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In memory of
Evelyne Andreewsky
and
Nicholas Paritsis

Systemic Properties: acquisition and persistence over time

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Abstract
We introduce some comments and elaborations about fundamental theoretical aspects related to the definition of system and approaches to model its dynamics and acquisition of properties. We consider the theoretical role of the observer generator of cognitive existence as in constructivism and suitable for considering systems as models; define in the framework of logical openness the concept of property and distinguish between systemic and non-systemic properties. We explore necessary and sufficient conditions for the establishment of systems in such a way as to be able to later consider, as central focus of the contribution, emergence as the process of *acquisition* of new properties, the research towards a general Theory of Emergence, the new approach based on the search for meta-structural properties and how to keep acquired properties without the support of lower levels.

Keywords: Acquisition, Emergence, Model, Observer, Self-Organisation.

Introduction

In the first part we introduce some theoretical comments and elaborations about a) the concept of System, b) the modelling of its behaviour, c) distinction between transformation from a state and acquisition of a systemic property, and d) the concepts of multi-, inter-, and trans-disciplinarity necessary to set the theoretical framework for allowing systems research.

In the second part we deal with the theoretical role of the observer no longer considered as generator of relativism, but rather of cognitive existence as in constructivism.

In the third part, on the basis of the concepts introduced before, we deal with necessary and sufficient conditions for the establishment of a system. Particularly, we consider systems established by a) components interacting respecting an explicit structure, b) processes of self-organisation, c) processes of interaction between components without following explicit structure or self-organisation, and d) through processes of evolution.

In the fourth part we deal with the concept of property as observer dependent and distinguish between systemic and non-systemic properties.

In the fifth part we deal with the concept of emergence focusing on processes of acquisition of new properties by the system.

In the sixth part we summarize how the concepts introduced relate to different and defining levels of Systemics, such as Systems Theory, General Systems Theory, and System Approach.

Sections seven and eight focus on the core and conclusive aspects of this contribution related to the research of a General Theory of Emergence, the new approach based on using meta-structures and the problem related to how to keep acquired properties when substituting or even without the support of lower levels.

1. Systems

1.1 What *are* Systems?

In the scientific literature a System has been defined in various ways. For instance as "A set of objects together with relationships between the objects and between their attributes" [1] or ". . . a set of units with relationships among them" [2]. A system has been intended as an entity having properties different from those of what are considered elements by the designer (for artificial systems) or by the observer (for natural systems). A set is an entity having properties different from those of its component elements (for example, the number of elements).

A necessary and sufficient condition for the establishment of systems is that elements, as *designed* (for artificial systems) or *represented* (for natural systems) by the observer, interact in a suitable way.

It is possible to distinguish between two conceptual cases (Guberman and Minati, 2007):

- Systems are considered in an objectivist way when they are artificially designed, i.e., we know the component parts and how they interact because they were designed that way.
- Systems are considered in a *constructivist* way (as for natural systems which have not been artificially designed) when the observer decides to apply a level of description (i.e., partitioning and interactions) to those systems, as if they had been designed as such. In this case, the observer constructivistically (Butts and

Brown, 1989; von Glasersfeld, 1984) models phenomena as systems, by assuming elements and interactions. When this level of description *works* for applications, it is often assumed to be the *true* one within the conceptual framework of a *discovery*, thus resuming an objectivist approach.

1.2 Modelling Systems behaviour

The theory of dynamical systems is based on the fundamental intuitions introduced by H. Poincaré (1854-1912). A dynamical system is based on two different kinds of information:

Information about the system and representation of its state;

The dynamics of the system, through a rule describing its evolution with time.

Let us consider an open interval *w*. A *continuous dynamical system* in *w* is described as an autonomous system of ordinary differential equations which hold for a vector of dependent variables *x*. The meaning of *autonomous* relates to the fact that right hand members are time independent. An example is:

$$dx/dt = F(x) \tag{1}$$

Examples are models used to model simple systems such as the motion of the pendulum or planets moving along their orbits, by using the equations of motion of classical mechanics. We remember that thanks to this way of modelling systems it was possible to identify the so-called *Three Body Problem*, i.e., the problem of computing the orbits of three separate masses resulting from their mutual gravitational interaction. This problem represents the shift from classical physics to the physics of complexity.

If we consider simple systems like the pendulum, a state variable describing the microscopic behaviour of elementary components is sufficient to describe the behaviour of the entire system.

If we consider more complex systems, like mechanical and electronic devices, biological matter and social systems, we must consider macroscopic variables as state variables suitable for describing the system as a dynamical system using those variables. In this conceptual framework Ludwig von Bertalanffy (1901-1972), considered as the father of *General System Theory*, described a system *S* by using suitable macroscopic state variables $Q_1, Q_2, \ldots, Q_n$, whose instantaneous values specify the state of the system. Evolution of the state variables over time is modelled by a system of *ordinary differential equations*, such as:

$$\begin{cases} \dfrac{dQ_1}{dt} = f_1(Q_1, Q_2, \ldots, Q_n) \\ \dfrac{dQ_2}{dt} = f_2(Q_1, Q_2, \ldots, Q_n) \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ \dfrac{dQ_n}{dt} = f_n(Q_1, Q_2, \ldots, Q_n) \end{cases} \tag{2}$$

In this way it is possible to formally represent how the change in the value of a given state variable affects all other state variables.

1.3 Transformation from a state and acquisition of a systemic property

The two approaches mentioned above relate to the study of such entities, i.e., systems, able to acquire properties. We will elaborate this point further but for now I would like to focus your attention on this crucial point. We do not refer to processes of *transformation* from a state of matter to another one, be it stable, unstable or dynamic like equilibrium, volume, and density, but to processes of continuous acquisition and persistence of properties like life due to biochemical processes, functionalities of electronic and mechanical devices assumed when suitably powered and profitability of corporations continuously processing raw material. Furthermore systems not only acquire properties thanks to the continuous interacting of components, but are in their turn able to acquire *subsequent* new properties through processes of emergence. Examples of emergence of systemic properties in systems, named *complex systems*, are given by the establishment of properties such as cognitive abilities in natural and artificial systems, collective learning abilities in social systems such as flocks, swarms, markets, firms and functionalities in networks of computers (e.g., in Internet).

Systems scientists are devoted to the study of the second case from an enormous variety of disciplinary approaches like in physics, biology, cognitive science, informatics, medicine, and economics. Moreover, because the same processes of acquisition of new properties take place in almost every discipline, the study of systems was performed in almost any discipline like music and language.

The problem to study, model and explain the establishment of general entities able to acquire properties became the problem of a *trans-disciplinary* approach named Systemics.

1.4 Multi-, Inter-, and Trans-disciplinarity

The term Trans-disciplinarity is widely used, but often neither with a clear nor with a precise meaning having general consensus. Probably Jean Piaget first used this term at workshop "L'interdisciplinarité - Problèmes d'enseignement et de recherche dans les universités", Nice (France), September 7-12, 1970. Paradoxically, we may count different meanings in different disciplines.

We refer to this term in a very precise way. We consider Trans-disciplinarity as the study of systemic properties *per se*, i.e., considered in general as properties of models and representations without any reference to specific disciplinary cases. Some examples are the study of acquisition of properties *in general* trough a) processes of self-organisation and emergence; b) generation -for instance through design- or induction -for instance, through suitable boundary condition- of establishment of systems; c) influence of systems through environmental changes; d) transformation of open to closed systems; e) merging of systems; and f) replication of acquired properties in other systems. Trans-disciplinarity also relates to the study of relations *between* systemic properties, e.g., between adaptability, chaos, dissipation, equilibrium, and openness,.

We underline that *Inter-disciplinarity* relates to considering problems and approaches of one discipline for another one.

This take place when changing the meaning of variables and keeping the same model. Examples occur when models of physics are used in economics and in biology to represent, for instance, markets and ecological equilibria in ecosystems. In this case, theoretical issues consist of formulating problems of a discipline by using models of another.

Multi-disciplinarity relates to the *use* of different disciplines to deal with the same problem like psychology, economy, laws and organisation to deal with a managerial problem occurring in corporations.

2. The theoretical role of the observer

In the systemic literature the concept of *logical openness*, as opposed to *thermodynamic openness* [4, 31, 32], has been introduced. Logical openness relates to the constructivist role of the observer generating *n-levels* of modelling by assuming *n* different levels of description, representing one level through another and modelling a strategy to *move* amongst them, and considering simultaneously more than one level as in the Dynamic Usage of Models (DYSAM). With reference to the concept of systemic complexity, i.e., the occurrence of the acquisition of new properties within a system through processes of emergence or multiple dynamic roles of components, as for Multiple Systems (MSs) and Collective Beings (CBs) considered in 3.2.4, the number of levels, *n*, of modelling adopted by the observer can be considered as a *measure of the complexity* of a system [32]. An implementation of DYSAM based on Neural Networks was introduced by Minati and Pessa [4]. The DYSAM approach [4, 33] was introduced to deal with the dynamical emergent properties of complex systems. While a dynamical system is defined by the existence of a set of suitable state variables describing it and evolution laws specifying how the values of these variables change over time, DYSAM relates to the dynamics of emergent properties of a system and to properties of MSs and CBs as well. DYSAM is based on approaches already considered in the literature having the common strategy of not looking for a unique, correct, optimum solution. Strategies not based on such a simplistic approach are, for instance, the well-known Bayesian method, Pierce's abduction, Machine Learning, Ensemble Learning and Evolutionary Game Theory. The concept of DYSAM relates to situations in which the dynamical adoption of properties by the system is such that any single model is, in principle, unsuitable to model such dynamics, because single models are assumed to model a specific system. DYSAM is composed of a repertoire of different possible models and a strategy for selecting, on the basis of general and transitory goals, the most suitable one and on modelling interactions between the adopted models (for instance, through representing and learning).

3. Establishing systems

In this section we consider and distinguish between some possible necessary and sufficient conditions to establish systems. Confusions of the two categories is typical of reductionism when assuming that processes establishing systems may be, for instance, *regulated* by acting on necessary conditions. Sufficient conditions are listed only to introduce the reader to this problem and not to provide a comprehensive set of possibilities.

3.1 Necessary conditions for the establishment of systems

There is a general consensus that models adopted by an observer (for natural systems) and a designer (for artificial systems) explicating the process of establishment of a system are based upon, as a *necessary condition*, the interactions between elements, i.e., inter-relating elements. This emphasizes the conceptual nature of systems, as effective models. We may assume, in short, that two or more elements interact when *one's behaviour affects the other's* as observed by the observer. Examples of such interactions are processes of mutual exchange of energy (e.g., collisions and magnetic fields, where vector fields exert a magnetic force on magnetic dipoles or moving electric charges), matter (e.g., economic interchange) or information (e.g., prey-predator). Moreover, control devices are based on interactions between processes to regulate the value of a given variable (e.g., the Watt regulator using steam pressure and the induced speed of a rotating mechanism to keep the rate of rotation constant by adjusting the steam pressure). Interactions may occur in different ways. For example, short- and long-range correlations are interactions between elements on short or long time or distances scales (even simultaneously) which can display coherence as in the famous *binding problem* (regarding the *coherency* of the combination of information from distinct populations of neurons such as for visual, acoustic, olfactory, tactile or memory systems establishing a unified perceptual experience). Coherence is a concept having several disciplinary meanings. For instance, in physics, the coherence of two waves relates to how well correlated they are, allowing to predict the characteristics of one wave by knowing the characteristics of the other. Examples of other disciplinary meanings relate to usages in philosophy when considering the consistency of concepts, in cognitive science for cognitive states, and in linguistics with reference to semantics. In Systemics we consider coherence, as in the binding problem and collective behaviour, as the dynamic establishment and perpetuation of a property *continuously* established by interacting components. For instance, the property of a set of boids establishing a flock is continuously established and this *continuity* is considered as the coherence of the collective or coherent behaviour of boids. It should be stressed that systemic properties are not the *result* of interactions. Systems and their properties are established by the *continuous* interaction among elements (e.g., an electronic device acquiring a property when powered on, leading to interactions amongst the component elements) and are not a *state*, as in the formation of a new colour by mixing primary colours (e.g., Red-Green-Blue).

By referring to the concept of *level of description*, i.e., the disciplinary knowledge and the scaling used by the observer to model a phenomenon in an effective way, systems may be intended as *models* to design or to represent phenomena [3]. Because multiple representations are possible, the Dynamic Usage of Models [4] has been introduced. A very important distinction relates to the particular kind of elements which are assumed to establish a system through their interactions:

a) Elements assumed as indistinguishable (*homogeneous hypothesis*). In this case elements are assumed to be particles. Their interaction may be modelled by mathematical equations and often by very simple rules. An example is given by gases consisting of particles and adopting systemic properties such as pressure and temperature. The hypothesis applies even when interacting elements are autonomous systems, i.e., provided with cognitive systems, all being considered as equal in a simplified, reductive, way. This is, for example, the case for models based on agents interacting according to a few, simple rules (e.g., eco-systems and markets).
b) Elements assumed to be different, and distinguishable (*heterogeneous assumption*). In this case each element interacts in a different way. This is the typical case of autonomous agents *processing* interactions and not simply reacting. Here, the processing is performed by the cognitive system and the result is non-deterministic. A typical example is given by families of human beings. Human beings establish systems, in this case families, assuming sociological properties different from those of its components, such as decisions emerging from

discussions, i.e., interactions, regarding educational choices for children and economic behaviour. In some cases the cognitive system is so elementary that it is possible to simplify, by adopting a suitable particle representation, as for swarming and flocking modelled by assuming elements react according to very simple rules.

3.2 Sufficient conditions for the establishment systems

A sufficient condition for the establishment of a system is that elements interact by respecting suitable relationships, or modelled as such, in some particular ways. Moreover, it must be stressed that at the moment there is no way of demonstrating whether the following ways (see Sections 3.2.1-3.2.4) of establishing systems are the *only* ones. This point is particularly important given that new levels of description have emerged, such as the quantistic one, requiring new conceptual approaches in which the very concept of interaction needs to be properly redefined.

3.2.1 The structured way

In the *structured* functional way of establishing organised systems, organisation is intended as a network of pre-established functional relationships which control the manners of interacting. Rules of interaction are either a) determined by following a design or b) *constructivistically* intended as such by the observer. In both cases they are *sufficient conditions* for establishing systems. Structured rules *completely* define the way in which elements interact, i.e., they define *all* the degrees of freedom possessed by interactions between elements at the specified level of description. Examples of case a) include mechanical devices, such as machines, and electronic devices, such as circuits. Examples of *non-designed* systems, as in case b), are natural entities modelled as organised systems by the observer, such as organs performing given functions in living beings and eco-systems.

3.2.2 Self-organising way

A process of *self-organisation* takes places when a structure or a change in structure is acquired or lost, as in phase transitions due to environmental perturbations (e.g., change of temperature or pressure) and in *collective phenomena* such as swarming and flocking (see Section 5 for usage of the term in the scientific literature and Section 7 for our proposed conceptual definition). Changes are not prescribed from the outside, as in theoretical models of phase transitions, by adopting the homogeneity hypothesis. The same theoretical model adopted for phase-transitions is used to model self-organisation by identifying *order parameters* as in Synergetics [5, 6]. Examples of systems modelled in this way are flocks, swarms, industrial districts, lasers, ferromagnetic and superconducting systems. In any case, the use of Dynamical Systems Theory approaches based on the *homogeneity assumption*, i.e., neglecting *any differences* between the components, whether they are particles, planets or molecules, has been very successful in science. *Emergence* deals with a generalisation of such processes by considering the *heterogeneity assumption* and the process of hierarchically acquiring new properties as properties of systems of systems. Examples of models based on Dynamical Systems Theory and proposed for modelling emergence are Noise-induced phase transitions and Spontaneous Symmetry Breaking (SSB) in Quantum Field Theory. Such models are *unsuitable* in light of the *heterogeneity assumption* because emergence has to be considered in this case as arising from a suitable combination of dynamical rules and fluctuations, e.g., produced by noise, quantum effects, impurities or other effects instead of using *heterogeneity-based* models when considering differences between components such as in biology, e.g., life, or for cognitive systems, e.g., learning [7]. Examples of this kind for modelling emergence are Agent-based systems, Artificial Life, Neural Networks, and Immune Networks.

3.2.3 Unstructured, non-self-organising way

Systems may be established in an *unstructured* although neither self-organising nor emergent way, i.e., when an interaction does not follow structure nor models of self-organisation nor emergence. In the case of a) autonomous systems, i.e., provided with cognitive systems, interaction is due to the processing of input by cognitive systems. In this case interaction derives from the cognitive processing modifying, for instance, information, emotions, knowledge, inference and the making of decisions, which can affect the behaviour of the autonomous systems. In these cases the system is produced by the way of processing and affecting behaviour. One processing affects the other. In the case of suitable cognitive systems, coherence is ensured by the cognitive processing and this is a sufficient condition for the establishment of a system. Examples are social systems (e.g., families, classrooms, and micro-communities such as an audience). When the cognitive system is very simple (e.g., as in the case of ants) the process may be simulated by a particle system having structured or self-organised interactions. In the case of b) non-autonomous systems, such as systems in physics, new systems and corresponding new systemic properties occur by spontaneous symmetry breaking when the system acquires properties such as superconductivity or superfluidity. Such processes are modelled within the theoretical framework of Quantum Theory [8] and are considered by some physicists not only as non-structured, but also as the real models of self-organisation [9,10]. Moreover, as mentioned above, they are unsuitable for the heterogeneous case.

3.2.4 Evolutionary way

Systems may be established in an *evolutionary* way, i.e., through a process considered for species, when elements of a specific species interact amongst themselves (e.g., competing for food or territory, and for reproduction), with individuals of other species (e.g., prey-predator or establishing symbiotic processes) and with the environment, for instance, by adapting and modifying their behaviour. In this case the focus is not on the properties acquired by the established collective systems (e.g., ecosystems and prey-predator systems), but on changes produced in single systems to better accomplish the process of interaction. We may distinguish the cases where the process of interaction is ruled by a) fixed evolutionary rules establishing a system acquiring a new property with reference to components. For instance, ants possess fixed evolutionary rules corresponding to a simple cognitive system having a very limited or no ability to learn, i.e., to improve it. An anthill displays multiple but non-evolutionary acquired properties, such as shape, food recruitment, defence strategies and an *ant cemetery* [11]. Evolutionary rules are b) variable, for instance, through processes of mutation and learning. Previous cases may not only occur in well-separated, well-defined ways and at different times. They may also occur in any combination and at any time, e.g., simultaneously, alternately, or in short- and long-term correlations. Theoretical approaches towards this multiple combination in the establishment of systems have been introduced, for instance, with the concept of Collective Beings based on Multiple-

Systems [4]. We recall that a Multiple System (MS) is a set of systems established by the *same* elements interacting in *different* ways, i.e., having multiple simultaneous or dynamical roles. Examples are the Internet where different systems play different roles in being used in continuously new ways (e.g., the same software codes and services can be used to perform different tasks) and dynamic infrastructures of electric power networks adopting emergent properties (an unfortunate example being the black-out). Collective Beings (CBs) are particular MSs established by autonomous agents possessing the *same* cognitive system allowing them to decide different, simultaneous or dynamic belonging to the various simultaneous or dynamic systems. Examples of multiple, *alternative* belonging can occur when human beings give rise to different systems in temporary communities, such as passengers on buses, audiences at performances and queues in general. Examples of multiple, *simultaneous* belonging occur when *same* human beings give rise to different systems over time as for workers in a company, families, traffic on motorways, and mobile telephone networks. In these examples workers in a company are also *simultaneously* (i.e., they behave as components of a system simultaneously considering they belong to other systems) members of families, of traffic on motorways and of mobile telephone networks. Moreover, the *same* elements interacting in *different coherent* (see above) ways may establish a *single* system like cells in biological systems interacting in electrical and chemical ways, elements of an ecological system interacting in acoustic, visual, olfactory ways, human beings in social systems interacting in linguistic (through text, voice), pictorial (through images) and sounds. In this case a system is established by Multiple Coherent Interactions acting on vectorial elements, as in the binding problem mentioned above. Another theoretical approach has been introduced by considering the *combined* effects of evolution and self-organisation [4, 12, 13].

> A MS is a set of systems established by the same elements interacting in different ways, i.e., having multiple simultaneous or dynamical roles. The role of single systems in a MS must be not confused with that of *subsystems* related to different *functions* in the same system. Within the conceptual framework of MS concurrent/cooperative effects of different interactions affecting the same elements perturb the effects of single interactions. Moreover, the action of concurrent interactions may be neither simultaneous nor regular. The same interacting components may establish different systems through organization or emergence and at different times (i.e., simultaneously or dynamically).
>
> Examples of MSs in *systems engineering* include networked interacting computer systems performing cooperative tasks, as well as the Internet, and electricity networks (an unfortunate emergent property is the black-out) where different systems play different roles in continuously new, emerging usages.

CBs are particular MSs established by agents possessing a (natural or artificial) cognitive system. In CBs the multiple belonging is *active*, i.e., *decided* by the composing autonomous agents (Minati, 2001; Minati and Pessa, 2006).

It is possible to identify two kinds of processes for the emergence of CBs:

- in one case agents interact by using the *same* cognitive model implying multiple roles, such as cooperation and competition (e.g., in predator and prey behaviour), to be simultaneously or dynamically adopted in the model constructivistically designed by the observer;
- in the other case agents interact by simultaneously or dynamically using, in the model constructivistically designed by the observer, *different* cognitive models.

The first case relates to contexts having *fixed evolutionary rules*, whereas the second relates to contexts having *variable evolutionary rules*.

Examples of the second kind of system are *Human Social Systems* for cases where:

(a) agents may *simultaneously* belong to different systems (e.g., behave as components of families, workplaces, traffic systems, as buyers, of a mobile telephone network). *Simultaneously* is not only related to time, but also to agent behaviour, considering their simultaneous belonging, and their roles in other systems;

(b) agents may *dynamically* give rise to different systems, such as temporary communities (e.g., audience, queues, passengers on a bus), at different times and without considering multiple belonging.

Modelling social systems has been based on considering families, corporations, cities, hospitals, schools, and so on, as *subsystems*. We postulate the effectiveness of also considering them as CBs. The management of the multiple systems of a CB by considering them as subsystems is a source of serious *managerial* problems. The various multiple roles assumed by a subsystem within a system must be not confused with the multiple roles assumed by autonomous agents when making emergent a new system**.** For instance, consider hypothetical marketing problems.

4. Systemic and non-systemic properties

What are *non-systems*? Depending on the level of description and on the model adopted by the observer, an entity is not a system when its properties are ***states***, *considered as not necessarily being supported by a continuous process of interaction amongst its components*. Systems are thus entities assumed to be *continuously acquiring* systemic properties. Non-systems are entities *possessing* non-systemic properties. Only systems may acquire systemic properties, while both systems and non-systems may possess non-systemic properties. The novelty is that systems may *acquire* themselves or collectively (i.e., through systems of systems) *new* further systemic properties through processes of emergence at different levels. Examples are given by the establishment of properties such as cognitive abilities in natural and artificial systems, collective learning abilities in social systems such as flocks, swarms, markets, firms, and functionalities in networks of computers (e.g., on the Internet). *Evolutionary* processes establish properties in living systems. Properties are detected by an observer using a level of description as introduced above. We consider properties within the framework of the constructivist approach. In this view we do not find properties *as they are* in an objectivist view. To clarify this point, we can metaphorically say that we design experiments, intended as *questions* to Nature, and Nature *answers* by making them happen. There are no answers from Nature without questions. Effects may be intended as answers waiting for the proper questions able to model and make them usable. The repeatability of experiments, i.e., the consistency of answers, is a confirmation about the consistency and appropriateness making knowledge possible. Knowledge has been developed, such as uncertainty principles, fuzzy theory, incompleteness, entropy, ergodic behaviour, statistical mechanics, and emergence, to model non-linear answers. What is a property? In general a property is intended as a *characteristic* of an entity detected at some level of description. Examples are the numbers of the Periodic Table of elements introduced by the Russian chemist Mendelejev; the Avogadro number; the speed of light; the pressure-temperature where water is transformed into ice and the period of the earth's orbit around the sun. The idea is to consider properties as *context-independent*, i.e., having universal and constant values. Non-dependence upon the context of observation, i.e., the level of description, is the objectivist view and it is often confused with the *stability* of the context adopted. The problem is that there are no properties without a level of description, no statements without a language. It is not merely a *relativistic* point of view, but a *generative* one, assuming reality has to be linguistically generated as for constructivism [15, 16]. The approach may be understood as the *translation* (not *transposition*) of a property at one level of description to another. The observer is expected to have available a model of the *hierarchy* of levels of description. In an objectivist world the perspective is to make the model *coincide* with the phenomenon. Systemic *properties* are intended as characteristics which can *only* be assumed by entities, i.e., systems, established by interacting components, when they are designed or modelled as such by the observer. Systemic properties are not the *result* of the interacting components, but supported, as a *necessary condition*, by the continuous interaction of components. Examples of systemic properties, adopting a suitable level of description, are: adaptiveness, chaos, dissipation, life, learning and openness. Examples of non-systemic properties, adopting a suitable level of description, are: weight, age, geometric measurements, spatial position and speed in classical physics, and numeric properties in calculus. Non-systemic properties may *become* systemic when they *coherently change* or become inter-related and their changing gives arise to new properties. How can we distinguish systemic from non-systemic properties? Non systemic-properties do not need to be supported by the continuous interaction of components, they are constructivistically modelled by the observer as *stable or unstable states* to be detected and measured. Systemic properties are supported by the continuous interacting of components. A system may have non-systemic properties, while only systems may have systemic properties. Moreover, it is possible to *simulate* not only systems, but also *effects* of systemic properties reducing them in this way to non-systemic properties (e.g., music reproduction and movies). The *Falsification* of Systemics can be considered equivalent to the possibility of finding systemic properties as properties of non-systems [17]. The reason why we distinguish between systemic and non-systemic properties is that there are different approaches for managing them at different levels of description. A reductionist view is based on considering a systemic property as non-systemic, i.e., using an inappropriate level of description. Can processes of emergence establish non-systemic properties? It depends on the level of description adopted. For instance, emergent cognitive properties may be considered as properties *tout-court* of living systems when focus is placed, for instance, on managerial or economic issues. Properties have to be considered as systemic when dealing with illnesses and how to cure them. In this latter case, the observer must have a model of the process establishing a system through the acquisition of such systemic properties.

5. Emergence as the *acquisition* of new properties

Processes of the establishment of hierarchies occurring in emergence is of a general, abstract, nature such as the establishment of acquired, hierarchical properties, one being based upon interactions with the other as for physiological-psychological-mental levels, Multiple Systems or Collective Beings [4, 30]. In this view complex systems and complexity may be intended as referring to the ability of systems to acquire new properties through processes of emergence, focusing on the transformational ability of systems.

In the literature it is also possible to find different definitions related to different kinds of emergence which will not be discussed here, including *strong* and *weak*, *computational* and *phenomenological* emergence [4, 18, 19, 20, 21, 22, 23]. A short overview of the *emergence of the concept of emergence* has been previously published [4, 24]. Some approaches are based on considering the concept of emergence related and, almost, identified with that of *self-organization*. In physics, processes of so-called *order-disorder transitions* have been identified as *self-organization* processes [25] and, thanks to the works of I. Prigogine, related, for instance, to *dissipative structures* [26] and of H. Haken, related, for instance, to *Synergetics* [27], the terms *emergence* and *self-organization* being considered as synonyms. Distinctions should be made between:

1. Phase transitions relating to changes in structure, e.g., water-ice-vapour transition and ferromagnetism.
2. Processes of self organisations considered as phase transitions when a new acquired structure is dynamic and stable, i.e., repeated in a *regular* way. Examples are non-perturbed swarms, i.e., synchronised oscillators, established by suitable initial conditions, reaching stationary states in a non-perturbed way such as populations of synchronized fireflies [28].
3. Processes of emergence may be understood as phase transitions when newly acquired dynamic structures *coherently* change over time. The process of emergence relates to changes in dynamic structures over time. This way of understanding processes of emergence is suitable for modelling collective behaviours of entities provided with cognitive systems allowing the collective system to process internal and external perturbations. The active role of the observer is fundamental detecting, representing and modelling emergent properties. Coherence is a property primarily generated by the cognitive system of the observer [4].

It should be recalled that changes in the ergodicity of a system is a useful index for detecting the establishment of processes of self-organization, such as structural changes in phase transitions [29].

6. Systemics

Considering systemic issues in general (such as the use of the concepts of system, interactions, inter-disciplinarity, trans-disciplinarity, and systemic specifications and properties often defined within specific disciplines) and not at a specific level of description/theorization has given rise to the more general aspects of the approach known as *Systemics* in English, *Systémique* in French, *Sistemica* in Italian and Spanish, intended as a *cultural generalization* of the principles contained in *GST*. The point is illustrated in Table 1. The term is widely used, although not precisely defined, even in the titles of journals and books.

Table 1: A general overview on Systemic issues.

Systemics

This term is used to denote a *corpus* of systemic concepts, *extension* of systemic principles by using, for instance, analogies and metaphors.

Systemic Approach

This expression is used to denote the general methodological aspects of Systemics, considering, for instance, identification of components, interactions and relationships (structure), levels of description, processes of emergence and role of the observer.

General System Theory

This expression has been introduced in the literature to refer to the theoretical usage of systemic properties considered within different disciplinary contexts (inter-disciplinarity) and *per se* in general (trans-disciplinarity). It also refers to applications in specific disciplinary fields. Current research identifies it with the *Theory of Emergence*, i.e., acquisition of properties.

System Theory

This expression, often inappropriately used as shorthand for *General System Theory*, relates to First-order cybernetics and Systems Engineering for applications such as Control systems and Automata.

7. Towards a General Theory of Emergence: the search for meta-structural properties

An innovative way to conceptually model processes of self-organisation and emergence is introduced in [34]. The idea is based on considering dynamics no longer referred only to variability of the behaviour of components with time, but to the structure between them. Particularly,

- Self-organisation is intended to occur when variability of the structure is stable, i.e., repetitive and foreseeable. An example is given by stationary waves in cyclic swarms iterate the same cyclic configurations over time; as in phenomena of *cyclic behaviour* in flocks and swarms, regular fluctuations and spontaneuous synchronization in biological systems.
- Emergence is intended to occur when variability of the structure is, dynamic, irregular, but coherent. An example is given by swarms and flocks adopting variable non-regular behaviour as in the presence of any suitable environmental condition, but displaying the same property to the observer.
- Emergence of hierarchies of systemic properties occur when variability of the structure is not only dynamic, irregular and coherent, but also generates hierarchies of systems like for cognitive abilities emerging from physiological levels.

This theoretical approach to modelling processes of emergence is under investigation and based upon considering *meta-structures*, i.e., on mathematical properties adopted by sets of *mesoscopic and global (macro) variables* used by the observer to model collective behaviours [34]. In this approach we consider *coherence* generated no longer by dynamics between *state variables* related to components, but by properties of mesoscopic and global variables and of their inter-relations. *Multiple variable structures are those established between mesoscopic and global (macro) variables*. Making reference to collective behaviours established by agents, examples of suitable mesoscopic and global variables changing over time are: *D*, density; *V*, volume; *Su*, surface; *Mx- Mn* maximum-minimum distance between two agents; N_k number of agents having the *same* value of some variables and levels of ergodicity of the sets of values adopted by single mesoscopic and global variables in a given timeframe.

If this approach will be successful it may be a suitable step towards a general theory of emergence, trans-disciplinary based on meta-structural properties independent from any particular disciplinary field. Today models of phase transition are generalised when transposing from physics by changing, when possible, the meaning of variables. The meta-structural approach is based on considering relations between variable structures regardless to variables and their meaning.

8. How to keep acquired properties

The emergence of hierarchies of systemic properties is *necessarily* established by other lower levels. We already mentioned, as example, how cognitive properties are based on necessary lower levels such as the physiological ones. This is also the case for maintaining the properties of MSs and CBs.

A research issue relates to the possibility of *sustaining* a systemic property acquired from subsequent processes of emergence *without* keeping the lower levels involved. In our models lower levels are *necessary* and are as well influenced by the higher ones.

One approach can be based on ***substituting*** lower necessary levels by suitable other ones, in order to **reproduce** acquisition of same properties through different processes.

The process of substituting is possible for virtual systems, such as Artificial Neural Networks. In this case the process may even be reproduced because of the *virtuality* of the system. In short, *virtual systems* are established by some resources *instead* of others unavailable at that particular moment. It is possible to produce indefinite numbers of copies of the *same* system, by reproducing the process of acquisition of properties from equivalent resources.

Another approach is based on *reproducing* emergent properties without reproducing the process of emergence. For example, it is possible to reproduce some effects without reproducing the generating processes, for instance when recording and reproducing music.

Another case related to natural systems considering the process of *reproduction* together with the representation and transmission of knowledge. In this case processes of transmission from one supporting system to others take place through representation of knowledge and education.

We may also consider different kinds of processes characterised by *gradualism* in the replacement of supporting lower levels. We may consider, for instance, teams replacing over time their members, in the same way new cells replace dead cells in living matter replacing in time mostly of the entire body. We may consider a new concept, that of *re-emergence*, related to reproducing emergent process of acquisition of properties supported by the presence of new replacement elements.

By considering emergence of mind and consciousness, the subject relates to the general problem of *qualia* introduced in 1929 by Clarence Irvine Lewis [40].

Moreover, in the same theoretical framework we may consider the similar problem consisting in the ability to maintain emergent *mind* without the original living biological matter. Religions refer to that when dealing with the concept of *eternal life*. We may understand this expression as referring to the adoption of mind as an acquired property by another, biological (metempsychosis) or not, system [41].

Conclusions

Some of the advanced border problems that we have deal with in Systemics were introduced. We have to deal with systemic problem a) in disciplinary ways, b) in a interdisciplinary way when approaches and modelling successful in a discipline are applied in another by changing the meaning of variables, and c) in a trans-disciplinary way when dealing with systemic problems non in specific disciplinary contexts, but in general. This general conceptual framework is especially considered for the problem of emergence, acquisition of properties and new possible theoretical approaches.

References

[1] Hall, A. D. and Fagen, R., E., «Definition of a system», *General Systems* Yearbook, 1956 **1**, p. 18-28.
[2] von Bertalanffy, L., *General System Theory. Development, Applications*, George Braziller, New York,1968.
[3] Guberman, S. and Minati, G., *Dialogue about systems*, Polimetrica, Milano, Italy, 2007.
[4] Minati, G., Pessa, E., *Collective Beings*, Springer, New York, 2006.
[5] Haken, H., Synergetics: An Approach to Self-Organization. In: *Self-organizing systems: The emergence of order* (F. E. Yates, ed.), Plenum, New York, 1987, p. 417-434.
[6] Haken, H., *Information and Self-Organization. A macroscopic approach to complex systems*, Springer, Berlin, 1988.
[7] Minati, G., Pessa, E., *Collective Beings*, Springer, New York, 2006, p. 128-134.
[8] Sewell, G. L., *Quantum Theory of Collective Phenomena*, Oxford University Press, Oxford, UK, 1986.
[9] Anderson, P. W., Can broken symmetry occur in driven systems? In: *Equilibrium and Nonequilibrium Statistical Mechanics* (G. Nicolis, G. Dewel and P. Turner, eds.), Wiley, New York, 1981, p. 289-297.
[10] Anderson, P. W, and Stein, D. L., Broken Symmetry, Emergent Properties, Dissipative Structures Life. Are they related? In: *Self-Organizing Systems: The Emergenceof Order* (F. E. Yates, ed.), Plenum, New York, 1985, p. 445-457.
[11] Martin, M., Chopard, B. and Albuquerque P., «Formation of an ant cemetery: swarm intelligence or statistical accident?», *Future Generation Computer Systems archive*, 2002, 8(7), p. 951–959.
[12] Kauffman, S., *Origins of Order: Self-Organization and Selection in Evolution*, Oxford University Press, New York, 1993.
[13] Kauffman, S., *At Home in the Universe.* Oxford University Press, New York, 1995.
[14] Kauffman, S., *Investigations*. Oxford University Press, New York, 2000.
[15] Butts, R., and Brown, J., (eds.), *Constructivism and Science*, Kluwer, Dordrecht, Holland, 1989.

[16] von Glasersfeld, E., An introduction to radical constructivism. In: *The invented reality.* (P. Watzlawick, ed.), Norton, New York, 1984, p. 17-40.
[17] Minati, G., Pessa, E., *Collective Beings*, Springer, New York, 2006, p. 446-447.
[18] Bedau, M. A., «Weak emergence», *Philosophical Perspectives*, 1997, **11**, p. 375-399.
[19] Corning, P., «The Re-emergence of "Emergence": A Venerable Concept in Search of a Theory», *Complexity* 2002, **7(6)**, p. 18-30.
[20] Cruchtfield, J. P., «The Calculi of Emergence: Computation, Dynamics and Induction», *Physica D* 1994, **75**, p. 11-54.
[21] Ronald, E. M. A., Sipper, M. and Capcarrère, M. S., Design, observation, surprise! A test of emergence, *Artificial Life*, 1999, **5**, p. 225-239.
[22] Rueger, A., Physical emergence, diachronic and synchronic, *Synthese*, 2000, **124**, p. 297-322.
[23] Pessa, E., What is emergence? In: *Emergence in Complex Cognitive, Social and Biological Systems* (G. Minati and E. Pessa, eds.), Kluwer, New York, 2002.
[24] Minati, G., Towards a Second Systemics, In: *Systemics of Emergence: Applications and Development* (G. Minati, E. Pessa and M. Abram, eds.), Springer, New York, 2006, p. 667-682
[25] Holland, J. H., *Emergence from Chaos to Order,* Perseus Books, Cambridge, MA, 1998.
[26] Nicolis, G., and Prigogine, I., *Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations.* Wiley, New York,1977.
[27] Haken, H., *Synergetics, an Introduction: Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry, and Biology*, Springer, New York, 1983.
[28] Buck J. and Buck E., «Biology of Synchronous Flashing of Fireflies», *Nature*,1966, 211, p. 562 – 564.
[29] Minati, G., Emergence and Ergodicity: a line of research, In: *Emergence in Complex Cognitive, Social and Biological Systems*, (G. Minati and E. Pessa, eds.), Kluwer, New York, 2002, p. 85-102.
[30] Minati, G., Multiple Systems, Collective Beings, and the Dynamic Usage of Models, *Systemist*, 2006, 28(2), p. 200-211.
[31] Minati, G., Penna M. P. and Pessa E., Thermodynamic and Logical Openness in General Systems, *Systems Research and Behavioral Science*, 1998,15(3), p. 131-145.
[32] Licata, I., *La logica aperta della mente*, Codice edizioni, Torino, Italy, 2008.
[33] Minati, G., Brahms, S., The Dynamic Usage of Models (DYSAM), In: *Emergence in Complex Cognitive, Social and Biological Systems, (*G. Minati and E. Pessa, eds.), Kluwer, New York, 2002.
[34] Minati, G., *New Approaches for Modelling Emergence of Collective Phenomena - The Meta-structures project*, Polimetrica, Milan, 2008.
[40] Lewis, C.I., *Mind and the World Order: Outline of a Theory of Knowledge*, Dover Publications, New York, NY, 1929.
[41] Minati, G., Acquired emergent properties, In: *Proceedings of the Fourth National Conference of the Italian Systems Society (AIRS), Processes of emergence of systems and systemic properties. Towards a general theory of emergence*, (G. Minati, E. Pessa and M. Abram, eds.), World Scientific, Singapore, 2008.