The cybernetic concept of multialternativity in the evolution of biological systems

S L Podvalny and E M Vasiljev
Department of Automated and Computer Systems, Voronezh State Technical University, 14, Moscow av., Voronezh, 394026, Russia

E-mail: vgtu-aits@yandex.ru

Abstract. The article describes the results of mathematical simulation and quantitative analysis of the biological property of diversity. The purpose of this work is a methodological generalization of this wildlife property in the form of a cybernetic concept of multialternativity as an evolutionary strategy of functioning of complex systems. The process of mathematical simulation of evolutionary processes in a complex hierarchical ecosystem with the closed-loop trophic cycle is carried out on the basis of the differential equations of mass balance. Several substantive principles given in the conclusions formulate the concept of multialternativity, i.e., the principles of multilevelness, division of functions and discretization. The constructive nature of these principles opens the way to a practical realization of a strategy of multialternativity in the creation of complex control systems realizing various functions.

1. Introduction

This article discusses the property of wildlife which is obvious at first sight, namely, its diversity. The key role of biodiversity providing the stability of ecosystems in the changing living conditions has been disclosed in detail by an enormous number of explorers [1-9]. Yet, we dare make one more attempt, by means of the corresponding mathematical models shown below, to give a proof that this property is not a usual consequence of Mendel’s genetic laws of splitting, but the mandatory condition of an evolution of all biological systems.

The purpose of this work is methodological generalization of the specified property of wildlife in the form of the cybernetic concept of multialternativity as the evolutionary strategy of complex systems functioning.

The formation of the concept of multialternativity today is important not only for the creation of the environmental management policy, but it is mandatory for an understanding and use of its cybernetic principles in the spheres of the applied activity of a human race, viz., its social and economic systems as well as multipurpose information and technical systems [9-17].

Establishing the direct biological analogy and use of the principles of multialternativity in the creation of complex control systems may lead to the artificial reproduction in those systems of the highest adaptation properties inherent in the biological systems. Moreover, this analogy gives the chance to overcome the main problem of big systems control, namely, the problems of their high dimensionality.

Viewing from the gnoseological positions, the appeal to the property of evolutional multialternativity complies in general with the dialectics of the scientific cognition: from ascertaining
of the phenomenon to the theoretical generalization of the regularities of its internal processes. This generalization allows to position of any phenomenon in consideration into the uniform system of the knowledge’s of nature.

2. Multialternativity in ecosystems

2.1. Qualitative description of ecosystems functioning

Let's consider the strategy of multialternativity at the level of the organization of life, covering a set of biocenoses, the simultaneously existing populations of different species of organisms or, in a broader sense, taking into account the abiotic factors – the ecosystems.

The exclusive attention to evolutionary processes at the level of ecosystems is explained by the existence in them, according to V. I. Vernadsky [18], of «a new geological factor», viz., the mankind which is actively transforming the environment of its habitation, and demolishing simultaneously the natural balance and a diversity in biocommunities [6].

The relevance and the need of preservation of a diversity in ecosystems have been realized long ago and recorded in the Convention on biological diversity adopted by the UN in 1992 [1].

Unlike the molecular and genetic level, the processes of evolution in biosystems are implemented utilizing not only the mechanism of the competition for the resources of an existence but as a result of wider range of interactions of the biosystems' elements, from joint mutual aid known as symbiosis, to the «predator - victim» relations [19]. The qualitative feature of these relations is the emergence inside the biocenoses of the biologically isolated communities which form an additional or complementary trophic (food) levels of a system, i.e., the hierarchical structure of taxons [20,21]. The general scheme of interaction of trophic levels forming the closed-loop circulation of a substance and energy in an ecosystem is shown in figure 1.

![Diagram of ecosystem interactions](image)

**Figure 1.** The integrated scheme of interaction of ecosystem elements.

As we have noted already, the fight for food and spatial resources within each trophic level leads to the division and diversity of ecological niches between the competing species, i.e., their specialization. At the same time, in the current equilibrium conditions, the species with low competitiveness do not disappear, they remain in small niches as a biological reserve of an ecosystem [22,23]. Limitation of
the resources of each niche plays a role of natural restriction in the accumulation of the general biomass of an ecosystem; however it does not exclude a possibility of the development of new ecological niches, i.e. the growth of a diversity of components of an ecosystem. In general, the sustainable, balanced development of an ecosystem is characterized by the aspiration to the utmost development of the available energy resources and the development of new resources, e.g., in the niches subject to a pollution or extreme conditions. In other words, during the periods of sustainable development, the diversity in an ecosystem provides not a forcing out but an additive or accumulative character with the accruing differentiation (division) of functions of a substance and energy transformation [24].

The crises caused by a climate change or a human activity in an ecosystem cause a balance violation when the previously dominating species specie s lose their leading role in the circulation of substances in an ecosystem up to their extinction, but the balance in the system is restored by the alternative species from small niches, filling the freed or newly appeared niches. An example this phenomenon is the spasmodic increase of a biomass of earlier small salt marsh-resistant clams in the process of drying of the Aral Sea and increase of its salinity. As a result, the general biomass of soil organisms was restored despite the disappearance of their fresh-water species. It is characteristic that the process of the development of the transformed habitat was followed by the rapid formation of new species of molluscs. E.D. Cope, pointing out the growth of a diversity of taxons in an ecosystem during the crisis periods of its existence, defines this phenomenon as the general evolutionary rule [25].

The existence of hierarchical structure of an ecosystem (the so-called trophic pyramid) causes the additional multilevel regulating effect which can be considered as the internal stabilizing factor. It may be claimed, accordingly, that this factor has been developed as a result of an evolution of biocenoses for the purpose of the balanced development of all their components and fuller use and accumulation (concentration) of energy possessed from the outside [26,27]. The increase of energy stocks in a system promotes its stabilization and progressive evolution.

In the state of equilibrium or, more precisely, the balanced state, the ecosystem can exist without time limits. At the same time the ecosystem increases gradually the volume of energy concentrated within itself by way of formation and development of new ecological niches and increasing the number of trophic levels, i.e. by way of a growth of biodiversity.

Thus, the process of evolution at the level of an ecosystem can be presented in the form of the alternating periods of a stable balanced growth of a diversity and biomass of its components, with the periods of crisis change of living conditions. During these periods a diversity of the dominating species of an ecosystem is reduced (primarily, at the top levels of a trophic chain). The resulting weakening of the competition opens a possibility of the primary development of previously oppressed or even hidden forms at the genetic level. An emergence of these forms causes the spasmodic change of the whole structure of a trophic chain, i.e. it causes the most essential evolutionary changes in an ecosystem.

This 'basket' of basic principles of ecosystems functioning gives the chance to proceed to a composing of the mathematical model allowing to investigate the influence of a specific diversity and hierarchy of a structure on the evolutionary processes in an ecosystem.

2.2. Mathematical model of a multilevel ecological system
As a basic theoretical prerequisite of drawing up this model we will adopt the conservation laws and circulation of the substance processed by each element of an ecosystem [28,29]. The analyzed substance streams in an ecosystem are presented in figure 2.
Figure 2. The analyzed substance streams in ecological system.

In Figure 2 are indicated:

- $x^0, x^1, x^2, x^3$ – are the values of biomass of decomposers, producers and consumers of the first and second levels, respectively (hereinafter, a biomass is meant as the mass of solid state substance (kg/m²) determined at the end of the next (current) annual interval);
- $n_0, n_1, n_2, n_3$ – the number of species composing the specified system elements;
- $v^0, v^1, v^2, v^3$ – annual consumption of biomass equivalent to energy loss for breath, allocation of heat or commission of work of movement in the elements of an ecosystem, kg/(m²·year). These energy loss is compensated completely by the energy obtained from the external environment and, owing to this fact, it is included in the close-loop energy circulation in the form of equivalent substance;
- $y^1, y^2, y^3$ – biomass of egesta products and natural dying out of organisms within the specified annual period, kg/(m²·year);
- $z_j$ – biomass of a $j$ ($j=1…n_i$) specie of the $i$ ($i=0…2$) element of the system transferred in the specified annual period to all the next (subsequent) element of a trophic chain, kg/(m²·year);
- $z$ – the mass of the saved-up mineral (inorganic) components of an ecosystem that can be used by the producers, kg/m²;
- $s$ – the biomass received in the specified annual period by the $j$ ($j=1…n_i$) specie of the $i$ ($i=1…3$) element of the system from the total $i-1$ element being the predecessor in a trophic chain, kg/(m²·year).

Taking into account the accepted designations the differential equations of a mass balance in each element of a system take a form:

1. $x^0 = \sum_{i=1}^{3} y^i - n_0 z^0 + \sum_{j=1}^{n_i} z^0_j$, \hfill (1)
2. $x^1 = s^1 - \sum_{j=1}^{n_1} v^1_j - \sum_{j=1}^{n_1} z^1_j - y^1$, \hfill (2)
3. $x^2 = s^2 - \sum_{j=1}^{n_2} v^2_j - \sum_{j=1}^{n_2} z^2_j - y^2$, \hfill (3)
4. $x^3 = s^3 - \sum_{j=1}^{n_3} v^3_j - y^3$, \hfill (4)
5. $z = \sum_{i=0}^{3} v^i + \sum_{j=1}^{n_0} z^0_j - s^1$, \hfill (5)
where:  \( \dot{x}^i = \sum_{j=1}^{n_i} x_j^i \),  \( i = 0...3 \) – is an annual gain of biomass of the \( i \) element of an ecosystem, kg/(m\(^2\)·year);  \( \dot{z} \) – is the annual gain of mass of mineral components, kg/(m\(^2\)·year).

The conditions of inter-element balance of a transferable substance mass are:

\[
\sum_{j=1}^{n_1} z_j^1 = \sum_{j=1}^{n_2} x_j^2; \quad (6)
\]

\[
\sum_{j=1}^{n_2} z_j^2 = \sum_{j=1}^{n_3} s_j^3. \quad (7)
\]

In addition, the annual consumption of the producers  \( s_j^3 \) in numerical expression cannot exceed the current stocks  \( z \) of mineral components of the same system:

\[
\left( s_j^3 \right) \leq z. \quad (8)
\]

Now we will determine the models (1)-(8) of the ecosystem components with the following ratios. For the producers:

\[
s_j^1 = \sum_{j=1}^{n_1} x_j^1; \quad (9)
\]

\[
s_j^1 = x_j^1 a_j^1 z_j \sum_{i=1}^{n_1} b_{ij} x_i^1; \quad (10)
\]

\[
z_j = \frac{a_j^1}{\sum_{i=1}^{n_1} a_i^1}; \quad (11)
\]

\[
\sum_{j=1}^{n_1} z_j = z; \quad (12)
\]

\[
z_j^3 = x_j^1 \sum_{i=1}^{n_1} a_{ji}^2 x_i^2 - \sum_{i=1}^{n_2} b_{ij}^2 x_j^2 x_j^3; \quad (13)
\]

\[
n_j^3 = c_j x_j^1; \quad (14)
\]

\[
y_j^3 = d_j x_j^1. \quad (15)
\]

The designations below and hereinafter are:

\( a_j^1 \) – the coefficient characterizing the relative speed of consumption of mineral components by the \( j \) specie an element 1 of a system, m\(^2\)/(kg·year);

\( b_{ij}^k, k=0...3 \) – coefficient of influence on a gain of mass or on the consumption of biomass of by the \( j \) specie in the trans-species (\( i \neq j \)) and the intraspecific (\( i=j \)) competition for food or spatial resources within the \( k \) element of a system, m\(^2\)/(kg·year). For example, the \(- x_j^1 \sum_{i=1}^{n_1} b_{ij}^1 x_i^1\) addend in (10) reflects the reduction of speed of a gain of biomass for the producer \( j \) owing to the competition of
this specie with all other producers of \( i \) species (including the intraspecific competition as well), whereas the 
\[
    - \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} b_{ij}^2 x_{i}^2 x_{j}^2
\]
addend in (13) is the reduction in the rate of consumption by any kind of a producer \( j \) by a consumer of the first level owing to the competition of consumers;

\( z_{ij}, j=1\ldots n \) – the mass of mineral components available for the processing by species \( j \) of an element 1 of a system within the specified annual period, kg/m\(^2\);

\( a_{ij}^{12} \) – the coefficient characterizing the relative speed of consumption by the species \( j \) of an element 1 by the specie \( i \) of an element 2 of a system, m\(^3\)/kg-year;

\( c_{ij}^{1}, i=0\ldots3 \) – the coefficient (relative speed) of a biomass equivalent loss for breathing, heat generation \( t \) or as a work of specie \( j \) of the element \( i \) of a system, l/year;

\( d_{ij}^{1}, i=1\ldots3 \) – the coefficient of formation of egesta and natural dying out of organisms of specie \( j \) of the element \( i \) of a system, l/year.

For the consumer of the first level:

\[
    s_j^2 = \sum_{i=1}^{n_i} x_{i}^2 ;
\]

(16)

\[
    v_j^2 = c_{ij} x_{i}^2 ;
\]

(17)

\[
    s_j^2 = x_{j}^2 \sum_{i=1}^{n_i} a_{ij}^{12} x_{i}^2 - x_{j}^2 n \sum_{i=1}^{n_i} b_{ij}^2 x_{i}^2 ;
\]

(18)

\[
    z_j^2 = x_{j}^2 \sum_{i=1}^{n_i} a_{ij}^{12} x_{i}^3 - \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} b_{ij}^3 x_{i}^3 ;
\]

(19)

\[
    y_j^2 = d_{ij}^{12} x_{j}^2 .
\]

(20)

where: \( a_{ij}^{12} \) – is the coefficient characterizing the relative speed of consumption of specie \( j \) of the element 2 by the specie \( i \) of the element 3 of a system, m\(^3\)/(kg-year).

Similarly, for a consumer of the second level:

\[
    s_j^3 = \sum_{i=1}^{n_i} x_{i}^3 ;
\]

(21)

\[
    v_j^3 = c_{ij} x_{i}^3 ;
\]

(22)

\[
    s_j^3 = x_{j}^3 \sum_{i=1}^{n_i} a_{ij}^{23} x_{i}^2 - x_{j}^3 n \sum_{i=1}^{n_i} b_{ij}^3 x_{i}^3 ;
\]

(23)

\[
    y_j^3 = d_{ij}^{23} x_{j}^3 .
\]

(24)

For reducers:

\[
    y_j = \frac{\sum_{i=1}^{n_i} y_{i}^j \sum_{i=1}^{n_i} a_{ij}^0}{\sum_{i=1}^{n_i} \sum_{j=1}^{n_j} a_{ij}^0} ;
\]

(25)
\[
\sum_{i=1}^{3} y_i = \sum_{j=1}^{n_0} y_j = 0, \quad (26)
\]
\[
v_j^0 = \v_j^0 y_j^0 = 0, \quad (27)
\]
\[
z_j^0 = x_j^0 + \sum_{i=1}^{3} a_{ij}^0 y_i^0 - b_{ij}^0 = x_j^0, \quad (28)
\]

\(a_{ij}^0, i=1\ldots3, j=1\ldots n^0\) – the coefficient characterizing the relative speed of processing of biomass of an element \(i\) of system by a specie \(j\) of a reducers, \(m^2/(kg \cdot year)\);
\(y_j, j=1\ldots n^0\) – the biomass of products of egesta and natural dying out of all producers and consumers received by a specie \(j\) of a reducers within specified annual period, \(kg/(m^2 \cdot year)\).

It should be noted that \(b_{ij}^0 \sum_{x_j} = 0\) is accepted owing to the insignificant trans-species competition of producers caused by a narrow specialization of their feeding character and ecological niches. It should be noted as well that the biomass of the died-out reducers processed by the functioning reducers is implicitly included in \(z_j^0\). It is supposed also that the biomass \(y_1, y_2, y_3\) of products of egesta and natural dying out of organisms is processed completely by a the reducers, i.e. the loss in the form of unused organic components in an ecosystem are absent.

2.3. Results of numerical simulation

The numerical research of an ecosystem expressed by the equations (1)-(8) was performed using the imitating model realized in the MatLab environment. The general structure of this model is shown in figure 3.

For the main hierarchical levels of an ecosystem in its steady state the values of biomass were selected as follows: \(x^1 = 38 \text{ kg/m}^2; x^2 = 4 \text{ kg/m}^2; x^3 = 0.3 \text{ kg/m}^2\).

Starting from the moment \(t = 300\) (figures 4, 5) the stream of external energy (or the equivalent mass of inorganic components) with the intensity of 0.025 kg per time unit is starts to feed the system.
which is in steady state. The general biomass of all components of the system begins to grow, however at \( t = 350 \) the critical event is entered into the system: due to the adverse conditions of the environment the absorption speed by the primary consumer of biomass of the third specie of producers the third specie decreases by 40\%, which means that the coefficient \( a_{33}^{12} \) decreases at: \( t > 350 \) the third column of the \( a_{33}^{12} = 10^{-3} \cdot [39.5, 30.3, 32.9]^T \) matrix become equal to \( a_{33}^{12} = 10^{-3} \cdot [39.5, 30.3, 20.4]^T \).

The reaction of an ecosystem to this event for its truncated version of said ecosystem with two levels of hierarchy \( x^1 \) and \( x^2 \) (where \( x^3 = 0 \), i.e., the secondary consumers are absent) is shown in figure 4, for biomass \( x^2 \). The initial ratio of biomass of species \( x^2 \) which was characterized until \( t < 350 \) by a dominant position of specie \( x^2_3 \) and the depression \( x^2_1 \), has changed as: the decrease in biomass \( x^2_3 \) of the third specie caused by the external reasons is compensated by growth of biomass \( x^2_1 \), \( x^2_2 \) of the first and second species of this system level. After the oscillatory transition process lasting about 150 time units, the growth rate of the general biomass of system is restored. It is a characteristic feature that in the new conditions the earlier oppressed second specie \( x^2_2 \) of this level of a system has occupied a significant share in the biomass processing, i.e., as a result of a critical event all available three species of a primary consumer have begun to participate in the functioning of an ecosystem.

![Figure 4. Reaction of a two-level ecosystem to a critical event for the third specie of a consumer \( x^2_3 \).](image)

The research of a role of system’s hierarchical structure after the critical events in it was made for the full version of an ecosystem (where the third level of ‘consumer-predators’ is entered) saving all parameters of the elements of a two-level system invariable. The reaction of the three-level system to the decrease of \( x^2_3 \) is shown in figure 5 and significantly differs from the previous case shown in figure 4.
First of all it should be noted that in the initial, steady state of a three-level ecosystem \((t < 300)\) there is no observable essential distinction of a biomass \(x_3^3\) and \(x_1^2\) of the third and first species of a primary consumer any more. It demonstrates that despite a rather small biomass \(x_3^3\) of the third level (about 10% of \(x_2^3\) biomass of the second level), the existence of the secondary consumer has reduced the competition at the previous hierarchical level, and all three types of primary consumers became comparable in terms of their importance in the circulation of substance.

The stabilizing influence of the third level of hierarchy was shown also at the moment of a critical event \((t = 350)\): the character of the transition process became monotonous and came to its end much quicker, i.e., for 50 time units, see figure 5.

**Figure 5.** Reaction of a three-level ecosystem to a critical event for the third specie of the consumer \(x_3^3\).

**Figure 6.** The trajectories of the development of an ecosystem with two and three levels of hierarchy.
For fuller assessment of an evolutionary role of the specific diversity and a hierarchical structure of ecosystems we will consider the phase trajectories of system’s behavior in the coordinates $x_1^2$ and $x_2^2$, i.e., in the plane of biomass of the first and second species of the primary consumer, as shown in figure 6.

The analysis of figure 6 shows that in all modes of functioning the system seeks to reach some balanced (linear) trajectory of the development which is characterized by a constancy of such proportions between the biomass of species. These proportions provide maximum assimilation of the resources coming to an ecosystem: in all the modes considered above the system after the completion of the transition processes absorbs completely the arriving stream of external energy (substance) at a speed equal to the speed of receipt.

To shaped lines in figure 6 correspond to the trajectories of growth of biomass $x_1^2$ and $x_2^2$ after the beginning of receipt of external energy ($t > 300$) without the subsequent introduction to the system of a critical event described above. The trajectory $R^2$ in the two-level system contains the considerably extended length of a transition process during which the ratio of biomass $x_1^2$ and $x_2^2$ gains the new established value ($R^2$ tilt angle). In the system version with three levels of hierarchy the system accepts and starts moving along the trajectory $R^3$ of a balanced development practically without a transition process.

Continuous lines in figure 6 demonstrate the reaction of an ecosystem to a critical event (reduction of the absorption rate by the third specie of a primary consumer of biomass of the third specie of producers). The transition of a trajectory $R^3$ in the two-level systems to the new section corresponding to the balanced growth has the pronounced oscillatory character with the repeated change of absolute values of biomass $x_1^2$ and $x_2^2$. In an ecosystem with three levels of hierarchy the trajectory $R^3$ is changed but slightly, i.e., in a multilevel ecosystem the efficiency of system’s stable progress along the trajectory of the balanced growth is significantly higher.

Thus, the diversity of species and the developed hierarchical structure of an ecological system provide favorable conditions for its development: the diversity of species due to redistribution of their biomass brings the system to the trajectory of the balanced growth; the existence of a hierarchical structure as a result of influence of inter-level feedback accelerates considerably this process and makes it monotonous.

To ensure steady evolution in the conditions of unlimited variety of the external environment it is sufficient for an ecosystem to possess a limited set of the behavioral strategy of a structural level. Each strategy, according to the principle of incomplete specialization, is capable to parametrical adaptation within an arbitrary range of influences of the environment.

It is very pertinent to mention here that the well-known Ashby’s principle of the necessary diversity of information has been confirmed.

3. Discussion of the simulation results

The above research gives the grounds to claim that the ability of biological systems to an adaptive evolution is based on a set of relatively simple principles comprising the concept of multialternativity, they are: the principle of a multilevelness of a structure and functioning of system; the principle of diversity and division of functions activated depending on the current environmental conditions; the principle of discretization (modularity) providing the realization of the principles listed above as a result of combinations of a limited discrete set of elementary modules.

Let us take some time to analyze the interrelation of these principles with the tasks of management of anthropogenous (i.e., created by human) systems and we to demonstrate their constructive,
cybernetic nature, namely, the possibility of their use for the solution of the corresponding applied tasks.

The main practical problem of big systems management is the problem of their high dimensionality, i.e., their «non-simplified complexity» resulting in the dynamic uncertainty of their models and in the decrease in the quality of control indicators. The more complex is an artificial system, the more complex is the provision of its reliable operability, especially in the boundary, critical modes of functioning. At the same time, the biological systems do not experience any complexities with the growth of complexity of their structure and the number of internal interrelations [30]. Moreover, as it was shown above, the diversity of a structure and ways of its functioning provides steady existence and development of biosystems in the changing environmental conditions. This fact indicates an expediency of a biological analogy and the purposeful reproduction of the principles of multialternativity in the tasks of complex systems control.

In particular, the known technique of the control systems design is their decomposition to several hierarchical levels, each of them is «turned on» depending on the exhaustion of the material or temporary resources of a subordinate level. The development of this technique originated in the elementary systems of the subordinate control, has resulted recently in the creation of two particular diverse trends in the theory of control, the homeostatic control and the main control.

The principle of the division of functions is used widely in the systems with diverse structure in which the discrete change of control rules is applied according to a current state of a system in the space of its coordinates. In the design of safety systems of technological processes the so-called diversity approach is used providing the reservation of system functions provided on the element base comprising various physical principles, e.g., the software is reserved using the hardware, volatile equipment is reserved by non-volatile (passive) appliances, etc [14].

The principle of modularity is most demanded in highly reliable computing and power systems providing the hierarchical structure and diversity of functioning modes of these systems.

The examples of use of multialternativity principles in the systems of technical control can be found in the works listed below [31-34]. Thus, in a broad sense, the evolutionary principles of multialternativity are the component of the general cybernetic principles of open-loop control systems design of complex objects, of both natural and artificial origin [14]. It can be noted that the cybernetic essence of biological evolution in general as data processing has led to the formation of the domain of science known as «evolutionary cybernetics» [35].

4. Conclusion

The analysis of the evolutionary behavior of self-organizing systems and its cybernetic models considered above shows that this behavior is based on a general fundamental strategy, namely the strategy of multialternativity.

The evolutionary processes in large ecosystems are essentially feasible only in the multilevel hierarchical structure with the diversity of species having the differentiated adaptive functions at each level of hierarchy. The result of simulation shows that the increased structural and specific diversity improves the ecosystem resistance to crisis situations and its ability to preserve the balanced trajectory of system’s development. This unique evolutionary property of a «non-complicated simplicity» of complex biological systems is the result and consequence of multialternative strategy of their structure and functioning.

Considering the results of this research from the viewpoint of applied cybernetics, several considerably plain when viewed separately constructive principles can be formulated which are the essence of the evolutionary concept of multialternativity:

the principle of a multilevelness and hierarchy of a structure and functioning providing the emergence of the property of homeostasis in complex systems;

the principle of diversity and division of subsystems’ functions providing an adaptive transfer of control between them and the general high flexibility of system in the conditions of its open interaction with the changing external environment;
the principle of a modularity generating the combinatorial diversity of variants of the system construction and possible operating modes of a system comprising the limited number of diverse standard modules. Realization of these principles in practice removes the existing and relatively actual «dimensionality curse» in the artificial high complexity control systems.

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