Creativity as Cognitive *design*

The case of mesoscopic variables in Meta-Structures

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Abstract: Creativity is an open problem which has been differently approached by several disciplines since a long time. In this contribution we consider as *creative* the *constructivist* design an observer does on the description levels of complex phenomena, such as the self-organized and emergent ones (e.g., Bènard rollers, Belousov-Zhabotinsky reactions, flocks, swarms, and more radical cognitive and social emergences). We consider this design as related to the *Gestaltian* creation of a language fit for representing natural processes *and* the observer *in an integrated* way. Organised systems, both artificial and most of the natural ones are designed/ modelled according to a *logical closed model* which masters *all* the inter-relation between their constitutive elements, and which can be described by an algorithm or a single formal model. We will show there that *logical openness* and DYSAM (Dynamical Usage of Models) are the proper tools for those phenomena which *cannot be* described by algorithms or by a single formal model. The strong correlation between emergence and creativity suggests that an *open model* is the best way to provide a formal definition of creativity. A specific application relates to the possibility to shape the emergence of Collective Behaviours. Different modelling approaches have been introduced, based on symbolic as well as sub-symbolic rules of interaction to *simulate* collective phenomena by means of computational emergence. Another approach is based on modelling collective phenomena as sequences of Multiple Systems established by percentages of conceptually interchangeable agents taking on the *same roles at different times and different roles at the same time*. In the *Meta-Structures* project we propose to use mesoscopic variables as creative design, invention, good continuity and imitation of the description level. In the project we propose to define the coherence of sequences of Multiple Systems by using the values taken on by the dynamic mesoscopic clusters of its constitutive elements, such as the instantaneous number of elements having, in a flock, the *same* speed, distance from their nearest neighbours, direction and altitude. In Meta-Structures the collective behaviour's coherence corresponds, for instance, to the scalar values taken by speed, distance, direction and altitude along time, through statistical strategies of interpolation, quasi-periodicity, levels of ergodicity and their reciprocal relationship. In this case the constructivist role of the observer is considered *creative* as it relates to *neither non-linear replication* nor *transposition* of levels of description and models used for artificial systems, like reductionism. Creativity rather lies in *inventing* new mesoscopic variables able to identify coherent patterns in complex systems. As it is known, mesoscopic variables represent partial macroscopic properties of a system by using some of the microscopic degrees of freedom possessed by composing elements. Such partial usage of microscopic as well as macroscopic properties allows a kind of Gestaltian continuity and imitation between levels of descriptions for mesoscopic modelling.

Key-words: constructivist design, complex systems, dynamical usage of models, emergence, logical openness, mesoscopic variables, meta-structure

Introduction

The observer's cognitive system, - dynamic memory, image processing, high cognitive skills for input representations -, carries out a plurality of choices in the world description.
It leads to the creation of languages to describe the possible representation states. In particular, in the scientific description of the Nature it is necessary to choose the proper description level as well as the significant variables in order to outline the behaviors of the system under consideration.
Such kind of languages are thus a bridge between theory and praxis, a mind- world cognitive isomorphism according to Gestalt principles. For example, Bongard proposed an approach to *visual pattern recognition* where choosing a suitable language makes possible speaking about and describing an object (Arnheim, 1997; Bongard, 1970). Actions and rules effectively used in the world of the observer are used to carry out cognitive models.
Our approach is close to those introduced to model and simulate creativity (Creativity Machines and Imagitron: Holmes,1996; Thaler, 1996a; 1996b,1994; 2005), with a further effort in the direction of intrinsic emergent phenomena (Licata, 2008a).
The designing of intrinsically non observer-related erratic devices is a typical problem which can be handled by Meta-Structures (Minati, 2008a; 2009) and in dissipative quantum model of the brain (Vitiello, 2001; Minati and Vitiello, 2006).
Differently from some disciplinary usages like in physics and logics, we will use the term *coherence* with the meaning of *detecting emergence* in collective interactions as the invariant properties in flocks and swarms.
In other words, cognitive activity responds to the emergent patterns of coherence by constructive designing, so drawing out a shape from the world's noise and entropy.

1. Creativity and Emergence

The problem to model creativity is a problem deeply connected to one of the central research topic of current research, i.e., emergence. Usually creativity is conceived as the ability to make emerging unusual cognitive strategies to deal with the complexity of the relation observer-observed. It is well-known how processes of emergence may be classified in two huge categories:
a) Computational emergence, completely describable by a single formal model and by an algorithm;
b) Intrinsic or radical emergence, non describable by a single formal model because of the dynamical complexity of interactions between system and environment.

The latter, contrary to what generally assumed, is the simplest and most diffused in nature, e.g., phase transitions, folding protein , cognition, socio-economic processes, and so on, see, for instance, (Licata, 2009). So, the problem of scientifically describing creativity finds its proper formulation within the approach to emergence. In particular, the key question is: once a process of intrinsic emergence -unforeseeable on the basis of any available model- has occurred, how can we analyse it, even partially, by computational tools? (Licata, 2008b).

Let's note that old Artificial Intelligence had tried and fared poorly in reducing creativity to an "algorithmic machinery". What we are going to propose here is totally different. Without taking into consideration all the creativity aspects, we will focus on a specific problem: to fix the suitable variables in order to describe some significant features of highly complex systems.

One of the greatest successes of theoretical physics at the end of the eighth centuries was the ability to find a connection between the microscopic and macroscopic representations of perfect gases thanks to the contributions introduced by Boltzmann, Maxwell and Gibbs. The study of mesoscopic systems was found much more difficult, because it is not always possible the identification of significant variables related to the dynamics of the *Middle Way* (Lauglin & Pines, 1999; Laughlin *et al.*, 2000). In this case the more suitable cognitive strategy is to find step by step, on different spatial and temporal scales, the parameters able to allow a coherent representation of global aspects of the system. In this conceptual framework the term 'coherent' takes on a formal meaning only after the observer has selected a description level. In this sense the Meta-Structures project defines an approach to creativity based on the updating of models for complex systems as based on the cognitive design performed by the observer updating models used for complex systems.

1.1 The good-continuation principle, the Bongard's Problems (BP) and "imitation principles"

One the difficult and traditional problem in understanding the dynamic observer-observed relationship lies in the *naïve* realism, which is to say the idea that the world with its laws and properties already exists "out there".

As Einstein wrote: "theories are under-determined by experimental data; they are, rather, a free creation of human mind".

A deep analysis of such a kind of cognitive processes has been historically approached by the Gestalt tradition (Guberman, 2005).

> "The "good continuation" principle – one of the basic principles of Gestalt psychology – assumes that perception of a drawing includes the imaginable process of recreating (or imitating) the drawing (Guberman and Minati, 2007, p.121).
> …Imitating the way the drawing was created is a right thing to do when looking for a short and sensible description. … (Guberman and Minati, 2007, p.122).
> …From all potentially possible partitions of the whole such set of parts has to be preferred, which has the **simplest description**. The simplicity of the description reflects 1) the number of parts (the less is the number the simpler is the description), 2) the relations between the parts (touching, crossing, above, to the right), and 3) the simplicity of description of each of the parts… (Guberman and Minati, 2007, p.121).
> …In the process of perception we understand not only the right partition of the object but also how successive parts should follow one another (Guberman and Minati, 2007, p.123).
> …Many facts support the idea that a character is not only an *image pattern* but also a *movement pattern*…. (Guberman and Minati, 2007, p.130)."

In cognitive science the *Bongard Problems* are problems on *visual pattern recognition* and first appeared in the appendix of a book published by the Russian scientist M. M. Bongard in 1967

(Bongard, 1970). We introduce the topic with reference to the need to use a proper level of description representing continuity between perceptions, possible ways to imitate, image creation and possible coherent evolutions.
The subject is well represented by considering the epistemology of the so-called Bongard's squares, (Gerovich, 2002). Bongard presented one hundred problems. Each problem consists of twelve figures subdivided per six classes of two. The problem relates to finding what differentiates classes and what the figures of the same class share in common. They are very interesting and fascinating problems, because different solutions are possible depending on which description level is assumed. Each problem has its specificity, but all the problems, as they are solved, can display background correlations which could be said "The Bongard's World Theory of Everything".

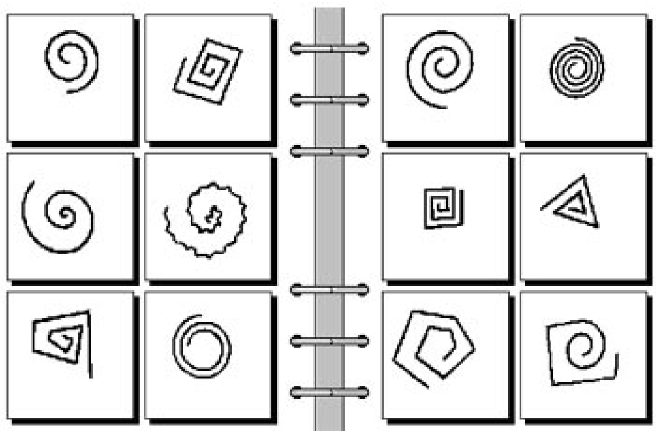

Figure 1: Epistemology of Bongard's squares, i.e., the problem of classes of configurations

The basic question is: are regularities in the figures or in our mind? Answering to such question defines the *hard* or *soft* attitude of a scientific discipline, at least in the current view of science. Such question is actually a false problem. The crucial point is that the laws we 'discover' in the Bongard's world depend on what approach we choose to study the figures. For instance, from the table in Fig. 1, it is possible to get different results depending on whether we make use the notion of 'curvature' or 'angle' or 'rolled around a central point'. This observation should warn us from theories having too general ambitions: they could actually include everything, but the price to pay is to lose sight of the most interesting and subtle aspects!
"Assemblages of lines and dots are not perceived as unrelated, piecemeal units or as a chaotic mass, but are instead grouped into meaningful configurations based on their similarity, proximity, closure, continuity, and the like, and governed by dynamic processes such as Pregnanz, a tendency toward **simple Gestalten**" (Brett *et al.*, 1994).
It has to be made clear that our epistemological position has nothing to do with the idealist assumptions negating any reality to the external world. We just point out that the configurations we detect in the world are a homeo-cognitive 'compromise' between mind and world.
There is a substantial difference between the small Bongard's world and the Nature: dynamics. In the 'squares world' nothing changes and identification of different possible classification classes is completely due to the creativity of the observer. In Nature we never observer static structures, but interactions, evolutionary processes, dissipations and emergences. So, there arises the problem of describing the emerging patterns on different, variable spatial and temporal scales.
As the outstanding Russian mathematician I. Gelfand said in 1970: **the language of description of a given situation or a given object is crucial for problem solving**; **it has to be described in an adequate language** (Gel'shtein *et al.*, 1971; other interesting quotations can be found in Arnheim, 1997; Wertheimer M., 1959, collected in Guberman and Minati, 2007, pp. 148-174).

1.2 Logical openness

An emergent process may be initially defined as a dynamic process that modifies correlations between significant variables of the system and produces a redefinition of rules to represent and generate information and their semantic 'value'. A consequence will be the appearance of new relations between environment and system in terms of input-output. This may obviously occur at different levels of complexity. In simplest cases of computational emergence, a system is completely represented by a *logically closed model*, so that:

- A complete description of relations between state variables is available;
- It is possible to explicitly define, by assuming the precision desired, interaction between system and environment;
- It is possible to write equations representing evolution of the system.

Those characteristics allow quite accurate previsions relating to evolutions and structural aspects of the system. They therefore do not imply processes of intrinsic emergence. Processes of intrinsic emergence require a further condition, i.e., *logic openness* represented by introduction of a hierarchy between system and environment (Minati, Penna, Pessa, 1998; Licata 2008b). Let consider the case when interactions between system and environment depend on the *internal* state of the system both as *values* like in phase transitions and as *forms* of interactions depending from system' reactions. We refer to the first case, i.e., logically closed models, as systems having logical openness of level one. We refer to the second case, i.e., when considering interactions between system and environment, as systems having logical openness of level two. Level two may be considered as indicator of the ability of the system to process the information available in an unforeseeable way, by acting on the external world in a way non describable by a formal model , as for phenomena of intrinsic emergence. This may be considered as the *ability of the system to play a game different from the one established by the model*, i.e., its ability to express new semantic dominions. This is the reason why we may identify intrinsic emergence with the attitude of the system to produce autonomous knowledge representations. This is, therefore, a formal representation of creativity of the system.

We will define, in general, a system as *logically open at level n* if it is characterised by *at least n* constraints, with *n* finite. From a thermodynamic point of view the immediate meaning of this definition relates to the fact that the more a system is structured and the more the keeping of the structure must deal with dissipation required by thermodynamic openness. The system keeps its autonomy thanks to some constraints and it is rather intuitive that the number of constraints is an indicator of the thermodynamic compromise between system and environment, also index of the internal complexity of the system. It is possible to demonstrate: (a) a logically open system allows more formal complementary representations; (b) each representation of a logically open system by a model at logical openness *n*, i.e., having *n* completely specified constraints, is valid in a limited dominion, i.e., it is able to deal only with a limited percentage of the information processes between system and environment. From a global point of view the two previous points a) and b) correspond, in the systemic framework, to the famous Gödel' and Turing' undecidability theorems related to the theoretical incompressibility of the two point into an algorithm. In particular, from point (a) we derive all undetermination principles, to be then considered as indications related to the selection of the optimum model in relation with the purpose.

1.3 Dynamic Usage of Models

It has been introduced in the scientific literature the concept of dynamic usage of models, DYSAM (Minati and Brahms, 2002; Minati and Pessa, 2006, pp. 64-75). We consider the need to use *different* models to deal with *different* acquired properties in emergent phenomena. "Dynamic" refers to the changing of models, rather than the changing of values the variables take on along time. The situation under study is the one considered by Logical Openness introduced above, when

the observer is assumed to process the input by continuously using new models, for instance through processes of *learning*.
It is possible to consider DYSAM as a process of *selection* between available models or *invention* of new ones, see Fig. 1. In the former case selection could abstractly given by usual processes of optimisation. In the latter case, the more realistic and interesting one, DYSAM represents a meta-model based, for instance, on abduction, *hypothesis inventing or selection process* based on the idea that *because B is true probably A is also true, since if A were true the truth of B would be obvious*. 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). We may consider specific related approaches already introduced in the literature such as the well known Bayesian method, statistical treatment by using an approach based on continuous exploration of the events (Bayes, 1763; Licata, 2008c). Machine learning techniques and algorithms, the so-called Ensemble Learning (Hinton and Van Camp, 1993), combining an uncorrelated collection of learning systems all trained in the same task making, for instance, an ensemble of neural networks, to perform better than any individual neural network. Another approach we may mention is the so-called Evolutionary Game Theory (Maynard-Smith, 1982; Weibull, 1995). An example of DYSAM implemented by using Neural Networks is presented in Minati and Pessa (2006, pp. 75-84).

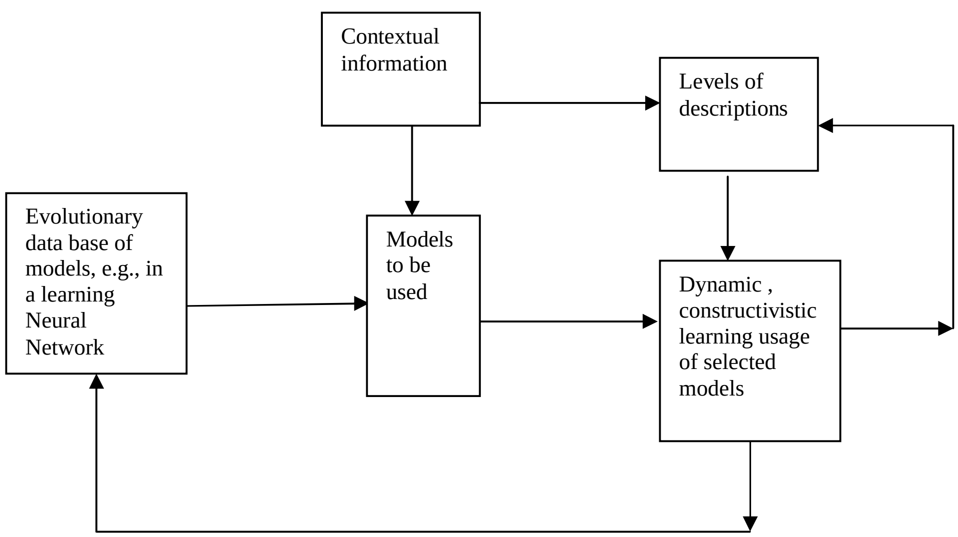

Figure 2: A scheme representing how the Dynamic Usage of Models works

2. Introduction to the Meta-Structures project

The Meta-Structure project (Minati 2008a; 2008b; 2008c; 2009) has been introduced to model *changing* occurring in processes of establishment and keeping of Collective Phenomena where new emergent properties are continuously acquired. The purpose is to find a level of representation sufficiently abstract to represent properly general processes of emergence based on the theoretical construtivistic role of the observer. Multiple Systems and Collective Beings have been proposed to represent general processes of emergence like for flocks and swarms (Minati and Pessa, 2006). Multiple Systems are considered as sets of *different simultaneous coherent systems* established by the same elements interacting in different ways, i.e., having multiple simultaneous or dynamical, i.e., at different times, roles like *multiple and simultaneous phase transitions*. Collective Beings are Multiple Systems when elements are autonomous, i.e., they decide how to interact. Examples of Multiple Systems are given by networks of interacting cooperative computer systems like the

Internet assuming properties such as *homogeneous* and *instantaneous* availability of the same information and electricity networks, where different systems play different roles, assuming emergent properties such as the black-out and overloads. Examples of Collective Beings are given by systems constituted by elements *simultaneously* belonging to other different systems, e.g., people simultaneously components of families, drivers in the traffic, user in a telephone network system, employers in an economic system, like a corporation, and consumers in a market, and *dynamically*, i.e., at different times, giving rise to different systems, such as queues, passengers, audiences.
However, the general aim is to look for a description level able to represent, by values of considered variables, general processes of emergence in themselves without dealing neither with microscopic and macroscopic change nor model changing.

2.1 The concept of Meta-Structure

The general idea is based on moving from the classic approach of modelling dynamics by sequences of values assumed by the *same* model over time. The aim is also to move from considering sequences of Models as for Multiple Systems and Collective Beings suitable to represent the *keeping* and *reproducing* of Collective Behaviours, but not structural changes, mergers, splitters and transients in general. In Multiple Systems and Collective Beings collective properties are set by rules establishing multiple and simultaneous roles. In turn, such rules can be fixed or variable, such as context-sensitive, evolutionary by using a model. In this case continuity and coherence are given by the existence of these rules.
In the project we use a mesoscopic level of description where to identify -in constructivist way- variables representing the collective properties the observer detects . We study coherence and continuity as *represented* and *modelled* by values assumed by mesoscopic variables and by their properties over time.
By conceptually considering flocks or swarms, examples of mesoscopic state variables are given by the number of elements having the *same instantaneous* values assumed by some specific microscopic or macroscopic variables like speed, altitude, direction, distance from their nearest neighbours, maximum distance, minimum distance, and *instantaneous* values of measurement of the surface and volume. Examples of Meta-Structures are mathematical properties, like statistical, represented by interpolating functions, quasi-periodicity, levels of ergodicity, and possible relationships between them, of a) the sets of values defining moment by moment mesoscopic variable, like speed, altitude, direction, max distance, min distance, surface, volume at time t_i , and b) values assumed by mesoscopic variables, i.e. numbers of elements having same *instantaneous* values.

2.2 The project

The project consists in finding suitable experimental confirmations. The problem relates to the need to have all the available instantaneous values assumed by the considered variables in order to process mesoscopic representations and evaluate Meta-Structural properties at the end.
The aim of the project is to explore existence of general Meta-Structural properties as regularities corresponding to different *kinds* and *phases* of Collective Behaviours. Examples of *kinds* of Collective Behaviours are flocks, swarms, markets, industrial districts, traffic, functionalities in networks of computers, Bènard rollers, Belousov-Zhabotinsky reactions, coherence in light emission typical of the laser, and dissipative structures, such as whirlpools. Examples of *phases* are given by behavioural changes, collective learning, mergers, splitters and transients.
Meta-Structures can thus be considered to represent families of *kinds* and *phases* of Collective Behaviours. Meta-Structures can be also considered to induce or change a Collective Behaviour.

Another area of research relates the possibility to find correspondences between Meta-Structures and suitable environmental boundary conditions.

2.3 Creativity as design of suitable mesoscopic description level

The Meta-Structures project is based on the theoretical role of the observer identifying the suitable mesoscopic level of description. The theoretical, active role of the observer consists on self-designing mesoscopic levels of description to represent processes of emergence of detected properties.
Creativity is regarded as self-considering the cognitive *continuity* between mesoscopic levels of descriptions and related Meta-Structural properties, *as* representations of stability and dynamics of multiple, variable, local processes occurring in Collective Behaviours.
Cognitive models used for dealing with non-collective processes are not just assumed to be *recursively* applied and *extended* by considering different local applicability like for rule-based models.
The abductive process is not *approximated* by recursively considering populations of processes considered singularly analogue to non-collective processes. In this way it is not possible to represent level changes and local asymmetry systems going towards a global symmetry, e.g., dissipative systems. We must deal with non-Turing computability such as quantum systems (see Licata, 2008a). Moreover, analogical reasoning is possible only *after* selecting a specific structural representation.
Creativity in designing mesoscopic variables relates to representing multiple *partial instantaneous aspects* of macroscopic properties, e.g. *same* speed, distance from their nearest neighbours, direction and altitude, suitable to be considered in a network of relations as well network properties by themselves, i.e., Meta-Structures.

2.4 Creativity as design, invention, good continuity and imitation, of the level of description

Creativity as design of mesoscopic levels of description to detect Meta-Structures intended as *indicators* and eventually tools to act on processes of emergence. In this case Meta-Structures are indicators of the occurrence of processes of emergence when a suitable cognitive model allowing detection of related emergent properties is not available to the observer. This is, for instance, the case of variations of ergodicity as indicators that restructuring processes are in progress (Minati, 2002; Minati and Pessa, 2006, pp. 291-313; Boschetti *et al.*, 2005).
We can say that a virtuous feed-back takes place: the identifying of Meta-Structures in a system suggests new models, and those, in turn, show how to refine the search for Meta-Structures.
However, Bongard considered, in a deep Gestalten framework, that the best language to describe an object, a configuration and a phenomenon is the one in which the *creation* of an object could be described. The *good continuation* principle states that perception of a configuration also *includes* the imaginable process of recreating or imitating so allowing the *imitation principle,* i.e., imitation of the way by which the configuration is an effective way to describe it (Arnheim, 1997; Bongard, 1970).
Multiple and replicated roles in Multiple Systems as introduced above, are considered as peculiar to represent dynamics of local quasi-periodical processes establishing Collective Behaviours like flocks and swarms. However, we use mesoscopic variables by considering agents performing the same multiple roles, but in a non regular ways, i.e., not prescribed by *fixed* rules as in the case of Multiple Systems and Collective Beings. While coherence was given by fixed rules, in the more generalised case coherence is given by suitable Meta-Structures.
Creativity is considered as given by identifying mesoscopic roles performed by agents, clustering them, imaging multiple roles, their relations and related properties.

3. Generalising the approach

Possible generalisations allowed by the project "Meta-Structures", consist of using Meta-Structures to represent general coherence, i.e., the process of assumption of emergent properties. This may be related to assumption of *variability* and self-creation of a description level as an expression of creativity, for instance, level of descriptions for processes of vision adopted by the observer, like temporal, syntactical and semantic (Licata, 2008c). Creativity starts from sensorial relations with the external world and *continues* with cognitive processes, such as production of theoretical modelling and representations, being them a rooted strategy to perform effective selections, in the nature of evolutionary advantages.
Continuity and coherences with cognitive models used to detect a phenomenon of emergence are methodological constraints and tools to self-create new, effective the levels of description.
Several possible lines of research may be introduced. For instance:

- Is it possible to *transform* Meta-Structural properties into suitable boundary conditions to be prescribed as environmental constraints suitable for inducing emergence of collective behaviour by interacting agents? Meaning for managing social systems should be very important as introduced in Minati and Collen, (2009) and Minati (2009b);

- What kind of relation between the *Fisher information* (Frieden, 2004) and Meta-Structures?

- Is it possible to prescribe a Meta-Structure by merging two Collective Behaviours when one is represented by the Meta-Structure to be prescribed?

Conclusions

We presented the very strong, even definitional, relation between emergence and creativity.
We discussed the subject with relation to the well-known Gestaltian topics introduced by Bongard, like its famous one hundred squares and his *imitation* and *good continuation* principles studied for visual pattern recognition in Artificial Intelligence. We introduced how the general problem may be theoretically dealt with by *logical openness* and the *dynamic usage of models*.
We then presented the Meta-Structures project having the aim to model *general coherence*, like in Collective Behaviours, by using formal properties, i.e., Meta-Structures, trough suitable mesoscopic variables created by the observer as design, invention, good continuity and imitation, of the level of description. We presented possible lines of research for the generalisation of the approach under study that appears extremely rich in suggestions for the comprehension of both the world and cognitive processes.

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