves of burning" is developed and studied by our scientific school), and, on the contrary, when they decrease, the distance increases. One can integrate structures with different powers of intensity by arranging them at different distances from the center and by observing certain forms of organization.

The factor of unification of parts into a whole structure is chaos, dissipation, fluctuations or – for social structures – their analogue (exchange processes of various kinds). Chaos 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). To put it figuratively, chaos serves as a "glue" that binds parts into a united whole.

If a complex structure is constructed from more simple ones in a right topological way (that is, if there are a certain degree of interaction and overlapping of substructures and a certain symmetry of "architecture" of an emerging united structure), the united structure finds itself on a higher level of hierarchical organization, 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 their tempo of life the slowly developing structures. In case of right unification, a ratio of maxima of more developed structures to maxima of less developed ones remain constant, i.e. small, underdeveloped structures don't fall out into another tempo-world, they don't become a simple background for development of structures with bigger maxima, there is no decay of tempo-worlds.

Besides, if an evolutionary whole is organized in a right topological way, 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 tearing off from the whole and inclusion in it, the slowdown 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 super organism. 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 humankind 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 point of view of the theory of complexity, 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 is not 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 Nikolai D. Kondratiev, the oscillatory regimes of John K. Galbraith, the ethnogenetic rhythms of Lev N. Gumilyov.

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 are not simply put together; they do not 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".

Construction of Complexity in the Process of Co-evolution

Co-evolution is *per se* "the art to live together". To follow the rules of co-evolutions signifies to construct a preferable and sustainable future. An important task can be set: to define order parameters of evolution of states that determine a corridor of their sustainable co-evolution. General rules of co-evolution of complex social, economic and geopolitical structures on national, international and global scales, which arise from the methodological analysis of mathematical models, can be summarized in a form of the following key notions:

a) it is *a common tempo* of development that is a key indicator of connection of complex structures into a single whole;

b) *non-uniqueness and involuntariness* of ways of assembling of a whole from parts;

c) structures-parts enter the whole not in an invariable form, they *are transformed and became deformed* in a certain way in accordance with the peculiarities of an emerging evolutionary whole;

d) for assemblage of a new complex structure, for re-crystallization of a medium, one need to create situation *"at the edge of chaos"* when small fluctuations are able to initiate a phase transition, to throw down the system in another state, and to set another course to the process of morphogenesis, another way of assembling of the complex whole. "The very nature of co-evolution is to attain the edge of chaos";

e) to make a dynamically evolving integral structure, a *proper topology* of combination of structures is of great importance;

f) in case of right, resonant unification of complex structures into the whole, a united super complex structure begins to develop at a higher rate ("it is profitable to live and to develop together").

Co-evolution is not simply a process of adjustment of parts to each other by formatting a complex whole, of their resonant positional relationship and of synchronization of tempos of development, but it is enactive cognition of the world by a human being, synergism of cognizing and constructing subject and of a medium surrounding him. This is also an interactive connection between human organizations and single individuals, the universal collaboration, complicity and solidarity, concerted efforts in construction and rebuilding of the world, and thereby of one's own mentality. This is disclosure of universal affinity of all with everything and of mysterious connection between the past, the present and the future.

Constructing of a Desirable Future

Effective management of complexity should be: a) soft and non-linear, b) strategic (i.e. oriented to attain remote ends and to actively construct the preferable future), c) should include social and economic risk management (diagnostics of social risks, estimation and justification of allowable risks, prognostication of consequences of venturesome decisions).

The following notions are considered as core ones in the modern forecasting (futures studies): a) the image of the future, b) alternative possible futures, c) creating the future rather than predicting it. The vision of the world, which is future-oriented, in based on solidarity with the future. We should not wait for gifts from the future, we rather should create, construct a desirable and preferable future. This attitude towards creation of the future is an intermediate interpretation of constructivism in futures studies.

In relatively simple mathematical and computational models, a result of fundamental importance has been obtained: a continuous nonlinear medium potentially contains in itself different kinds of localization processes (different kinds of structures). Medium is a united source that acts as a carrier of different forms of future organization and as a field of different evolutionary paths. In other words, there are discrete sets of evolutionary paths of complex systems into the future (Knyazeva 1999).

The future states of complex systems escape our control and prediction. The future is open, not unequivocal. But at the same time, there is a definite spectrum of "purposes" or "aims" of development available in any given open nonlinear medium. 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.

The principles of strategic management based the theory of complexity show 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, they demonstrate 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 non-linear and open. The world is creative. An unexpected and often charming new appears in it. The future is multiple and uncertain in our non-linear world; it is a fuzzy future. The non-linear world often gives surprises to us. In such a world, the probability of fulfilment of even improbable events increases. The science of complexity is an optimistic attempt to cope with nonlinear situations and to make use of the methods of effective nonlinear management of complex systems in their states of

instability. This is the way of attainment of a desirable and at the same time feasible future, the future that is coordinated with the own properties of complex systems.

In order to succeed in constructive and management activity in the modern complex and globalized world and to build oneself properly in co-evolutionary processes, one should:

a) know how to take robust decisions under the conditions of deep uncertainty which is determined by the increasing complexity of social processes. And for that an intellectual alliance (intellectual synergy) between prediction, production of innovations and entrepreneurial (management) activity is necessary;

b) know how to think globally and to act actively and interactively, in a way that is adequate to a situation (the principle of situatedness of action);

c) to be in synergism with a medium, with an organization or enterprise which is under our management control (the principle of non-linear feedbacks which is being established between a subject and a medium if his/her activity);

d) to create a coherent and mutually concordant world fitting not only his/her own cognitive and constructive possibilities, but also inner latent tendencies of a medium (attitude towards not only desirable but also feasible future).

The Construction of Complex Structures is Connected with Time Management

Complexity is the unity of plural and diverse elements. According to E. Morin, who argues the problem in the true philosophical context, complexity is "unitas multiplex". i.e. both "unity of diversity" and "unity in diversity" (Morin 1977, p. 147).

According to the models of non-linear dynamics and evolution of open dissipative structures elaborated by the Moscow school, complexity of structures and of their behavior is conditioned, first of all, by their *tempos of evolution*. The tempo, or the rate of evolution of open nonlinear systems, is a key characteristic in exploring complexity.

The thesis can be explained by a few ideas that are more concrete:

a) there are very fast, avalanche-like processes, the blow-up regimes, which are of great importance. An effect of localization, i.e. the structure formation, and the appearance of extremely complicated structures may be observed in these very regimes;

b) periodical alternation of various evolutionary regimes may take place. The change of tempo of evolution as well as of general character of the occurring processes is a basis for self-maintenance of complex structures in the world;

c) it is the tempo of evolution that serves as indicator of integration of structures developing with different speeds in a whole complex structure;

d) synchronization of tempos of evolution of different complex structures is a way of co-evolution and sustainable development in the world.

To manage time, to put it more precisely to master time, is to know how to unify complex structures in a resonant way, i.e. to create a common tempo-world which is able to accelerate development of a produced whole and its constituent parts. The path of co-evolution is a mutually beneficial path into the future.

Co-evolution of complex systems is "the art to live in one tempo-world", when not curtailing diversity but maintaining and developing it on the levels of elements and separate subsystems. Then, in a self-organizing society, it is necessary to cultivate a feeling of

responsibility of each state structure and of each individual for the whole in a plural and united world.

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