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# *Inducing emergence of a system rather than designing a system*

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***Abstract*—In this article we consider how the activity of design and manage a system within the conceptual framework of the classical systemics assumes validity of concepts and approaches based, for instance, on explicit and symbolic representations; completeness; explicit decisions; adoption of control, degrees of freedom, optimisation, regulation and planning. Complex systems instead require different approaches since they are combinations of functioning and emergence. The systemics of complexity is rather based on concepts like coherence; incompleteness; induction; multiplicity of representations, levels of descriptions, and models; multiple systems; non- explicitness; non-invasiveness; non-prescribability; structural dynamics; and usage of degrees of freedom. This requires new competences and approach for the managerial activity in any field by using new appropriated knowledge and approaches in order to combine, i.e., allow multiple usages of design and emergence, to induce, keep and act on complex systems.**

***Keywords- combination, complexity, emergence, multiplicity, systemic.***

## I . INTRODUCTION: COMPLETE-INCOMPLETE

Classic systemics introduced by Bertalanffy and successively elaborated in a huge variety of contributions is based on some epistemological assumptions like

1. Completeness;
2. Possibility to control;
3. Possibility to take the best decision;
4. Degrees of freedom;
5. Possibility to forecast;
6. Possibility to set objectives;
7. Optimisation always possible;
8. Possibility to plan;
9. Reversibility;
10. Separability and unconnectedness.
11. solvability
12. symbolic modelling; and
13. Standardisation.

Complexity deals with negations of such assumptions. For instance with theoretical incompleteness as introduced by Logical Openness [1, 2].

Logical openness considers phenomena, such as system-environment and phenomenon-observer interactions, that can not be described:

- explicitly, i.e., by using analytical models like equations;
- completely, and

- uniquely.

There is logical closure when the three conditions above occur simultaneously.

In real cases the three conditions may occur partially and in different dynamical combinations when combine functioning and emergence.

The term logical openness refers to the fact that a hypothetically indefinite variety of approaches and possible strategies are available to be constructed or selected by the researcher.

This is the case when there is incomplete analytical knowledge due not to instrumental unsuitableness, e.g. unsuitable level of description, but because of theoretical aspects characterizing the knowledge itself like for a) Principles of Uncertainty, b) Gödel's incompleteness theorems, and c) non-computable uncertainty such as for phenomena of emergence, d) fuzziness, and the e) noisy role of the environment.

It is to be considered undecidability, i.e. when does not exist a single algorithm that leads to a correct yes-no answer, and uncertainty, not as limitations, but, rather, as specifications, properties, indicating areas of equivalent configurations to be explored by complex systems to select unique and irreversible configurations and options

This is typical for processes of emergence where the complex system acquires coherent sequences of new properties and the observer must use n-different levels of description corresponding to n-different models, such as for collective behaviours [3] of swarms, flocks, bacterial colonies, cells, protein chains, mobile phone networks, industrial districts, markets, morphological properties of cities [4], networks such as the Internet, queues and traffic signals.

Logical Openness refers to the constructivist role of the observer that generates abductively [5], i.e., process of invention of hypotheses which can also be understood as a choice of the most effective ones available, n-levels of modelling by assuming n-levels of description and

- adopting a strategy to move between levels;
- representing one level in the other;
- representing their coherence;
- simultaneously considering more than one level.

The theoretical lack of explicit, complete, and unique representations represent, in turn, fundamental aspects of emergent complexity.

## II. The conceptual framework

Before mention approaches to deal with complexity we must clarify that complexity and non-complexity are intertwined systemic contexts coexistent at different levels. Their separation and consider one for the other or even assume hierarchical relationships among them should be understood as contextual simplifications and to be intended as aspects of new reductionism.

It is very important the ability to recognise, detect complexity and realise occurrence of combinations of complexity and non-complexity within phenomena under study as dynamic and multiple combinations of functioning and emergence.

Referring to what introduced above about logical openness it must be observed that researchers should operate with

- non-explicit, non-analytical representations having sub-symbolic nature rather than symbolic, such as with neural networks and connectionist approaches;
- inability to give symbolic orders to complex systems since they are unable to process them having a different non-symbolic nature.

An important distinction to be considered is the difference between classical dynamics and structural dynamics.

While concepts of organization refer to the kind of relationships between elements such as sequential, hierarchical, networked, mutually dependent, and with regularities, the concept of structure refers to the relationships of an organisation with specific parameter values. This is the typical case for Neural Networks where while keeping the same organisation, i.e. kinds and number of layers, the structures specifies the weight used for connections.

After made this specification, we may remind that the classical understanding of dynamics relates to the keeping of the same structure while changing input and output and spatial and temporal parameters. A typical example is given by keeping the same procedure for deal with different cases.

Dynamic Structure relates, on the contrary, to the change of the structure itself. It should be matter of changing procedure in front of specific cases.

This is the case when dealing with coherence among dynamical multiple structures of interactions. Examples of some typical dynamics of change are given by collective behaviours of flocks, swarms, ecosystems, traffic, markets, social groups and communication processes.

In such phenomena we deal with processes of change that can not be described by the laws of motion and conservation used in classical physics. Focus is on how rules are used while the knowledge of rules only is not sufficient to model the process [6,7]. Significant parts of the mathematical apparatus used to study collective dynamics fails.

This is related to the need to distinguish between a) ideals and b) non-ideal approaches:

- an approach is ideal when assuming the 'philosophy of prediction' and that it is possible to 'compress' the essential features of the system into a set of equations, i.e., by using symbolic models [7];
- an approach is non-ideal when assuming that the processes of change are essentially 'historical' and irreversible, unique. A usual non-explanatory approach is given by statistics. The crucial fact is that we deal with non-standardised and non-repeatable phenomena in which small deviations vary drastically evolution of the system, e.g. in physics dissipative systems-vortex-liquid systems; chaotic diffusion of smoke in the air and the changing weather conditions. As we will consider this is typical for emergent collective social systems where agents posses complex cognitive systems and a huge variety of dynamical interactions occur.

Example of approaches used to model complex systems [8] are as in Tab. I.

TABLE I.

| **Ideal and non-ideal approaches** | |
|---|---|
| ***Ideal models*** | ***Non-ideal models*** |
| − Collective Beings (multiple roles, ergodic-like)<br>− Network Science (ideal scale-free networks, power laws)<br>− Noise-induced phase transitions<br>− Spontaneous Symmetry Breaking in Quantum Field Theory | − Agent-based models<br>− Artificial Life<br>− Cellular Automata<br>− Dissipative structures<br>− Immune Networks<br>− Meta-structures<br>− Neural Networks |

## III. APPROACHES TO DEAL WITH COMPLEXITY

As it is well known in the literature there are various ways of understanding complexity. For example, there are various approaches to model the establishment of the phenomena of self-organization, chaotic [9] and emergent [10] *sources* of complexity. These are models that use different strategies [11], based, for example, on scale invariance, power laws, networks topological properties, cellular automata, neural networks, and quantum.

A useful distinction, among the many possible, that we consider here relates to self-organization and emergence [6]:

- “Self-organisation processes considered here as corresponding to continuous but *stable*, for instance, periodic, quasi-periodic and predictable, variability in the acquisition of new structures, as for Bènard rolls, structures formed in the Belousov-Zhabotinsky reaction, swarms having repetitive behaviour, and dissipative structures such as whirlpools in the absence of any internal or external fluctuations. Stability of variability, e.g., periodicity, corresponds to stability of the acquired property;
- Emergence considered here is that corresponding to the continuous, irregular and unpredictable acquisition of shapes, which become new *coherent* structures through the observer choice of a suitable cognitive model at a specific level of description, as for swarms and flocks adopting variable behaviours in the presence of given environmental conditions. *Multiple* and *subsequent* coherent sequences of configurations corresponding to different structures are not hierarchical, but sequential and coherent over time, i.e., they display to the observer the *same* emergent, acquired property.”

## IV. ACTING ON PROPERTIES OF REPRESENTATIONS

It is possible to act on emergent properties of complex systems rather than on or in addition to what is considered the *cause*. It is matter to deal with properties of representations of emergent properties, such as topological properties of networks. Actions of this kind posses *activating*, *inductive*, *steering*, and *suggestive* nature for the system expected to *decide*, for instance, removal of equivalences, restore symmetry, and adapt fractality. Approaches are beyond than *macroscopic*, e.g. how to intervene on temperature, pressure, etc., being indeed *mesoscopic*[1], respectable by the system when assuming a large variety of microscopic states, but such as to ensure coherences, like proportionality and combinations between them in elementary cases, networked, meta-structural and chaotic in other cases.

Because of structural dynamics, non-ideal models, processes of emergence, and the nature of the different properties considered above for complex systems, there is in the literature the introduction of **multiple, non-equivalent approaches**.

Multiple approaches can not only use symbolic and non-symbolic, ideal and non-ideal models but also *combine* structure- and emergence- based models **corresponding to processes of functioning and emergence in any sequence, timing and eventual superimposition**. Social systems have almost *twin, interweaved interacting*, and not always separable, *natures* when actions, roles and decisions cannot be modelled by using a single model since simultaneities and superimpositions occur. **These two natures are given by their explicit structures and procedures, and by their non-explicit, informal, emergent processes asking for multiple approaches corresponding to dynamical different natures of the multiple phenomena.**

Examples of approaches are those introduced, for instance, by Network Science, scale-invariance, power laws, symmetry, fractality, meta-structures and all the quantum-based discoveries and elaborations. Examples focus on Coherence, Development, Dynamic Usage of Models (DYSAM) to maintain coherence, Emergence, Entanglement, Incompleteness, Irreversibility, Logical Openness, Meta-structures, Multiple non-homogeneous, Multiplicity, Network properties, Non-linearity, Non-symbolic aspects, Quantum, Quasi, Scenarios, Self-organisation, Simultaneity, Uniqueness, Uncertainty and Incompleteness.

Complex systems should be addressed by using multiple models which can **model multiple simultaneous processes** occurring within them and their coherence.

We list in the following sections examples of approaches in use to act on complex systems related to suitable representations.

### *A. Acting on the environment*

Actions on various properties of collective behaviour may relate to the environment such as the use of perturbations, possibly inserting dynamic obstacles, inputting perturbative phenomena such other collective behaviours; actions, like *deformation* and *noising*, of communication between the elements and on the available energy.

### *B. Chaotic Systems*

Referring, for instance, to the behaviour of chaotic systems that evolve with different possible trajectories, but always around their attractor(s), we can say that actions may be on attractor(s) to be eventually restored or changed.

### *C. Degrees of freedom*

A non-invasive approach used to influence systems is given by setting suitable, variable degrees of freedom to the behaviour of interacting elements or agents establishing a complex system.

One example is the *structuring of space* in which agents interact as in urban planning when deciding the shape and size of roads, the inclusion of roundabouts and speed bumps in order to influence the properties of traffic, crowd evacuation in case of emergency or long queues; rooms in schools, hospitals and offices [12] and **procedures in corporations and business.** However, a more interesting aspect appears when considering not only degrees of freedom as for mechanical devices and procedures, but how they are *spent*. For instance, while respecting the degrees of freedom, a number of generic agents, e.g., workers respecting safety procedures may use them at (a) the maximum or (b) the minimum levels or (c) in regular oscillating or completely random ways [13].

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[1] The *mesoscopic* level of description considers macroscopic variables, but only for partial aggregates of elements rather than for all. A simple illustration of a mesoscopic variable is to consider in the traffic the variable representing the number of cars that in an instant *can not accelerate*. In doing so the mesoscopic variable considered *simultaneously* the cars stopped, that must proceed at a constant speed and those which should slow down.

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*D. Non-invasiveness and low energy*

Non-invasiveness is suggested by the limited strategic value of explicitly prescribing, administering behaviour of establishing states as mentioned above. Very important is the use of soft, low-energy approaches, which do not require explicit system interventions or energy administered at high levels assuming it to be processed as through *communicating vessels*. In the latter case the system can not explore equivalent spaces of states and trajectories from which to choose on the basis of fluctuations and influences of any kind.

The reference relates to fundamental research in *theoretical biology*, for instance, by Erwin Bauer (1890-1938) who considered living systems as being different from physical ones because they do not consume the supplied energy *immediately* being able to manage it. It is matter of coherence rather than thermodynamic equilibrium, i.e. coherence between multiple and dynamic equilibriums, levels of coherence.

*E. Actions on coherence rather than on equilibrium*

Dissipative systems keep stationary states far from thermodynamic equilibrium [14] through the transfer of entropy to the environment due to dissipation of matter and energy. Examples of non-living dissipative systems are vortices of liquid and atmospheric phenomena such as hurricanes that dissipate continuously streams of liquid received from outside, the Belousov-Zhabotinskyi chromatic chemical oscillating reaction and the Bénard cells. Living dissipative structures dissipate material flows such as air, water and food. The process of dissipation allows emergence and keeping of ordered structures and properties. However, there are processes of emergence that do not require dissipation to establish coherence(s) as it is for collective behaviours in general.

Life, for instance, could be inextricably intended as a series and keeping of emergent coherence(s) and stationary states far from equilibrium. In both cases the focus is on the search for coherence rather than equilibrium and coherence(s) among multiple dynamic equilibriums, and levels of coherence. Interventions are then on processes of dissipation and the establishment of coherence(s) [15].

## V. METHODS AND APPROACHES

Methods and approaches are, for example, those of the Science of Networks [16, 17, 18], the DYnamic uSAge of Models-DYSAM [8,19], the methodology of the Giroscope [20], the study of meta-structures [6, 7, 21, 22], and quantum [23].

*F. Science of Networks*

In the case of the Science of Networks there is study of properties such as:

- Power Laws
  When the frequency of a phenomenon varies in function of a certain its attribute then the phenomenon is said to follow a power law. For example the number of cities varies according to the size of their population. An exponential power-law is of the type $f(x) = x^k$. If, for example, x refers to the size of the population, f refers to the number of cities with that population, being k a constant , the scale invariance is given by ...
- Scale invariance
  ... the fact that if we scale x of a parameter q we obtain $f(qx) = (qx)^k = q^k f(x)$. A network is then said scale invariant if its degree of distribution, i.e. the probability that a randomly chosen node has a certain number of links, follows a power law without depending on scalar parameters of the structure. Examples are given by the Internet, metabolic networks, the network of blood vessels and neurons.

This is the case of fractality [24] and symmetries [25]. In addition, we study the properties of networks of nodes like neurons, individuals of social groups, websites, biological macromolecules, genes, or atoms able to determine their behavioural scenarios, represented by their topological properties [18, 26].

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*G. DYnamic uSAge of Models (DYSAM)*

The use *Dynamic Usage of Models (DYSAM)* is based on the use of multiple models in situations where within a systems there are processes of acquisition of coherent multiple emergent properties and the usage of a single model is not sufficient. Accordingly the system can be represented only by a number of partial, non-equivalent (one can not be *derived* from the other) representations and not by one while having different parameters and variables.

No partial representation can claim to represent the system completely. A classic example is given by the duality of atomic representation as particle or wave, being both valid at the same time. It is the case of Multiple Systems [8] when the same elements play interchangeable roles constituting overlapping sequences of different systems. Examples are given by the Internet and Electrical Networks where we deal with different, overlapping systems made by the same elements. In one case the model concerns the reliability (fault tolerance), in another the availability, serviceability, consumption, etc.

It is also the case of the establishment of multiple properties in complex systems and having different disciplinary representations for which it is possible to consider interdependencies but not complete equivalences like for polypathology and consider diseases simultaneously, for example, from the biological, chemical, psychological and physical standpoint. The reference is on well-established approaches in the literature, such as the ensemble learning and the Evolutionary Game Theory.

Furthermore DYSAM refers to logical openness introduced above and to *n*-levels of modelling. DYSAM consists of considering different models and levels of description available or to be invented to be suitably used, by using strategies to switch from one to another, to mutually represent one into the other, and use them simultaneously.

*H. Giroscope*

It is a tool [20] introduced on the basis of considerations close to the ones listed above and for DYSAM:

"...a systemic implementation based on a clear definition of the system and its components does not give enough possibilities to our representations.

It limits our capacity of understanding to be able to act in complex situations.

...we develop a model that could be considered as an analogy to the field theory.

The Giroscope is born on the observation of human organisations..." [27].

The Giroscope is a modelling tool based on '12 Managing Principles' to be considered within a context:

1- Finality
2-(sub) systems versus 3-Borders
4-Totality versus 5-Members
6-Information sending versus 7-Circularity
8-Information delivery versus 9-Rules
10-Feedback versus 11-Homeostasis
12-Equifinality

Structure of an organisation is considered as *emergent*.

*I. Meta-structures*

In the approach based on meta-structures, collective behaviours [3] are considered as coherent sequences of configurations established by same elements interacting in different ways over time -that is, through sequences of different structures of interaction-. The sequence of configurations is considered coherent when it takes on and keeps emergent properties, e.g. 'Sequences of images constitute a movie, i.e. emergent meaning'.

It is a non- idealistic, non-symbolic and not explicit approach inasmuch it considers *a-posteriori* properties of sequences of structures of interactions among agents constituent processes of emergence. The approach considers

- structural dynamics (and not the dynamics of the system consisting of the same, invariant structures of interaction), and
- properties of the sets of structures applied per instant, i.e. meta-structures, such as various regularities and correlations.

Complex systems, collective behaviours (CB), are understood as systems of structurally, dynamically, and coherently interacting agents using multiple structures of interactions. The focus is on *how* rules of interaction are used, while the knowledge of the rules and parameters *only* is not sufficient to model the process.

Usual approaches (not for DYSAM ...) consider single and constant models of interaction, i.e. invariable systems of rules.

In the meta-structural approach individual agents interact differently over time by adopting one or more different rules of interaction -multiple and variable models - a) selected from an available library depending on properties valid per instant of other agents, selected with a 'appropriate variable strategy; b) combined; and c) made, for example, through mutation and adaptation.

An example for flock-like collective behaviours is available in tab. 2.

TABLE II.

| **Multiple structural interactions within a lock-like collective behaviour** | | |
|---|---|---|
| ***Agents*** | ***interacts by varying its*** | ***depending on*** |
| $e_k$ | Speed | speed of the closest agent or the average speed of the closest agent |
| $e_k$ | Speed | speed of agent(s) having its same direction |
| $e_k$ | Speed | speed of agent(s) having its same altitude |
| $e_k$ | Speed | speed of agent(s) having symmetrical, topological position |
| $e_k$ | Direction | direction of the closest agent or the average direction of the closest |
| $e_k$ | Direction | direction of agent(s) having its same speed |
| $e_k$ | Direction | direction of agent(s) having its same altitude |
| $e_k$ | Direction | direction of agent(s) having symmetrical topological position |
| $e_k$ | Altitude by varying direction | altitude of the closest agent or the average altitude of closest agent(s) |
| $e_k$ | Altitude by varying direction | altitude of agent(s) having its same direction |
| $e_k$ | Altitude by varying direction | number of agents having its same altitude |
| $e_k$ | Altitude by varying direction | altitude of the agent(s) having symmetrical topological position |
| $e_k$ | Speed | speed of the closest agent or the average speed of the closest agent |

In this approach we look for significant 'a posteriori' correlations within the history of change itself in order to identify *structural regimes* adequate to not explicitly deal with complexity. For structural regime we intend the current validity, unless appropriate thresholds and distributions, of certain sequences and combinations of rules of interaction, networks and mesoscopic variables [28]. We consider, for example, a) families of correlations -having phenomenological and then eventual explanatory nature-, for example, between symptoms, diseases, environment and behaviours considered corresponding to structures of interactions, b) networks of various types such as scale-free, random and hierarchical, their eventual levels and intersections, and c) mesoscopic variables and parameters such as thresholds.

**The sequences of structures and their properties can be represented in various ways such as by suitable mesoscopic variables and their properties**. For example, in a collective behaviour of agents it is considered groups having per instant the *same* - at suitable threshold- speed, distance, direction or topological position (centre, at the edges, etc.). We will consider their number per instant and properties of these numerical sets such as trends over time and eventual quasi-periodicity, distribution and statistical properties.

**Properties of mesoscopic variables are intended as meta-structural properties representing communities of usage of structures of interaction and coherence characterizing specific complex systems.**

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## VI. Complexity of Social Systems

The conceptual frameworks introduced above are more or less *necessarily* used in scientific disciplines to deal with new problems of complexity. Disciplines are assuming new, advanced systemic approaches, interdisciplinary used thanks to the availability of computer-based tools and models.

**The mission for a second generation of Systemics should be the generalisation of concepts within a unifying theory and support usage of new concepts still not fully applied yet**.

It is urgent to suitably represent and made available new systemic knowledge to social systems where social projects are still often understood in a classical way. This is the case, for instance, for

- Economics,
- Education.
- Health,
- Management, and
- Politics.

The complexity of social systems may take on a vast range of natures and forms. We consider here as example the complexity of socio-economical systems associated with problems of their management. First of all we must identify the *sources* of complexity of social systems. As an example, consider the following aspects (see Tab. 3):

TABLE III.

| **Sources of complexity of social systems** | |
|---|---|
| Their being knowledge-intensive; | Reduced time between design, implementation, and marketing; |
| Delocalisation and globalisation; | Short general life span; |
| Duplicability; | Technological innovations and solutions creating new problems; |
| Highly general networked interconnections; | Epiphenomena, i.e., secondary phenomenon occurring alongside or in parallel to the primary phenomenon; |
| High manipulability; | Multiplicity; |
| High virtuality | Non-linearity and non-sustainability; |
| Hyper connections; | Augmented reality through simulations and multi-dimensional, simultaneous, and coherent information; |
| Importance of individuality; | Data availability (Big Data); |
| Instabilities to be recovered with coherences; | Networked availability of knowledge; |
| Interchangeability; | Products and services come with induction for use more than directions for use; |
| On-line actions; | Rapid transformation of solutions into new problems. |
| Their being knowledge-intensive; | Reduced time between design, implementation, and marketing; |
| On-line actions; | Short general life span; |

Table 4 shows some contrasting examples of industrial and post-industrial concepts [29] easily understandable in the terms introduced above.

TABLE IV.

| Examples of contrasting concepts in Industrial and Post-Industrial Societies | |
|---|---|
| ***Concepts in Industrial Society*** | ***Concepts in Post- Industrial Society*** |
| Completeness | Non-completeness as a resource; |
| Symbolic computability | Non-Symbolic computability; |
| Linear correspondence between micro and macro | Non-linear correspondence between micro and macro; |
| Decisions from optimisation | Process of decisions from emergence; |
| Equilibrium | Coherence; |
| Measurement | Properties of multiple measurements; |
| Multiplicity as a set | Multiplicity as a system; |
| Optimise | Generate coherence; |
| Properties possessed | Properties acquired; |
| Reversibility-irreversibility | Non-reversibility as a source of uniqueness; |
| Solve | Manage using multiple approaches; |
| Stability | Coherent Dynamics. |

Such contrasts show interesting correspondences with the general frameworks considered above [29, 30]).

## CONCLUSIONS

We outlined some new properties of complex systems and related suitable approaches.

The general meaning is that the previous approach to design systems based on assuming validities of properties like completeness, possibility to control, forecast, standardise and plan is unsuitable for complex systems. New understandings, approaches and tools should be assumed by properly *mixing* classical functioning and emergence.

This is urgent when dealing with social systems, particularly Economics, Education, Health, Management, and Politics still largely based on a pre-complexity culture.

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