Synergetic Modeling of Sustainable Development

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1. Introduction: Sustainable development as such

Generally sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. The term becomes the most often-quoted definition of sustainable development which ties together concern for the carrying capacity of natural systems with the social challenges facing humanity. The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability.

The Universal Declaration on Cultural Diversity [1] further elaborates the concept by stating that "...cultural diversity is as necessary for humankind as biodiversity is for nature"; it becomes "*one of the roots of development understood not simply in terms of economic growth, but also as a means to achieve a more satisfactory intellectual, emotional, moral and spiritual existence*". The concept of sustainable development does not focus solely on environmental issues. Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behavior. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally [2,3]. Inherently the concept of sustainable development is intertwined with the concept of carrying capacity. Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity. The sustainable development debate is based on the assumption that societies need to manage three types of capital (economic, social, and natural), which may be non-substitutable and whose consumption might be irreversible [4].

The concept of sustainability tries to represent a moving and adaptable response to networks of theoretical, methodological and practical questions, related to joints, interrelationships and interactions within and between series of couples which firmly link (or separate) intelligibility of our world, human solidarities, biosphere unity, and efficiency of social activities. Practically, sustainability in development brings up the qualitative and quantitative problem around energy and raw materials flows and storages, either picked up or emitted; it doesn't dissociate ethical and normative solidarity, horizontally with the impoverished and vertically between successive generations [5].

The sustainability concept invites us to consider the systemic interrelationships and to come within the scope of a framework taken into account a holistic methodological structure in which the affirmation of the world unity implies its diversity and also requires – concerning the human society – to recognize the specificity and degrees of freedom of this diversity, and to develop solidarities which conditional to its own reproduction. Principles of sustainability assume circulation, transparency, crossing, and stimulating synergism of information, as well upwards as downwards. The holistic structure of sustainability meets and rebuilds qualitatively – on the mode of systemic conciliation – scientific knowledge without separating during their rebuilding the normative project, ethics and the scientific approach.

Any service being not storable, within society composed of users, the industrial ecology then increases meaning of social responsibility, local interpersonal relationships and individual

initiative. Solidarity economy which is characterized by social capital concerns information and its production is social link, is in possession, together with the industrial ecology, one of the other keys of sustainability. Territory based associations of inhabitants acting for themselves, appear essential vectors of local sustainability and of novel tasks for implementing the global sustainability. Implementation of sustainable development lies within the core of its project: the principles of individual implication and social responsibility [6]. It requires a transversal circulation of information, compels a rebalancing order of importance about the three poles characterizing the economic rationality: market, plan and reciprocity, in insisting on the last one, the reciprocity.

2. Sustainability through synergy

This section focuses on the new approach for a formal description of the complexity with respect to the viewpoint of modeling and sustainability, that is conditioned by the existence of nonlinear environmental, economic or natural factors [7].

It often appears that there are several contradictions between environmental, economic or sociopolitical sustainability. If we consider any of them as multiple interacting agents, sustainable development can be associated with its complexity, which one corresponds to the degree of system dimension and diversity of objects from viewpoint of modeling.

Agents interact (communicate, coordinate, negotiate) with each other, and with their environment. Usually, in a multi-agent system, interaction dynamics between an agent and its environment lead to emergent structure or emergent functionality. Structurally multi-agent system represents the hierarchy of epistemological levels, every level of which corresponds to the degree of system dimension and complexity.

Development as recursive process, in general represents ascending process in hierarchy when transition to the upper level occurs only after the formation of the lower level. At the same time, at any level multi-agent system may be considered just in two aspects: horizontal (epistemological) and vertical (hierarchic). As the more complex the system is or has a multilevel structure the more developed it is [8]. So sustainability of development as system complexity is the function of diversity (functionality) and dimensionality.

Let us briefly outline some touches to the development. The study of sustainability is still in its nonage. Yet, it already provides us with a powerful new perspective and a number of promising conceptual and modeling tools for understanding the environmental phenomena that surround us, including organisms, ecosystems, markets and communities.

Any change or evolution of the system can be described as a transition from one state to another one, which is closely related with the changing of entropy. In thermodynamics, entropy is often associated with the amount of order, disorder, and chaos in a thermodynamic system. A property frequently used to characterize development is an increase or decrease of order (disorder) which intuitive notion is to identify it with the entropy. We can imagine disorder as disoriented agent behavioral vectors [9].

In this study, we have focused on the epistemological case. So we can consider the development

as optimization processes with system entropy minimization criteria [10].

The fundamental claim of this paper is that the relation between development in multi-agent systems and entropic concepts such as the Shannon or Information Entropy. Contemporary

systems models are more likely to be nonequilibrium models emphasizing the concept of entropy. Entropy has a number of advantages over equilibrium for system. It has led to the development of a number of models using entropy, including Shannon information theory, synergetics, and complexity theory.

As regards to synergy (also called synergic/synergistic science or synergetics), it means that wholes have properties (functional effects) different than those of the parts. Without synergy, there is no complexity, no adaptation, no development and no life.

Nature provides infinitely many examples of emergence and evolutional development.

One of the evident examples is biological organisms evolution, when perfect organism were formed from unicellular microorganisms. The first cells were antagonistic to each other due to the self survival instict. But in the struggle for existence the weak homeostasis failed to save them. As a result unicellular colonies appeared in the evolution process. They created, so called, population having collective homeostasis in the case of interest coincidence on the bases of the social heterostasis. When the stability of the system can not be restored, then it applies for external help. Only those species survived which could adapt, overcome egoistic insticts and formed social heterostasis. In the given context, the criterion of the society security is associated with stability, and in biological viewpoint with the idea of homeostasis or fitness-function. The presented concept is based just on it.

This example may appear too specific to support our argument. Nevertheless collective behaviour of agents or clusters in different environmental conditions can be formalized for modeling of evolutional developing systems.

3. Synergy-based modeling approach

Every system is characterized by a *structure, composition and state*. The state of a system is described by the different degree of incompatibility. Any scale the social processes are characterized by acute confrontational background, therefore often proceeding on sub-critical limit of disbalance. The so called "strong" social cluster try to widen by oppression of clusters with "weak homeostasis" and strive for getting a leader but disbalanced cluster. On their part, the small clusters try to seek external assistance as social heterostasis, for strengthening own homeostasis.

In this paper, on the basis of aforementioned preliminary studies and our currentwork with biological and social processes we formulate a new approach, which is based on an fuzzy entropy minimization of system.

For generalization various approaches we introduced a new conception of entropy as an internal bihavioural incompatibility (resistibility) or antagonism between the agents of system, which is related with energy consumptions. We discuss conceptual and practical possibilities of such admission which is an important interpretation for systems approach on the whole.

Based on above overview we introduce the new notions which are based on the brain model, composed of neural cells networking system, which are activated depending on the subject's location. Such a network is made of two neurons layers (input, and output), and usually follows a regular two-dimensional grid of neurons. This grid represents a topological model of the application to cluster.

Any system, including multi-agent systems and its components can be considered as so called "a synergic graph", where an agent is corresponding with "neuron". For convenience, let us define a synaptic graph to correspond to the topological model of any complex system i.e. axon-dendrite model with synaptic connections between them.

Formally axon-dendrite model can be represented in the form of a graph [11]

$$B = \{b_i\}, \quad i = \overline{1, N}, \qquad (1)$$

with: "dendrites" as the set of system requirements, needs; "axons" as the set of possibilities.

Neuron can be represented in the following form:

$$b_i = \{t_{ik}\}, \quad k = \overline{1, L}, \qquad (2)$$

Generally, each axon or dendrite can be described as a terminal:

$$t_{ik} = \{s_{ik}, d_{ik}, \omega_{ik}\}, \qquad (3)$$

where: $s_{ik} \in \{-1, +1\}$ - is the sign of terminal; $d_{ik} \in D$ - is the type of terminal; $\omega_{ik} \in [0,1]$ - is the weight coefficient of terminal.

The total number of terminals:

$$Q = \sum_{i=1}^{N} \sum_{k=1}^{L} t_{ik}, \qquad (4)$$

Connection between neurons is realized by synapses

$$C_{ij} = \{t_{ik} \circ t_{kj}\}, \qquad (5)$$

where: $\circ$ - is the synapse or cohesion.

Each synapse is established in case of respective conditions:

$$C_{ij} = \left\{ (s_{ik} = -s_{kj}) \wedge (d_{ik} = d_{jk}) \wedge (|\omega_{ik} - \omega_{jk}| = \min_{k}) \right\}, \qquad (6)$$

where: $s_{ik} = -s_{kj}$ is opposite polarity of terminals; $d_{ik} = d_{jk}$ - is the identity of types; $(\omega_{ik} - \omega_{jk}) = \min$ - is minimum difference of weight coefficients, which actually determines the degree of incompatibility; $\wedge$ - is the special symbol (the *conjunction)* make the connective the conditions.

Let us consider the environment as virtual element of system. The weight coefficients for all its terminals will be $\omega_{or} = 0$, where: $r = \overline{1, F}$; R – number of synapses: $R = Card\{C_{ij}\}$; *Card* - means the cardinality the number of elements in the set of synapses; F – number of free terminals: $F = Q - 2R$; μ – degree of incompatibility.

After reindexation $(ik) \rightarrow r_{(ik)}$, it will be:

$$\mu_{r_{(ik)}} = |\omega_{ik} - \omega_{jk}|, \qquad (7).$$

Entropy is determined by the number of ways you could achieve a state. And entropy is calculated as the following function:

$$H = -\sum_{r_{(ik)}=1}^{F} \mu_{r(ik)} \log \mu_{r_{(ik)}} - \sum_{r_{(ik)}=1}^{R} P_{r_{(ik)}} (\mu_{r_{(ik)}} \log \mu_{r_{(ik)}} + (1 - \mu_{r_{(ik)}}) \log(1 - \mu_{r_{(ik)}})) , \qquad (8)$$

where: P - is the probability of the event $r(ik)$.

System behavior is determined in the area of external and internal freedom. Compatibility of the synapses is the necessary condition of synaptic graph unity.

Generally, a model of the system is a multidimensional graph, where the degree of dimension is defined by the number of types of terminals. We can consider a cluster as a subgraph or projection of graph on any type of terminal. So, the graph is the set of clusters.

Synergy of the graph, on its part, is the function:

$$S = \log \sum_{i=1}^{n} \mu_i - \sum_{i=1}^{h} p_i \log p_i , \qquad (9)$$

where: h – number of the orbits of isomorphic groups; p – probability of the orbits of isomorphic groups.

Based on quantum theory, the fuzzility of each synapse is determined the quantum probability of entropy- synergy superposition, which is main cause of the graph upon the whole. System stability or homeostasis in the given moment of time is determined as the difference of synergy and entropy:

$$M_h = S - H , \qquad (10)$$

As a result of synapses there takes place the merging of neurons, creation of a new ensemble that consists of synergic-entropic union.

We can consider this phenomenon as clustering. Every synapse or interaction between any two (or more) clusters recursively form the new entity i.e. the new united cluster, which has mutually modified or provoked redistribution of synergy-entropy, its balance and fitness (homeostasis). Creation occurs when entropy converts into synergy and vice versa, when breaking up synergy converts into entropy. Clustering processes generally can be realized in the following sequence: *Confrontation → Cooperation → Consolidation.*

Three forms of agent interaction are determined:

1. *Confrontation* caused by antagonism of interests between subjects:

$$\text{when Synergy} < \text{Entropy and } \sum_{i=1}^{n} \mu_i > 0.$$

2. *Cooperation* or collaboration (low degree of heterostasis) conditioned by coincidence of interests between subjects in case of internal antagonism:

$$\text{when Synergy} > \text{Entropy} \quad \text{and} \quad \sum_{i=1}^{n} \mu_i > 0.$$

3. *Consolidation* or harmonious coexistence (high degree of heterostasis) which is conditioned by coincidence of interests between subjects without any internal antagonism. This is an ideal case of social state.

$$\text{When Synergy} > \text{Entropy} \quad \text{and} \quad \sum_{i=1}^{n} \mu_i = 0.$$

So sustainable development through synergy can be realized in the following sequence:

$$\textit{Confrontation} \rightarrow \textit{Cooperation} \rightarrow \textit{Consolidation}$$

These are the destructive (antagonistic) and beneficial (cooperative) interaction forms. The very essence of any synergistic behaviour is that the two parts both benefit, and in larger systems all participants should benefit. In each given case the realization of the following versions of optimization is possible by criterion of the stability maximization [12,13].

4. Conclusions

The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. It often appears that there are several contradictions between environmental, economic or sociopolitical sustainability. So we can consider any of them as multiple interacting agents, sustainable development can be associated with its complexity, which one corresponds to the degree of system dimension and diversity of objects from viewpoint of modeling.

As the tools of mathematic formalism, we present a new approach which is based on the use of so called "a synergic graph", which represents the topological model of any complex system i.e. axon-dendrite model with synaptic connections between them. System stability or sustainability in the given moment of time is determined as the difference of synergy and entropy. Three forms of agents interaction are discussed.

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