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SPATIAL NANOSTRUCTURES AND DYNAMICS OF THE TERRITORIAL SYSTEMS. A THEORETICAL INTRODUCTION[1]

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ABSTRACT - The present paper attempts to demonstrate the theoretical role of elementary structures in the dynamics of territorial systems. Territorial systems are conceived as complex entities, defined by differentiated quantities of interdependences between natural and anthropic components, spatially projected. Analogously to physical structures at a spatial level, territorial macro-systems (global, continental, national), territorial medium-systems (regional, intraregional), and micro-systems (local and infra-local) could be individualized. At the level of the last category, it is important to individualize an **indivisible territorial organization structure** whose dynamics is essential for all the territorial systems placed at upper scales.

By their number, such structures **–** having thresholds defining their critical mass, by cluster or functional integration types – respond to anthropic and natural interventions through specific forms resulting from adaptation-type processes, with great self-organizing capacity. Synthetically, we could define such a hypothesis as being connected with spatial structures similar to those existing in physics, called **spatial nanostructures**. Since such a structure, as a physical size compared with the Earth size, could be a multiple of 10^{-9}.

Key words: spatial nanostructures, dynamics, territorial systems.

INTRODUCTION

The present special interest in space and in its resources has revitalized geography as science – one of the few able to analyze territorial components in an integrated way and non-discriminatorily, to discover the laws governing the interactions among them, to measure the differentiated dynamics of territorial structures and to design their future evolution. The analysis conceptual and *instrumental* advance at a micro- and nano-scale level, recorded in certain exact sciences – mathematics, physics, biology, chemistry, information science, etc. – might become the strongest challenge for the 21st-century geography. Following inter-, multi, and trans-disciplinary approach of territorial systems, geography can make conceptual and methodological acquisitions with effects in the organization of practical space, able to ensure its reposition within the present scientific context.

Geography admits a certain dead end of its investigations in the absence of spatial structures having constant referentiality. All the structures depend on the analysis scale: what is macro at a certain level becomes micro at another and there is practically no constant independent of the analysis level. Therefore, we consider that the discussion about certain elementary geographical categories – that can later determine multiscalar analyses either by complex processes or by aggregation ones – is interesting not only academically, but from an applicative point of view as well.

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RESPECT FOR SPACE AND INTELLIGENT TERRITORIAL SYSTEMS

Correct understanding of the basic structures and emergent structures in the territorial systems supposes a brief presentation of certain elements belonging to the quasi-conscious behavior of the territorial systems, of the ability the communities have to respect space they administer and to act intelligently in this operation.

In other words, the present paper attempts to materialize an idea connected with the role of elementary structures in the dynamics of territorial systems, aiming at a clearer definition of the sustainable development focused on a central variable: **"respect" for space.** The study lays the foundations of defining and managing **intelligent territorial systems.**

This central variable built on the idea of respect for space intends an approach in which the space is no longer a container where a complex process is taking place, such as development, but it includes the results of development historical processes. Such processes have represented interactions between people and nature, and among human collectivities at varied scales and the space associated to them. Therefore, the respect for space has two components: a realistic one, defined by its present configuration being the effort of numerous generations that fashioned and accomplished it, and a moral one. The latter supposes that any intervention at a certain anthropization threshold can have catastrophic effects on the resources of the respective space that has to be administered with much care for the future generations.

The latter idea is that the territorial systems are intelligent systems administered by communities that rely on processes developing in accordance with certain logics. In reality, these logics are ways of solving certain problems or desiderata defined by communities. If the problems focus on insignificant elements or represent parts of a community only, then the system cannot work intelligently.

An intelligent territorial system is defined by several characteristics, i.e.: it is able to analyze reality rather objectively, can notice dysfunctions and rank them according to their importance in the system future dynamics; can define clearly a global development strategy; and is able to assess its own resources for implementing the policies selected to achieve the objectives in view.

The estimated results of this theoretical approach may thus back several European and national initiatives connected with space cohesion by territorial development. Both at the level of the European Union and of Romania, there exist numerous final or in-preparation documents such as: European Development Perspective (1999); III European Cohesion Report (2004), EPSON projects (2004–2006 and 2008–2013); Strategic Environmental Assessment (2001); Territorial Agenda (2007); Strategic Concept on Spatial Development in Romania; etc. At the same time, the European research programs include research networks focused on territorial development; one of the most interesting is the European Network of Territorial Intelligence (REIT). They all establish the framework for encouraging cooperation among the disciplines meant to study territory, with emphasis on three analysis levels: interaction among territorial actors, social-economic dynamics, and spatial structures, their evolution included.

TERRITORIAL SYSTEMS, COMPLEXITY, AND SPATIAL NANOSTRUCTURES

The present paper aims at answering a complex set of questions on the self-organization of territorial systems in an extremely dynamical context – defined by acceleration of the globalization process but also by the necessity of sustaining the processes of human society development at local and regional levels. The paper has got both academic valences in that it attempts to know and to formalize the dynamics of elementary structures in space organization, and potentially applicative valences by drawing up models on sustainability of the territorial systems acting at the level of their nanostructures.

Territorial systems are complex entities, defined by ***differentiated quantities of interdependences between natural and anthropic components, spatially projected.*** Territorial systems belong to the category of big systems and are characterized by ***differentiated anthropization degrees.*** From the very beginning, human society has been a continuous pressure factor on nature and on its resources. It has thus tried to adapt itself actively to an environment having differentiated resources from one place to another, both quantitatively – from the viewpoint of regeneration ability – and qualitatively (Ianoş, 2000).

The complexity of territorial systems leads to the idea that the whole of elements coupling unity with diversity (Morin, 1978) is associated with a field of knowledge having as object of study nonlinear, adapting, dynamical systems, but sensitive to the initial conditions (Lewin, 1994). Starting with the 1970s, the progresses of such modern theories as those connected with the evolution of the living, with cognitive systems and artificial intelligence, and with self-organization processes first determined the shift of the fundamental research interests from the autonomy of systems to the role of attractors dictating their dynamics; quite recently they have focused on the creative capacity of the systems (Pumain, 2007).

Therefore, where does the creative force of the territorial systems come from? Could it result from the fine mechanisms of a common process of evolutional adaptation and self-organization developed at lower scales? The processes of demographic growth and informational explosion determine a great diversity of nanostructures in territorial systems. It is common knowledge that when diversity exceeds a certain threshold, phase changes take place (Kaufmann, 1993). Could such a phase change leave its mark on a territorial system at a macro scale? When and under what conditions? This should be analyzed taking into account that phase transitions are collective effects resulting from the influence of the neighboring structures on a microscopic structure in the process of evolutional adaptation. The ratios among these structures at an inferior level result in collective and cooperating effects that can lead to a phase transition. The second-order phase transitions, generated by a micro-level fluctuation, visible at a macro-level are scale invariable; they are closer to what we intend to demonstrate.

The dynamics of territorial systems has two component parts: a **natural** one, dictated by the historical ratio established among the natural component parts and between them and the anthropic ones; an **anthropic** one, defined by society intervening directly in the natural structuring by implementation of decisions (Ianoş, 2000). If in a natural dynamics there is a clear dominant of the society *adaptation processes* to the natural environment, in the anthropic one the stability limits of the latter are forced. By inserting the temporal scale and the resulted effects, the territorial systems could be considered ***short- and medium-termed, top-down organized*** by decisions taken at a macro-spatial level (i.e. where the spatial representation gathers a great deal of "unknown"). On a long- and ultra-long term, these systems ***self-organize bottom up,*** thus correcting an important part of the wrong decisions taken by a society often "blinded" by solid and rapid efficiency. In other words, substantiating sustainable development policies on the knowledge of lower-scale processes and structures (i.e. where the individual's insertion in the real space is made by adaptation processes to natural, socio-economic, and cultural media) could be essential for the future of the human society.

For better understanding such a dynamics, it is essential to give up classical territorial analyses and individualization of the role of elementary structures in the self-organizing process of territorial systems. Analogously to physical structures at a spatial level, territorial macro-systems (global, continental, national), territorial medium-systems (regional, intraregional), and micro-systems (local and infra-local) could be individualized. At the level of the last category, it is important to individualize an **indivisible territorial**

organization structure the dynamics of which is essential for all the territorial systems placed at upper scales.

The **central hypothesis** of the paper is the presence of elementary and indivisible structures of the organized space lying at the basis of the territorial systems dynamics. By their number, such structures **–** having thresholds defining their critical mass (Ball 2004), by cluster or functional integration types – respond to anthropic and natural interventions through specific forms resulting from adaptation-type processes, with great self-organizing capacity. Synthetically, we could define such a hypothesis as being connected with spatial structures similar to those existing in physics, called **spatial nanostructures** (Ianoş, 2004). Since such a structure, as a physical size compared with the Earth size, could be a multiple of 10^{-9}.

Structuring geographical space and territory has been a constant concern. For instance, G. Bertrand (1966) underlined the existence of the smallest geographical structures, called geotops, on a time-space scale. By defining choremes, so-called units of space organization, R. Brunet (1980) became one of the most refined and famous territorial analysts. Multi-scale analysis revealed the relativity of scales in the territorial study. Countless studies focused on detailed analyses of the problems imposed by macro- and micro-ratio, their relativity included. Wilson (2000) considered that the micro-level in complex spatial systems could be represented by household, farm, production enterprise, service supplier, etc. together with the associated territory. By his examples, Wilson seems to have defined the very indivisible organization structures of space that can be considered as spatial nanostructures.

For instance, household gathers the smallest community and is associated a certain space with differentiated functions. The dynamics of such a nanostructure is based on the **imitation capacity** of the organization in the neighboring nanostructures or in those belonging to the same territorial subsystem, material **inheritance,** good practices (experience) included, and also a source coming up from the **deep fundamental reality**, as info-matter (Draganescu, 2000). If evolutional selection fails to explain everything in such a very complex dynamics, then the changes at those levels could be explained due to quantum gravitation, by introducing anthropic principle. The elements offered by the chord theory and by "spin networks" could explain the finest processes underlying the decisions at the inferior levels of space organization. All these elements from deep fundamental reality play an important role in creation processes, evolutional adaptation included.

Some of the most resounding results in analyzing the complexity of the systems, the territorial ones included, have been recorded at the Santa Fe Institute; they succeeded in applying there concepts and ideas of exact sciences to socio-economic sciences. Among them, the concept of adaptative or evolutional molecular landscape (defined in 1931 by S. Wright) that can be used for getting a space cartography where each point corresponds to a number – defined by a certain level of aptitudes (Benkirane, 2006). Kaufmann's important contribution to mathematical modeling of evolutional landscapes can be used, among others, in analyzing dynamics of the territorial system lower structures. In this way, the complex change-related problems imposed by the selection and dominance processes of some of these structures can be explained.

When the diversity of elementary, lower structures in a territorial system increases, the interactions in those systems increase exponentially; thus a phase transition can appear – a fact that can be mathematically proved. Actually, analysis of the ratio between nano- and macro-spatial scale shows that an increasing number of researchers try to design the territorial system evolution starting from certain characteristics found at the basic elementary system. Qualitative changes generated at this level are called phase transitions. They are the result of a collective effect: each nanostructure tends to have a fluctuating behavior owing to the agitations at that level. Since each structure is influenced by its neighbors the effect is collective.

NEW EMERGENT SPATIAL STRUCTURES

In such conditions, emergent phenomena appear – the result of a common characteristic that cannot be found at the level of elementary structures. It follows to be demonstrated the connection between the mathematical laws of the phase transitions and the laws governing new emergent spatial structures.

Emergence is one of the concepts that, if applied in the territorial system dynamics, can change the clichéd views on space organization. The concept, suggested as far back as the second half of the 19^{th} century by psychologist G.H. Lewes, was recently found to be extremely productive in the field of social and economic sciences. Some authors have defined the emergence as the appearance of structures having new and coherent properties during the self-organization process of the complex systems. Generally, one can distinguish a *poor emergence*, when the new properties appear at the level of an elementary structure, and a *strong emergence*, meaning new qualities of the system that cannot be traced back to the system of components, but to that of the interactions among them. These new qualities are irreducible to the parts of the system, using some ideas from L. von Bertalanffy (1973).

An emergent behavior in the case of territorial systems is difficult to predict because of the numerous interactions existing among its components. The increase of interactions versus the number of components is of a combinatorial type, thus enabling the appearance of very subtle behaviors at the level of territorial entities. On the other side, only a great number of interactions are sufficient to ensure an emergent behavior because, by creating "noise", some of them can destroy any "emergent" signal. Hierarchical structures, characteristic of some of the territorial structures, can generate an emergent behavior, but the decentralized structures seem to be most interesting from the viewpoint of the emergent behavior genesis. Therefore, a cluster-structured territorial system can reach a threshold of diversity, organization, and connectivity before adopting an emergent behavior.

The emergent processes in the territorial systems can be generalized by building computational models, such as cellular automata, complex networks, ant colonies, swarm intelligence, and others. **Cellular automata** represent discrete models in computational theory, represented by a matrix of cells in a certain state (Kari, 2005). Analogically, the number of possible states for a basic structure of a territorial system is finite, but each of these structures can change its initial state as a function of the state of the neighboring structures. Each structure can be associated with sets of modification rules based on the values recorded in the neighboring structures. If generalized, they can have emergent effects at the level of the territorial system taken as a whole.

Another model used in analyzing emergent structures is **complex communication network.** Each component element or a spatial nanostructure can correspond to a network knot. Each knot can appear in a finite or predetermined number of states. The knots change their state according to the state of the neighboring knots. The key to these changes is the creation of some forms of organization in networks as part of a new network-type society (Castells, 1997). The emphasis is laid both on forms and on the fluxes between component parts. At present, the study of the formal networks is largely replaced by the study of the emergent networks, with four measures of the informal structures: connectivity, hierarchy, efficiency, and command unity (Krakhardt, 1994). However, such a notion as emergence poses problems connected with the interaction among organization levels, starting from the idea that micro-determination appears when parts of the elementary level influence the behavior of upper levels (Kontopoulos, 1993). Similarly to neuronal networks, each appearance of emergent structures is accompanied by a procedure of free-generated possibilities coupled with a set of restrictions that limit those possibilities (Holland, 1998).

With territorial systems (which are by definition nonlinear systems), the intensity of the relations between two or more variables depends on the system history and on its position on the time scale of the evolution process. In that context, Contractor (1994) identified the importance of historicity and time irreversibility, and also the discontinuity notion applied to the qualitative changes in some systems.

A territorial system is characterized by a network of agents, characteristics, interaction rules, and structures emerging from those rules. The network is important in that is gives the individual agents a general evolution environment. The characteristics of a complex system, such as the territorial one, are the following: localization, capability, memory, and intelligence level. The interaction rules largely explain performances, adaptability, and survival, proving that territorial systems are adaptive complex systems.

The self-organizing ability of territorial systems is defined by four characteristics: at least one of their structures is self-catalyzing (ability of a component to create itself and to renew itself independently); there exists a mutual causality relation between at least two components; the system is environment-open, in relation to mass, energy, and information exchanges; and the system operates far from equilibrium (Glansdorff and Prigogine, 1971). The self-catalyst is synonymous with a positive feedback plus the idea of continuity. Following an accumulation process, the papers couple among them and can generate collective decisions and spatial patterns (Benkirane, 2006).

The knowledge networks among agents are very important in self-organizational ability of territorial systems. Information integration, analysis, and synthesis define what is generally understood by knowledge. The knowledge localization in the network of agents varies along a continuum – it can be centralized and distributed among several agents.

IS SPATIAL NANOSTRUCTURE A CHALLENGE FOR GEOGRAPHERS?

The paper might contribute to deciphering territorial dynamics starting with the individualization of the role the basic cells play in structuring territorial systems. If their organization is ensured from the upper levels of territorial structuring with a view to getting an efficient management for a certain stage, self-organization seems to be generated by the dynamics of the basic elements. The feedbacks at the levels of nanostructures and nanoclusters determine, in time, the self-organization of the territorial systems at a global scale. If the hypothesis proves to be true, the premise of a more complex approach of sustainable development will be created.

The literature, mainly after 2000, abounds in studies on territorial development, although most often than not these are case studies, having an applied character. Very frequently, they have in view elements of regional development, territorial development and urbanism, urban dynamics and rural development, territorial governing. Territorial dynamics, treated as an independent process by the management structures, has been scarcely studied and the organization vision prevails. For a sustainable development of human society, emphasis has to be laid on the self-organizing capacity of the territorial systems and on the roles the nanostructures and nanoclusters play at that level. However, it is this very aspect that the research in the field of territorial dynamics has left aside.

The paper challenges by the answers given to the following questions:

a) Is there a limit between the organization and self-organization of the territorial systems? If so, can it be defined by a trans-scalar approach?

b) Can the elementary indivisible structures (of the nanostructure type), having a fundamental role in territorial structuring, be individualized in the context of inter- and trans-disciplinary approach?

c) Which are the sources substantiating spatial nanostructures? What is the infomatter role in explaining the central position of the laws of nature in the dynamics of the territorial systems?

d) What is the role of territorial emergent structures in the self-organizing process of the territorial systems?

e) Under what conditions can nanostructures produce phase changes at the level of territorial structures when certain critical masses have been reached?

f) Is there a dependence ratio between the amount of interdependences and their critical mass at the level of territorial nanostructures?

g) Can the production of interdependences be controlled at the level of territorial nanostructures for getting a new quality in the self-organized territorial systems?

The challenging result resides in: building as simple as possible computation models able to permit the interpretation of a territorial system as a discrete system having an emergent and unpredictable dynamics; revealing new characteristics by making analogies with the cellular automaton, in which each nanostructure can be a cell and change its state in relation to the neighboring cells; defining the similarities in functional aggregation and integration of spatial nanostructures with different types of networks; defining the health state of the territorial systems taking into account the behavior of spatial nanostructures and the role played by different actors in the territorial system dynamics.

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