Emergence of Collective Beings
Systemics, Collective Behaviours, Dynamic Usage of Models

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Abstract
This paper briefly reviews the concepts of *observer* and *emergence* as used in modern scientific disciplines. By using these concepts we outline the research devoted to modelling and managing behaviours of *Collective Beings*, emergent from the same agents simultaneously interacting in different ways. Collective Beings are systems in which each interacting component can simultaneously belong to different systems. The *DYnamic uSAge of Models* (DYSAM) is then introduced as a tool to model and manage Collective Beings, by using different disciplinary types and levels of description.
Keywords: collective, emergence, model, observer, systems.

1 Introduction

The purpose of this paper is to sustain and propose fresh approaches in systems sciences. At the moment it seems that *interdisciplinary* (i.e., dealing with the *same* issues in different disciplines, such as adaptation, autonomy, bifurcation, dissipation and openness in physics, biology, economics and psychology) research established in the various disciplinary fields actually constitutes the *entire* systems research. We posit that systems research, based on *transdisciplinarity* (i.e., dealing with interdisciplinary issues *per se* and not from within different disciplines, such as the study of emergence) should focus on more abstract, generalized problems able to give *orientation* to interdisciplinary research, such as those described in chapter 4.

In the **second chapter** we introduce and clarify some theoretical issues related to the concept of *observer* focusing upon its new theoretical role in science, generator of *cognitive existence*, rather than that of *relativism* as in classical approaches. In this chapter we deal with issues such as *kinds of description* and *levels of description*; *creation* and not only *detection* of reality; abduction and the choice by the observer of components *assumed* to be interacting to establish a system. The **third chapter** deals with the process of emergence as introduced in the literature by presenting a brief review of the principal issues, approaches and problems. This includes issues such as so-called 'British Emergentism'; computational emergence; phenomenological emergence; concepts of coherence and *intrinsic emergence*; and an approach for the detection of the establishment of processes of phenomenological emergence. In the **fourth chapter** we discuss the concepts of Collective Behaviours and *Collective Beings*, systems established when the same elements play different roles, *simultaneously* interacting in different ways. In this case elements simultaneously

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belong to different systems. This kind of phenomenon also occurs when elements possess cognitive systems able to simultaneously use different cognitive models to mutually interact. The approach, based on considering Collective Beings as systems emerging from the same elements interacting in different ways, enables one to introduce a new way of managing such dynamics in interactions, by considering a strategy of *multi-modelling*, the so-called *DYnamic USAge of Models* (DYSAM).

2 The Observer

Considering the role of the observer has introduced new strategies for science. In a simplistic approach the observer introduces *relativism*, for instance, in judging, evaluating and measuring. Different views are then compared and compete. In philosophy we had, for instance, *knowledge-relativism*, *truth-relativism*, *cultural-relativism* and *ethical-relativism*. *Independency from the observer* was related to the *absolute* existence of reality, intended as *metaphysical objectivism*, in contrast to *metaphysical subjectivism* related to subjective experiences (i.e., *qualia*, introspectively accessible, phenomenal aspects of mental lives. See, for instance, Churchland, 1985).

In physics the term *relativity* is used with reference to the observer in different ways. For instance:

- for Galileo the *principle of relativity* states that the laws of physics are the same for all observers;
- After the contributions introduced by Einstein's relativity, the concept of *absolute time* was no longer valid. Einstein's special relativity and general relativity, are based on the *constancy* of the speed of light. Because of this constancy it is the *spacetime* which must vary with reference to the observer. In *general relativity* the *curved* spacetime introduced new ways to understand the source of gravity. The *absolute observer* was deprived of absolute time.

A new theoretical approach to the concept of observer has been introduced, for instance, by *Gestalt psychology* (Wertheimer, 1925; 1959; Guberman and Wojtkoski, 2001; Guberman and Wojtkoski, 2002; Kohler, 1975), *Cognitive Sciences* (Anderson, 1983; 1993), and *Constructivism* (see, for instance, Von Foerster, 2003; Maturana and Varela, 1992; Watzlawick, 1983; Von Glasersfeld, 1995). We may synthesize the core of the new approaches by saying that within this new framework *science studies itself* and so the observer studies the observing process (Von Foerster, 2003).

For all of them the term 'observer' refers to a *theoretical role* and no longer to a single agent developing *relative* points of view.

What is this *theoretical role* taken on by the *observer*? The new framework may be synthesized as follows. Previously, the observer was assumed to be an agent equipped with rules to process input and tools intended, in short, for measuring, controlling and regulating. Francisco Varela (in Von Foerster, 1981, p. xviii) names the two concepts as

> "First order cybernetics: The cybernetics of observed systems.
> Second order cybernetics: The cybernetics of observing systems."

The so-called *first order cybernetics* relates to classical cybernetics (see, for instance Asbhy, 1956; Wiener 1948; 1961) and the so-called *second order cybernetics* focuses on the observer as an agent equipped with the ability to *design* new rules and not only *regulate and control* by applying the original rules (see, for instance, Von Foerster

1979; 1981). There are vast, related and still unexplored territories considering the role of the observer in Quantum mechanics, Consciousness and Cognition (Vitiello, 2001). The *non-objectivistic* view was no longer considered as *metaphysical subjectivism*. Let us now look at some other aspects of this non-objectivistic approach, based on the observer no longer being considered as a generator of relativism, but as a reality-builder (see, for instance, Watzlawick, 1983). This approach is increasingly interesting for designing artificial agents-observers such as robots having the purpose of *inferring* new behavioural strategies (e.g., learning) in unknown environments rather than by applying inbuilt ones.

2.1 The *description* used

This relates both to the:

a) *Kind of description* – referring to different ways of describing a phenomenon taking into account different aspects, i.e., by using different disciplinary knowledge (for instance by considering a behavioural problem to be dealt with using models related to physics, chemistry, biology and psychology and a company problem as organizational, financial and marketing) or different cognitive models (for instance in cognitive science this refers to cognitive processing by using approaches and schemas - i.e., computer programs as cognitive models - to process data). In short, a cognitive system may be assumed as a system of models interacting within a cognitive architecture (Anderson, 1983; Anderson and Lebière, 1999).

b) *Level of description* – considering different levels in a *hierarchical* classification, for instance, different levels of generalization. In this case the expression *level of description* may refer to:
   1) a generalization of the same kind of description (for instance by extending the scale and extending the number and kind of variables considered) and
   2) different kinds of descriptions as well, dealing with problems having different levels of generalization, such as considering single behaviour by using psychology and collective behaviour by using sociology. In this case it is the kind of description adopted which possesses different levels of generalization.

2.2 *Creation* and not only *detection* of reality

As mentioned above, in a non-objectivistic view, so-called reality is intended externally (i.e., independently) *existent*, silent *per se*, **until** the observer searches for it through experiments. In this process the observer needs knowledge and objectivistic reality as such disappears, becoming a collection of answers to experiments and inputs to be modelled. **As soon as the observer attempts to search for absolute, external reality, the latter, as such, disappears !**

Thus the observer *builds*, and then *sees*, for instance, systems, rules and regularities, *into* phenomena. This amounts to modelling and using cognitive models.

This may be exemplified by the fact that in order to communicate, represent, evaluate, compare, apply and so on, in short, cognitively process *something* (metaphorically corresponding to *absolute reality*), the agent-observer must use a *language* (metaphorically corresponding to *modelling* by using available knowledge).

On the one hand, so-called absolute reality when represented no longer exists as such and, on the other hand, in order to exist for agents only able to carry out cognitive processing, it must be represented. **We may say, overall, that *existence* is intended as a *cognitive* and not as a *phenomenological* aspect.**

2.3 Abduction

This is a logical inference following the classical *Deduction* and *Induction*.

Consider a collection of data *D* and that the hypothesis *H* may explain *D*. Consider also that no other hypothesis available can explain *D* better than *H*. The observer may then assume that *H* is probably true, i.e., this assumption is *valid*.

Abduction is a *hypothesis inventing process* which may even be viewed as a *selection* amongst the most suitable ones for explaining *D*.

Charles S. Peirce defines his concept of *abduction* in the following way: "Abduction is the process of forming an explanatory hypothesis. It is the only logical operation which introduces any new idea" (Peirce, 1998).

Quoting (Von Foerster, 1979), there is *no information, or anomalies* in the environment. If a given phenomenon looks strange, this only means that the theoretical framework used to interpret this phenomenon is inappropriate. This cognitive process of reformulation of the model is labelled *abduction*, and its aim is to 'normalize' anomalies (Andreewsky and Bourcier , 2000).

2.4 The choice by the observer of components *assumed* to be interacting to establish a system

This point refers to different ways of representing the same phenomenon.

Depending upon the *description* taken on by the observer it is possible to deal with what are intended to be *systems* and *non-systems*.

a) *Systems*, in short, may be intended as sets whose properties are *non-linear* combinations of properties of components (identified as such at the level of description used by the observer). See Section 3.2.1 for the difference between *linear structured set* and *systems*. On this point we recall Bertalanffy's expression showing his belief that systems *exist* only in our mind: "A system as a total of parts with its interrelations has to be conceived of as being composed instantly" (Von Bertalanffy, 1968), and that transformation is possible in the mind of the observer (Guberman, 2004).

b) *Non-systems*, in short, may be intended as sets modelled by the observer as indivisible unities (such as *objects* having functionalities). For instance:

- A ballpoint pen may be intended
  - as an object (for a user) or
  - as a system of interacting components (for instance for the designer).
- A device, such as a TV set, may be intended
  - as an object (for a user) or
  - as a system of interacting components (for instance for a technician having to fix it).

- An *autonomous* system (that is, a system provided with a cognitive system) may be intended
  - as a buyer (i.e., an agent carrying out a single role, such as an economic transaction) or
  - as a system able to play different interacting roles (i.e., buying, travelling, using, working, etc., see the concept of Collective Being in 4.2).

We are interested in modelling systems because they relate to a higher level of *generalization*, for example, the possibility for an observer to *create* new *entities* (i.e., anything *which can be considered using a specific description*) from interacting objects having mutual relationships. This point refers to different ways of representing the same phenomenon.

3 Emergence

The subject of emergence is present in many disciplinary approaches, epistemologically and ontologically. It is not the purpose of this short paper to present a complete review of these various approaches. This chapter begins with some introductory historical references to the concept.

3.1 The emergence of the concept of emergence

This short historical introduction begins by quoting G. H. Lewes when, in 1877, he introduced the concept of emergence:

> "Every resultant is either a sum or a difference of the cooperative forces; their sum, when their directions are the same – their difference, when their directions are contrary. Further, every resultant is clearly traceable to its components, because tnese are homogeneous and commensurable ... It is otherwise with emergence, when, instead of adding measurable motion to measurable motion, or things of one kind to other individuals of their kind, there is cooperation of things of unlike kinds... The emergent is unlike its components in so far as these are incommensurable, and it cannot be reduced to their sum or their difference" (Lewes, 1877, p.414).

Reviews on emergentism usually start by focusing on the so-called *British Emergentism* (see, for instance, McLaughlin, 1992) of the late-nineteenth and early-twentieth centuries. It should be noted that at this time the concept was present in the fields of chemistry and biology. The concepts of *emergentism* were those used to confute *reductionism*, i.e., the assumption that principles of *higher level sciences* were reducible to those of *lower level sciences*, such as biology to chemistry and chemistry to physics. The subject was extended to consider processes of life reducible to physico-chemical processes or established by higher level processes. The so-called *vitalists* postulated the existence of a primitive substance responsible for guiding life processes such as regeneration and embryonic development. Emergentists established a new approach, different from vitalism, but assuming the *non-reducibility* of life processes.

A couple of references and quotations may give an idea of the debate. J. S. Mill in 1843 presented his view on the subject in the book 'System of Logic' (Mill, 1843):

> "All organised bodies are composed of parts, similar to those composing inorganic nature, and which have even themselves existed in an inorganic state; but the phenomena of life, which result from the juxtaposition of those parts in a certain manner, bear no analogy to any of the effects which would be produced by the action of the component substances considered as mere physical agents. To whatever degree we might imagine our knowledge of the properties of the several ingredients of a living body to be extended and perfected, it is certain that no mere summing up of the separate actions of those elements will ever amount to the action of the living body itself." (Mill, 1843, Ch.6, §1).

In 1923, C. L. Morgan first introduced the concept of 'emergent evolutionism' (Morgan, 1923). In 1925, C. D. Broad in his book 'The Mind and Its Place in Nature' (Broad, 1925) discussed not only the Mechanist-Vitalist controversy, but the more general and theoretical question related to the reducibility of special sciences to the more general sciences (e.g., biology to chemistry, chemistry to physics). He wrote:

> "[One] wonders whether the question ought not to have been raised long before the level of life ... The question: Is chemical behaviour ultimately different from dynamical behaviour? seems just as reasonable as the question: Is vital behaviour ultimately different from non-vital behaviour? And we are much more likely to answer the latter question rightly if we see it in relation to similar questions which might be raised about other apparent differences of kind in the material realm." (Broad, 1925, p. 44).

The subject took on a philosophical aspect when dealing, for instance, with issues such as *mind* and *consciousness* (see, for instance, Humphreys, 1996; 1997a; 1997b; Kim, 1993; 1996; 1998; Lowe, 1993; Silberstein,1998). Other issues relate to the difference, in *epistemological* emergence, between *weaker* and *strong* emergence, as introduced by Mark Bedau (Bedau, 1997):

- ☐ *strong emergence* is closer to the British Emergentism mentioned above and relates to the non possibility, even in principle, to *deduce* a high level phenomenon from a lower level domain;
- ☐ *weaker emergence* relates to the fact that a certain phenomenon is *unexpected* with reference to a lower domain. Another way of understanding a *weaker emergent state* is to consider it as a macroscopic state which *could* be derived from knowledge of the dynamics of the system and of external conditions *only* by using processes of *simulation*, i.e., by modelling and reproducing *all* the interactions. This would include, for instance, *chaotic* phenomena.

Another issue relates to *ontological emergence* (see, for instance, Silberstein, 1999). In this paper Silberstein considers ontological emergence as an *irreducible relational holism*. In this view an ontologically emergent phenomenon cannot be analysed into 'elements' and the extrinsic relationships between them. In ontological emergence elements are *definable only* because they are related to each other.

3.2 Computational and phenomenological emergence

The purpose of this short paper is to focus on some general and usually common aspects of emergence used in various approaches relating to collective behaviours such as, for instance, in physics, biology, economics and artificial intelligence.

In short, processes of emergence may be considered as taking place in two ways:

- ❑ so-called *computational emergence* when there are unexpected effects by using a specific model (e.g., the 'Three Body Problem', deterministic chaos);
- ❑ so-called *phenomenological emergence* when the observer must change the model, i.e., *abduce* a new one, dealing with an evolving phenomenon (e.g., collective behaviours in physics, biology and economics).

Let us now consider more specifically the two cases.

3.2.1 Computational emergence

We define *linear structured set* as a set whose properties are *linear* combinations of the properties of components (identified as such at the level of description used by the observer). We recall that a linear function $f(x)$ satisfies the following two properties:

- ❑ *Additivity*: $f(x+y) = f(x) + f(y)$. In mathematics, addition and multiplication are associative, subtraction and multiplication are not. For instance: $(a + b) + c = a + (b + c)$ and $(a - b) - c \neq a - (b - c)$.
- ❑ *Homogeneity*: $f(\alpha x) = \alpha f(x)$ for every α. In mathematics, examples of non-commutative operations are subtraction ($a - b$), division (a/b), exponentiation (a^b), function composition ($f \circ g$), and the conditional operator since *if p then q* is not equivalent to *if q then p*.

Because *properties of linear structured sets* are linear combinations of the properties of the components, *they are not emergent*. As examples we recall any classical optical system, which does not include fluorescent parts, networks of amplifiers and filters. **The final behaviour may always be determined *a priori*.**

In the literature two components are assumed to *interact* when the behaviour of one influences that of the other. More precisely, two components interact when the output of one *sets* the parameters of the other. We define *system* as any *non-linear structured set*, i.e., sets whose properties are *non-linear* combinations of properties of their components (identified as such at the level of description used by the observer). We mention the case where properties may be established *both* by linear *and* non-linear composition of the properties of the components. By considering additivity and homogeneity it is easy to show that linear compositions of non-linear compositions are non-linear compositions and non-linear compositions of linear compositions are non-linear compositions. The interactions of components makes a linear description impossible *per se*. A classical example is Watt's regulator.

In this case, considering the evolution of the system, we have two possibilities.

1. The final behaviour may be determined *a priori*;
2. *In principle* the final behaviour may be *not* determined *a priori*, for instance, it is impossible to obtain an algorithm able to *deterministically* compute the final evolutionary state of a Cellular Automaton, without computing *all* discrete intermediate states; when there are unexpected effects by using a specific model (e.g., the case of the 'Three Body Problem', see Barrow-Green, 1996); in the case of *chaotic behaviour* referring, for instance, to a) *deterministic chaos* (Lorenz., 1963), characterized by long-term unpredictability and sensitivity to the initial conditions, and b) *stochastic chaos* (Freeman *et al.*, 2001), due to external or inner sources of noise.

In the second case there is *computational emergence.*

3.2.2 Phenomenological emergence

In this case the concept of emergence may be introduced as:

- a process of formation of new *self-organized* (in literature self-organization is identified with the so-called *order-disorder transitions*, establishing, within suitable boundary conditions, ordered frameworks as systems, such as ferromagnetism and superconductivity, see the following point) collective entities from the *coherent* behaviour of interacting components (e.g., flocks, automobile traffic, laser light);
- a process which can be considered as observer-dependent *only*, that is, by considering that
  - collective properties emerge at a level of description higher (i.e., more abstract) than that used for the components;
  - collective properties are detected as *new* by the observer, able to detect the establishment of coherence on the basis of the cognitive model used.

The role of the observer is related to the subject of the previous chapter.

The concept of *coherence* is used in this case not as in logic, by referring to logical inferences, but, we may say, from a *phenomenological* viewpoint. For instance, a collective behaviour is not established by the behaviour of components assumed to be coherent *a priori* because they follow a rule, but *it is up to the observer* to realize a phenomenon as a collective behaviour and disaggregate and partition it into the behaviour of what the observer identifies as components. In this view *it is the phenomenon defining coherence in the mind of the observer and not vice versa.* Although different definitions of emergence exist in the literature, there is agreement by most researchers on four fundamental aspects of processes of emergence (Baas, 1994; Baas and Emmeche, 1997; Bedau, 1997; Corning, 2002; Crutchfield, 1994a; Ronald *et al.,* 1999; Rueger, 2000; Pessa, 2006):

1. Possibility to describe, specify, and measure interactions between components, i.e., how one's output *sets* the parameters used by another;
2. Existence of intrinsic fluctuations of various origins (stochastic noise, chaotic behaviour, quantum-like phenomena);
3. Openness of the system of interacting components. The system must be open with respect to the external environment, by distinguishing thermodynamic, logical and parametric openness, see Minati *et al.,* (1998). Logical openness, for instance, is necessary for the *continuous* process of modelling by the observer. Thermodynamic openness is necessary for the survival of the emergent coherent entities, by allowing for contributions from the external environment (e.g., as a source of energy and as a medium for conveying information;
4. It occurs at a level of description higher than that used for individual components.

Emergence (Corning, 2002; Minati, 2001; Pessa, 2002) is not intended as a process taking place within the domain of any discipline, but as *transdisciplinary modelling* meaningful for any discipline.

It is important to note that the traditional tools used for dealing with systems from Dynamical Systems Theory are unable to deal with the problems related to emergent behaviours and, as we will see, are related to *Collective Beings* (see 4.3). As we know there is an intense discussion in the scientific community about the concept of emergence (see, for instance, Pessa, 2002). Here, it is worth mentioning the classification introduced by J. P. Crutchfield (Crutchfield, 1994a; 1994b), distinguishing between three kinds of emergence:

a) *intuitive* (or *naïve*) *emergence*, when the attribute 'emergent' is intended as synonymous with 'impossible to foresee, new, unexpected';

b) *pattern formation*, when the process of emergence consists in the occurrence of a new **structure** as a *consequence* of the model adopted. The pattern comes from making explicit the usually non-trivial dynamics already *implicitly* contained from the start, in the laws and the constraints adopted, for instance the solution patterns arising from bifurcation phenomena in systems of differential equations. This is the case of the so-called *Dissipative Structures* (Prigogine, 1967; Prigogine and Glansdorff, 1971). With regard to this, it should be noted that in physics, thanks to the works of *I. Prigogine* (Nicolis and Prigogine, 1977) and *H. Haken* (Haken, 1983), processes of emergence have been considered equivalent to the so-called *order-disorder transitions*. Those processes were identified as *self-organization* processes (Holland, 1998) and the terms *emergence* and *self-organization* considered as synonyms. Another example is that of *morphogenesis by diffusive instability* (Turing, 1952) re-elaborated, for instance, as agent-based models of pattern formation by E. Bonabeau (Bonabeau, 1997) and D. Dubois by introducing the concept of *diffusive chaos* (Dubois, 1998).

c) *intrinsic emergence*, when the occurrence of **behavioural** patterns cannot *in principle* be foreseen in advance by relying only on the laws and the constraints in use. In distinguishing *pattern formation* and *intrinsic emergence* Crutchfield refers to the emergence of features conferring *additional functionalities* to the system in which the process takes place, such as global computational features as in Collective Intelligence or Swarm Intelligence (Bonabeau *et al.*, 1999; Franks *et al.*, 1991; Millonas 1993a; 1993b; Theraulaz *et al.*, 1990; Theraulaz and Deneuburg, 1994), when the system is able to do what single agents can not.

The notion of 'intrinsic emergence' is more powerful than the notion of 'pattern formation'. In the latter case it is always possible, by using suitable mathematical tools, to foresee the patterns arising as a consequence of a given law and/or of given constraints. However, such mathematical tools are not sufficient for forecasting the patterns occurring in a situation of 'intrinsic emergence'. In the case of pattern formation the complexity consists only in making explicit information already present in an implicit format. When dealing with complex systems we are forced to rely only upon the notion of 'intrinsic emergence'. We will not discuss here the approach introduced by the physicist W. Anderson (Anderson, 1981; Anderson and Stein, 1985) for which the focus is upon processes of *spontaneous symmetry breaking* dealing with special features occurring within the quantum-mechanical framework.

3.2.3 Detecting the establishment of processes of phenomenological emergence

Regarding detection we mention, amongst other approaches, those in Bonabeau and Dessalles (1997), a criterion based upon a suitable measure of the variations of *ergodicity* of the system under study (Minati, 2002; Minati and Pessa, 2006). As is well known, a system, described at a microscopic level as an assembly of mutually interacting elementary components, is *ergodic* when the average, at a single instant of time, of all microscopic behaviours present within the system, is equal to the time average of the behaviour of a single component.

Normal systems can be considered ergodic systems, in which it is possible to apply the traditional methods of statistical mechanics, in order to connect in a clear way the microscopic features with the macroscopic phenomenology detected through experimental observations. This phenomenology consists in a relaxation process towards a stable equilibrium state, in which the macroscopic features of the system can be observed with the minimum possible uncertainty. As is well known, *the property of ergodicity is completely lost during a structural change or a phase transition*. On the basis of this observation, by detecting an increase in ergodicity (measured in a suitable way) within a system it is possible to recognize that it is evolving from a structure towards a new form of equilibrium, emergent from the previous state. **It is up to the observer to realize this process as a process of emergence and not *only* as a structural change**.

4 Collective Behaviours, *Collective Beings* and the *Dy*namic U*sa*ge of *M*odels *(DYSAM)*

This chapter introduces the concept of Collective Being from that of Collective Behaviour, and the *Dy*namic U*sa*ge of *M*odels from Machine Learning, Ensemble Learning and Evolutionary Game Theory.

4.1 Collective Behaviours

As it is well known from the literature, the expression *Collective Behaviour* relates to non-linear phenomena involving a macroscopically large number of particles or agents establishing a *coherent* behaviour (see 2.2.2). It relates to processes (e.g., the formation of ecosystems) which occur not due to an explicit design regarding roles and functions of agents (e.g., prey, predator), but as a consequence of their *interaction* (e.g., flocks), even when structured in specific functions and roles such as in ant-nests (see, for instance, Bonabeau *et al.*, 2000; Mikhailov and Calenbuhr, 2002).

Examples of Collective Behaviours in physics have been observed in condensed matter, especially as a consequence of phase transitions, such as in the process of the establishment of ferromagnetism and superconductivity. **With reference to the concepts introduced above (see 2.2, 2.3 and notes on *coherence* in 3.2.2) and by distinguishing between the detection of effects and modelling of the processes establishing the detected effects, the process of the establishment of collective behaviours is a process of emergence, observer-dependent. The *cognitive existence* as *collective behaviour* is emergent.**

When considering Collective Behaviours established by agents provided *with cognitive models*, it is possible to distinguish between two different kinds of *collective behaviours*:

- that occurring, for instance, as a consequence of cooperative/competitive processes amongst populations (such as the balance between prey and predators) of different types, leading the synergic effects to the formation of ecosystems;
- that emerging from interactions between *agents of the same typ*e for which it is possible to presume behaviours based on *the same cognitive model.*

4.2 Collective Beings

Collective Beings have been introduced (Minati, 2001; Minati and Pessa, 2006) as particular systems in which the multiple belonging of components, agents equipped with a cognitive system, is *active*, that is, depending upon the cognitive models adopted for their interactions. The concept of Collective Being refers to the fact that the same components of a system may *simultaneously* or *dynamically* give arise to *different* systems. The emergence of Collective Beings is related particularly to two quite general kinds of processes of emergence taking place from interactions between agents provided with a cognitive system:

- ☐ In a context having *fixed* evolutionary rules, interacting agents, using the *same* cognitive model, make emergent collective behaviours establishing both cooperative and competitive effects (i.e., *collective* nest-building);
- ☐ In a context having *variable* evolutionary rules, i.e., when agents are provided with the *same cognitive system*, and are also
  - (a) *able to play* different rules at the *same* time or
  - (b) *able to play* different rules at different times.

The latter systems may be modelled as being equipped with *different* cognitive models *simultaneously* or *dynamically* used to perform cognitive processing, such as making decisions. By considering *Human Social Systems* the difference between the two ways, i.e., *simultaneously* or *dynamically* performing cognitive processing, is not given by an *objectivistic* property of the system, but rather by the role assumed by the observer-agent. For instance, in systems such as attendance, families, markets, passengers, queues, sports teams, telephone networks, traffic systems and workplaces, it is up to the observer-agent to decide to act by considering his/her multiple belonging in a simultaneous or dynamical way.

4.3 *Dy*namic U*sa*ge of *M*odels (DYSAM)

We need to point out, first of all, how the concept of DYSAM is based upon approaches already introduced in the literature having as a common strategy not to look for only one, single, optimum solution. The first approach to be mentioned is surely the well known Bayesian method, a statistical treatment based upon a conceptual *continuous exploring* of the events occurring within an environment. This approach is based on the Bayes theorem, named after Thomas Bayes (1702-1761). It states that the probability of A given B is equal to the probability of A times the probability of B given A divided by the probability of B: $P(A|B) = P(A)P(B|A)/P(B)$.

Another approach is **Peirce's abduction,** a *hypothesis inventing process* already mentioned in Chapter 1. Other approaches to be mentioned are, for instance, **Machine Learning, Ensemble Learning** and **Evolutionary Game Theory**.

The concept of Dynamic Usage of Models (DYSAM) (Minati, 2001; Minati and Brahms, 2002; Minati and Pessa, 2006) relates to situations in which the complexity of the system is such that it is impossible, in principle, to completely describe it using a single model or a sequence of models, each of which is a refinement of the previous one. This situation occurs when the process of emergence enables the dynamic establishment of different systems, such as Collective Beings. Such a case has never been taken into consideration within the framework of classical scientific inquiry because the systems studied were so simple (such as a moving electrical charge or a planet revolving around the sun) that the usage of a single model was sufficient to describe their behaviour. In this case the problem is rather the choice of the best, the most suitable model, under the assumption that the problem has one solution and that the best solution exists. Within the framework of the new approaches used in many scientific fields, we now know that such a simplistic situation does not occur.

It must be stressed that dealing with different simultaneous systems calls for a simultaneous usage of different kinds and levels of description. This is the conceptual framework of DYSAM. DYSAM does not refer to the availability of different theories for dealing with phenomena, such as in physics with classical and quantum theories: in this case the perspective is the *unification* of theories.

5 Conclusions

We have introduced here a brief review of the concepts of *observer* and *emergence* (in particular *computational* and *phenomenological* emergence). On this basis we have mentioned the novel concept of *Collective Being* and a related methodological approach (DYSAM) as introduced by Minati and Pessa (2006).

In our view these concepts should be taken into account in modern and fresh approaches to systemic issues going beyond older objectivistic and observer-independent frameworks still being used in systems research.

What is it possible to do now, following the introduction of the concepts of Collective Being and DYSAM, which was not possible before? As introduced in this paper the concept of Collective Being relates to *simultaneous roles* for components. It refers to influencing and managing the behaviour of one system by acting on the behaviour of others established by the same components having multiple roles, rather than by acting, as is usually done, upon the interaction *between* systems. This concept and the related DYSAM methodology are very important for dealing with complex systems having features established by the multiple roles of components and by the *multiple roles of systems acting as components at a higher level* rather than as sub-systems. This is the case, for instance, when modelling and simulating

- social systems where a social designer may establish or detect processes of social manipulation (see Minati, 2006);
- corporations where classical approaches based upon optimisation and *organised* sub-systems, without taking into account processes of emergence, are not effective;
- multi-layered networked systems such as the Internet, where unexpected usages continuously emerge;

- cognitive systems; with reference to memory as implicitly introduced by Tulvin (1985).

DYSAM refers to the simultaneous use of different kinds and levels of description for the same phenomena, such as considering a behavioural problem as biological, neurological, social and psychological. In the DYSAM framework, one is not forced to select a single model, but can use them simultaneously by using different approaches. Both the concepts are of interest, for instance, for designing agents equipped with artificial cognitive systems for undertaking complex tasks, such as robots dealing with learning, making decisions not as *selections*, but creating multiple scenarios of unknown environments. A model of DYSAM based upon Artificial Neural Networks has been presented by Minati and Pessa (2006).

References

Anderson J.R. (1983). *The Architecture of Cognition.* Harvard University Press, Cambridge, MA.

Anderson J.R. (1993). *Rules of the Mind,* Erlbaum, Hillsdale, NJ.

Anderson J.R. and Lebière C. (1999). *The atomic components of thought.* Erlbaum, Hillsdale, NJ.

Anderson P.W. (1981) Can broken symmetry occur in driven systems? In: *Equilibrium and Nonequilibrium Statistical Mechanics* (G. Nicolis, G. Dewel and P. Turner, eds.), Wiley, New York, pp. 289-297.

Anderson P.W. and Stein D.L. (1985) Broken Symmetry, Emergent Properties, Dissipative Structures, Life. Are they related? In: *Self-Organizing Systems: The Emergence of Order* (F. E. Yates, ed.), Plenum, New York, pp. 445-457.

Andreewsky E. and Bourcier D. (2000) Abduction in Language interpretation and Law making, *Kybernetes* **29**:836-845.

Ashby R. (1956). *An Introduction to Cybernetics.* Wiley, New York

Baas N.A. (1994) Emergence, Hierarchies and Hyperstructures, In: *Artificial Life III* (C. G. Langton, ed.), Addison-Wesley, Redwood City, CA, pp. 515-537..

Baas N.A. and Emmeche C. (1997) On Emergence and Explanation, *Intellectica* **25**:67-83.

Barrow-Green J. (1996) *Poincaré and the Three Body Problem.* American Mathematical Society, Providence, RI.

Bedau M. (1997) Weak emergence. *Philosophical Perspectives* **11**:375-399.

Bonabeau E. (1997) From classical models of morphogenesis to agent-based models of pattern formation, *Artificial Life* **3**:191-211.

Bonabeau E. and Dessalles J.-L. (1997) Detection and emergence, *Intellectica* **2**:85-94.

Bonabeau E. Dorigo M. and Theraulaz G. (1999) *Swarm Intelligence: from natural to artificial systems.* Oxford University Press, UK.

Bonabeau E. Dorigo M. and Theraulaz G. (2000) Inspiration for optimization from social insect behaviour *Nature* **406**:39-42.

Broad C.D. (1925). *The Mind and Its Place in Nature.* Routledge & Kegan Paul, first edition, London.

Churchland P. (1985) Reduction, Qualia, and Direct Introspection of Brain States, *Journal of Philosophy*, **82**:8-28.

Corning P. (2002) The Re-emergence of 'Emergence': A Venerable Concept in Search of a Theory, *Complexity* **7(6)**:18-30.

Crutchfield J.P. (1994a) The Calculi of Emergence: Computation, Dynamics and Induction. *Physica D* **75**: 11-54.

Crutchfield J.P. (1994b) Is Anything Ever New? Considering Emergence, In: *Complexity: Metaphors, Models, and Reality*, (G. Cowan, D. Pines and D. Melzner, eds.), Santa Fe Institute Studies in the Sciences of Complexity, volume XIX, Addison-Wesley, Reading, Massachusetts, pp. 515-539.

Dubois M. D. (1998) Hyperincursive Simulation of Ecosystems Chaos and Patchiness by Diffusive Chaos, *International Journal of Computing Anticipatory Systems*, CHAOS, **1**:51-68.

Franks N.R., Gomez N., Goss S. and Deneubourg J.L. (1991) The blind leading the blind: Testing a model of self-organization (Hymenoptera: Formicidae), *Journal of Insect Behavior* **4**:583-607.

Freeman W.J. Kozma R. and Werbos P. (2001) Adaptive behavior in complex stochastic dynamical systems, *BioSystems* **59**: 109-123.

Guberman S. (2004) Reflections on Ludwig Bertalanffy's "General System Theory: Foundations, Development, Applications", *Gestalt Theory* **26**(1):145-57.

Guberman S. and Andreewsky E. (1996) From Language Pathology to Automatic Language Processing… and Return (*on transdisciplinary approaches*), *Cybernetics & Human Knowing* **3**(4):41-53.

Guberman S. and Rozentsveig V. (1976) Algorithm for Recognition of Handwritten Text, Automatika i Telemekhanika, **5**:122 - 129.

Guberman S. and Wojtkoski W. (2001) Reflections an Max Wertheimer's "Productive Thinking": Lesson for AI, *Gestalt Theory* **23**(2):132-142.

Guberman S. and Wojtkoski W. (2002) Clustering analysis as a Gestalt Problem, *Gestalt Theory* **24**(2):143-158.

Haken H. (1983). *Synergetics, an Introduction: Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry, and Biology*. Springer, New York

Holland J.H. (1998). *Emergence: from Chaos to Order*. Perseus Books, Cambridge, MA.

Humphreys P. (1996) Aspects of Emergence, *Philosophical Topics*, **24**(1):53-70.

Humphreys P. (1997a) How Properties Emerge, *Philosophy of Science*, **64**:1-17.

Humphreys P.(1997b) Emergence, Not Supervenience, *Philosophy of Science*, **64**:S337-S345.

Kim J. (1993). *Supervenience and Mind*. Cambridge University Press, Cambridge.

Kim J. (1996). *Philosophy of Mind*. Westview Press, Boulder.

Kim J. (1998). *Mind in a Physical World*. MIT Press, Cambridge.

Kohler W. (1975). *Gestalt Psychology. A mentor Book*. New York and Scarborough, Ontario.

Lewes G.H. (1877). *The Physical Basis of Mind. With Illustrations. Being the Second Series of Problems of Life and Mind*. Trübner, London.

Lorenz E. (1963) Deterministic Non Period Flow, *Journal Of The Atmospheric Sciences* **20**: 130-141.

Lowe E.J. (1993). The Causal Autonomy of the Mental, *Mind*, **102**:629-644.

Maturana HR. and Varela F. (1992). *The Tree of Knowledge: The Biological Roots of Human Understanding*. Shambhala, Boston, MA.

McLaughlin B.P. (1992) The rise and fall of British emergentism. In *Emergence or Reduction?: Prospects for Nonreductive Physicalism*. (A. Beckermann, H. Flohr, and J. Kim, eds.) De Gruyter.

Mikhailov A. S., and Calenbuhr, V., (2002). *From Cells to Societies. Models of Complex Coherent Action*. Springer, Berlin-Heidelberg-New York.

Mill J.S. (1843). *System of Logic*. Longmans, Green, Reader, and Dyer, London: [8th ed., 1872].

Millonas M.M. (1993a) Swarms, Phase Transitions, and Collective Intelligence, In: *Proceedings of ALIFE III* (C. G. Langton, ed.), Santa Fe Institute, Addison-Wesley.

Millonas M.M. (1993b) Cooperative Phenomena in Swarms. In *Cellular Automata and Cooperative Systems*, (N. Bocara, E. Goles, S. Martinez and P. Pico, eds.), Kluwer, New York.

Minati G. (2001). *Esseri Collettivi*, Apogeo, Milano, Italy.

Minati G. (2002) Emergence and Ergodicity: a line of research, In: *Emergence in Complex Cognitive, Social and Biological Systems*, (G. Minati, E. Pessa, eds.), Kluwer, New York.

Minati G. (2006) Consent manipulation and democracy. In *Proceedings of the Third Conference of the Italian Systems Society* (G. Minati, E. Pessa and M. Abram eds.), Springer, New York, pp. 569-584.

Minati G. and Brahms S. (2002) The Dynamic Usage of Models (DYSAM), In: *Emergence in Complex Cognitive, Social and Biological Systems*, (G. Minati, E. Pessa, eds.), Kluwer, New York.

Minati G. and Pessa E. (2006). *Collective Beings. Springer*, New York.

Minati G. Penna M.P. and Pessa E. (1998) Thermodynamical and Logical Openness in General Systems, *Systems Research and Behavioral Science* **15**:131-145.

Morgan C. L. (1923) *Emergent Evolution*. Williams & Norgate, London.

Nicolis G. and Prigogine I. (1977). *Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations*. Wiley, New York.

Peirce C.S. (1998) Harvard Lectures on Pragmatism. In: *The Essential Peirce: Selected Philosophical Writings, 1893-1913*, (N. Houser, J. R. Eller, A. C. Lewis, A. De Tienne, C. L. Clark and D. B. Davis, eds.), Indiana University Press, Bloomington, IN, Chapters 10-16, pp. 133-241.

Pessa E. (2002) What is emergence?, In: *Emergence in Complex Cognitive, Social and Biological Systems*, (G. Minati, E. Pessa, eds.), Kluwer, New York

Pessa E. (2006) Physical and Biological Emergence: Are They Different ? In: *Systemics of Emergence: Applications and Development* (G. Minati, E. Pessa and M. Abram, eds.), Springer, New York, pp. 355-374.

Prigogine I. (1967) Dissipative Structures in Chemical Systems. In: *Fast Reactions and Primary Processes in Chemical Kinetics*, (S. Claesson, ed.), Interscience, New York, pp. 371-382.

Prigogine I. and Glansdorff P. (1971). *Thermodynamic Theory of Structure, Stability and Fluctuations*. Wíley, New York.

Ronald E.M A., Sipper M. and Capcarrère M.S. (1999) Design, observation, surprise! A test of emergence, *Artificial Life* **5**:225-239.

Rueger A. (2000) Physical emergence, diachronic and synchronic, *Synthese* **124**:297-322.

Silberstein M. (1998) Emergence and the Mind-Body Problem, *Journal of Consciousness Studies*, 5:4, pp. 464-482

Silberstein M. and McGeever J. (1999) The Search for Ontological Emergence, *The Philosophical Quarterly*, **49**:182-200.

Theraulaz G. and Deneubourg J.L. (1994) Swarm Intelligence in Social Insects and Emergence of Cultural Swarm pattern. In: *The Ethological Roots of Culture. Proceedings NATO Advanced Study Institute* (A. Gardner, B. Gardner, B. Chiarelli, and F. Plooij, eds.) Cortona, Italy, June 21-July 3. Series D: Behavioural and Social Sciences - Vol. 78, Kluwer Academic/Plenum Publishers, Dordrecht.

Theraulaz G., Goss S., Gervet J. and Deneubourg J.L. (1990) Swarm Intelligence in Wasps Colonies: an example of task assignment in multi-agents systems. In: *Proceedings of the 1990 IEEE International Symposium on Intelligent Control* (A. Meystel , J. Herath and S. Gray, eds.), IEEE Computer Society Press, Philadelphia, PA.

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

Turing A.M. (1952) The chemical basis of morphogenesis. *Phil. Trans. Roy. Soc. B* 237: 37-72.

Vitiello G. (2001). *My double Unveiled: the dissipative quantum model of brain*. Benjamins, Amsterdam.

Von Bertalanffy L. (1968). *General System Theory: Foundations, Development, Applications*. New York, George Braziller, (revised edition March 1976).

Von Foerster H. (1979) Cybernetics of Cybernetics. In: *Communication and Control in Society* (K. Krippendorff, ed.), Gordon and Breach, New York, pp.5-8.

Von Foerster H. (1981). *Observing Systems, Selected Papers of Heinz von Foerster*. Intersystems Publications, Seaside, CA.

Von Foerster H. (2003). *Understanding Understanding: Essays on Cybernetics and Cognition*. Springer, New York.

Von Glasersfeld E. (1995). *Radical Constructivism: A Way of Learning (Studies in Mathematics Education)*. RoutledgeFarmer, New York.

Watzlawick P. (ed.) (1983). *Invented Reality: How Do We Know What We Believe We Know?*. Norton, New York.

Wertheimer M. (1925) Vortrag vor der KANT-Gesellschaft, *Philosophische Zeitschrift für Forschung und Aussprache* **1**:39-60.

Wertheimer M. (1959). *Productive thinking*. New York, Harper & Brothers Publishers..

Wiener N. (1948). *Cybernetics or Control and Communication in the Animal and the Machine.* MIT Press, Cambridge, MA.

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