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Architecture as the Cybernetic Self-Design of Boundary Conditions for Emergent Properties in Human Social Systems

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Some concepts crucial in the contemporary interdisciplinary study of complex systems are reviewed, namely emergent properties of systems, the constructivist role of the observer, and approaches to modeling emergence. Considered is the generalization of boundary conditions to constraints able to induce processes of emergence and acquisition of new and emergent properties within human social systems. A cybernetic and systemic view of architecture is discussed beyond the functional aspects but with an emphasis on the constructivist representation by the observer. In this multi-layered system processes of emergence and acquisition of new properties occur. We propose the study of this system that is inclusive of its architecture, as a specific project able to unify, that is, cohere the various interrelated aspects of an architecture that is inherently part of the system. The human dimension is present in terms of the observer. By means of the cybernetics of architecture that humans experience, they come to know the emergent properties of architecturally designed places and dwellings for human inhabitation. Participation and responsibility for human social systems, inclusive of their architectures, bring into consideration the ethical dimension and its power to induce social emergence, which may be understood as an application of cybernetics to human knowing.

Introduction

In this paper we use the term *architecture*[3] to refer to the art and science of designing buildings and structures to be used by human social systems. We purposively sequence the paper as a series of parts to argue for the important place architecture inherently has in human social systems.

In the first part we visit some concepts fundamental to our framework, such as the ones of systemic property and level of description crucial for a cybernetic discussion. In the second part we briefly discuss two ways of establishing systems, one through organization and the other by emergence.

In the third part we present our preferred definition of *emergence* in regard to architecture and human social systems, and some conceptual basics for modeling emergence, referring to self-organization and collective behavior.

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In the fourth part we discuss the concept of *boundary conditions* (from mathematics) to introduce approaches covered in the fifth part. They pertain to the acquisition of systemic properties through changes, due to the establishment of a new structure through a phase transition; a new way of interacting by components (e.g., assumption of new rules in social systems); the establishment of (new) subsystems (e.g., differentiation and specialization in social systems); processes of emergence occurring within the system (e.g., collective phenomena, learning); and multiple and simultaneous roles of components, as in Multiple Systems (MSs) and Collective Beings (CBs).

In the sixth part, using the concepts introduced above, we discuss a systemics of architecture, particularly with the system established by a) its physical nature as defined by structural, functional aspects, and b) the model of the physical system as represented by the autonomous agent-observer. The two levels are cybernetically interacting, and continuous processes of emergence are established in which acquisition of emergent properties occur. The modeling of such a very complex, multi-layered system may be approached, for instance, by using the Dynamic Usage of Models (DYSAM), Logical Openness, MSs and CBs based on the constructivistic role of the observer as in second-order cybernetics. We propose a research project to articulate this conceptual framework by using established results related, for instance, to environmental psychology, the cybernetic role of the designer, Post-Occupancy Evaluation (POE), Building Performance Evaluations (BPE), urban design, and how people perceive architectural and landscape values in their settlements and built environment. The relevance of modeling and the proposed research project to emergent systemic properties of architecture and human knowing are discussed. The cybernetics of these ideas follows with special consideration given to multiple modeling as DYSAM and perspectives of humanistic psychology, designing of space for human inhabitation and use, and architectural knowing as a special case of human knowing.

Finally, in the seventh part, we underline the ethical responsibility of those affiliated with and making use of architectural knowing, given its potentiality to activate, induce and sustain hierarchies of emergent human social processes.

System and Its Properties

The concept of system has a long, multidisciplinary history. Many different definitions of systems have been introduced, such as: "A set of objects together with relationships between the objects and between their attributes" (Hall & Fagen, 1956, p. 18), and intended as a set of units with relationships among them, such as in Bertalanffy (1950, 1968, 1975). As a result, two different approaches have developed. One approach, used to design artificial systems, applies the definition to machines, computer software, and assembly lines. The other approach, used to model the natural world, applies the definition to nonhuman made phenomena.

> In case of artificial systems we know the design, we know from which parts it was assembled, we know what the relations between the parts are. In case of natural objects the representation of the whole system is not granted, we have to choose an adequate partition between an infinite number of possible partitions. (Guberman & Minati, 2007, pp. 1-2).

In this paper we will consider the concept of *systemic property* as one that can be witnessed and modeled by the observer at a specific level of description. Two presumptions are helpful to us to provide a working definition of system suitable for the purposes of this paper: 1) level of description and 2) interaction. Level of description relates to the representation, variables, and interactions among them, disciplinary knowledge (e.g., physics, biology and psychology) and a scalar used by an observer to design or model any aspect, portion or totality of the system. Interactions between any two components are assumed to take place when the behavior of one affects the other. A necessary but insufficient condition for the establishment of systems is that components interact.

Applying these presumptions to a working definition of system, we may state: At a specific level of description adopted by the observer, a system is an entity, established by interacting components, assuming properties different from those of its components. The transition from a set of components to a system of interdependent components takes place during and not as a result of interaction. In the process of interacting, new properties are established, as detected by the observer, thanks to the continuous process of interacting. Congruent with the above distinctions, two principal categories of examples are 1) human made devices assuming properties, that is those becoming systems, such as electronic and mechanical devices (specifically TVs, radios, telephones and engines) when power is supplied to enable their components to interact; and 2) natural, living systems comprised of human beings interacting in social contexts (specifically, transportation, markets, businesses, governments, festivals, sports events, ceremonies, private celebrations, and community affairs). While elements are considered to possess non-systemic properties, like age, quantity, location, speed and weight; in contrast, systems acquire new properties when interactions among components occur. Of great interest is the blurring of this distinction increasingly over the course of human civilization, where a given human social system makes use and becomes interdependent with human made devices and structures (specifically, electronic communications, transportation, and dwellings). This increase in complexity often makes it difficult to separate and know when a property is possessed or acquired, and consequently, whether the property needs to be supported by the continuous interaction among elements. This increase may also be related to what is considered real and virtual, because virtual is an increasingly common present day experience of knowing others only through, for example, Internet communications and neglecting technological layers.

Our central interest is human social systems, their organization, and emergent properties. The context in which we find human beings is always an important consideration. We can discuss the particular organization of human beings, who interact and act individually and collectively in a given context, as an interface with an architecture. Since human beings increasingly exist and interact in habitats to shelter and facilitate their activities (e.g., homes, schools, offices, stores, and factories), the architecture is a component of the system. Thus, fundamentally, a human social system consists of the human beings, their interactions, the environment (other objects and topography), cultural processes of self-observation and modeling (e.g., artistic, political, and religious), and its architecture (organizational structure). The dynamics that result emerges and induces particular properties, and this focus constitutes the main subject of this paper. We are also especially interested in the application of cybernetics to describe, model, and know the architectures of such systems, as they may induce and emerge properties of the system. The conceptual framework assumed in this paper is both an application and extension of the one adopted by second-order cybernetics devoted to study how observers construct models of other cybernetic systems. We extend this study to the crucial constructivistic role of the observer required to detect and model processes of emergence, particularly of new acquired properties. Specifically, the cybernetic role of the observer relates to the ability of the observer to model *coherence*, for example, the continuous detection of collective behaviors that model coherence between single different behaviors keeping the collective and dynamic identity of a flock and a swarm. This entails processes of acquiring and maintaining new properties by dynamically using and generating models, as illustrated by DYSAM (Minati & Pessa, 2006) and embedded hierarchies of models (Bass, 1994; Baas & Emmeche, 1997).

Two Means of Establishing Systems

From the study of systems over the course of the last century, we may state with some confidence that we know at least two ways sufficient to establish systems from their interacting components: 1) through organization, and 2) through self-organization. One way to establish a system is to make the components interact in a pre-ordained, organized, or structured manner. This is the usual way for building artificial systems where components interact by following plans (the structure), such as those generated by an architect to construct a building, or a designer to produce a consumer product (automobile, appliance, clothing, container). Related examples are assembly lines and mechanical systems.[4]

The process of self-organization is the second way for the establishment of systems. The meaning of the prefix *self* relates to the fact that the structure by which components interact, namely its organization, is not imposed from the outside, but adopted autonomously, either as a reaction or not, to an external input. Processes of self-organization are those that can make components to adopt a (new) structure, as in phase transitions. Processes of self-organizations may be also modeled by considering very simple micro behavioral rules assumed by interacting agents able nevertheless to establish coherent behavior, such as micro rules for simulating flocks (Raynolds,

4. The subject is dealt with by systems engineering, the interdisciplinary field of engineering focusing on the design, production, testing and usage of artificial systems; see, for instance, Klir (1991) and Porter (1966).

1987), Artificial Life (Langton, 1989, 1990), and a model of virtual ants (Bonabeau, Dorigo, & Theraulaz, 1999). More examples can be found with superconductive and ferromagnetic materials and their fields, transitions between different phases of matter (a liquid to solid), swarming of insects,[5] and industrial districts.[6]

Interestingly, organization and self-organization may occur at the same time. Social systems may be considered as organizations ignoring emerging processes taking place within them and vice versa, such as the case of anthills, where there are well-defined organizational roles (solder and worker ants, and ants for reproduction). For human beings, it may be viewed similarly, in that they take prescribed roles very familiar to us, such as named members of a family, and titles of responsibility with job descriptions in a corporation. However, in the case of human social systems, we must include considerations beyond roles and the organization generally, because regardless of organizational names and titles, persons interact in ways to self organize into subgroupings that may have little to do with assigned hierarchical line authority and responsibility that defines the overall organization of the human social system. Such subgroup activity may be the source of emergent properties coincident with those of the organization as formally defined, and such subgroups may blur as well as variegate boundary conditions of the organization. Expected and non-expected effects of organized interventions, like colonization, deforestation, energy waste, population increases and changes, pollution and urbanization, may self-organize. The systems of such effects may acquire emergent properties, such as criminality, new uses of buildings, change in the average age of populations, and changes in population density. Such effects induce additional functionality like the closing of traditional commercial markets and the opening of new ones.

Emergence

The concept of emergence has long been part of the scientific literature as very well presented, for instance, in Corning (2002) and Goldstein (1999). The philosopher G. H. Lewes between 1874 and 1879 published a collection of five books with the title: *Problems of Life and Mind*. He introduced in this way 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 in its components, because these are homogeneous and commensurable … It is otherwise with emergence, when, instead of adding measurable motion to measurable motion, or

5. For general references, see Anderson & Stein (1985), Ashby (1962), Banzhaf (2001), Millonas (1992, 1994), Nicolis & Prigogine (1977), Theraulaz & Gervet (1992), and von Foerster (1960).
6. Marshall (1920) described the industrial district in terms of competition-cooperation established in the same geographical area among small companies dealing with the same business. This circumstance was named co-opetition by Brandenburger & Nalebuff (1997). Marshall considered that industrial districts enjoy the same economics of scale that only very large companies normally enjoy. This is the emergent property of industrial districts. Outstanding examples in the United States are organizations in information, communication and biotechnology forming the industrial districts known as Silicon Valley in California and the Washington Beltway in Washington, DC.

> 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)

The concept of *emergentism* was used to confute *reductionism* of Lewes' time having the assumption that principles of *higher level sciences* were reducible to the ones of *lower level sciences*, such as biology to chemistry. In this framework the concept of emergence was thought to counter the possibility life could be reduced to and explained in terms of chemical-physical processes. For example, anticipatory of Lewes' contribution, in the his book *System of Logic* (Mill, 1843, Chapter 6, §1) J. S. Mill stated:

> 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.

In 1923 the British psychologist Conwy Lloyd Morgan (1852-1936) first introduced the concept of *emergent evolutionism* (Morgan, 1923).

There are three exemplary areas where we may illustrate the contribution of the concept of emergence: 1) phase transition and self-organization, 2) collective behavior, and 3) modeling emergence. As a set of illustrations they show the wide spread usefulness of the concept across various fields of study, which suggests to us its potential application to architecture as well.

Phase transition and self-organization

In physics a *phase* relates to the state of matter, and it is intended as a set of states of a physical system having uniform properties, namely electrical conductivity, density, and index of refraction. The classical example is the states of matter in solid, liquid, and gas phases.

The unsuitability of equating emergence to self-organization, and vice versa, rests on two essential points. First, it is difficult to assume validity of this equivalence primarily due to the problem of generalizing the concept of phase transition when dealing with similar processes taking place in different disciplinary contexts. In physics, for example, the indicators relate to physical variables, such as temperature and pressure. If we want to apply the same model to other disciplines we need to find the *corresponding indicators*, for instance, in cognitive science, social systems and biology as well as suitable time scaling. Second, to be discussed below, processes of self-organization may be modeled by considering very simple micro level behavioral rules assumed by the interacting agents. Moreover, the problem of accepting the validity of this equivalence is the lack of reference to the constructivist role of the observer who is able to detect not only processes establishing coherence, but also to realize new properties through modeling and meaning as in second-order cybernetics.

Collective behavior

The expression *collective behavior* (Minati & Pessa, 2006) relates to the establishment of collective entities both for particles, as in physical systems (Iberall & Soodak, 1978), and for *autonomous agents*, that is, agents possessing a cognitive system that is either natural or artificial (derived from the computational modeling of cognitive processes), such as birds or robots, respectively. These agents characteristically process inputs and do not just react simplistically to stimuli.

Processes of collective behavior should be intended as processes able to give rise to emergent entities (systems) having new properties. Major examples are found in physics (lasers, fluids and plasmas), biophysics (DNA replication), chemistry (pattern formation, dissipative structures), biology (morphogenesis, evolution), economics (industrial districts), sociology (urban growth), brain activities (learning), computer sciences (pattern recognition performed by Neural Networks), meteorology (chaotic behavior), and non-linear phenomena involving a macroscopically large number of agents as in the case of insect societies and swarms (suggesting the idea of and new directions for research on *collective intelligence*). A list of corresponding interdisciplinary approaches in second-order cybernetics is given later in this paper under "Cybernetics, architecture, and human social systems."

Modeling emergence

Emergence is considered in the scientific literature as both a process of formation of new self-organized *collective entities* from the coherent behavior of interacting components (swarms, traffic and laser light) and a process requiring the constructivist role of the observer (coherence detected at the *level of description* assumed by the observer when modeling phenomena). modeling takes into consideration that collective properties emerge at a level of description more abstract than that used for components, and that collective properties are detected as new by the observer depending upon the cognitive model adopted able to model more general aspects such as collective ones.

Different definitions of emergence have been introduced into the scientific literature and there is a large debate on approaches to be used to represent it.[7] Of general interest is that the processes of acquisition of new emergent properties may be formalized as a hierarchy of processes of emergence, when a property emerges from the interaction of entities emerging from lower structures, such as in Baas hierarchies.

7. See Anderson & Stein (1985), Baas (1994), Beckermann, Flohr, & Kim (1992), Cariani (1992), Cruchtfield (1994), Forrest (1990), Haken (1987), Holland (1998), Huberman & Hogg (1993), and Minati & Pessa (2006).

Boundary conditions

The subject of boundaries has been addressed in several different disciplinary ways. In systemics, boundaries are *borders*, such as those we find in thermodynamics dividing inside from outside. The laws of form (Robertson, 1999; Spencer-Brown, 1969) considered *distinctions* as *boundaries*, which introduced a very powerful generalization. The concept of boundary conditions has been introduced in mathematics. In the field of differential equations, we name the *boundary value problem* a differential equation and a set of additional restraints we name boundary conditions. In this paper we propose to generalize the concept of boundary condition to the degrees of freedom or constraints respected by interacting agents establishing collective behavior. Collective behaviors may be induced by facilitating the establishment of *necessary boundary conditions*, for example, avoiding perturbations by shooting into a flock, sending a high speed wind into a swarm, inserting an obstacle into collective behaviors. It can also be done by reproducing *sufficient boundary conditions*, for example, situations in which previous collective behaviors are detected, like speed, density, aggregation, direction, distance, and agent dimensions. Finally, there are ways of changing that are assumed by agents and suitable constraints like the structures of ant-hills and beehives. The latter approach is assumed for simulations of collective behaviors in a very large number of cases reviewed in Minati and Pessa (2006).

modeling is based on identifying variables, parameters, and interactions suitable to represent a phenomenon and then manage it by acting on such variables, parameters, and interactions, like in physics, economy and ecosystems. In the same way, available approaches and techniques introduced to model processes of emergence can also be used for identifying crucial variables and parameters useful to manage and possibly even induce processes of emergence.

With respect to human beings and architecture, the boundary conditions for a system are the constraints imposed on interacting agents. Such constraints may be behavioral rules due to the cognitive processing of the autonomous agents or degrees of freedom due to structural aspects of the environment.

The subject of boundary conditions has been considered particularly in the fields of environmental psychology, design, proxemics (personal space), and post-occupancy and building performance evaluations.

Modeling processes of emergence

As introduced above, processes of emergence are intended as processes of formation of new self-organized collective entities (swarms, traffic and laser light), requiring the constructivist role of the observer. This is what is meant by coherence detected at the level of description assumed by the observer. Technically, we may distinguish between traditional and non-traditional models of emergence (Minati & Pessa, 2006, pp. 145-279). Particularly multi-modeling of the observer is based on traditional models founded on dynamical systems and dissipative structures, and non-traditional models founded on theory of phase transitions, Synergetics, Artificial Life and connectionistic models, such as Neural Networks and Cellular Automata. An example of a constructivistic model is the role of the observer in *Dynamical Usage of Models (DYSAM)*, introduced in Minati and Pessa (2006), based on approaches having the common strategy of not looking for the only, correct, optimum model but a strategy for usage of different ones, such as the Bayesian method, Ensemble Learning, Evolutionary Game Theory, Machine Learning and Pierce's abduction and second-order cybernetics.

Inducing processes of emergence

The verb *induce* is intended to refer not to a logical inference, which from a finite number of particular cases leads to another case or to a general conclusion, but to a process establishing a suitable configuration of constraints in such a way to make possible and facilitate a specific process of emergence. It relates to the use of models to describe in part or whole the establishment and regulation of the processes of emergence.

We mentioned above how to induce processes of emergence by acting on boundary conditions, the configuration of elements, their ways to interact and the cognitive model of the observer used to model the process. Related problems are the ability to regulate, mix, sustain, reproduce and de-activate processes of emergence. We are well aware that such problems are largely unaffordable with the models and tools available today, while they are expected to be approachable in the future. In the meantime, we limit ourselves to partial approaches to restricted contexts, such as architecture.

To move to the central concept of the paper, the delineation of suitable boundary conditions induces the establishment of a system. The establishment of a system occurs through organization, that is, the functional aspects of the space structured by architecture, as well as through self-organization, that is, non-functional aspects of the space structured by architecture and able to induce specific individual and collective behaviors.

Examples of two kinds of constraints considered as boundary conditions for architecture able to induce emergence of systems can be noted. Organization involves the geometrical and topological aspects that influence collective interactions between agents, such as shapes, forced paths, connections, barriers, stairs, dimensions, and visibility allowed in the urbanization of cities. These aspects influence traffic and crowd management in marketplaces and queues to obtain products and services. They influence home design by means of the verticality of buildings, number of entrances and exits, and limiting the number of bathrooms, kitchens and bedrooms. Self-organization is psychological when the aspects influence the cognitive system possessed by autonomous interacting agents through the use of color, illumination, density, and variety of objects in time and space.

Before we consider more carefully the two processes of establishment of systems through organization, self-organization and their combined effects for architecture, we need to elaborate the process of acquisition of emergent properties in general systems.

Acquired Emergent Properties

A phenomenon, modeled as a system or explicitly designed as such by the observer, has embedded the possibility to acquire new, unexpected and emergent properties not explicitly designed by the observer (Minati, 2008a). Moreover, such new, acquired properties are able to influence the original system.

In sum, systems as modeled by the observer not only possess properties, but also are able to make emergent new properties by various means. First, emergent properties may be acquired by means of changes in the system when a new structure forms (through phase transitions) or a new way of interacting is established (assumption of new rules in social systems). Second, a system can establish (new) subsystems (by means of differentiation and specialization in social systems). There are many examples of processes of organization taking place in human social systems, such as a corporation that needs to specialize the production or the delivery activity. Emergent processes of specialization occur in living matter when establishing specialized functions, as organs (liver, kidneys and lungs) or multi-functionality (areas of the brain able to assume different functions in case of traumas). These phenomena involve processes of emergence, and in combinations, they further both processes of emergence and organization. Third, processes of emergence manifest within the system (namely, emergent behaviors evidenced in traffic flows, industrial districts, and the establishment of *collective intelligence*[8]). Fourth, there are multiple and simultaneous roles of components as in Multiple Systems (MSs) and Collective Beings (CBs) (Minati & Pessa, 2006). The concept of MSs relates to sets of systems established by the same elements interacting in different ways; in other words, they have multiple simultaneous or dynamic roles. As a result, they establish processes of emergence of different systems having different properties. In systems engineering examples of MSs are infrastructures of networked electric powers assuming emergent properties (an unfortunate example being the black out) and the Internet where different systems play different roles in being used continuously in newly emergent ways. CBs are particular MSs when components are autonomous agents possessing

8. The term relates to collective behavior allowing solutions to problems, which individual components cannot solve. An outstanding example of collective intelligence is given by ants able to establish a collective representation while they are singularly unable to generate one. The example relates to the behavior of ants looking for food. It is well known that an ant detecting a source of food marks the path followed with a chemical track (pheromone). The mark induces other ants to follow it, and they move toward the source of food. In the same way ants returning with food add a reinforcing track of pheromone. In this way ants amplify the importance of a discovery and allow ants to assess the level of interest of different paths by their strength. In other words, ants are able to evaluate through a collective behavior the closest source of food, the one having the strongest chemical track. Other sources are deemed of lesser importance, those associated with weaker tracks (Franks, Gomez, Goss, & Deneubourg, 1991; Bonabeau et al., 1999; Millonas, 1992, 1994; Theraulaz,Goss, Gervet, & Deneubourg, 1990; Theraulaz & Deneuburg, 1994).

the same (natural or artificial) cognitive systems. In this case, the belonging of autonomous agents to different, simultaneous or dynamic systems is active, that is, the composing autonomous agents decide their membership in the systems.

The concept of CB is of particular interest for human social systems because of the number of cognitive models available and the mutual influences among them. We note two separate cases in particular. First, human beings in temporary communities give rise to different systems in a dynamic fashion as observed for passengers on buses, audiences at performances, and queues in businesses. In these cases, one element belongs to one or another system at different times. Second, human beings simultaneously belong to different systems as observed among workers in a company, families at a picnic, traffic on autobahns, and mobile telephone networks.

At different times, one element simultaneously belongs to one and other systems. For instance, with cognitive functions like memory, workers in a company, members of families, drivers in traffic systems and users of telephone networks simultaneously perform the same role in different systems. In the cases considered above, a worker behaves as member of the company, but in doing this s/he is also aware of being a member of his/her family. The same when s/he is in traffic or makes a telephone call. This duplication and overlap of behavior between systems is very well known to advertisers who know how influencing the behavior in one system can influence the behavior in another one. This becomes possible by establishing the same components for CBs (specifically, correlations among marketing behaviors).

To reiterate a key point, the multi-modeling approach, known as DYSAM, is suitable for dealing with MSs and CBs. DYSAM is related to situations in which the system to be studied is so complex, such as when elements assume multiple roles, that it is impossible in principle to describe it exhaustively using a single or a sequence of models. This is the case when the process of emergence gives rise to the dynamic establishment of different systems, like MSs and CBs, establishing cybernetic loops of communication between levels.

The processes mentioned above should not be considered as completely separate, but rather, simultaneous and integrated. An effective modeling of such processes should be based not on separate models but rather on meta-models able to describe interactions between levels. A first approach may be represented by DYSAM. Processes of acquisition of new emergent properties may be formalized as a hierarchy of processes of emergence occurring when a property emerges from the interaction of entities emergent from lower structures, such as in Baas hierarchies mentioned above.

The Case of Architecture

Di Battista (2006) presents and discusses various historical definitions. The etymology of the word comes from the Greek *arkitecton* and the Latin *architectura*, identifying an activity that "nascitur ex fabrica et ratiocinatione."[9] We assume for the

9. "it comes from practice and ratiocination," Vitruvius, *De Architectura*, I, 1

purpose of this paper the definition of architecture as “a whole of artifacts and signs that establish and define the human settlement” (Di Battista, 2006, p. 395). Moreover, architecture is generated and represents a specific physical and social context leaving aside any explicit artistic intention (Di Battista, 2008). And further, architecture is an “emergence” of a settlement system. In this framework we may consider the combined inductive, structural, cybernetically interactive, and non-structural aspects of architecture.

In the conceptual framework of second-order cybernetics, architecture may be intended as the self-design by a social system of boundary conditions suitable to keep or make emergent what are considered important aspects by the social system itself and related, for instance, to military, religious and economic power. The homogeneity between architecture and language, music, literature, religion and science must be detected by an observer who is able to model the processes of emergence sustaining the system (Guberman & Minati, 2007, p. 22).

The self-architecture of social systems designs is seen in three kinds of examples structurally and functionally representing: a) homes, architecturally designed to be inhabited in particular ways and then we inhabit our homes as they are designed to be inhabited; b) schools, organized into classrooms by subject domains and separate disciplines, confusing fragmentation for specialization, and then we study subject matter in schools as they are designed; and c) hospitals, built to treat ill bodies (patients) to be repaired and then we care for patients in hospitals as they are designed for patient care.

This self-designing is evolutionary for social systems whose elements are autonomous systems having variable evolutionary rules due to having a complex cognitive system. Such cases are human beings, the living elements of the system, who change their evolutionary rules through learning and inventions. Self-designing is not evolutionary for social systems whose elements are autonomous systems having fixed evolutionary rules, due to simpler cognitive systems typical of other species (ants, bees, and beavers), programmed genetically always to building their nests, for example, in the same ways.

The structural aspects of architecture, specifically building materials, stability, shapes, dimensions, illumination, acoustic properties and energy consumption have functional effects on those who behave in the structured space. Autonomous systems also cognitively represent the space in which they live, and because of that, they become inhabitants. As a result, they not only respect the boundary conditions from a functional point of view, but also cognitively process and use the representations they have of the space structured by the boundary conditions to adapt their behavior. This is why there are different architectures for different ages and social systems (Collen, 2008).

Architects have the power and responsibility to set the boundary conditions, because they make the plans and models that organize the space for the inhabitants. In other words, they provide a major input to the process of representing and elaborating the space for others to inhabit. It is because the inhabitants are human beings that the system established by architecture has a double valence, or in other terms, levels of description. On one level, the system is physical, defined by its structural and functional aspects. On another level, the models of the physical system are represented by the architect, inhabitants, and other observers. The two levels are interacting, and continuous processes of emergence are established as in a second-order cybernetic conceptual framework. The two levels interacting create a very complex, multi-layered cybernetic system, in which several processes of acquisition of emergent properties occur. We name this system, for our convenience, *A-Multiple System* from architecture for the design of Multiple Systems.

Components of an A-Multiple System assume different roles. Subsystems, multiple systems, and collective beings are established in a hierarchy of processes of emergence. This hierarchy is well related to the consideration that if we assume creativity as the infinite use of limited resources, activity peculiar to human beings (Arecchi, 2007), then any structure in which human beings behave may be realized as a resource to be used in infinite ways.

There are several cases by which the same human beings use in different ways the same structures over time. An example that illustrates the different uses of the same structure in time is the building constructed to be a school, then subsequently serving as a monastery, then a barracks, and finally a hospital. The same structures may have different inhabitants at different times, and the same school may house different generations over several decades. The same structures may be reproduced in different contexts, for instance, the architecture of a barracks may be replicated in different geographical areas of the country.

Furthermore, urban effects can be functional and emergent. In medieval Europe, very narrow streets in cities were built for military reasons to allow only one person at the time to follow the street, so that during an invasion, the city was easier to defend. Narrow and winding streets had the advantage of forcing an invader to advance only by single soldiers toward the center of the city. The penetrating enemy could be attacked from above and find obstacles closing paths. This defense strategy was the general approach taken against raiding pirates and gangs. It was also a strategy for large towns having an army dedicated to defense. In this latter case, the large town was equipped with suitable architectural defenses, such as special walls and external moats of water around the walls. Large troop and supply movements could occur inside the external walls of defense without having to cross the center of the town.

In modern times, very large areas are given to passage to facilitate collective behaviors evidenced in automobile traffic, shopping malls, and sporting events. Since modern times, the efficient movement of human beings from one location to another has emerged to become the main priority, instead of defense from outside enemies.

Another class of cases is the relationship between A-Multiple Systems and natural environments. For example, A-systems established to deal with exploitation of natural resources like oil extraction, fishing and sport. Functional aspects are then represented and used by inhabitant agents establishing emergent communities influenced and having influence on the physical environmental aspects. Emergent communities acquire emergent properties, such as local interests, waste production, and functional needs to copy with increasing number of agents or reduction-consumption of natural resources. These influences induce acquisition of new emergent properties by ecosystems. The newer emergent properties influence local pre-existing communities and produce environmental changes. A mountain with avenues from its top to bottom provides a natural environment for winter skiing. The mountain full of skiers serves to illustrate this case of A-Multiple System in a natural setting.

And still another class of cases covers the relationship between A-Multiple Systems in space and time. To illustrate, consider two A-Multiple Systems, the town and its port. The town is an A-Multiple System in the sense that it has a structure that is continuously redefined and modified by different usages in time, such as parking places, marketing centers, new houses, and facilities. People aggregate in corresponding ways and induce changes when they aggregate in different ways. The port is also an A-Multiple System in the sense that it has a structure that is continuously redefined and modified by different usages in time in the forms of the daily, weekly and monthly flows of goods and energy transportation, and tourist traffic. When two A-Multiple Systems interact, the services of one can be redefined into services of the other, such as we see in banking, tourist, and transportation activities.

What is the difference between human social systems and A-Multiple Systems? When dealing with social systems the focus is on the processes of emergence activated by individual and collective behavioral rules that are economic, sociological, political, moral, and religious; see Sawyer (2005) and Johnson (2002). In the case of A-Multiple Systems, the focus is on the functional aspects designed by architects and the models as realized by the inhabitants.

Our interest in this paper is to introduce and specify the framework for a systemic approach to the cybernetic effects of architecture on shaping human social systems. This paper is more a proposal for a large, interdisciplinary and systemic project based on second-order cybernetic principles than a result. We already mentioned some interdisciplinary approaches in systems science able to define the conceptual framework. Next we describe how this possible project may start from already available consolidated interdisciplinary contributions in architecture.

Design research deals with the cybernetic combination of functional aspects, the complex role of the designer (the architect) as the agent of design, and emergent acquired properties. These matters also deal with the necessity of standardization by allowing sets of non equivalent choices and industrial constraints (Krippendorff, 2006).

Problems of design research may be considered in the framework of environmental psychology that deals with interdisciplinary areas like architectural psychology, behavioral geography, ecological psychology, ecopsychology, environmental design research, environmental social sciences, environmental sociology, environment-behavior studies, person-environment studies, proxemics or personal space, social ecology, and socio-architecture.[10]

Environmental psychology started with the so-called Hawthorne experiments in the 1930s. The term was introduced by H. A. Landsberger (1961) when analyzing older experiments conducted at the Hawthorne Works, Cicero, Illinois, a large factory built by Western Electric. He defined the concept of Hawthorne effect as temporary behavior or performance improvement in relation to changes in environmental conditions. Environmental psychology came to the attention of architects some years later when focusing on relationships between architecture and psychology, originally developed in the United States to reduce criminality and make prisons more suitable (Fairweather & McConville, 2000).

There is also the interdisciplinary contribution considering the relationship between architecture and psychoanalysis (Eisenman & Lacan, 2006). There are areas related to the study of A-Multiple Systems are Post-Occupancy (POE), Building Performance Evaluations (BPE), and urban design (Blyth, Gilby, & Barlex, 2006; Preiser, Rabinowitz, & White, 1988; Federal Facilities Council, 2002). Additional areas involve development of new methods to investigate how people perceive architectural and landscape values in their settlements and built environment (Spens, 2007; Swaffield, 2002; Waldheim, 2006).

The variety of approaches stated above corresponds to the multiple dimensions of A-Multiple Systems. The novelty of the approach that we introduce is the unifying theoretical systemic framework able to allow better descriptions, representations and models of the interactions among different levels. Our focus is the cybernetic system of levels, in which meta-phenomena emerge, that is, from lower levels we observe emergent effects. This complexity has been approached by using several, and often non-interrelated, approaches. We propose that the project outlined consider also other possible approaches, such as DYSAM described earlier.

The conceptual framework introduced above may be suitable for representing the continuity among different disciplinary aspects of the culture produced by human social systems in different places and times, providing continuity (realized as such by the observer) among architecture, music, philosophy, language and religions. We find outstanding examples in the coherence between baroque music and the architecture of Venice, jazz music and the architecture of American cities, and religion and the structures of churches. The interdisciplinary, systemic essence of the project is to model and understand the source of this coherence. We find meaningful in this regard, "to imagine a language means to imagine a form of life" (Wittgenstein, 1953, Part 1, §19). Following this thought, it is possible to state metaphorically to imagine an architecture means to image a form of life (Minati, 2006).

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10. The concept of environmental psychology was probably introduced by the U. S. American psychologist Roger Garlock Barker (1903-1990) in a series of contributions in the book *The Stream of Behavior* (Backer, 1963), successively elaborated in Bell, Greene, Fisher, & Baum (1996), Ittelson, Proshansky, Rivlin, & Winkel (1974), Stokols & Altman (1987), and Hall (1966).

Cybernetics, Architecture, and Human Social Systems

A-Multiple Systems of many levels have integrity by means of cybernetic loops of communication between levels. Among its founders, such as J. Watt, W. R. Ashby, N. Wiener, J. von Neumann, W. McCulloch, and G. Bateson, cybernetics has been introduced, studied and applied as the interdisciplinary study of communication processes, control mechanisms and feedback. In the early 1970s, cyberneticians focused on cognition that allowed autonomy and self-organization. With the emphasis placed on the role of the observer and the observer's cognitive system in modeling phenomena, this movement became known as second-order cybernetics, leading to constructivism. Contemporary cybernetics covers a very huge interdisciplinary area modeling processes in complex systems, such as anticipatory systems, architecture, artificial intelligence, biocybernetics, bioengineering, bionics, computer vision, control systems, entrepreneurial cybernetics, evolutionary biology, game theory, homeostasis, learning organizations, logic modeling, management cybernetics, medical cybernetics, neuroscience, operations research, organizational cybernetics, psycho-cybernetics, robotics, sociocybernetics, synthetic biology, systems biology, and systems engineering. With reference to architecture, the analysis of the designer/ architect is of central importance because it is the involvement of this agent that makes design suitable for being studied in the framework of second-order cybernetics. The work of Glanville (1980, 1997ab), Goldschmidt and Porter (2004), Lindekens (2004), Jonas (2004), and Lawson (2000) represent important contributions to converge architecture, design, and second-order cybernetics.

We consider DYSAM in the framework of new cybernetic models related to meta-modeling. Dynamic Models relate to changing in time of any kind of regulatory and self-regulatory processes. Dynamics of DYSAM relates to the changing of models invented and used by the observer to deal with the dynamics of complex systems acquiring new embedded properties through processes of emergence. The cybernetic content of DYSAM specially relates to interrelations between models when the observer generates n-levels of logical openness (Minati, Penna, & Pessa, 1998) by a) assuming n different levels of description; b) representing one level through another by making models of models, that is, meta-modeling processes of learning and adaptation; and c) having the ability to move among models to decide which one to use. Of interest in our proposed framework is the emergent effects, properties emergent from these inter-level communication loops in the case of architecture dealing with A-Multiple Systems. Different approaches dealing with cybernetics and architecture have been introduced to associate and promote connections between cybernetics and design (Glanville, 2007a; Krippendorff, 2006, 2007). Where the relationship between cybernetics and design was explored in Glanville (2007b), cyberarchitecture was introduced in Pearce and Spiller (2008) and more recently discussed in Baltazar (2007). Cybernetic principles for learning design are debated, for instance in Scott, Shurville, Maclean, and Cong (2007). Examples of other contributions to the study of relations between architecture and cybernetics are found in Frazer (1993) and Spiller (1998, 2007, 2008). A selection of critical sources for the digital era is available in Spiller (2002). Moreover, the cybernetic relation between client and architect was made and elaborated by Pask (1969; Frazer, 2001) and in the related concept of *brief* (Blyth & Worthington, 2001). The purpose of this contribution is to propose another possible approach to model inter-relations between architecture, processes of self-organization and emergence occurring in social systems inhabitant architectures and their cybernetic relations.

Regardless of the extent of participation inhabitants have in the making of the dwellings they inhabit, they change them to suit their interests and needs to the extent they can afford and are able under the rules of occupancy, according to the social institution and context that govern the habitat. Homeowners often have a broad range of possibilities for modification and renovation at one extreme, where apartment dwellers have a minimum at the other extreme. To follow this illustration, the neighborhood imposes some restrictions on what homeowners can do, and landlords do the same for their tenants. Perhaps the growing presence of homeowner associations in the United States, for example, falls in the middle between the two extremes. The dimension represents the interactive cybernetic quality that is an ongoing process coupling together those who own buildings and those who inhabit them over various possible architectures for human betterment, in other words, the qualities of living spaces that promulgate human relationship, happiness, health, productivity, rejuvenation, and longevity. Importantly, from the viewpoints of sociocybernetics and complexity theory, the basics of the cybernetics between these two principal parties (owners and occupiers) are compounded when other parties are included, specifically city service agencies, residents of bordering buildings and neighborhoods, and alternative uses of space other than places for private ownership (namely, public parks, commercial enterprises, agoras of commerce, communication networks of utility companies, and avenues of transportation). De facto, any given building in a given city today across the civilized world becomes a complex human social system.

Contemporary environmental psychology, emergent of the previous century, may be viewed as a more recent application within a broader ecology. This kind of psychology becomes increasingly important with each passing decade of human population growth over the surface of the planet. What we can know of human ecology that can interface with other relations, inherently interdependent with other forms of life, has to be a part of our consciousness and global ethics in the architectural design and construction of each human dwelling (Collen, 1992).

Human Knowing, Humanistic Psychology, and Architecture

The convergence of two psychologies (environmental and humanistic) of the last century becomes a renewed source of interest when applied to architecture for the current century. There is a kind of human knowing emergent from this marriage, one we can call a neo-architectural knowing. Certainly, the field of architecture has a form of human knowing that comes from the disciplined study, application, and experience of designing, constructing, and being in living spaces for human habitation. But the increasing emphasis on a green architecture, that is, one that consciously applies established principles of ecology, energy conservation, and healthy sustainable living, increasingly brings a newer more contemporary consciousness to architecture as a discipline, profession, and practice.

Central to the enterprise is the human observer. The human observer lies at the core of the framework and provides the human foundation of the social systems under study. Although the knowing observer is often assumed to be the architect, the one who designs human dwellings for inhabitation, the occupants soon become the knowing observers. They are in vivo the inhabitants of the space, and as such, they typically alter it in a variety of ways to suit their needs, preferences, and lifestyles.

Besides their functional purposes, we cannot avoid that architectural decisions and artifacts to organize living spaces also act as boundary conditions. They influence processes of emergence in human social systems living in the structured space. Traditionally, the original owner-to-be and architect are the progenitors of the building. But increasingly, post-construction modifications as well as subsequent alterations, as a building develops a history, various owners and occupants acquire a more prominent place in the system. From a broader perspective, both in time and space, the architect is only one of the co-creators of the social human system. Culture produces the language that social systems use to formulate the statements of their living and vice-versa. Architecture is a very important part of this language and this awareness, that is, human knowing is an important cultural contribution for any future generation of architects. But this knowing is embedded in and imbued throughout a larger context involving many other vested parties that impact on any specific building which represents only one location of this complex socio-cultural, economic, political, ecological context.

Humane uses of living spaces communicate major interests in a humanistic approach. The approach emphasizes concerns regarding human health, safety, happiness, service to others, ecological sustainability, and personal fulfillment. Human knowing of these concerns and their applications and interactions with different architectures are paramount to human welfare and betterment. The framework we propose is aimed ultimately at that horizon.

Ethical Responsibilities

The ethical imperative is to consult in the planning and involve in the occupation those who are impacted by decisions to use, alter, maintain, and improve living spaces occupied by human social systems. The subject of ethics is very difficult and debated from an interdisciplinary view. See for examples ethics considered from a second-order cybernetic perspective (Glanville, 2004), an emergent property of the behavior of living systems (Minati, 2002), and designing social systems and inducing processes of emergence within them (Collen, 1992; Minati & Pessa, 2006, pp. 336-346).

There is a responsibility and accountability of course that comes with the design and construction of human dwellings. Naturally we expect the organized spaces in which we inhabit to support our occupancy and not collapse for many decades. Typically we maintain them to ensure their sustainability. But soundness and safety of physical construction is becoming more of a concern with climate change, to reduce risk of harm when the uncontrollable strikes, namely tornados, hurricanes, and earthquakes. Increasingly we may extend beyond soundness and safety to the inducements of aesthetics, human health and longevity, creativity, productivity, and altruistic collaboration.

In regard to the governance of human beings, we may consider the correspondence between architecture and law. Architecture sets functional constraints to social behavior through the imposition of boundary conditions in designing the spaces we inhabit. As such, architectural decisions indirectly induce processes of emergence in social systems. In correspondence, laws prescribe single as well as collective constraints, that is boundary conditions, limiting social behaviors in the design, construction, and use of these living spaces, and as such, they also are able to induce at another level of description processes of emergence in social systems. Even though as a profession architecture has its inherent ethical code of conduct, through civil regulation, law does explicitly bring to architecture the ethical dimension. Laws impact all participants co-creating, developing and defining a given human social system. Laws define some of the most obvious and prominent boundary conditions of the system. Some well known examples in the United States are no building may be more stories high than the city ordinance defines, the asbestos level of any material used in a building cannot exceed its legally defined percent, smoking is permitted only outside on terraces of buildings and public places (typically parks and streets), and the number of persons occupying a given elevator of a specific construction for load cannot exceed the number of persons stated on the posted sign inside the elevator.

As humanity propagates to become a planetary society, how far to generalize from regional to global ethics represents a globalizing issue. To what extent is there to be a global ethic for architecture? Standards of building construction and safety appear basic. But the socio-culturally diverse architectures of humanity may be threatened and increasingly brought into question, as adopted architectural decisions, standards, and modes of construction become more and more evidenced from city to city, despite hallmarks of national and historic cultural character. Principally through personal travel and news media coverage, we are witness today to the subtle and cumulative obliterations of national and cultural character in every urban center around the globe. Perhaps the most blatant illustrations are transnational franchises that bring not just familiar logos, business practices, products, and services into nation after nation, but also architecture as well. As the national and cultural character of peoples becomes more homogenized, where is the balance, the emergent boundary conditions to regulate this trend? It is both a challenge and risk of our future.

Turning to the emphasis on emergence, it is important to comprehend how ethics of architecture is a cooperative, collaborative, and collective emergent phenomenon of the global social system, not a dictatorially determined and forced consolidation of more regional social systems. Global ethics of architecture cannot become a blanket standardization of the rules of behavior to be imposed on humanity. Such an imposition would bring perhaps too easily an Orwellian reality to human affairs and global governance, as well as a commonplace and dominant homogeny to architecture. Emergent globality in the ethics arena, like other emergent phenomena, comes about from the interactions among concerned and impacted ethical and social domains in regional arenas. It works only when there is preservation and interdependence among the regional entities through their interactions that sustain the emergent global reality. Through interactions of interdependency the emergent global characteristics are recognizable, sustainable, and appreciated. Such globality represents a rich co-existence of diverse architectures reflecting worldwide the variegated nature of human groupings. A vital global ethics of architecture would not allow replacement of its diversity with any kind of uniformity but would ensure its richness in perpetuity.

To secure the ethical dimension in architectural decision-making, the presence of the human dimension is essential. Specifically, those who are destined to inhabit the dwellings, undergoing design and construction, are necessary consultants and participants in the process. These human relations are cybernetic. The creation and ongoing involvement of probable occupants provide input, feedback and correctional influences over the course of designing and constructing human dwellings. These relations bring a vital contribution to the cybernetics of architecture. Sensitivity to the human sides of living in organized spaces needs greater emphasis to balance the convenience of standardization and motivation for profitability, which typically come at the expense of areas manifesting human diversity. How best to achieve and apply the balance for coming generations of our emerging global society represents an area of human knowing that is complex and multidisciplinary.

Conclusion

In this paper we have discussed the continuity, as a project, between phenomena of emergence studied and modeled in disciplines like physics, mathematics and biology required to design and construct a place for human inhabitation, and architecture, the ways in which space is organized for human beings to carry out their activities of daily living. In a cybernetic and systemic view this continuity should be theorized as coherence and identified generally inclusive of languages, economics, arts, and medicine that cover more holistically human interests, needs, and aspirations, rather than constraining this continuity solely to disciplines, know-how, and knowledge domains pertaining to the rudiments of building construction. The availability of cybernetic and systemic perspectives does not reduce an approach but establishes a hierarchy of interacting levels like those described in DYSAM, Logical Openness, MSs and CBs.

We elaborated the case of architecture proposing a project able to identify the strong effects of architectures on human social systems. Architecture is intended, from the perspective of a second-order cybernetics, as the self-design by a social system of material, built substance, boundary conditions suitable to keep and make emergent spatially and psychologically what are considered important aspects by the social system itself. It is a way that self-design processes of emergence for social systems implicitly set, maintain, and adjust boundary conditions over time.

The purpose of the project is to identify and utilize approaches for studying inductive processes of emergence within social systems in a responsible and comprehensive fashion. This is expected to establish the theoretical framework for different, seemingly unrelated and non-homogeneous approaches used today in architecture for the betterment of human inhabitation.

Consequences for architects, educators, and social scientists are the systemic cultural extension of architecture as a single discipline to inform by means of a cybernetic and systemic, complex design the multi-layered coherences among different aspects of human settlements. A cybernetic and systemic approach has effects on related professions, ethical aspects, and educational processes shaping new generations of architects. Increasingly evident today, adopting this cybernetic, systemic and cross-disciplinary stance is an emergent requirement of any discipline in the age of complexity where any single, isolated discipline cannot remain suitable to deal with the emergent problems of complexity having prevalent multi-disciplinary aspects.

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