"*GENERAL* SYSTEMS THEORY" AS "THEORY OF EMERGENCE"

Gianfranco Minati
Italian Systems Society, http://www.airs.it
Via Pellegrino Rossi, 42 20161 Milano MI ITALY
Email:gianfranco.minati@AIRS.it http://www.geocities.com/lminati/gminati/index.html

Abstract

The concept of system, due to the complexity of problems, is currently *necessarily* used in many disciplinary fields (i.e. engineering, economics, physics and biology), but in a *reductionistic* way, based on considering a system as a structured and organised set of interacting elements with focus on structure, organisation, and roles of elements rather than on interaction. That accounts to considering Systems Theory as First-order Cybernetics. Within this framework only a limited number of systemic properties are considered and the wide range of collective phenomena are ignored. This reductionistic approach is used for methodologies and representations, by considering systems established by *organised behaviour and structures* (e.g. devices, corporations and networks) in an *objectivistic* framework rather than in a *constructivistic* one, without using more *general* (as in *General* Systems Theory) theoretical frameworks explaining the process of establishment of systems and systemic properties, such as the process of *emergence*. Emergence is the process of formation of new, self-organised *collective* entities from the *coherent* behaviour of interacting components – a process that can *only* be considered as *observer-dependent*, depending on the *level of description* (as for *constructivism*, not only *relative* to the observer). In this case generalisation is not based on generalising modelling based on structure and organisation schemata - by reducing or simplifying complex problems to cybernetics schemas (such as controlling, regulating and optimising) - but rather on considering observer-dependent, self-organised, coherent behaviours of collective entities (e.g. swarms, flocks, traffic and industrial districts). In this view a larger variety of systemic properties became available.

Moreover, the reductionistic usage of the concept of system implies lack of focus on *trans-disciplinary* effects, i.e. systemic properties considered *per se*, but only on *inter-disciplinarity* between *adjacent* disciplines (such as physics and engineering, biology and chemistry) having common models, approaches and languages.

Emergence is the framework within which this kind of reductionistic usage of the concept of system is not possible because theoretically focusing on the process of self-establishment of *coherent*, *collective* systemic properties (e.g. adapting, chaotic, complex, dissipative, ergodic, growing vs. developing, open and closed, etc.) *and* on the creative role of the observer, integral part of the process (*constructivism*).

Some disciplinary problems and results *themselves* call for a *generalised* approach, such as in *General Systems Theory*, necessary and not only possible in the theoretical framework of emergence. A short review of those results is introduced, such as Collective Phenomena; Phase

Transitions in Physics; Dynamical Usage of Models (DYSAM); *Multiple systems*, emerging from the same components, but simultaneously having different interactions among them; Uncertainty Principles; Physical and Logical Openness; Modelling Emergence; Systemic meaning of theorisations like the ones of the Quantum Field Theories (QFT) in Physics with related applications (e. g. biology, brain, consciousness, dealing with *long-range* correlations). The purpose is to identify the systemic contents of disciplinary researches having the potentiality to produce profound innovations in systems research devoted to trans-disciplinarity.

Particular reference is to *emergence* and its modelling introduced in literature, as representing the core fundamental theoretical problems of *General Systems Theory*, related to *generalisation* by using systemic properties. The issue relates to modelling process *and* observer. Dealing with the new problems and results mentioned above calls for new theoretical approaches not reducible to classic, reductionistic, systemic methodologies, related to Systems Theory intended as First-order Cybernetics.

The change is expected to be so innovative to name this process with particular reference to emergence: from *General Systems Theory* to *Theory of Emergence.*

1. Introduction

This contribution has the purpose to introduce how, in the framework of the distinction between *Systems Theory*, based on First-order Cybernetics, and *General Systems Theory* the process of emergence is the *general* model of the establishment of systems, it is the core of *general* systems thinking, theoretically based on *constructivism* based on Second-order Cybernetics. The focus is on ***emergence***, real web of the theoretical problems of *General Systems Theory*.

We mention some disciplinary results and fields of research having very high relevance for *General Systems Theory*. We refer to some systemic contents of disciplinary researches having the potentiality to produce profound innovations in systems research devoted to trans-disciplinarity.

Paradoxically, systemic issues are dealt with by disciplinary researches such as Synergetics, Phase transitions, and Collective Phenomena in Physics; Neural Networks, Cellular Automata and Genetic Algorithms in Computer Science; Evolutionary Games Theory in Mathematics; Self-organisation in Biology, Physics and Chemistry; in Cognitive Sciences, Sociology, Economics, Education, and other disciplinary fields[1], more than by world-wide established systems societies officially devoted to trans-disciplinarity and expected to *culturally* support this purpose through conferences, workshops, research projects, by establishing networks, knowledge sources, research centres and networks, publications, and educational activities.

We also inform about the establishment in Italy of an *observatory* on disciplinary results to support general systems research allowing robust processes of systemic generalisation and theorisation as in *trans-disciplinarity*, mission of systems scientists.

2. The paradox of a *General Systems Theory* without *emergence*

The *General Systems Theory* [2] had very important conceptual and cultural effects at least related, if not linearly consequent, to its approach.

The *theoretical and scientific* aspects of the approach have been applied in many disciplinary fields, specially in physics, biology, cognitive science and information science making arising, for instance, the *science of complexity* [3].

---

[1] Mikhailov, A. S., and Calenbuhr, V. (2002), *From Cells to Societies*., Springer Verlag, Berlin.
Minati, G., and Pessa, E. (eds.), (2002), *Emergence in Complex Cognitive, Social and Biological Systems*., Proceedings of the Second Conference of the Italian Systems Society, Kluwer Academic/Plenum Publishers, London.

[2] Bertalanffy von, L. (1968), *General System Theory: Foundations, Development, Applications*., George Braziller, New York.

[3] Cowan, G. A., Pines D., and Meltzer, D., (eds.), (1994), *Complexity. Metaphors, Models, and Reality*, Santa Fe Institute Studies on the Sciences of Complexity, Addison-Wesley, Aldershot Brookfield Singapore Sydney.

By the way, the *cultural* impact of the usage of the concept of *system*, related to the acceptance of a non-mechanistic, non-deterministic view of reality, has been tremendously reduced because of its ***reductionistic usage*.**

2.1 *Reductionistic* usage of the concept of system

The concept of system is often used in a way that we may name reductionistic.

On this subject let remind, in short, that:

- *Set* is intended as a group of elements having a rule of belonging, allowing to decide if an element belongs to it or not.
- *Structure* is intended as given by relationships among components, such as order, ratio, and connection;
- *Organisation* is intended as given by behavioural rules for elements, such as prioritising, synchronising and selecting;
- *Interaction* between elements takes place when the one's behaviour influences the other's behaviour,

and that the three last concepts have *some* overlapping.

The reductionistic usage of the concept of system is based on considering a system as a structured and organised set of interacting elements with focus on structure and organisation rather than on interaction. In this conceptual view *interactions take place within the framework of structures and organisations*. Such kinds of systems are artificially designed (e. g. electronic devices or networks) or, in the other cases, modelled by using this level of description (e. g. corporations or living bodies) focusing on *roles*. In this view systemic properties are related to structure and organisation. Examples of such properties relate to automation, availability, energy-consumption, robustness and reliability, concerning, for instance, electronic and mechanical devices or teams.

This level of description in using the concept of system has been the one related to Cybernetics, based on self-regulation capabilities as in the well-known Watt regulator. Theoretically, it relates to the *First-order Cybernetics* concerning circular causal processes such as control, negative feedback, automatism, and computing optimisation as well. This approach gave arise to *Control Theory*. This approach is used not only for devices and organisations, but has been *generalised*, that is applied to different kind of systems, by considering it coinciding with *General* Systems Theory. As we will see this approach is only a minor part of General Systems Theory.

We named this, historically initial, approach to systems, *reductionistic* because considering interaction among elements in organisations and structures ***only*** and because it is a subset of a larger class identified, as we will see, by *emergence*. In this case systemic properties are *reduced* to effects of structures and organisations only. In this view each element has a role, a function, and may be substituted, if not properly working, without acting on all other elements (such as for machines). This may be related to symbolic processing compared to sub-symbolic processing[4].

Moreover, this approach is considered in the philosophical framework of *objectivism*.

Such a reductionistic usage of the concept of system is at the basis of Systems Theory rather than of General Systems Theory.

This approach is considered in several disciplines having the focus on problems like self-control and self-regulation: they relate to *First-order Cybernetics* as introduced by Wiener [5], and developed

---

Flood, R., and Carson, E., (1988), *Dealing with Complexity. An Introduction to the Theory and Application of Systems Science*. New York, Plenum Press.

Serra, R., Zanarini, G., Andretta, M., and Compiani, M., (1986), *Introduction to the physics of complex systems*. Pergamon Books, Oxford.

Serra, R., and Zanarini, G., (1990), *Complex systems and cognitive processes.* Springer Verlag, Heidelberg.

[4] Pessa, E. (1994), Symbolic and sub-symbolic models, and their use in systems research, *Systems Research and Behavioral Sciences.*, 11:23-41.

[5] Wiener N. (1948), Cybernetics, MIT Press, Cambridge, Mass.

by Ashby [6]. *Generalisation* of this approach is allowed by recognising suitability of same modelling in different contexts, such as when the eye is hit by light and the eyelid's closure acts as a regulator process or in economics financial actions (e.g. on rate exchange and interest rates) regulate markets.

In *General Systems Theory*, as introduced by Bertalanffy [7], generalisation relates to usage of systemic properties in general, independently from conceptually adopting same organisation and structure in modelling, see par. 2.3. General Systems Theory is *reducible* to Systems Theory and related methodologies when considering, for instance, designing, controlling and self-regulation only: this is only one of the ways, and less general, to establish systems. It has been realised that systems belong to a larger class established by *Second-order Cybernetics* and *processes of emergence.*

2.2 Bertalanffy's view

Bertalanffy [8], introduced the concept of system as constituted by interacting elements P_i $(i = 1,2, \ldots, n)$. Let us shortly recall his approach. Let us consider a measure Q_i for elements P_i. In a system S any variation of Q_i is function of *all other* variations Q_i. In the same way variation of a measure Q_i induces variations in *all other* Q_i. This situation is well described by a system of simultaneous differential equations:

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

If elements are all of the same kind it is possible to consider the single equation:

$$dQ / dt = f (Q).$$

Interdependence is in *general* and not related to particular roles in organisations and structures. In the case introduced by Bertalanffy it is not possible to consider such kind of system as a machine where elements may be substituted without acting on others. This kind of modelling systems is based on variations of a measure Q_i, function f_i of *all other* variations Q_i. This interaction *always* takes place even in machines, but it is not relevant for certain levels of descriptions. It is not relevant when focusing, for instance, at certain levels of description on regulation, control and reliability.

How does the transformation of interacting elements into a new reality (i.e. system) - different than a machine, structure or organisation (like flocks, swarms, industrial districts and traffic) - happen?

The answer is through the process of emergence.

2.3 Emergence: a non-*reductionistic* usage of the concept of system

What is emergence and why is it so important in the new cultural and scientific approaches?

Wiener N. (1961), Cybernetics: Or control and communication in the animal and the machine. Second edition. Cambridge: MIT Press.

[6] Ashby R. (1956), An Introduction to Cybernetics, John Wiley, New York

[7] Bertalanffy von, L. (1968), *General System Theory: Foundations, Development, Applications*., George Braziller, New York.

[8] Bertalanffy von, L. (1968), *General System Theory: Foundations, Development, Applications*., George Braziller, New York.

A formal definition of emergent properties has been introduced by Baas [9]:

Let $\{S_i\}_{i \in I}$ be a family of general systems or "agents". Let Obs^1 be "observation" mechanisms and Int^1 be interactions between agents. The observation mechanisms measure the properties of the agents to be used in the interactions. The interactions then generate a new kind of structure

$$S^2 = R(S_i^1, Obs^1, Int^1)$$

which is the result of the interactions. This could be a stable pattern or a dynamically interacting system. We call S^2 an *emergent structure* which may be subject to new observational mechanisms Obs^2. This leads to the following definition:

$$\text{P is an emergent property} \Updownarrow \text{P} \in Obs^2(S^2) \text{ and } \text{P} \notin Obs^2(S_i^1)$$

Property P of S^2 is *emergent* if and only if it is observable on S^2 but not at a lower level, i.e. at S^1 level.

For instance, while observing the behaviour of a group of people or cars, the flight path of a group of birds, one might conclude that they respectively form crown, traffic jam and a flock (property P). The property P, not observable by looking at individual behaviour, is said to be an emergent property of the group.

In short, emergence is

- **a process of formation of new, self-organised, *collective* entities from the *coherent* behaviour of interacting components (for instance flocks, automobile traffic, industrial districts, superconductivity, ferromagnetism and laser effect). Emergence is identified with *order-disorder transitions*, when ordered frameworks occur within systems fulfilling suitable boundary conditions. Such processes were denoted *self-organisation processes* and the term has become synonymous with *emergence*.**
- **a process that can *only* be considered as *observer-dependent*, that is by considering that:**
  - **collective properties emerge at a level of description *higher* (i.e. by using more *general* cognitive model) than the one used for components;**
  - **collective properties are detected as *new* by the observer depending from the cognitive model assumed, able to detect the establishment of coherence.**

The role of the observer is related to what has been introduced by von Foerster in the *Second-order Cybernetics* [10].

The concept of emergence allows to avoid the classic *objectivistic* approach without assuming a merely *relativistic* one, but supporting and inducing a *constructivist* one based on Cognitive Science.

We considered in the previous paragraph suitable interactions, structures and organisations as conditions for the establishment of a system.

Without considering structures and organisations, interaction is still a *necessary*, but not *sufficient*, condition for the emergence of a system: ways of interacting must be such as to establish self-organised *collective* entities from *coherent* behaviours, *detected by an observer*.

In *Systems Theory* focus is on organisation and on structure (such as for machines and corporations: the design is explicitly *established or assumed by the agent- designer*).

---

[9] Baas, N. A., Emmeche, C., (1997), On Emergence and Explanation, *Intellectica* 1997/2, no. 25, pp. 67-83 (also as: the SFI Working Paper 97-02-008. Santa Fe Institute, New Mexico, USA) http://www.nbi.dk/~emmeche/coPubl/97d.NABCE/ExplEmer.html

[10] Foerster von, H. (1981), *Observing Systems*, *Selected Papers of Heinz von Foerster*., Intersystems Publications, Seaside, CA.
Foerster von, H. (2003), Understanding Understanding: Essays on Cybernetics and Cognition., Springer-Verlag, New York.

In emergent phenomena there is self-organisation detected by using the cognitive model of the observer (such as flocks and industrial districts: *realised* as self-organised by *the agent-observer*) and may be detected at a lower level by considering ergodic behaviour of agents[11].

At different levels of descriptions and with reference to the cognitive model used by the observer

- interacting elements may make emergent a system having emergent properties supported by *continuous* processes of interaction (e.g. swarming);
- interacting elements may generate stable or unstable *results* of processes of interaction (e.g. ferromagnetism);
- interacting elements may generate processes of emergence realised to be such only *in a second time* by the observer, thanks to higher levels of knowledge, that is of modelling (e.g. social process in history; physical processes);
- elements may interact without making emergent (i.e. not recognised as such by an observer) new properties, such as incoherent sounds, words or chemical elements without composing.

2.4 Emergence and General Systems Theory

The general conceptual framework based on *interaction between elements* used to describe the *establishment* (*emergence*) of systems having properties different and non deducible from the ones of the components is the basis of the systemic approach making evident that the way to manage emergent processes is not to act on explicit (symbolic models) rules nor on single elements, but on interaction (sub-symbolic models). This is possible by acting on comprehensive parameters (such as *order parameters*) identified, for instance, in Synergetics [12] and in the study of *Dissipative Structures* [13]. Moreover it is possible to influence systems behaviours by acting upon their boundaries (i.e. by opening and closing) and on the general context, that is on the availability of energy and space or by influencing ways of processing information (e.g. by changing weights and layers in Neural Networks and cognitive model for systems provided with cognitive systems).

The theoretical framework of emergence does not enable a reductionistic, non-systemic usage (i.e. by using *Systems Theory* instead of *General Systems Theory*) of systemic properties. That is because it relates to collective, self-organised processes in which reduction of systems to structures and organisation is not suitable for using and managing them. In the framework of emergence a non-reductionistic usage of the concept of system is given by the availability of a larger variety of systemic properties related, for instance to chaos, complexity, dissipation, ergodicity, growing vs. developing, learning, openness, symmetry breaking, etc.

The process of emergence may be considered as the *general* model for the establishment of systems, as the core of *general* systems thinking, theoretically based on *constructivism* [14]. The reductionistic usage of the concept of system, based on designing organisation, structure and functionalities is a *particular* case of the more general framework of emergence.

2.5 Inter- and Trans-disciplinarity

When the conceptual schema of interaction is applied by considering disciplines instead of agents, the process of interacting is named ***inter-disciplinarity***. We have *inter-disciplinarity* when the *interaction is intended to take place between approaches and disciplinary knowledge* by using

---

[11] Minati, G. (2002), Emergence and ergodicity: a line of research. In *Proceedings of the Second Conference of the Italian Systems Society* (G. Minati and E. Pessa, eds.), Kluwer Academic/Plenum Publishers, London, pp. 85-102.

[12] Haken H. (1983), Synergetics, Third Ed., Springer-Verlag.
Haken, H. (1987), Synergetics: An Approach to Self-Organization, in Self-Organizing Systems, (F. Eugene Yates, ed.), Plenum, New York.

[13] Prigogine I. (1967), Dissipative Structures in Chemical Systems, in Fast Reactions and Primary Processes in Chemical Kinetics, Stig Claesson (Ed.), Interscience, New York.
Prigogine I. (1980), From Being to Becoming, Freeman, San Francisco

[14] Butts, R., and Brown, J., (eds.), 1989, *Constructivism and Science*. Kluwer Academic/Plenum Publishers, Dordrecht, Holland.

same models, representations and simulations based on systemic properties, such as adaptive, anticipatory, autonomous, autopoietic, balanced, chaotic, complex, connectionist, deterministic, dissipative, equifinal, ergodic, far from equilibrium, goal-seeking, growing vs. developing, heuristic, hierarchic, homeostatic, in equilibrium, open and closed, oscillating, self-organised, symmetry breaking, etc.

In this way approaches, problems, and solutions adopted for systemic properties considered in a discipline are also used for systemic properties considered in other disciplines. In the reductionistic usage of the concept of system only few systemic properties are available for designing inter-disciplinarity and, as we will see, for trans-disciplinary research.

Trans-disciplinarity studies systemic properties *per se*. Trans-disciplinarity deals with systemic properties and problems *in general*, with no reference to specific disciplinary contexts. This is the strong connection with *General* Systems Theory. Tasks of trans-disciplinarity are to identify systemic properties and study them in general. For instance the study of openness or complexity as systemic property *per se*.

Research at trans-disciplinary level is at an higher level of generalisation and abstraction than disciplinary and inter-disciplinary research, *but not independent*. **If it is considered *independent* we *don't watch into the telescope as Galileo's adversaries* did when the current culture was based on the assumption to be autonomous, independent from any other level of knowledge. *Telescope of trans-disciplinarity is the disciplinary and inter-disciplinary research.***

The study of emergence is a trans-disciplinary issue. Trans-disciplinarity allows questions such as: How may systemic properties be induced? How may systemic properties be managed? How are systemic properties related? How may systemic properties be measured? How may systemic properties be represented? All those questions refer to a single, specific, crucial theoretical issue: **modelling emergence**, that is the establishment of systemic properties.

It is important to clarify that the trans-disciplinary approach relates to the establishment of robust theoretical ***generalisations*** (that is, on knowledge based on systemic properties, applicable to different disciplinary fields) and **not to a metaphorical, *generic* usage** of disciplinary knowledge.

Generalising asks for a crucial theoretical effort, while making *generic*, *metaphoric* allows to extend the usage of the concept by *trading* with less rigour, less specificity, and lower theoretical level. This relates to the role of *popularising* - very different from, in systemic terms, *generalising*.

3. *General Systems Theory* and *Emergence*

General Systems Theory has often been identified with scientific disciplinary theories, approaches and methodologies based on a limited, reductionistic, usage of the concept of system as introduced above. **We are now facing the process by which *General Systems Theory* is more and more becoming a *Theory of Emergence* looking for suitable, general models and formalisations of its fundamental bases.** *Emergence* [15] refers to the core theoretical problems of the processes from which systems are established. By considering *Systemics* as a cultural extension of General Systems Theory (i.e. *corpus* of concepts, principles, applications and methodology based on using concepts of interaction, system, emergence, inter- and trans- disciplinarity) we correspondingly need to look for, and to be ready for, the establishment of a *Second Systemics*, a *Systemics of Emergence* relating to new crucial disciplinary and *general* issues, such as:

1.Collective Phenomena

Examples of *Collective Phenomena* in physics are, for instance, *superconductivity*, *ferromagnetism*, and *laser effect*, which are manifestations of collective effects and cannot be described by using the traditional models of physics [16]. *Collective Behaviour* emerges in social

---

[15] Minati, G., and Pessa, E. (eds.), (2002), *Emergence in Complex Cognitive, Social and Biological Systems.*, Proceedings of the Second Conference of the Italian Systems Society, Kluwer Academic/Plenum Publishers, London.

[16] Minati, G. (2001), *Esseri Collettivi.*, Apogeo scientifica, Milan, Italy. (Minati G., and Pessa E. *Collective Beings.*, Kluwer Academic/Plenum Publishers, London, revised edition in progress).

systems making up, for instance, the emergence of traffic, markets, ethics [17], and *industrial districts* [18]. In biology Collective Behaviour makes emergent swarms, anthills, herds, biological growth, and societies [19].

2.Phase Transitions, as in physics and in learning processes

For instance in physics a *phase transition* is the transformation of a thermodynamic system from one phase to another. Examples are transitions between solid, liquid and gaseous phases (boiling, melting and sublimation); transitions from the paramagnetic to the ferromagnetic state; the *emergence* of superconductivity in certain metals when cooled below a critical temperature.

Phases are sometimes called *states of matter*, but this may be misleading by introducing a confusion with thermodynamic states. For instance, two gases are in different thermodynamic states when maintained at different pressures, but they have the same *state of matter*. Phase transitions take place with the changing in one or more physical properties when small changes occur, for instance, in a thermodynamic variable, such the temperature [20]. The theoretical schema of the phase transition process has been considered in other domains as well, like in learning (such as in neural networks) by considering learning as a phase transition process [21].

3.Dynamical Usage of Models (DYSAM)

On the basis of the research made in different fields like the

- *evolutionary Game Theory* [22];
- so-called *Evolutionary Stable Strategies (ESS)* applied to model ecosystems [23], biological systems [24], and markets [25];
- so-called *iterated prisoner dilemma game* of great interest for game theorists [26];

it has been well established how, in games with incomplete information and having a high enough level of complexity (such as the *iterated prisoner dilemma*) it is impossible to have a *single equilibrium point*, but only a *multiplicity* of different equilibrium points [27]. On this basis

---

[17] Minati, G. (2002), Ethics as emergent property of the behavior of living systems. In *Encyclopedia of Life Support Systems (EOLSS)*, Vol. 1, Physical Sciences Engineering and Technology Resources, Systems Science and Cybernetics: The Long Road to World Sociosystemicity, (Parra-Luna F. ed.), EOLSS Publishers, Oxford, UK
Minati G. (2004), Buying consensus in the "free markets", *World Futures*., 60(1-2): 29-37.

[18] Pyke, F. and Sengenberger, W. (eds.), (1992), *Industrial districts and local economic regeneration*., International Institute for Labour Studies, Geneva, Switzerland.

[19] Mikhailov, A. S., and Calenbuhr, V. (2002), *From Cells to Societies*., Springer Verlag, Berlin.

[20] Goldenfeld, N. (1992), *Lectures on Phase Transitions and the Renormalization Group*., Perseus Publishing, Cambridge, MA.

[21] Penna, M. P., and Pessa, E. (1995), Can learning process in neural networks be considered as a phase transition?, In *Neural Nets, Proceedings of the 7th Italian Workshop on Neural Nets, WIRN VIETRI* (M. Marinaro and R. Tagliaferri, eds.), Italy, World Scientific, Singapore, pp. 123-129.

[22] Maynard-Smith, J. (1982), *Evolution and the Theory of Games*., Cambridge University Press, Cambridge
Weibull, J. W. (1995), *Evolutionary Game Theory*., The MIT Press, Cambridge, MA.

[23] Huberman, B. A., and Hogg, T. (1993), The Emergence of Computational Ecologies, In *1992 Lectures in Complex Systems* (L. Nadel and D. L. Stein, eds.), SFI Studies in the Sciences of Complexity, Lectures Vol. V, Addision-Wesley, Reading, MA, pp. 185-205.
Huberman, B.A. and Hogg, T. (1988), The behavior of computational ecologies. In *The Ecology of Computation* (B.A. Huberman, ed.), Elsevier North Holland, Amsterdam, The Neederlands, pp. 77-115.

[24] Hines, W. G., (1987), Evolutionary Stable Strategies: A Review of Basic Theory., *Theoretical Population Biology*., 31:195-272.
Schuster, P. (1998), Evolution at molecular resolution. In *Nonlinear Cooperative Phenomena in Biological Systems*, (L. Matsson, ed.), World Scientific, Singapore, pp. 86-112.

[25] Gintis, H. (2000), Game Theory Evolving: A Problem-Centered Introduction to Modeling Strategic Interaction., Princeton University Press, Princeton.

[26] Pessa, E., Penna, M. P., and Montesanto, A. (1998), A systemic description of the Interactions between Two Players in an Iterated Prisoner dilemma Game. In *Proceedings of the First Italian Conference on Systemics* (G. Minati, ed.), Apogeo scientifica, Milano, Italy.

[27] Nash, J. (1950a), The bargaining problem, *Econometrica*., 18:155-162.
Nash, J. (1950b), Equilibrium points in n-person games. In *Proceedings of the National Academy of Sciences of the United States*, 36: 48-49.
Nash, J. (1951), Non-Cooperative Games, *Annals of Mathematics*., 54: 286-295.

the so-called *Dynamic Usage of Models (DYSAM)* has been introduced, related to the fact that when dealing with processes of emergence and *multiple systems* – so-called *Collective Beings* [28] -, see point 4, the strategy based on looking for **the** most effective model is largely ineffective. The strategy introduced with *DYSAM* is based on the *simultaneous* usage of multiple models allowing usage of errors and redundancy (like in models of cognitive science) instead of having the only strategy to avoid them or to optimise [29].

4. Multiple systems, emerging from the same components, but simultaneously having *different* interactions among them

   The concept of *multiple-systems* has been introduced several years ago in diverse fields, such as in psychology with multiple-memory-systems [30]. The concept also relates to *multiple belonging* of elements. Multiple systems are considered emerging from the same elements when simultaneously some of them are coping with different kinds of interactions [31], naming them *Collective Beings*. The concept has been introduced especially for dealing with agents equipped with cognitive models and able to simultaneously handle different kinds of interactions. Examples of *Collective Beings* are constituted by families, workers, buyers, and students: components simultaneously belong to different systems, that is, they handle different interactions.

5. Uncertainty Principles

   Uncertainty Principles arose in situations in which the processing of observing was detected interfering itself with the system under study. It is well known how this has been the case in physics in studying phenomena at atomic scale as introduced by Heisenberg in 1927 [32]. Similar approaches have been introduced in more general contexts with reference to problems of cognitive science, when *science studies itself* as in the fundamental contributions of von Foerster [33].

6. Physical and logical openness

   A distinction between *thermodynamic and logic openness* has been introduced [34].
   In logic openness reference is not only to thermodynamic flux of matter and energy as in the classic definitions. Reference is made to the processing of information and to the mutual modelling adopted by interacting agents. *Behaviourism* introduced by Skinner is a good example of theory carried out on thermodynamic rather than on logical openness: stimuli and reactions are carried through borders by matter-energy, but they are *not processed* by cognitive models. "Logic closeness" means in this case lack of cognitive processing for information, reduced to stimuli. With reference to an observer, by avoiding objectivistic assumptions, it is possible to consider, for instance, different *degrees of logic openness*.

---

[28] Minati, G. (2001), *Esseri Collettivi*., Apogeo scientifica, Milan, Italy. (Minati G., and Pessa E. *Collective Beings*., Kluwer Academic/Plenum Publishers, London, revised edition in progress).

[29] Minati, G. (2001), *Esseri Collettivi*., Apogeo scientifica, Milan, Italy. (Minati G., and Pessa E. *Collective Beings*., Kluwer Academic/Plenum Publishers, London, revised edition in progress).
Minati, G., and Brahms, S. (2001), Experimenting with the DYnamic uSAge of Models (DYSAM) approach: the cases of corporate communication and education. In *Proceedings of the 45th Conference of the International Society for the Systems Sciences (ISSS)*, Asilomar, CA.
Minati, G., and Brahms, S. (2002), The DYnamic uSAge of Models (DYSAM). In *Proceedings of the Second Italian Systems Conference* (G. Minati and E. Pessa, eds.), Kluwer Academic/Plenum Publishers, London.

[30] Tulving, E. (1985), How many memory systems are there? *American Psychologist*., 40:385-398.

[31] Minati, G. (2001), *Esseri Collettivi*., Apogeo scientifica, Milan, Italy. (Minati G., and Pessa E. *Collective Beings*., Kluwer Academic/Plenum Publishers, London, revised edition in progress).

[32] Heisenberg, W. (1971), *Physics and Beyond*., Harper & Row, New York.

[33] Foerster von, H. (1981), *Observing Systems, Selected Papers of Heinz von Foerster*., Intersystems Publications, Seaside, CA.
Foerster von, H. (2003), *Understanding Understanding: Essays on Cybernetics and Cognition*., Springer-Verlag, New York.

[34] Minati, G., Penna M. P., and Pessa E. (1998), Thermodynamic and logical openness in general systems, *Systems Research and Behavioral Science*., 15: 131-145.

7. Modelling emergence
The problem of *modelling emergence* is a very crucial problem in modern science. The issue relates to modelling process *and* observer, *theoretically an integral part* of the process itself, assuming and iteratively redefining models. *Modelling emergence* is a still open issue. To cope with this problem we need *more* than *dynamic modelling*: dynamics is required not at the same level of description (dynamics of data), but between different levels of description (dynamic of models). The subject relates to modelling as in *logic openness* [35] mentioned above. The subjected may be considered, in some ways, related to *user modelling* when observer *and* observed process both interactively change.
8. Systemic meaning of theorisations such as ones of the Quantum Field Theories (QFT)
Systemic meaning of theorisations such as ones of the Quantum Field Theory (QFT) in physics with related applications (e.g. biology, brain, consciousness, dealing with long-range correlations), making reference, for instance, to the concept of quantum, quantic vacuum, simultaneity of effects, and *long range correlations* [36]. These concepts are already disciplinary applied not only in physics, but in the study of the brain and in theories about consciousness [37].

The urgency to adapt and improve the current reductionistic *systemic approach* comes from the need to deal with some disciplinary problems as the ones listed above and with results reached in disciplinary research (such as in physics) having such a level of *architectural abstraction* calling for their *re-formulation in a systemic view*, suitable for trans-disciplinary usage more than to be just popularised or only metaphorically generalised. This is also a challenge for systems thinking.

4. The *Disciplinary Observatory for Systemics (DOS)*
The Italian Systems Society, in order to design some tools and strategies to deal with the scenario illustrated above, is in the process of establishing, based at the *Polytechnic of Milan/Department 'Building Environment Sciences and Technology'*, http://www.polimi.it, in collaboration with several Italian universities, an **observatory** having the purpose to find out the systemic meaning of *disciplinary* results, problems, approaches, methodologies and perspectives.

4.1 Mission of the DOS
The mission of the DOS is to *identify* and *make available* to systems scientists disciplinary research issues, results, approaches, and models of particular interest for trans-disciplinary activity.
The mission of the DOS is to *identify* in disciplinary research activities what is interesting for its trans-disciplinary potentiality. Reference is made to the identification of systemic properties that can be used anywhere it is suitable to model the process or phenomenon under study as a system, that is, in short, as *emergent*. Systemic properties may then be considered for themselves, in systemic conceptual architectures and for developing suitable approaches.
The mission of the DOS is to *make available* disciplinary contributions at such technical level of detail to be suitable to trigger trans-disciplinary reasoning, hypothesising, and theorising. Problems of trans-disciplinarity are to deal with systemic properties in general, to consider relations between them, and the validity of inquiring about the meaning of a specific systemic property in a field where this property has not been detected or considered yet.

4.2 Activity of the DOS
The DOS will organise :

[35] Minati, G., Penna M. P., and Pessa E. (1998), Thermodynamic and logical openness in general systems, *Systems Research and Behavioral Science.*, 15: 131-145.
[36] Pessa, E. (1998), Emergence, Self-Organization, and Quantum Theory. In *Proceedings of the First Italian Conference on Systemics* (G. Minati, ed.), Apogeo scientifica, Milano, Italy.
[37] Vitiello, G. (2001), *My double unveiled.*, John Benjamins Publishing Company, Amsterdam, The Netherlands.

- *disciplinary* workshops with invited contributors where identifying disciplinary research issues, results, approaches, and models of particular interest for trans-disciplinary activity;
- *trans-disciplinary* seminars where the board of systems researchers introduces results, perspectives, and projects.

The DOS will also organise :

- a network of researchers sharing the common interest to identify the systemic meaning of their disciplinary activities;
- conferences of invited speakers.

The DOS will publish a specific on-line journal or a session in systemic journals already established.

The DOS may also yearly publish a summary of its activities of identifying the systemic meanings of disciplinary results and disciplinary publications selected because of their relevance for *General Systems Theory*.

The DOS organises seminars and presentations in schools, universities, research centres and cultural institutions.

4.3 Organisational aspects of the DOS

The DOS is to be organised like a scientific journal, having an editor (*manager of knowledge*) and an editorial board (*a team of systems researchers having different disciplinary backgrounds*). The DOS is also expected to yearly publish a summary of its activity of identifying the systemic meanings of disciplinary results and disciplinary publications selected because of their relevance for *General Systems Theory* as *Theory of Emergence*. The observatory should be lead by a *manager of knowledge* and driven by a team of systems researchers having different disciplinary backgrounds.

Conclusion

The mission of the systems community is to *continue* the approaches introduced by L. von Bertalanffy not only by applying and popularising, but also by innovating them in the context of new disciplinary results.

We think that the systems community has the mission not just to diffuse methodologies (often based on reductionistic concepts of system), but to care about *procedures of scientific and artistic production and application* of knowledge dealing with technological, scientific, ethical, and humanistic aspects in the framework of emergence.

Trans-disciplinarity is the core value and to honour it we should continuously deal with disciplinary and interdisciplinary results obtained thanks to systemic approaches applied in disciplines in the general framework of emergence.

If the process of establishing *General Systems Theory* as *Theory of Emergence* will not explicitly take place, supported by systems movement, then it will be established anyway, emergent from disciplinary researches, but without the extended generalisation that the systems movement can give.

The Italian inter-university ***Disciplinary Observatory for Systemics (DOS)*** going to be established with the Italian Systems Society wants to be a new presence in the systemic movement.