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Morphogenesis and complex thinking

Morfogénesis y pensamiento complejo

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Abstract

The present article reviews teaching-learning methods in the architecture career (involving complex creative processes), appealing to mediated and self-regulated experiences through the use of morphologies such as fractals, iterated systems, pattern modeling, growth, fragmentation and diachronic and scalar transformation, according to levels of procedural complexity. This supposes an open framework of assimilation from the planes of spatial, material, functional, aesthetic and habitability expression within a projectual continuum, governed by the principle of pure forms, foundationally dictated by modern architecture. This determines a new and constant encounter with the morphological-architectural object, which admits various solutions, variations, and even inflections of the same problem, according to similar or changing requirements and conditions. Given the above, it is derived as an objective, to review, initially, what we have to understand as complexity, to then define certain principles and procedural levels, which act as meta-models, which derive from the so-called Complex Thought, as well as from the MOSIG Model, and current parametric design in relation to teaching, especially creative processes. In a third part, a reference material of some teaching experiences based on this type of model must be offered.

Keywords

Mental models, modular growing and fragmentation process, parametric design, MOSIG, auto-regulation.

Resumen

En el presente artículo se examinan los métodos de enseñanza-aprendizaje en la carrera de arquitectura (que entrañan procesos creativos complejos), apelando a experiencias mediadas y autorreguladas mediante el uso de morfologías como los fractales, los sistemas iterados, la modelización de patrones, el crecimiento, la fragmentación y la transformación diacrónica y escalar, según los niveles de complejidad procesal. Esto supone un marco abierto de asimilación desde los planos de expresión espacial, material, funcional, estético y de habitabilidad dentro de un continuo proyectual, regido por el principio de las formas puras, dictado fundamentalmente por la arquitectura moderna. Esto determina un nuevo y constante encuentro con el objeto morfológico-arquitectónico, que admite varias soluciones, variaciones e incluso inflexiones del mismo problema, de acuerdo a requerimientos y condiciones similares o cambiantes. Por todo lo anterior, se deriva como objetivo, revisar, inicialmente, lo que debemos entender como complejidad, para luego definir ciertos principios y niveles procedimentales, que actúan como meta-modelos, que se derivan del llamado Pensamiento Complejo, así como del Modelo MOSIG, y del diseño paramétrico actual en relación con la enseñanza, especialmente los procesos creativos. En una tercera parte, se debe ofrecer un material de referencia de algunas experiencias de enseñanza basadas en este tipo de modelo.

Palabras clave

Modelos mentales, crecimiento modular y proceso de fragmentación, diseño paramétrico, MOSIG, autorregulación.

1. Introduction

The expression "Complexity Theory" first appeared more than twenty years ago, in an article published in Scientific American (1978), but the birth of a "complex thought" occurred much earlier, at the end of the forties. Cybernetics scholars (Wiener, Weaver, Ashby, von Foerster) and information

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theory (von Neumann, Shannon, Marcus, Simon) were the first to address complexity. Over the years, thinkers of all disciplines have been adding to them. In 1984, while in the Old World the birth of the new epistemology was ratified by a series of international conferences ("Science and the practice of complexity" in Montpellier, "The challenge of complexity" in Milan. America would immediately become the most important international center for complex studies, particularly the Santa Fe Institute. Currently, as Doyne Farmer and Sidorowich (1987) point out, the theory of complexity is still very fragmented and resembles the theory of thermodynamics in the first half of the 19th century, when scientists began to have an idea of the basic concepts, but not all the issues had been outlined and there was no consensus in the scientific community.

The theory of complexity can be defined as the interdisciplinary study of complex adaptive systems and the emerging phenomena associated with them. Since we are talking about complex systems, it may seem obvious that complexity is an objective and intrinsic property of certain systems. In fact, according to leading theorists, the complexity of a system is not so much a property of that system, but a property of the currently available scientific representation of the system, that is, of the system model, or more precisely, since it is always the observer of the system who builds a model, a property of the system which consists, according to Le Mogne (1999) in: (a) the observer who builds the model and (b) the model itself.

Adopting this perspective is a bold step, because it means abandoning the objectivism of classical science, that is, the conception of being as a set of manageable and measurable objects, subject to the theoretical and practical domain of the human subject, and from a relational point of view towards being. From this new point of view, according to Gell-Mann (1995) a complex system is understood as a system whose current available model, built by the observer of the system, is complex. It is evident that complexity, thus understood, acquires a purely historical dimension: the models change with time and what is represented today as a complex may not be tomorrow, or vice versa. But how to evaluate the complexity of a model? The scientific model of a system is a not redundant description of the system in question; and the complexity is the length of this description. In summary, one can define the complexity of a system as the minimum length of a scientific description of it, obviously made by a human observer (Gell-Mann, 1995).

There are some features common to all complex systems, which can be synthesized in the following points:

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- Many more or less complex components: in general, the more complex the (sub) component systems, the more complex the system as a whole; in the more complex systems, the subsystems (i.e., the components) are also highly complex; components can be hardware (molecules, physical processors, cells, individuals) or software (virtual processing units).
- Interactions between components: the components interact when passing information (in the form of energy, material or digital information); the number of connections and the presence of recursive substructures and feedback circuits (the so-called rings) increase the complexity of the system, but the information exchanged by the components cannot be too numerous (otherwise the system becomes chaotic), nor too scarce (the system crystallizes).
- Absence of a pyramid hierarchy: if only one component governs the behavior of the whole, the system cannot be complex; in fact, its description can easily be reduced to that of the main subsystem.

This article aims to focus the issue of complexity in the study of gradients and processes of scalar fragmentation in the formation of modular fabrics and landscapes. The philosophy and history of science unite to see how to face this challenge in an interdisciplinary or transdisciplinary way, always from the perspective of Complex Thought (Morin, 2008).

Transformational modeling

In the study of form, two elements of contemporary thought stand out, which constantly recur in the aesthetic debate:

a) According to authors such as Martín López (1970) and Marinovic and Limone (1995), the distinction and possible integration, between diachronic and synchronous representation models within patterns, that according to Marinovic, Glaria and Marinovic (2017) are susceptible to a more or less wide variety of transformations. These approaches were presented by authors such as Piaget (1969), from the structuralism of the sixties, for whom the notion of transformational structure constitutes the axis of cognitive development, as adaptive dimension, therefore, in its last decades, should be devoted to the dynamic-functional dimension of the structure, where the diachronic structuralist analysis is insufficient, as a mere identification and characterization of periods, sub-periods and stages, and should rather be approached from its deepest scope. For all these periods, taken as a whole, would constitute a successive balancing

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process, that is; when achieving a dynamic equilibrium, where the previous structure is integrated in a new system in formation until reaching a new more stable equilibrium and with a wider field or new stadium (Piaget, 1969; Labra, Labra, Quezada, Cañete, Basaure & Mora, 2000). It is therefore essential to point out, following Labra (1995), that although:

> Each stage is characterized by the appearance of original structures, whose overall constitution distinguishes it from the previous structures, each period also stands out for having a series of momentary characteristics, which are modified by the subsequent development according to the needs of a better balance (p. 4).

This evolutionary continuity of cognitive structures then requires an analytical continuity, which explains the change of structures. At this point in the Piagetian explanation, we refer to Inhelder, García and Voneche (1981) to understand the complementarity of structural analysis with a functional approach and analysis:

> It is clear that such a structural analysis has its complement: a model that accounts for change. In fact, Piaget is not limited to the framework of a structural analysis of equilibrium states; its focus is mainly on the transition from one form of equilibrium to the next, that is, on the mechanisms of overcoming old structures by the construction of new structures (p. 11).

It can be said that these approaches have been the reference on which the problem of the phenomenal emergency has been installed from connectionism. These notions extend even to the concepts of scale, not only spatial, but temporal, because an object in scalar transformation can be described in different ways according to the scale with which it is observed or modeled. Therefore, the notion of scale becomes a bridge to the phenomenal field, generated from the notion of dynamic operation and structure or in balance.

Underlying the elements mentioned above, is the problem of temporality, expressed in concepts such as evolution and historicism (Prigogine & Stengers, 1992; Marinovic, 1995; Guzón, 2002), in relation to the problem of knowledge and the historical context, are also relevant on the aesthetic plane, from different confluences in relation to the models associated with the study of space and physical time, from changing dynamics emerging from the so-called dissimilar structures in constant transformation, but which, according to Prigogine and Stengers (1992) and Guzón (2002) present a surprising meta-stability. As these authors pointed out, with regard to their work The *New Covenant* (1979):

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> There we exposed the reversal of the classical paradigm that identified Entropy's growth with evolution towards disorder. We described the constructive role of irreversible phenomena and self-organizing phenomena that take place far from equilibrium (p. 10).

This meta-stability of the dynamics and processes far from equilibrium would point, according to this author, to the fact that time is finally irreversible, and therefore leads us to re-evaluate the notion of a phenomenal-existential time that points out: towards the need to overcome the negation of irreversible time, a negation which is the legacy bequeathed by classical physics to relativity and mechanics (p. 12).

b) Thus, on the one hand, at present, there seems to be a relative consensus that the phenomenology of the present body, following authors such as Francisco Varela and Evan Thompson (2000) regarding the phenomenon called as emergence, observed and described in connectionist models in neural networks, and that allows, according to authors such as Flores and Soto (2007) in Ibáñez & Cosmelli (2007), to approach the understanding of consciousness processes. In this context, the notion of mental image plays a rather modulating role within the models of functionalist cognitive currents and cognitive psychology in relation to the problem of intentionality. A nosological debate derived from the notion of essence, associated with the attribute of timelessness and mnomological universality, is thus installed and reinforced, in contrast to the material and historical temporality inherent in the existential debate. As a consequence, the notion of transformation and generative interaction of knowledge and cultural practices derived from it, especially in contexts of globalization and assimilation of new technologies to everyday life, appears as relevant and contingent (López, 1970). Moreover, this has revitalized neuro-phenomenological postures in function of action (enaction, in terms of Varela, 1999) and emergence in the world of the various types, degrees and ways of making conscious the activity of the subject, in its experiential flow. In this framework, the approaches of phenomenology, consciousness, virtuality of experience, semiosis and morphogenesis, appear as clear elements of what we could call principles (generative and active mediators) of individuation between the universal and particular categories proper to the debate between structure and function (and between essence and existence).

(c) Finally, reference should be made to various approaches, which, partly derived from the decontructivist positions, initially articulated as critical of functionalist and structuralist systems, as globalizing systems, will revitalize the theme of the linguistic-cybernetic models of the 60s

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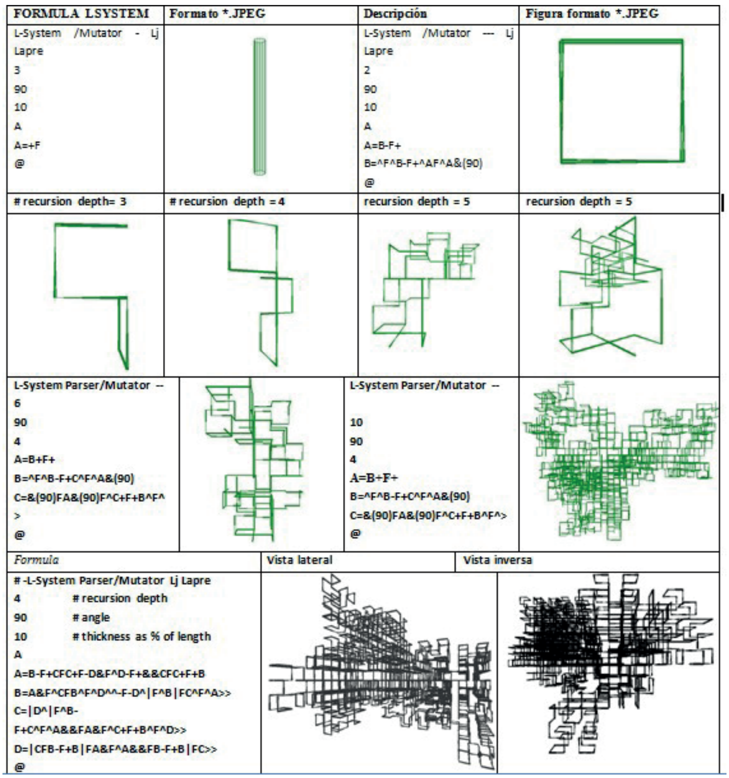
and 70s but from a post-modern perspective and, in many ways, quickly prefigure the hypermodernity (Baudrillard) that authors like Koolhas (2000) are going to develop in their famous book 'Mutations'. Rather, the impact of the deconstructivist postures allows us to explore and open the field of creative reflection towards notions such as portions, as pieces, fragments and partial or incomplete narratives, which could eventually be parts of larger chains, but that in their re-combinatoric and generative potential of alternating alterities, scenarios and proto-realities play a fundamental role. These reflections quickly offer a framework for what will be called generative design, and today called parametric design, where the algorithmic-operational notion, now articulated in operational metalanguages that privilege deformations, amplifications, and scale jumps, of diagrammatic-landscape type, which allow to configure, highly reversible and combinable, dynamic and changing networks and patterns.

Figure 1
Formal growth models of the iterated function language (L-Systems)



Source: Cañete, 2014

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It is clear that the development of the so-called morphogenesis is linked to this development framework.

Some key elements in this morphological framework of analysis will be reviewed below.

Aesthetics and morphogenesis

It is interesting to note that in art, especially in painting (so-called dynamic cubism, futurism, modern art, abstract painting, materism, abstract expressionism, minimalism, virtual or graphic computational art, kinetic art, etc., among so many others), have in different positions in this regard, not only from the principles and features that are postulated as eternal and immutable attributables to the aesthetic, but from conceptions where the properties of divergence, evolution, deterioration, transience, boom, degradation, fall stand out, in other words, transformation and mutability of knowledge and aesthetic enjoyment in plastic praxis.

In this scenario, an axis of debate of particular importance has been generated with the emergence and consolidation of models and geometries such as chaos theories, fractals, n-dimensional folds, neural networks, and so many others, usually associated with the so-called Theories and Models of Complexity (Morin, 1980; Oyarzún, 2000, Cañete, 2014) that has been relatively absent from the front line debate, highlighting several authors who have emphasized the importance of art and aesthetic understanding in culture and knowledge (Jay, 2003; Oyarzún, 2000).

In this context, from our points of view, we offer some elements of reflection on the problem of the fragment and the pattern as a framework of relative scopic confluence, in the words of Martin Jay (2003) in the post-modern epoch one entwines polarities usually associated with one or the other pole of debate (essential/existential; temporal/timeless; mnomological/contextual) and based on a kind of creative act that defines part of contemporary thought, by confronting, on the one hand, the minimal expressive elements of abstract painting (the point and the line as pointed out by Kandinsky) with the image and understanding of the inexhaustible and diverse natural world, still unexplored by the scientific mind (what Oyarzún (2000), has called synapses of the impossible) and which will be addressed below.

The study of irregular shapes and the formation of models

From the point of contemporary morphological modeling, the impact of the so-called Theories of Complexity (expressed in new geometries such

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as fractals) has revitalized the study of morphologies and morphological transformations at scale, generating a wide field of exploration that is generically referred to as the study of irregular forms. As noted by leading mathematician Benoît Mandelbrot (2000):

> Euclidean geometry is incapable of discovering the shape of the cloud, a mountain, a coast or a tree, because neither the clouds are spherical, nor the mountains conical, nor the coasts circular, nor the trunk of a tree cylindrical, nor a beam travels in a straight line. I believe that many forms of nature are so irregular and fragmented that nature not only presents a greater degree of complexity, but it reveals itself to us completely different (p. 9).

Consequently, this presents a challenge for the study of forms, which is:

> … the morphology of the amorphous. In response to this challenge, I conceived and developed a new geometry of nature and began to apply it to a number of fields. It allows us to describe many of the irregular and fragmented forms that surround us, giving rise to coherent theories, identifying a series of forms that I call fractals. Some fractal ensembles [have] such crazy shapes that neither in the sciences nor in the arts have I found words that describe them well (Mandelbrot, 2000, p.10).

A starting point then arises, in the progressive dissolution of boundaries in the operations between science and art, especially in the field of virtual modeling, where, as Oyarzún (2002) points out: the epistemological difference between the search strategies in science and in art is by no means irreconcilable (p. 65), and they are part of what we today even understand as our 'escopic regime' (Jay, 2007) which makes plausible the coincidence between what is seen and what the epoch considers normal to see, that escape to normality, to opinion, or to the taste of the epoch. This opening and dialogue between science and art takes place in the field of the study of morphologies, which brings us back to the approach of Kandinsky himself at the beginning of the 20th century, in relation to the importance he saw in the study of natural irregular morphologies for art, establishing a parallelism and ambit of confluences between science and art. As Kandinsky (1993) put it:

> The application of the line in nature is rich and profuse. Only a researcher, a scientist could carry out a study on this important topic. Especially valuable for the artist would be to realize to what extent the independent realm of nature applies the basic elements: which elements appear, what properties they possess and how they are combined. The

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> laws of composition of nature are offered to the artist, not to be imitated, since nature has its own purposes, but to be confronted with those of art (pp. 110-111).

Consequently, this notion of transformational structures, in which form or object at different scales are important, but also in different moments and times, out to think space and time united through form and its trans-formations. Thus, taking this broad, dynamic and still emerging field, it is possible to indicate various moments in its historical evolution, where the artistic development is configured as theoretical, from which certain parallels between principles can be articulated, artistic and scientific approaches. In this counterpoint stands out both minimalist and abstract pictorial expressions typical of modern art (pe. Kandinsky, Moholy-Nagy or Klee) as well as mathematical and morphologies such as fractals, iterated systems or theories of chaos (Lyndenmayer, 2000; Prigogine, 1999; Mandelbrot, 2000). In this affinity and confluence, it is possible to affirm that from the beginning of the twentieth century until today, a field of study of the so-called irregular morphologies has been configured, which has gone through various stages (see chart 1). A case study of these irregular forms, must be cases as the formation of landscapes, textures or major morphological conglomerates (with scalar properties) but that preserves an essential organization, as well as being moments of continuous complex transformation and interaction.

From the module in transformation to the conformation of textures and landscape

The study of forms has always required certain metaphors to guide their understanding and assimilation. Prominent roles have been assumed by the images of glass (Marchnt Fiz, 2008) or of the growing tree as the axis of botanical transformations in the modeling of iterated patterns (Lindenmeyer & Przemyslaw, 2000), or recently the image of the fragment in transformation in the so-called, fracture modelling (Cañete, 2014). As Bohm (1976) rightly points out regarding the role of the image as an underlying metaphor guiding an investigation:

> The proper role of metaphysics is that of metaphor that provides an immediate perceptive understanding of the global order and structure of our thoughts. It is, for this reason, a poetry class. Perhaps some stubborn individuals would object to the intrusion of such poetry. But, just as Moliere spoke of the man "who made prose throughout his life without knowing it", so the man of practical spirit "makes poetry

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> throughout his life without knowing it". The point I want to make here is that all of us will begin to think more clearly when in a frank and open way we admit that a great deal of extreme common sense and positive science is really a kind of poetry, which is indispensable for our overall functioning (pp. 244-245).

On the other hand, these images also tend to pose enigmas, as Aristotle has reminded us for so many centuries in his famous *Poetics*, especially with regard to how far and how to carry out the final consequences and inferences of such a metaphorization. In this case, one can focus on the interest in the metaphor of fragmentation as a mechanism associated with the study and modeling of transformation processes, which, especially in the light of another modern image, of "straight and pure lines", typical of much of modern art initially, such as cubism, Bauhaus, minimalism, abstractionism, materism, or various post-cubist forms of expressionist type and hybridization, among so many others, which have decisively influenced the development of contemporary art.

In the first place, as a background, it should be pointed out that, primarily, we have to study the so-called "textures", typical of the modern movement, especially of currents such as the Bauhaus, where this was initially approached as a property of the surfaces of the materials, whose purpose for the artist is only given to the extent of the possibilities that its use allows him through a functional biotechnique. Thus, initially the texture is assimilated as a mere ornamental quality associated with the use and functional sense of the working material. The importance of biotechnical use was understood to be associated with functional use, emphasizing in instances such as camouflage, ornamental colors or the assembly of layers in artisanal fabrications in order to avoid warping or torsions in wood or other material (Cañete, 2016b).

It is worth mentioning that despite the importance that the Bauhaus, in particular (and formalisms and constructivism in general), assign to the study of compositional and constructive processes, it has not been developed, in the texture, a mechanism that generates surfaces, planes, and spaces, as in the present it is conceived and studied, in addition to the previous properties. Possibly, the effort to avoid the problem of ornamentation, only allowed them to value it (the texture) in its functional properties in the design, such as camouflage. It seems that the exhaustion of structuralism, its dissolution in post-modernity, as well as the persistence of phenomenology in various fields, among other isms, is what configures a transversal field, where we can assess the fragmented or at least "in transformation", as a sharp and constitutive sphere of

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knowledge. In this new scenario, the linguistic-generative properties of textures have given way to other strategies, such as:

The tension and dynamic balance of Irregular Gestalt Perceptual Configurations.

- The morphological transformations associated with a Pattern Language, associated with the study of Iterate Systems (Lindenmayer, 2007) where the metaphorical image of growth predominates, on the one hand, and the image of fragmentation on the other.
- Strategies of Emerging Interactionism as in the works of Prigogine (1992), Maturana (2000), Verela (2000), Thompson or Kauffman (2002).
- The scalar qualities of Complex Geometric Transformation Processes (Mandelbrot, 2000). In this field, the attempts to shape and articulate holist metaphors will stand out, where the properties of scalar similarity or scalar differentiation, within the same system, stand out

Figure 2
Comparative table of morphological properties
in regular and irregular geometries

Regular Forms	Irregular forms
Regular closed forms	Open shapes, conurbated or fragmented
Euclid Geometry, Polyhedrons (regular and semi-regular)	Textures, gradients, fractals, landscapes, nodes and graphs, fragmented shapes, ect.
Symmetry, focusing on closing and balancing processes	Asymmetry, centered around equilibrium tension and rupture processes
Unique and defined centers	Multiple centers, centroids, and not fully defined
Generated by linear equations	Generated by non-linear equations
Without scalar properties	With scalar properties
Associated with finished and defined forms	Associated with incomplete shapes and in transformation process

Source: Own elaboration

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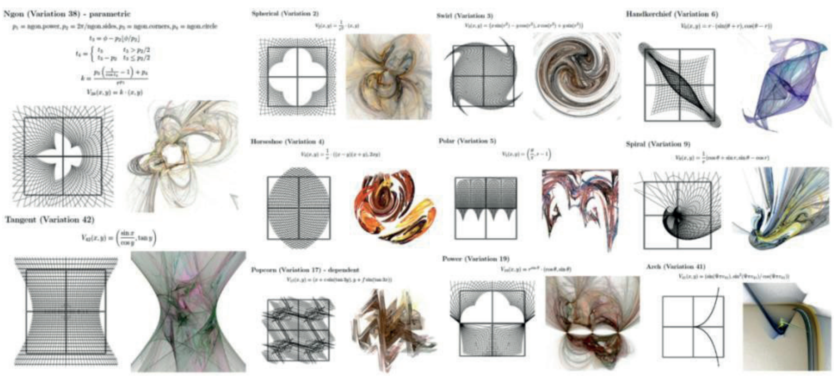
Morphology and digital modeling based on algorithms

In the current scenario, many of the new modes of plastic and aesthetic expression appear to be associated not only with the use of graphisms and morphologies, but also with the mixture and interdisciplinary polymic integration, that are progressively integrated and assimilated from the possibilities offered by contemporary digital design. In this way, together with the development of computing and the consequent acceleration in data processing, morphology modeling was enhanced by the cyber-systemic leap allowing to incorporate both positive and negative feedback processes (iteration of functions), such as amplifier mechanisms and deformators of an initial signal or noise. This step was decisive for the conformation of geometries such as fractals and the study of nonlinear equations, by incorporating into the algorithmic baggage the notions of language and metalanguage of functions, acting as a modulating mechanism in the morphological design.

Figure 3
Equations reveal different morphologies



Source: Draves and Rachase, 2008

The morphological modeling allows the design of different patterns that are modeled from equations, each acting differentially on the cloud of points. This generates a kind of aesthetic of the formations, and makes the equations a true generative morphological alphabet and language with aesthetic implications, especially when considering their possible combinatorics and dynamism at scale.

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Post-structuralist contemporary perspectives

In the current scenario, even considering post-modern objections and de-constructivist tendencies, it can be said that underlying a mechanism of transitions and flows are the notions of structure (as an organization), function (effects) and energy (dynamism). In this line, authors such as Marinovic (1995) and Vinet, Knox and Marinovic (2013) have formalized in meta-models where, they import transitions between these categories when describing a system more comprehensively, being these, true homeoretic dimensions based on a continuous generative balance between these dimensions and their transitions and emerging transformational interactions. By the way, this general scheme may give rise to a study in which one or other of the triad's poles predominate, minimize or unroll. In this context the balancing and homeoresis are the creative source and genetic morph of the system. It is therefore appropriate to review Marinovic's approach to this in his MOSIG model, which allows us to understand certain inferential relationships, as transitions between plans and design levels.

Precedent to post-structuralism

MOSIG MODEL

According to Vinet, Knock and Marinovic (1995) social systems show the same characteristic aspects of integrity of living systems or self-organized systems. From a simultaneity perspective (Synchronous vision) it is possible to identify three fundamental components in a self-organized system, which answer the questions with what? How? And for what? The answers to these questions generate the Energy, Structure, and Purpose components, respectively. From a succession perspective (a diachronic vision) these three components correspond to the primary functions of preservation, integration and development, respectively.

Thus, the MOSIG model distinguishes three additional perspectives: Relational Vision (system behavior), Vision of Stability (system stability) and Context Vision (system coupling and its environment) (see Figures 1 and 2).

According to Marinovic (2005, 2008), the behavior of a self-organized system can be observed during its coupling with the context (environment, scenario) in which it is immersed. In this way, and as the context gives meaning to the text, during this link the system will behave as a) stable, b) unstable or c) critical of collapse (Fig. 5).

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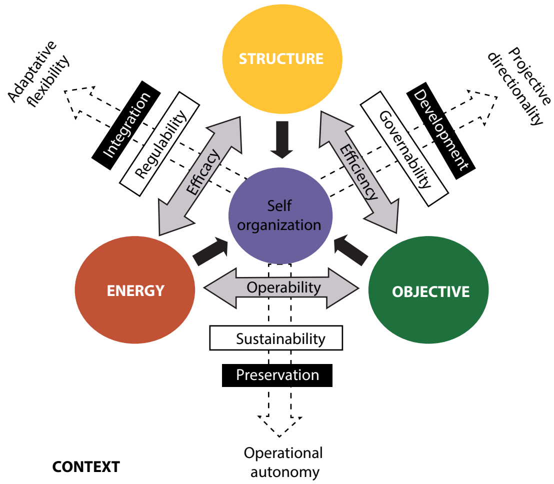
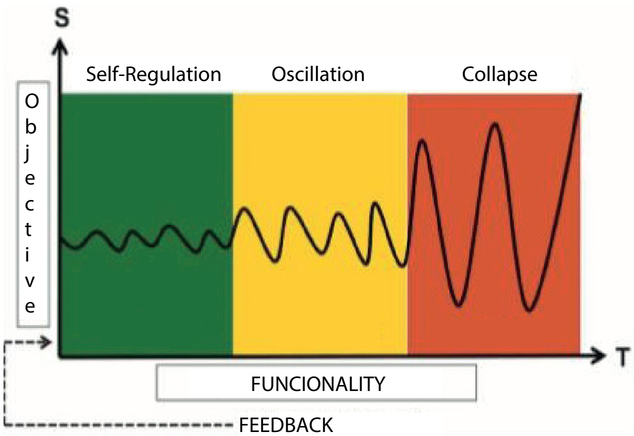
Figure 4
MOSIG model



Source: Marinovic, 1993; 2013

Figure 5
States of stability and instability of a system



Source: Marinovic

From the above, it have been opened, as morphogenetic field of exploration, models that allow to understand the transitions of a system, where some of the variations and systemic dimensions prevail, be it the structure, the function or the energetic state, in the sense of being able to

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understand the phase transitions or the relative and variable weights of each dimension within the dynamics and process through which a system goes, in its adaptation and linkage to the environment. In each of these transitions and states of phase, dynamic and generative balances must be created, which puts the dynamism and creativity at the heart of the debate, both within the social body and in the educational models (Figure 8).

Figure 6
Conceptual-operational levels of the MOSIG model

Hierarchical expressions	**CONFIGURES Special**	**DYNAMIZES Temporal**	**VISUALIZES Relational**	**EXPLAINS Stability**	**MEASURES Adaptability**
Social System	Constitutive Coherence	Axiological Coherence	Operational Coherence	Functional Coherence	Coupling Coherence
What for?	Objective	Development	Efficiency	Governability	Projective directionality
How?	Structure	Integration	Efficacy	Regulability	Adaptative flexibility
With what?	Energy	Preservation	Operability	Sustainability	Operational autonomy
Views on Systemic Analysis	Synchronic view	Diachronic view	Relational view	Stability view	Context view
Perspectives on Systemic Analysis	Simultaneity	Successions	Behavior	Stability	Coupling

Source: Marinovic, 2008

As can be seen, the MOSISG model not only proposes the alternation, continuity and discontinuity between the planes of order, chance and self-regulation, of utmost importance within a creative process that is affectively integrated to learning, but also poses complementary questions that must be addressed from pedagogy and teaching, related to how each intervention is configured, energized, visualized, explained and measured, which refer to the meaning, purpose, development, efficiency, handling and projection of the work.

In this framework, the possibilities offered by morphological explorations in general, and parametric design, in particular, as a procedural instance, that can be guided and integrated from creative processes, in our case, into the field of teaching-learning of architecture, expressed in the design of spatial, pre-architectural models that allow later integration into higher degrees of elaboration, subject to structural, functional, locational, programmatic, and, finally, project studies, must be addressed.

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Morphological exploration and parametric design

These explorations related to the importance of textures allow a polyphonic-operational integration from at least three fronts. On the one hand, it allows us to rethink the problem of the surrealist or even Duchampian *objet-trouvé* (associated with the study of installations and the so-called dynamic cubism) with regard to the subjective-objective encounter with chance as the source of the aesthetic enigma. On the other hand, this conception must be enriched with the minimalism of abstract painting and computer graphic artists (Atari, 2011). On a third front, it is the encounter and evolution of these historical influences with the virtual morphologies regulated by parametric operations, which generates a similar pattern of morphological exploration of our study (Schumacher, 2008).

This new type of formal operations allows modeling morphologies based on compositional processes such as: a) the scalar discontinuity and continuity of the line, b) the perceptual conformation of active lines and surfaces as an effect of vectorization, c) the transitive conformation and gradation of morphological interiorities and exteriorities, d) the relationships between cut and planar shape and the genesis of the vacuum in the volumetric projection, or e) the relationship of tension and dynamic and transformational balance between generative patterns in the nascent shape. This is detailed in some of the following points.

- The Triad: Linear Order-Complexity-Randomness. The inclusion of irregular forms and relationships has broadened the horizon from which the notion of order was understood, moving from a static and preconceived conception to a changing and generative notion. The linear order is seen as part, just a moment within a continuum, with maximum levels of completeness, delimitation, inclusion, order and symmetry, that coexists with the so-called orders out of balance or by fluctuation, generative and transformational, typical of the Theories of Complexity, where partial and changing scale symmetries predominate, with a range of gradients, textures typical of the scalar variations such as fractals, folds, bifurcations, thomian catastrophes, conurbations and theories of chaos. From this complex order, one passes to the plane of stochastic associations and variations, which tend to the temporal and spatial dispersion of any system, where the discontinuous repetition of patterns or proportions, is the most stable mode of harmony or symmetry (more typical of previous levels). In this framework, chance appears as the closest limit to systemic disintegration, typical of disorder and neguentropy.

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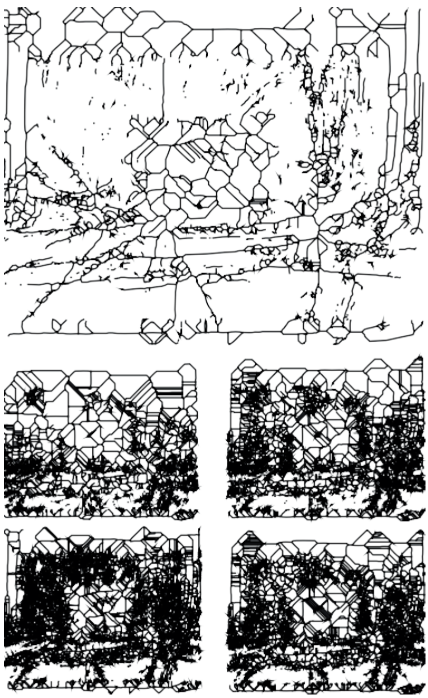
- The Study of transitions and hybrid formations, texture and landscape. The fractal lines that are conurbate and branch to scale, in processes of fragmentation and formation of gradients, allows the emergence of continuous interactions with the form and the environment, through proportions and tensions between planes and forms, alternating between regular and irregular compositional patterns. The above allows to explore, compositionally, the mixture and morphological variations from the continuity of the conurbation of the line or fragmented stroke, which allows to appreciate the forms thus created, as patterns and global figures, oscillating between points of greater or lesser opening or gestalt closing, multiplying, varying and alternating spaces of greater or lesser interiority or exteriority at the same time. The whole of this evolution process is a source of landscape generation.

Figure 7
Progressive morphological vectorizations
with different scale factors and transforming gradients



Source: Cañete 2012, 2016, 2017, 2018

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These principles allow us to rethink the classic distinction between regular forms, conceived as ideal forms, and the rich and still little systematized range of irregular forms and relationships, usually conceived as transformational and interactive.

Methodology

Given the above, the author has worked on a model based on the following principles:

- Linear Order and Order of Complexity: The study of complex forms has expanded the field from which the notion of order was understood, moving from a static conception to a changing and generative look. generating new irregular morphological configurations.
- Fractal morphology: This dimension will be modeled using image vectorization techniques such as the use of iterated languages, resulting in pure lines that branch, twist and scale into morphological units, maintaining a global compositional coherence from the same essential minimalist trace.
- The study of patterns and textures as transitional forms in morphological transformation: The fractal lines, which generate patterns through transformation to scale, allow the modeling of processes of growth or fragmentation, based on continuous interactions between regular and irregular patterns, varying and alternating spaces of greater or lesser interiority or exteriority. The whole of this evolution can be identified as a form of vectoral landscape.

Following these criteria, minimalist morphological patterns are generated that allow the design of shapes and spaces, with pre-architectural value and sense, that can progressively be assimilated and adjusted to architectural, projectual, functional criteria, and others, following levels and moments of complexity and development.

Morphological experiences of procedural modeling

The study of this type of morphology appears as the general framework for the development of teaching and learning strategies in creative ways in relation to the problem of the assimilation of form from a pedagogical framework of architectural teaching, which has been addressed by the author, both at the teaching level and in successive visual arts projects

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funded by FONDART (Cañete, Bahamondes, López, 2012). From these experiences and scope of digital morphological exploration the following work principles were derived:

- A general approach of the minimalist type.
- A generative-transformational approach.
- A relational-configurative process, ranging from the notions of module and assembly to the notions of landscape and digital landscape.

On the other hand, from the pedagogical point of view, the aim is to encourage in the student the exploration and individual expression, suggested from the very exploration of modeled forms. This allows us to distinguish levels of morphological-operational complexity, on the one hand, and levels of aesthetic-architectural assimilation explored on the other hand, directing morphological-spatial models oriented, both towards; a). a pre-projectual sense and/or; b). a morphological-aesthetic sense akin to the previous point. The above has resulted in the following model and general methodology of work, using various materials, in different experiences and commissions since 2015, called: Generative Minimalism, whose formal principles are associated with procedural mechanisms (operatory-algorithmic) modular growth and fragmentation scale defined by Cañete (2017). In this framework, a working model for morphological modeling is proposed, with the following general characteristics:

Architecturally mediated algorithmic modeling

The following complex exploration model can be summarized in three axes, morphological, algorithmic (procedural) and architectural, and can simply be abbreviated as MAA:

Morphological Complexity of the Pattern: This complexity ranges from:

- Individual or grain module level.
- Tissue, pattern or landscape level.

Level of Algorithmic Complexity: Spatial-morphological operations, such as: filled, void, extrusions, circulations. These have two algorithmic levels

- Joint operations.
- Local operations involving particular modules or sectors.

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Level of Architectural Complexity: A continuum of two formal poles:

- Pre-projectual sense.
- Morphological and spatial sense, as an aesthetic expression (includes approaches such as installations or formal interventions).

This is summarized in the following diagram of pedagogical complexity:

Figure 8
Working model, by type and complexity of design

Tipos de modelación morfo-espacial		Nivel de complejidad pre-arquitectural	
Modelación morfológica en base a ecuaciones no-lineales y tramas vectorizadas e iteración de funciones	Diseño espacial en base a crecimiento y fragmentación de tramas modulares Diseño espacial en base a deconstrucción de volúmenes y ensambles modulares	Nivel 1: Incluye Variables como: a). Vacío y espacio arquitectural, b). Circulación, recorrido y promenade. c). Jerarquía y relación espacial entre volúmenes	Nivel 2: Incluye, además, variables como: a). Niveles y accesos, b). Sub-unidades (piezas morfológicas) c). encajes o ensambles modulares entre niveles.

Source: Cañete, 2018.

This type of morphological modeling of textures and global landscape patterns has been approached within the framework of parametric design and modeling, and explored by the author, in successive visual arts projects funded by the Regional FONDART of visual arts. It has also been developed as part of the fractals and form module, at the City Workshop, in the third and second year of the architecture career of the University of Valparaiso, respectively. However, in addition to the formation of landscape textures, it was also interesting, as a means of exploring the process of morphological transformation as a generative language (taken to the plane of fragmentation and modular assembly) and its possibilities as a methodology for exploring interstices, volumes, assemblies and relationships between pre-architectural modules, which the texture suggests.

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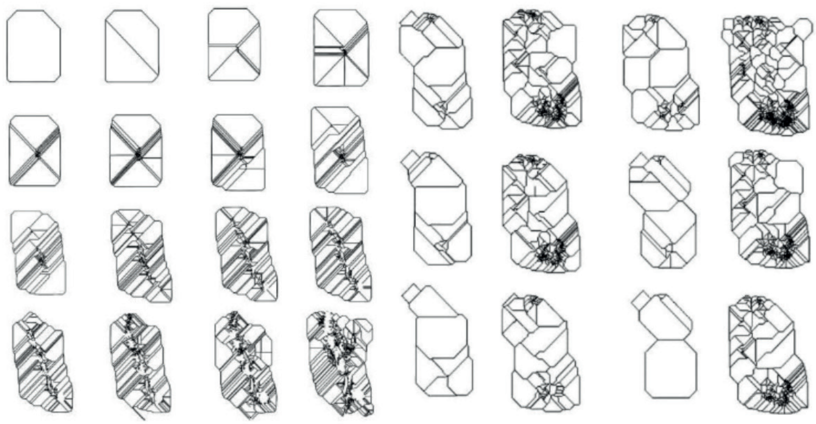
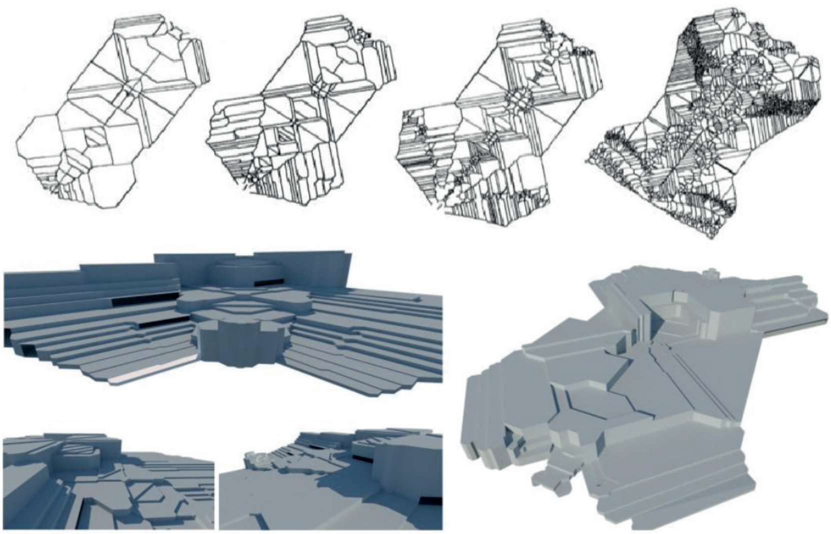
Figure 9 and 10
Studies of the formation of transformational morphologies based on fragmentation processes and vectorized modular growth



Source: Cañete 2014, 2016, 2018.

Fig. 11 and 12
Variations of configuration of independent modules, generated from a vectorized modular pattern



Source: Own elaboration

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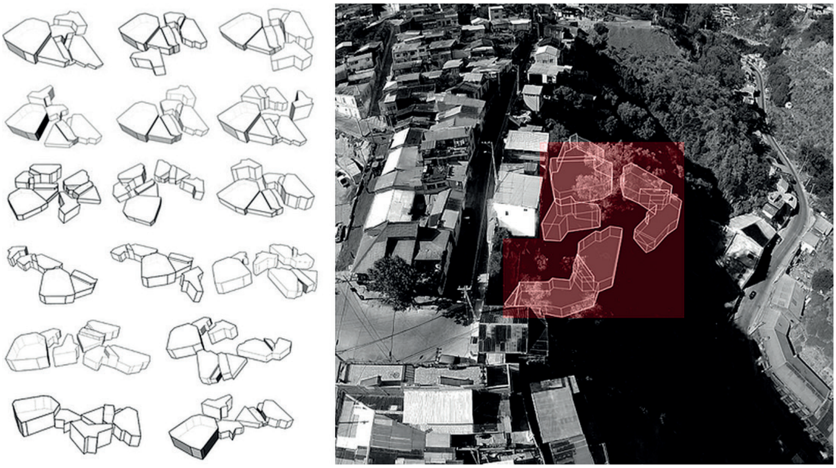
In this sense, experiences are articulated as a method of genetic morpho exploration that is generative and creative, proper to the so-called complex thought, since it requires processes of cognitive emergency, regulated by procedural planes, oriented to purposes, but from plans and metacognitive levels that allow him to orient the problem of the form to a formal field of modeling.

Moreover, this type of experience does not necessarily admit a single result, being able and allowing different solutions from the morphological point of view, but from the meta-regulatory level of the pre-architectural criteria to which it must conform. However, this is a self-regulatory and generative process that gives it flexibility and procedural robustness.

Figure 13
Exploration and placement of modular clusters in the territory



Source: Cañete and Bravo, 2018; in Review.

Conclusions

Complex thinking has developed on various bases and principles elaborated and refined during the debate of the twentieth century. Among them, the convergence of the transformational principles characteristic of structuralism stands out. Which derives in processes of creative and generative, and not only re-productive, modeling in addition to increasing regulation and understanding of these creative processes from perspectives and synchronous and diachronic principles of all process-inte-

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ractive levels. To this are added different levels and forms of information configuration to generate emergent fields, based on scalar adjustments of the primary data, in mechanisms of generative feedback. This allows us to assess a new feature, which is to generate multiple solutions and pathways, for similar initial working conditions, even if they meet the same purpose criteria.

A particular case of these emerging processes has been the study of complex patterns and morphologies, such as fractals, iterated systems or theories of chaos, progressively assimilated into and from fields and disciplines in art, in general, and architecture, in particular, of which some cases and teaching experiences relating to them have been presented. This clearly opens up a growing area of confluence between science and art, typical of complex interdisciplinary thinking, in which this era is breaking through.

In the strictly disciplinary sphere, from the point of view of the contents and themes that cross the debate in architecture, and from which the subject of forms, in general, and the various scientific or artistic models, currents, approaches that arise in other disciplines are assimilated, has been the framework generated from modern architecture, with the principle of pure forms that currently continues to have an important weight and project validity. This has conditioned that the problem of architectural forms, respond not only to its functionality and systemic capacity to solve or address the various design plans of a work, but rather, today, as an aesthetic-refining criterion of the morphological explorations that, from various authors, moments and currents, are continually raised, appealing to it.

That said, it is important to highlight this aspect of self-regulation of knowledge and its generation, linked to creative processes, since creativity is also part of a larger process that seeks to integrate and be guided by criteria and solutions to a problem, according to different conditions to be elaborated, according to levels of complexity. Indeed, this approach allows not only a new way of approximation to the plans related to the resolution of problems, on the one hand, but to the creativity underlying an approach that admits and enables various possibilities of development and results, refined since its act, as procedures that act on a form, following different criteria that regulate variables such as space, circulation and its integration with design, aesthetic, functional criteria, etc. that are acting, as layers of work in a creative process.

This allows to advance in the development of work models, through the notion of conditions of a problem, regulated by the active and mediating role of the teacher within a creative process. For this, it

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is necessary to ask not only the what, but also the how and the why of a creative process, establishing various levels of creative interaction, in a way that is sensitive to conditions, and especially to transitions and moments of interaction between one plane and another, and the open possibilities that its constant exploration creates.

Finally, this type of approach also opens a field of self-observation and regulation measured and mediated on the students' own creative processes, since they can have pre-project exercises that allow them to take the weight, impact and constant flexibility of a morphological-spatial act, from a perspective of continuous transition from and towards the project itself.

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