Lecture 9. Information and self-organization of systems

The purpose of the lecture: introduction to information synergy and familiarity with self-organizing systems.

Lecture plan:
Introduction
1 Self-organization
2 The dual nature of systems
3 Systems evolution
Conclusion

Keywords: open system, entropy, self-organization, functional organization, system, self-organizing, functional structure, attribute, path, computer generation, catastrophe, regularity, software, activity, activity, noosphere, stability, synergetics, sustainability, connection, evolution, system analysis, Historical method, information technology, operations, experience, trajectory, space, costs, place, efficiency, costs, banking system, profit, dynamic, predictability, principle of synergy, strategic planning, optimal strategy, neighborhood, coevolution, sustainable system, regulation, value, stable trajectories, rights, bifurcation, axiom, information synergetics, measure, synergetic principle, interpretation, information, disk, neuron, performance, decision making, memory, informatization, self-organizing system.

Contents of the lecture:

Introduction

The basic concepts of information synergetics are considered – self-organization, self-organizing system, axioms of self-organization of information systems, examples.

1 Self-organization

Any open system evolves, starting from the state of the greatest entropy (uncertainty), in a spiral manner, actualizing all new connections and relationships, striving for organization and order in the system in the process of relationships with the environment, rebuilding its structure in order to reduce entropy.

Example. At the TV game "What? Where? When?" discussion of an issue often begins chaotically, spontaneously, independently, and at the end of the discussion it can organize itself into a unanimous decision making.

Self-organization is the formation of a spatial, temporal, informational or functional organization, structure (more precisely, the desire for organization, for the formation of a new structure) at the expense of the internal resources of the system as a result of goal-setting interactions with the environment of the system.

A system is self-organizing if it acquires a spatial, temporal, informational or functional structure without targeted external influence (with the aim of creating or changing the structure of the system).

Example. When heated, one macrostructure (ice) transforms into another macrostructure (liquid) with completely different properties (for example, mechanical), and upon further heating, it transforms into another macrostructure (vapor), again with different microscopic properties.

Self-organization (explicit or implicit) occurs in complex open systems. Self-organization is inherent in the attribute - management. There is no automatic self-organization of the system; this requires a control action. Self-organization is only a possible way of development, evolution of the system. This is the way the system moves towards order, albeit relative. There are no clear measures, criteria for ordering, even for physical, chemical, biological systems, where the problem of order and balance has been studied for a long time.

Self-organization can be observed in both living and nonliving systems.

Example. The history of the development of computers is an example of self-organization: from the 1st generation of computers (40-50s of the XX century) with electronic lamps and a speed of about 10^4 operations per second, to the 1st generation of optical VMs (late 90s) with holographic memory, logic based on photon fluxes, neural-like architectures and a speed of about 10^{12} operations per second.

Example. Human society develops in a spiral, cyclical manner: disasters, droughts, crop failures, epidemics, etc. are cyclically repeated. For example, there is a transition from the Little Ice Age to a general gradual warming, and the number of extreme natural phenomena not only does not decrease, but also increases, in particular, in the 18th century there were only 66 years of earthquakes in Russia.

Example. The famous scientist A.L. Chizhevsky, observing sunspots in the 20s of the XX century and studying their formation, found that some periods of increased solar activity and periods of increased hostilities of the First World War coincide. An interesting pattern was discovered by R. Wolfe in the second half of the 19th century: $w = k(n + 10m)$, where k is the proportionality coefficient determined by the resolving power of the telescope, n is the total number of observed sunspots, m is the number of sunspot groups, w is Wolfe's number, which can be used to determine solar activity. Thus, there is an 11-year cycle of solar activity.

Any activity in spite of evolutionary processes in the system, contrary to the principles of self-organization, is anti-system.

Example. Any economic decisions that contradict the main regulator of the market, the main mechanism of its organization - the "supply-demand" ratio, lead to harmful consequences for the system and for its self-organization. For example, the release of goods in excess of market demand can lead to a decrease in demand.

2 The dual nature of systems

Within the framework of the idea of the noosphere, the harmonious relationship between man and nature, man acts as an organic part of nature.

The human environment (including nature and society) is unstable, unstable, non-equilibrium, developing. When considering the problems of such a world, it is necessary to take into account its two opposite and interrelated qualities, mutually conditioning each other – stability and instability, order and chaos, certainty and uncertainty.

Instability and instability are not always evil, a negative quality that must be eliminated. Instability can, in accordance with the laws of synergy, act as a condition for stable and dynamic self-development, which occurs due to the destruction, removal of non-viable forms. Stability and instability in the system, the formation of new structures and the destruction of old ones, replacing each other, develop and evolve the system. Order and disorder arise and exist simultaneously: one includes the other - these are two aspects of the same whole, they give us a different vision of the world. Because of this, we cannot completely control the world around unstable processes, for example, fully control socio-economic processes.

Modern science and technology deal with complex systems, the connection between which is carried out not only through order, through the structures of order, but also through chaos. Only in the unity of order and chaos can the evolution of a complex system be investigated. A complex system is a whole consisting of stable and unstable parts. Here the whole is already a simple sum of parts. The evolution of such a system leads to a new quality, including the relationship with a person. A person is not outside the object under study, but inside it, cognizing this whole by its component parts, uniting natural sciences, strengthening interdisciplinary ties, bringing together the natural and humanitarian problems of sciences, science and art. Ideas, principles, methods and technologies of modern natural science (synergetics, informatics, systems analysis, physics of open systems, etc.) are increasingly being introduced into the humanitarian and socio-economic spheres. There are also reverse processes.

Example. Natural science and the humanities are increasingly investigating processes and systems in conjunction with humans: medical and biological problems, environmental, including the biosphere as a whole (global ecology), biotechnology (genetic engineering), man-machine systems, etc. The specifics of modern science are increasingly determined by complex research programs (in which specialists from various fields of knowledge take part), interdisciplinary research. For example, beauty is not only a humanitarian category, a reflection of the harmony of the material world, but also a scientific category, the beauty of theoretical constructions. The search for beauty, i.e. the unity and symmetry of the laws of nature is a remarkable feature of modern physics, mathematics, biology, synergetics and other natural sciences. The historical method is applied to a wider range of systems, for example, it is even introduced into the quantum mechanical interpretation, where it has not been previously applied.

3 Systems evolution

Computerization and information technology allow more and more complicated logical operations to be transferred to the machine. The human brain is freed from formalized, standardized, routine logical activities.

Example. Heuristic procedures, intuition, experience of a person, an expert find application in programming, for example, in the development of anti-virus programs.

The evolution of a system, as mentioned above, can be understood as a purposeful (based on choice) movement, a change in this system (as a nonequilibrium one) along a certain trajectory of development, consisting of points of states.

Example. To live with dignity, people and government must be guided by a socio-economic perspective, i.e. the development trajectory of any country must be evolutionary.

The stability of a system is its ability to maintain its movement along a trajectory at a level of resource consumption that can be self-sustained, self-regulating for a long time.

Traditional macroeconomics focuses on continuous and, most often, quantitative growth rather than sustainability. For development, evolution requires more and more material, energy, information resources, and their growth narrows the space for sustainable development of society, reduces viability.

Example. With a sufficiently high level of education and a developed education system, the scientific, technical and technological fields have been poorly developed in Russia over the past two decades. For example, in the USA in 1996 the state expenditures on science were 2.8-2.9% of the country's GDP, in Japan - 3.3%, in Russia - 0.59%. In terms of sufficiency and skill level of labor resources, Russia ranks 46th. According to experts, if Russia does not rise even to the 20th in the coming years, then its economic collapse is guaranteed.

The efficiency of the system is the ability of the system to optimize (globally-potentially or locally-really) some criterion of efficiency, such as the relationship "costs of providing a resource - the volume of new resources."

Example. For the socio-economic system, this is the ability to produce a socio-economic effect and not worsen the movement towards achieving the set goal. For example, a criterion for the effectiveness of the banking system can be not only profit, but also lending, loan repayment.

Effective can be considered actions in the system that support the self-organization of the system at a low level of entropy due to non-equilibrium processes of mutual exchange of energy, matter and information with the environment.

It is relevant to develop mechanisms that would ensure the sustainable development of society (in particular, socio-economic systems) and each of its members separately without a quantitative increase in resources, using the produced labor, value and capital.

Example. The indicators of the development of society can serve as GNI - gross national income and GNP - gross national product, but they do not allow to fully assess the sustainability of the development of society, its systems, do not allow assessing whether a society lives within its means, taking care of future generations, i.e. are "credit socio-economic-ecological relations of nature and society" adequate, the development of culture, science, etc.

The evolution of the system is determined by the struggle between organization and disorganization in the system, the accumulation and complication of information, its organization and self-organization, the complexity and variety of intrasystem processes. An important criterion for the effectiveness of a system (policy) is its dynamic, structural and organizational predictability, the absence of anomalies and the provision of dynamic growth, the presence and dynamic updating of criteria for evaluating decisions made.

Modern society and nature, with their many possible paths of development, cannot be imposed on these paths, they are selected on the principles of self-government and self-regulation, namely, through targeted impacts on processes in order to return the evolutionary trajectory to the desired trajectory (if, as a result, for example, stochastic the system deviated from the trajectory).

At the same time, in accordance with the principles of synergetics, it is necessary to take into account that in an unstable socio-economic environment, the actions of each individual person (microprocesses) can affect the entire system as a whole (macroprocesses).

Example. In conditions of unstable economic policy, the actions of individual structures can affect the socio-economic processes of society, which was observed, for example, in Iraq and other countries.

Strategic planning in socio-economic systems is resource-based and purposeful management actions leading to the development of the best, in a sense (for example, locally optimal) strategies for the dynamic behavior of the entire system, which lead to the vicinity of the set goals.

Strategic planning is a tool that helps make management decisions on the implementation of the main tasks:

1. *resource allocation;*
2. *adaptation to changes in external factors;*
3. *internal coordination and mobilization;*
4. *awareness of organizational strategies and goals (short-term, medium-term, long-term), dynamic reassessment of the attainability of goals.*

Example. Planning in the social and humanitarian system is necessary to achieve the following goals:

1. *increasing control functions;*
2. *anticipation of the requirements of social and humanitarian policy;*
3. *ensuring timely response to changes in the system;*
4. *improving the social, humanitarian and economic situation;*
5. *reducing uncertainty, risk, increasing efficiency, etc.*

Coevolution is a conjugate, interdependent change of systems or parts within the whole. This is the principle of global evolution. The very concept came from evolutionary population theory.

The concept of coevolution is closely related to the concept of "self-organization". Self-organization deals with the structures, states of developing systems, and co-evolution - with the relationships between such systems, with the relationships of evolutionary changes.

Example. In recent years, a new direction of research has been actively formed – evolutionary economics. The undulating, cyclical nature of the action of the basic laws is observed in a stable system. The undulating nature of the socio-economic processes of the transition period is especially noticeable. Government regulation, its scope and significance undergo significant changes as the economy evolves. The decrease in the role of the state will alternate with periods of its wave-like increase. The decrease in the role and importance of the state regulation system during the evolution of the socio-economic system will alternate with its strengthening at certain stages of the transition period, there will be periods of liberalization and control over prices and wages, the undulating nature of the privatization process, etc. The undulating nature of socio-economic processes can be explained as follows. Despite the difference between market and non-market government methods of management, their action is largely complementary. Moreover, in a developed economy, market (often spontaneous) and state (often planned) methods combine and diffuse, providing a return to a sustainable development trajectory in case of deviations from it. This is the root cause of the undulation.

Many processes in the socio-economic and humanitarian spheres have a wave-like and cyclical nature, for example, in the field of politics, law, information and the press, religion, national relations, migration processes, the spread of technology, the activity of military operations, etc. Many of these cyclical processes are associated with cycles of solar activity.

Disasters are called abrupt destabilizing changes that occur in the form of a system response to a smooth change in environmental conditions. These changes are sudden, unpredictable with confident accuracy, sharp in relation to the rate of change in environmental conditions. If we imagine the trajectory of the evolution of the system as a set of points, each of which is a point in the space of environmental factors, then the trajectory of the system can have bifurcation points – bifurcation, a qualitative change in the trajectory.

Example. The so-called "Black Tuesday" in the foreign exchange market arose against the background of smooth, not foreshadowing anything catastrophic, environmental conditions (outwardly, these conditions were smoothly changing the day before).

A controlled socio-economic system with a certain goal, certain initial data and certain resources has a certain area of attainability, in which it can achieve the goal with these resources at any time.

Let us formulate the main axioms of the theory of information dynamic processes (information synergetics).

Axiom 1. Development (evolution) of a system is determined by a certain goal and information resources of the system, its information openness.

Axiom 2. While striving for a goal, the system perceives input information, which is also used to change the internal structure of the system itself, intrasystem information.

<u>Axiom 3.</u> Change of intrasystem information occurs in such a way that the negentropy (measure of order) of the system increases, the entropy (measure of disorder) in the system decreases.

<u>Axiom 4.</u> Any change in the internal structure of the system or intrasystem information affects the output of the system (ie, the environment of the system); internal entropy changes the external entropy of the system.

Synergetic principles formulated by I. Prigogine and his followers are of great importance in the study of the controllability of the system, its control parameters, the development of the system in time, in space, in structure, in particular, the following:

1. *the principle of system evolution, irreversibility of the processes of its development;*
2. *the principle of the possible decisive influence (under a certain set of circumstances) of small changes in the behavior of the system on its evolution;*
3. *the principle of plurality (or multivariance) of ways of development of the system and the possibility of choosing the optimal ones;*
4. *the principle of non-interference in the processes of self-governing development and the unpredictability of the evolutionary behavior of the system and, at the same time, - taking into account the possibility of organizing control actions on resources and processes in the system;*
5. *the principle of taking into account the stochasticity and uncertainty of processes (behavior of systems);*
6. *the principle of interaction between the complication of organization, stability and rates of development of systems;*
7. *the principle of taking into account the factors of stability and instability of the system (the emergence of stability from unstable behavior), order and chaos in the system (the emergence of order from chaos), certainty and uncertainty;*
8. *the principle of mutual influence of the stability of the environment of a separate subsystem or element (microenvironment) and processes in the entire system (macroenvironment).*

Since synergetics is a theory of the emergence of new qualitative properties and structures, and the emergence of meaning (interpretation and understanding of messages) is always associated with qualitative changes in the system, we can talk about informational self-organization. Information is a synergistic environment that supports the entire system, its individual subsystems, and which generates information about how the system should develop (self-develop).

An important condition for the birth of information in systems is their openness. In closed systems, according to the second law of thermodynamics (the entropy of a closed system cannot decrease and grows until it reaches a maximum, and, consequently, information becomes minimal), structures disintegrate (at the macroscopic level). Therefore, information cannot be generated and stored in systems in a state of thermal equilibrium, since thermal equilibrium is always established in closed systems.

Example. A magnetic disk in a state of thermal equilibrium is demagnetized and cannot store information. Over time, floppy disks come to a state of thermal equilibrium, and the magnetic coating is destroyed, information is lost.

Open systems maintain a "distance" from the state of thermal equilibrium – due to the flows of resources (matter, energy, information) and due to self-organization, as a result of which these flows exist and are constantly directed in accordance with subordination (from elements to subsystems, from them to system).

Example. The structural unit of the nervous system is a neuron - a nerve cell. The anterior cerebral cortex contains tens of billions of neurons. There are different types of neurons: sensory (from the skin receptor to the spinal cord); retina (from the receptors of the retina to the optic nerve); motor (from muscle receptors to the motor cortex). They form a kind of registers (visual, auditory, tactile, etc.). The neuron is used to transmit information through nerve impulses. Decoding of nerve impulses (information) occurs in the corresponding areas of the cerebral cortex. The neurons of the cerebral cortex function in parallel. This is their remarkable advantage (over other kinds of memory). There are about 50 billion neurons in the forebrain cortex. They are organized in approximately 600 million systems operating in parallel. The performance of this type of "processor" (distributed matrix or neural system) is very impressive (estimate it approximately!). A feature of the brain is high quality, speed of information processing. Neurons perform processing at a speed of only about 100 instructions per second (compare with a computer that executes millions of instructions per second), but they solve the most complex (for computers, in particular) problems of recognition and classification, decision-making and other poorly formalized and structured problems. The human brain is a system of parallel working subsystems, structures, self-organizing with the help of associative links for the development and adoption of logical (algorithmic, rational) decisions. Where it is impossible to make such a decision (i.e., it is not possible to associate such links), a heuristic decision is made. On each neuron of the cerebral cortex, excitations of different types are processed simultaneously (in parallel): motivation, goal-setting, external excitations - reflections of the current state of the controlled object, excitation of memory (experience). Their coordinated processing gives a picture of the object and allows making decisions. So, the brain, continuously going through the results of all past actions in similar situations and comparing them with the current situation, chooses the option that is most suitable, expedient and effective in this particular situation. If at the same time such a situation is not found, then such a state is selected (predicted multi-criteria), the result of which will be most adequate; this result is remembered further. A person has an independent need for information. Normal life activity is possible only when from the external environment there is an influx of not only matter, energy, but also information, when there are no phenomena of "information hunger". Obtaining new information is associated with the compression of information, for example, with the transfer of images, meanings, etc. to long-term memory (subconsciousness).

At the stage of self-organization, collective, corporate behavior is developed (i.e., a new level of the hierarchy of the formation of meaning, semantics). In living systems, in this case, not only communication with the environment is used, but also genetically embedded information or information of self-organization.

Example. A herd of buffaloes (each of which individually is quite defenseless against a flock of predators) self-organizes during an attack: young animals are in the center, males are in a circle ("horns out"). This is essential for the survival of the entire herd.

Information can be incomplete, figurative, for example, in the form of fragments, according to which more complete information is quickly restored (self-organizing). It is especially important to quickly and fully recover this information. Therefore, a process of training, compression and transfer of information, knowledge from generation to generation is necessary. Since the field of knowledge expands and deepens, and information grows like an avalanche, it is important to find synergistic invariants, principles, technologies for its transfer.

Conclusion

The observed mathematization and informatization of modern science convincingly shows that their effectiveness depends both on the given science, the complexity and the possibility of an adequate description of its laws and principles by mathematical and informational models, and on the mathematical apparatus used.

Control questions

See the manual on the organization of students' independent work.