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Paper: **ARCHITECTURE OF GENERATIVE SITUATIONS**

Topic: Architecture

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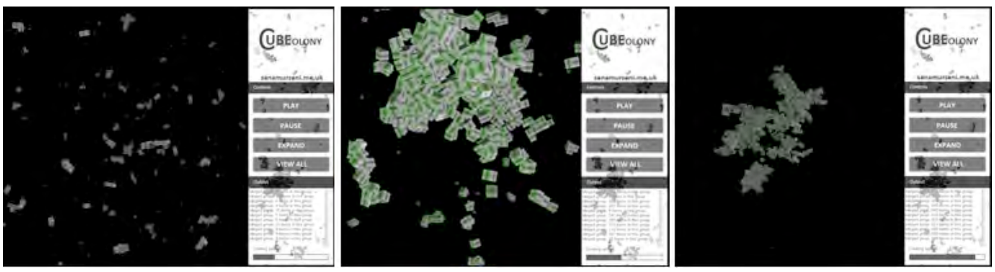
References:
[1] Marcos Cruz and Steve Pike, *Neoplasmatic Design,* in AD Vol 78, Issue 6, 2008.
[2] Sanford Kwinter, "*Architectures of Time: Toward a Theory of the Event in Modernist Culture*", MIT Press, Cambridge - MA, 2002.
[3] Humberto Maturana and Francisco Valera, *Autopoiesis and Cognition: The Realization of the Living,* D. Reidel Publishing Co, Dordecht, Holland, 1980.

Abstract:
Interdisciplinary debates focusing on the cybernetic and biotechnological advancements of semi-natural systems in architecture have contributed a great deal to the creation of new design imperatives and theoretical discourse in the field of experimental architecture (Cruz and Pike, 2008). This paper explores interim stages of such advancements theoretically and practically derived from biology and cybernetics, based on the writings of Francisco Varela and Sanford Kwinter, as well as the work of Marcos Cruz and Steve Pike.

The paper will exhibit and illustrate through a simulation elements of cellular automata and autopoietic system behaviour (Maturana and Valera, 1980). This research establishes that such principles and processes in biology have a direct impact on the creation of generative situations in architecture. Furthermore, it illustrates the difference between the being of architecture as an outcome of the process of design and the becoming of architecture as a generative and collective process of situations. *Situations* as opposed to mere forms and spaces in architecture are the elements of this paper.

Situations imply a spatio-temporal generation of objects, forms, spaces and events that exhibit unstable states in a system. They are considered as seeds of emergence in the process of becoming in architecture – singularity in-between complex systems and architecture (Kwinter, 2002). This is a theoretical paper – with an element of practice – that seeks to distinguish between generativity for the process of being in architecture and generativity for the *process of becoming*, where the latter is the central focus of this research.



Snapshots of the Cubeolony simulation (Murrani 2010).

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Keywords:
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Architecture of Generative Situations

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Abstract

Interdisciplinary debates focusing on the cybernetic and biotechnological advancements of semi-natural systems in architecture have contributed a great deal to the creation of new design imperatives and theoretical discourse in the field of experimental architecture. This paper explores interim stages of such advancements theoretically and practically derived from biology and cybernetics, based on the writings of Francisco Varela and Sanford Kwinter, as well as the work of Marcos Cruz and Steve Pike.

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Interim Stages: Experimental Architecture

The influence of interdisciplinarity in architecture accounts for the change in its generation through the media of representation from the past, present and future of design tools, presentation techniques and drawings to the experience of architecture as a whole, and is also the motivation of this paper. Both representation and experience have a direct impact on the development of the tools of design and generation as well as interactivity in architecture. This is due to the tools of representation and methods of generation that have changed and developed dramatically under the influence of the technological/digital and biological advancements of the current age [1]. This has had a great impact on the way we perceive and conceive architecture and to some extent has called for a divided age of representation. As a consequence our experience of architecture as well as our consciousness is constantly changing to adapt itself to new trajectories of perception and cognition [2]. The inputs of this paper – experimentation in architecture under the influence of the biotechnological age and the principles and processes of generativity – are at the core of interdisciplinary debates concerning complex systems and technological generation that have contributed a great deal to the dynamism of the architectural system of generation, representation and experience [3]; [4].

Nature builds architectures composed of trillions of moving components; the number of interactions between these components increases exponentially with the number of the components themselves and so these architectures are inevitably complex. This complexity confounds conventional design methods. Thus, superficial attempts to copy nature in which rigid modularity is enforced - for example by claiming a correspondence between cells and bricks – will be certain to fail. Architectural design methods must have some kind of basis in natural systems in order to model natural survival, but the outcome of such methods does not necessarily have to be the same as that of nature. In fact, this paper focuses on obtaining relevant knowledge from natural systems, analysing it, reconstructing it, and using it to build a new hypothesis, a hypothesis for design and generation evoked by experimental representation in architecture.

Attempts at reaching some levels of investigation in this field of semi-natural systems can be seen stretching from the work of artists such as Oron Catts and Ionatt Zurr in their Tissue Culture & Art Project (initiated in 1996), the work of architects such as Marcus Cruz and Steve Pike in their prosthetic architecture, and extending to Philip Beesley's immersive and interactive environment created for Venice Biennale 2010 Hylozoic Ground. Cruz and Pike's projects deliver a degree of integration between biological entities and design practices on a conceptual and experimental level. This can be seen in their publication Neoplasmatic Design which is full of vivid examples of experimentation and explorations of the field of biology in relation to design and representation practices in architecture. This collection features their own work such as Contaminant and that of invited guests from Comfo-Veg Club (1970s) by Peter Cook to Density Fields in Viscous Bodies (2008) by Tobias Klein [4]. In their own words, Cruz and Pike describe such new bio-architectures as composites that sometimes appear as constructed entities and other times as living beings, explaining "The line between natural and artificial is progressively blurred" [4].

In their work, Cruz and Pike strive to connect design processes to current biological phenomena such as genetic engineering, cloning, and transgenics. Such attempts to model biological principles in architecture are not unprecedented. They extend historically back to Le Corbusier's suggestion of buildings that function as an organism, passing by designs by Buckminster Fuller and Frei Otto (inspired by D'Arcy Thompson's key work On Growth and Form), reaching the Neoplasmatic designs of Cruz and Pike. In fact, this historical background of the use of different techniques in design and representation in relation to the current tools and media of representation has played a great part in shifting the purpose of technology from the use of mechanical and clinical machines into the involvement of prosthetic technoscientific devices that have become an extension of our own bodies. Such a shift was reflected in the tools and media of representation and communication.

Cybernetics and Architecture: Between Principles and Processes

Architecture, like nature, is composed of overlapping and interacting complex processes based on the methods and designs of its generation, tools and representation as well as the media in which it is experienced whether it is physical, digital or hybrids of both. Most such complex patterns in nature are formed out of equilibrium; i.e., they are not in their most thermodynamically stable state [5]. In other words, they are systems, which never reach equilibrium, and their processes always have a cyclic nature, such as, the flow of rivers, the growth of cities, and the complexity of networked societies.

Architects, engineers and designers have always been fascinated by nature's various patterns and their formation on multiple scales and levels of sophistication. Nevertheless, there is a single aim; it lies in learning techniques and rules that can be taken into another field, such as architecture, which have been tested in nature. Thus nature is the medium of all interim stages of experimentation and exploration on different scales, relating to the technology and potentiality of materiality, principles and processes of formation and existence, or meta-perception and cognition of its innovative speculations. The methodology of extracting principles and processes from a certain field and applying them into a different field is in its essence a cybernetic approach "[…] the science that studies abstract principles of organization in complex systems" [6].

In addition to this, cybernetics focuses on the possible behaviours of its variables rather than their material presence [7]. Most important for this paper is second-order cybernetics (also called the new order) and this is defined as "[…] the study of the role of the (human) observer in the construction of models of systems and other observers" [6]. Cybernetics was popularized in the late 1940s by Norbert Wiener, a mathematician and scientist who was especially interested in the structure and behaviour of machines. More importantly he focused on principles and processes of control and communication in self-regulating systems such as the animal and the machine as well as their elementary mechanisms of behaviour [8].

In an attempt to define behaviour in architecture based on Wiener's findings; change can occur to any architectural form and space in their environment and context. In architectural terms, output would mean changes in the material and immaterial representation of architectural form and space, while input can mean changes in the architectural experience; such as, the behaviour of the observer/user as well as changes in the environment, day and night, etc. Therefore, and in order to establish the behaviouristic approach to architecture as a system; generation, representation and experience are vital processes that feed back into each other, and hence, cannot be separated [9].

To imply behaviour in architecture through cybernetic principles does not mean referring to architecture which attempts to illustrate cybernetic processes, nor to an architecture which embodies cybernetic machines such as robots. On the contrary, it is the relationship between the underlying forces which construct a cybernetic system in architecture that is the crucial concern here. These underlying forces are what Wiener refers to as the changes between the output and the input which result in behaviour. On a deeper level the underlying forces link directly to the circularity, feedback and communication processes of cybernetic systems, such changes in behaviour will alter our perception, and allow us to realise and utilise new techniques of representation which in return will evoke new experiences, experimentations and conceptions in architecture on a theoretical and practical level.

Cybernetics contributes a great deal to inventions of current contemporary design and presentation tools in architecture such as Computer Aided Design (CAD) programmes. However, this is just the superficial relevance of cybernetics to architecture. Gordon Pask in 1969, described a deeper level of this relationship, where he states “The argument rests upon the idea that architects are first and foremost system designers who have been forced, over the last 100 years or so, to take an increasing interest in the organizational (i.e. non-tangible) system properties of development, communication and control” [10].

Pask referred in his famous article The Architectural Relevance of Cybernetics in 1969, to examples of system designs such as the ingenuity of Temple Meads Station (1840 by I. K. Brunel) and the Crystal Palace Exhibition (1851-1936 by J. Paxton). Their inventions of the use of iron and glass to fulfill certain emerged needs in society, were excellent examples of system designs. Pask had predicted a cybernetic theory of architecture which would make use of Computer Aided Design (CAD) programs to help develop useful instruments in design, and principles and processes in different disciplines such as psychology, ecology and economics. A cybernetic theory will have a greater unified influence on architectural theory for analyzing or generating system designs. Architecture will “act as a social control” where it will be difficult to isolate or separate it from its users and their experiences, and eventually be able to generate dialogues between the architectural environment and its inhabitants, users and observers through new material innovations and involvements in Artificial Intelligence (AI), Virtual Reality (VR) and later on Interactivity [10]. These predictions meant that architects will eventually be able to create complex architectural systems out of simple inputs. This is in principle what architecture in the mid 1800s evidenced by the innovative designs of Paxton and Brunel achieved, and this is at the core of the elementary principle of complex systems from which cybernetics as a field emerged.

The key writings by Gordon Pask of the New Cybernetics are about putting the observer in the heart of the system of observation [11] and emphasising von Foerster’s vision for “a cybernetics of cybernetics” where the observer enters the system and is allowed to stipulate his or her own purpose [12]. The cybernetics of cybernetics (also known as second-order cybernetics) carries principles of the first-order. It in fact came into being in the 1970s as a continuation rather than a break between the generations with its elementary focus on autonomy, self-organization and more fundamentally, cognition [13].

In their book Autopoiesis and Cognition: The Realization of the Living, Humberto R. Maturana and Francisco J. Varela define living systems as units of interaction that follow the structure of their organization while maintaining the circularity of their interactions with the observer [14]. “A living system defines through its organization the domain of all interactions into which it can possibly enter without losing its identity, and it maintains its identity only as long as the basic circularity that defines it as a unit of interactions remains unbroken. Strictly, the identity of a unit of interactions that otherwise changes continuously is maintained only with respect to the observer, for whom its character as a unit of interactions remains unchanged" [14].

This indirectly leads to the assumption that the cognition of spatial architecture is dependant on the articulate organizations recognized in patterns that can be derived from abstractions of biological systems. Concurrently, returning to the assumption that irregular patterns are formed out of equilibrium, meaning they never reach a stable state, we can conclude that architectural forms and spaces are patterns that are potentially transient too. As a consequence, layers of patterns of articulated organizations and abstractions become part of the spatial and temporal architectural system, which will evoke constant change in the outcome, whether the outcome is the entire system in general, or form and space in particular.

Generativity between Being and Becoming: Situations

One of the leading architectural critics, the first to write extensively about the effect of the complexity of natural systems on architecture, is Charles Jencks. In 1995 Jencks wrote a book The Architecture of the Jumping Universe, A Polemic: How Complexity Science is Changing Architecture and Culture. In this book he endeavoured to explain sudden changes in architectural influences at the time, from the idea of the static to the mechanical universe of the Modernist Era, eventually reaching a Cosmogenic Era in which development is constant [15]. Many architects such as Peter Eisenman, Rem Koolhaas, Greg Lynn and others, have written and practiced the extensions of a cosmogenic universe with its dynamism and complexity in architecture. They drew on the critical philosophies of Deleuze, Derrida, and Foucault, as well as cutting-edge scientific debates, to reach a supercritical position in architecture [16]. Eisenman comments on the supercritical future of architecture, where he states "A future as a constant becoming rather than being, not an avant-garde of the perceptually new but the becoming of the critical act of an art that can only destroy itself, and which only by destroying itself can constantly renew itself" [17].

The process of being ends when the object or architecture is represented physically and/or virtually, while the process of becoming implies constant change, transience and dialogue due to the reflections of the observer's interpretations of his/her own consciousness and experiences onto architecture. The process of becoming implies that architecture is not a static experience but rather unfolds patterns of behaviour reflected in its generation and representation and this is experienced both spatially and temporally. Hence the outcome of the process of becoming can be seen as an event or a situation generated through interactions between rules and processes to create unstable formative relational patterns rather than a descriptive form or space. For Doreen Massey and other contemporary philosophers, not only generation and experience, but also representation is a dynamic process. Representation produces space-time not through the process of fixation, but rather through the continuation in production of the process of becoming rather than being [18]. This paper takes on Massey's attributes of representation as an active and productive engagement within the process of becoming and a constitutive rather than a mimetic experimentation of the world in which its notions of materiality and immateriality are constantly influencing one another in an exchange of states.

Among the wide range of designers and architects who have attempted to generatively produce formative relational designs through the use of algorithms are Michael Hensel of the Architectural Association in London, Celestino Soddu, founder of the Generative Design Lab in Milan Polytechnic University, and others such as Benjamin Aranda and Chris Lasch who in their architectural pamphlet Tooling explored principles of morphogenesis in design by utilizing an algorithmic language for each process they suggested, creating, at the basic level, the first seed for the growth and development of patterns and later on forms. It seems that by inventing such algorithms they have created patterns of form that can be assembled according to the rules governing the formation of this particular pattern [19]. Kwinter undeniably expresses his support of such methods of form exploration, where he argues "[…] design must not focus uniquely on first order regulatory processes but must target the second order controls that regulate the regulatory processes themselves. The genius of nature and design meet precisely here" [20].

Mathematically and with the aid of digital computers Turing establishes a theory of morphogenesis where he explains the effects of random disturbances to the equilibrium of systems of chemical reactions. Based on the assumption that each organism – when slightly disturbed – develops from homogeneity into a pattern rather than from one pattern into another, Turing develops a non-linear theory of instability due to differences in reaction rates as functions of concentrations in patterns, later known as Turing Instability [21]. Such theories were the basis for the emergence of speculative and inspiring fields of computer science such as Artificial Intelligence (AI), and Artificial Life (AL), which have had a great impact on generation, pattern formation and experimentation in art and architecture.

Sanford Kwinter echoes much the same when he recalls Alan Turing's breakthrough of algorithms, where "numbers could be automated within functions" in order to explain the complexity of nature [20]. Kwinter goes on to describe the benefit of algorithms and the way they function in design when derived from complex natural systems, stating: "The rule derives the algorithm and the rule is not a number. The rule is a pressure that is always limited by another rule. Rules do not make forms – the limitations that rules impose on one another do" [20]. Kwinter in representing the world as a complex dynamical system and fluid manifolds identifies two kinds of influence that occur in time during the process of becoming. Kwinter distinguishes those that are random, and incoherent, passing through the system without influencing it, and others that leave a trace in the process and are called singular. The singular ones are the ones that "give rise to potential or real morphogeneses within and across the system" [3].

Kwinter builds his idea of singularity on the existing knowledge of the field of computer science and in particular the promise of ultra-artificial intelligence which will be marked by the development of machines or robots that achieve superhuman intelligence. Those machines will later be capable of building still more sophisticated intelligences creating what is known as "intelligence explosion" [22]. This hypothetical event in time is called "The Singularity"; the term was originally coined in the 1950s by the American mathematician John von Neumann as he described the impact of technological advancements on societies, cultures and their consciousness. In his book The Singularity Is Near: When Humans Transcend Biology, Ray Kurzweil predicts the “technological singularity” of human-like intelligent machines revolutionising most aspects of human consciousness where humans and machines will become one and the same [23]. The connotations and interpretations of the word Singularity were not limited to the field of Artificial Intelligence (AI), but rather extended to its use in architecture.

A model was created (Cubeolony) to illustrate the impact of simple rules that influence simple components to create complex patterns and structures based on notions of singularity. The description of the Cubeolony model is as follows:

Phase one: Growth, division and formation

- This phase is limited to generating cubes on the screen according to a given number, which can be altered by the user of the model.
- Each face of the cube will have six amino acids (a combination of six of the main four amino acids found in any DNA: Adenine (A), Cytosine (C), Guanine (G) and Thymine (T) where G is always attracted to C and similarly T to A, and vice versa.).
- In this initial phase, the cubes are not attracted to each other. It is merely a generation process.

Phase two: Gravity power (feedback)

- The simulation begins to identify matching pairs of faces (eg. AACATG matches TTGTAC). As each pair is identified, the faces become connected by a virtual spring that draws the cubes towards each other with a strong attractive force proportional to the distance between them where the force at a greater distance is higher than at a lesser distance.
- As a consequence of this process, small clusters of cubes begin to appear. At this stage the interactions between the elements of the system are simple and stereotyped (Figure 1).

Phase three: Energy flow (local rules – self-organization)

- In phase three, the simulation continues to progress according to the above rules; however, the resulting dynamics are very different due to the increasing level of organization of the system.
- Clusters of cubes begin to merge together to form bigger clusters. Larger clusters contain more faces (which are targets for potential connections to other cubes) and so have a greater ability to attract smaller clusters and single cubes.
- The system reorganises itself when the larger clusters are hit by a small cluster as the strength of the impact of the collision is higher than the strength of the springs holding the cluster together which are relatively relaxed due to the small distance between the cubes.

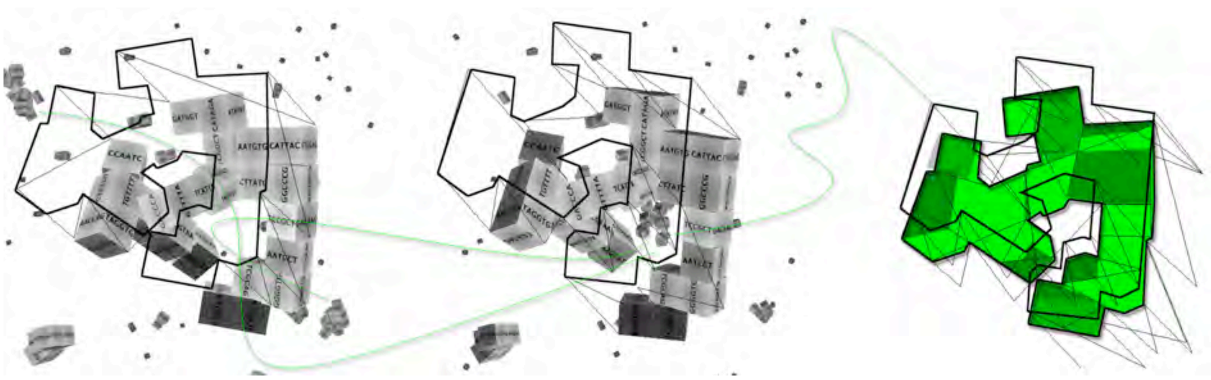

Figure 1: Connections and potential emerging generative form and space.

The simulation (Figure 2) can be found at: http://sanamurrani.me.uk/cubeolony/Cubeolony.htm. It provides the ability to control the number of cubes to be generated, the speeds at which cubes and springs are created, as well as the strength and damping of the springs. The display can be rotated using the W, A, S, and D keys and zoomed using the up and down arrow keys. The expand button temporarily causes all springs to be extended, which causes the forms to become unstable; they will be regenerated in different configurations when the button is released.

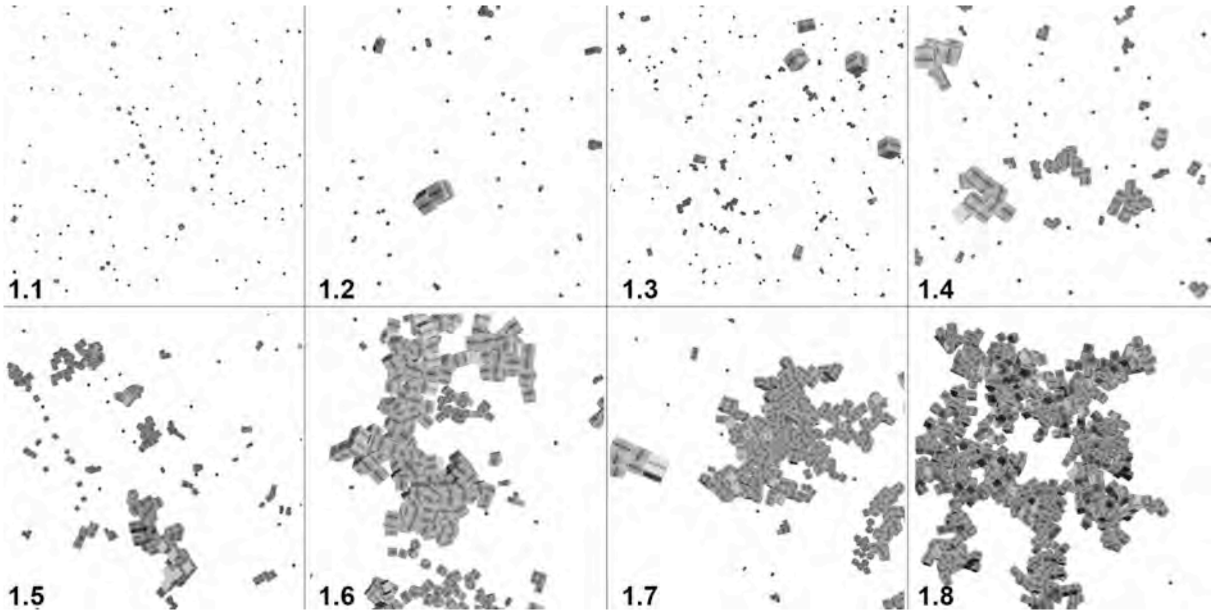

Figure 2: Snapshots of the simulation through time showing its behaviour.

The simulation exhibits generative behaviour for some time, however, it will eventually reach a stable state. This depends on various parameters of the simulation, most importantly the number of cubes given at the start of the simulation. The design of this simulation exhibits a complex relationship between the rules of the simulation and the physics of the environment leading to highly dynamic and unpredictable behaviour. A cube within a cluster exhibits collective behaviour in relation to the other cubes in the same cluster, at the same time, any cube can exhibit powerful individual behaviour when it becomes attracted to a cube outside its own cluster. Simple rules guide the whole system which results in the generation of different spatio-temporal forms. This simulation can work as a model for further projects to assist in the creation of emergent interactive architectural spaces and forms.

The simulation takes inspiration from the field of Cellular Automata and particularly Conway's Game of Life, where each unit follows a straightforward rule that produces emergent behaviour in the system as a whole. The initiated simulation is in fact an autopoietic system as it exhibits self-production behaviour through interactions between its constituting agents or components. The term autopoiesis is adopted from Maturana and Varela's descriptions of the processes of living machines. "An autopoietic machine is a machine organised (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components which: (i) through their interactions and transformations continuously regenerate and realise the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in the space in which they (the components) exist by specifying the topological domain of its realisation as such a network" [14].

The essence of this paper lies in both its explanation of the trajectories of the folds and thresholds of cybernetics in extracting life processes and principles of complex systems in their collective states, as well as its examination through a simulation of the possibilities of generating behaviour in architectural situations and declaring architecture as a transient product of the process of becoming. Thus, the influence of the field of biology and the technological generation has affected architecture directly and indirectly, through both bottom-up and top-down trajectories. This effect was embodied in its processes of representation and experience for the generation of unstable states and situations (Figure 3). "To be human, indeed to be living, is always to be in a situation, a context, a world. We have no experience of anything that is permanent and independent of these situations" [13]. Accordingly, the collective generative situations of architecture that emerge out of interactions between the processes of their formation, generation, representation and experience, exhibit notions of Maturana and Varela's autopoeitic system [24]. Through oscillations between the processes of being and becoming, the generative situations of architecture maintain their existence, instability and incompleteness.

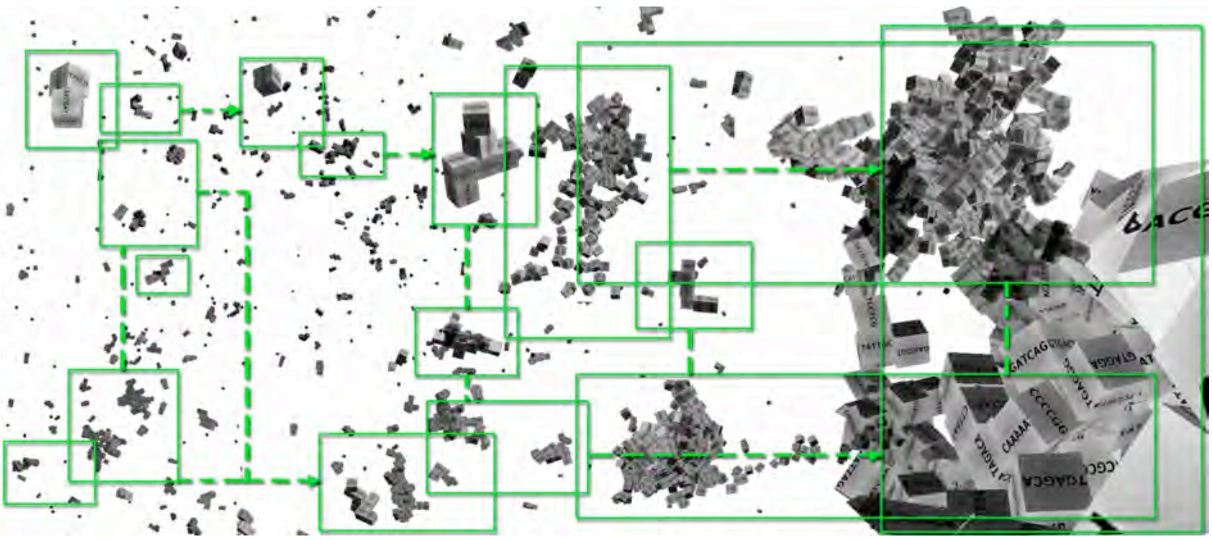

Figure 3: Map of spatio-temporal situations.

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