Actuating Auto(poiesis)

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Abstract: This paper claims that the use of the computer as generative methodological tool for designing urban and building scenarios (when perceived systematically) is a misnomer, because the typical approach does not account for the incompleteness of computational processes. We will argue that the computerisation of architectural and urban scenarios with autopoietic and/or artificial life simulations does not account for what Edsger W. Dijkstra called "radical novelty"; and Gilles Deleuze termed "line of flight". Typical computational methods do not open up genuine alternatives that produce radical morphologies. Our argument is predicated on the dominant notion of computation as opposed to a critique of computation per se. A critical analysis of the perception of novelty is made to support our view, and its connection with the incompleteness of axiomatic systems is explored in relation to three phases of cybernetic enquiry. Our argument draws on the ontologies of Alfred North Whitehead and Gilles Deleuze, which we utilise to reorient computational design to emphasise the potential of generating radical novelty and identify the inherent locus therein a matter of nonhuman decision-making.

Keywords: computation, incompleteness, incomputable, autopoiesis, emergence, novelty, decision-making.

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1 Introduction

Typical understanding of computation is based on the abstract machine invented by British mathematician Alan Turing. Barry Cooper, also a mathematician, argues "Turing computation does not create anything that is not there already in the initial data" (Cooper 2012). Why then do we compute if nothing new is produced through computing? We will argue in this paper that the manner in which we conceive computation is fundamental to the use, and role, of computers; particularly if they are to be employed as a device to extend creativity (as tends to be the case in design) and that if computing is to generate novelty then typical methodologies need to be reworked to account for the emergence of new information within the methods employed. The issue is not only pertinent to the development of computing and the question of process in computer science, but also to the proliferation of computational logic into observing and controlling human and nonhuman activities.

In a paper celebrating the centenary of the life and work of Alan Turing, Cooper asks whether 'information can increase in computation?' (Cooper 2012). A negative response to this question renders the mathematician's ambition of a closed system, whereby everything could be decided and computed, possible. In other words, a totalised axiomatic system is defined. A static closed theory of everything for all mathematics that would be like a dictatorship (Chaitin 2006). Consequently, the question "why do we compute?" becomes intrinsically concomitant with the notion of novelty.

In the search for novelty, computation has been introduced into architectural and urban design methodologies to enhance the design process and extend creativity. Based on the rationalisation of experts systems (i.e., knowledge based models (Gero and Lou Maher, 1988)), the adaptability of autopoiesis (Lynn, 1999) and artificial life (i.e., generative models (Coates 2010)) novel solutions to previously solved problems, novel morphologies and spatial organisations have been claimed. This has taken place over the last forty years since computers, and more specifically computer logic, was introduced into design (Alexander 1964 and Negroponte 1970). How then is it possible to argue for novelty through a process that doesn't produce novel data; as Cooper argues? We do not claim that the above mentioned pioneers in the field of computational design methodologies have not extended creativity or introduced some sense of novelty in their designed artefacts. Neither have we dismissed the sense of novelty conveyed to the designer engaging with such methodologies. What we argue is that novelty in computational design, which tends to be conceived of as a condition external to computation, must in fact be a product of computing: i.e. inherent in the process occurring in the machine.

The aim of this paper is to examine the notion of novelty as it is conceived through parallel advances in cybernetics, design and computation over the last sixty years. Since Cybernetics was an interdisciplinary effort to understand and control being in action and communication (Wiener, 1948) we unfold this story in three phases. Within each phase we identify convergent lines with respect to cybernetics, design and computation and their account with novelty. Our perception of novelty is informed mainly by Edsger W. Dijkstra's (1988) distinction between novelty and radical novelty and Gilles Deleuze's (1987) account on "absolute detteritorialisations".

The three different phases of cybernetics we refer to are not the classic stages; being first-order cybernetics (Wiener 1948), second-order cybernetics (Foester1995) and what Glanville implies as 'without-orders' (2006). We use those put forward by Luciana Parisi and Tiziana Terranova (2000), which correlate the cybernetic project to the concepts of turbulence, entropy and information. For each of the three phases we identify a primer

concept that characterises the effort within the cybernetic epistemology in order to account for novelty. This identification is informed by Katherine Hayles (1999), and thus 'homeostasis', 'autopoiesis' and 'emergence' reveal specific approaches and attitudes towards entropy, information and, eventually, novelty.

The paper is focused on post-war developments. However, we feel a brief connection between developments in logic, formal axiomatic systems and their ingression in the world of design is required in order to set the scene and identify how current computational design models have developed. We thus start with a definition of novelty before providing a brief introduction to the rationalisation of knowledge in respect to two central events at the beginning of the 20th Century. The first is the 1910 publication of *Principia Mathematica,* by Bertrand Russell and Alfred North Whitehead, the second being the 1920's Vienna Circle. The impact of those two events on the world of design is crucial, resonating throughout the post-war period. It is from this point that we start to unfold the three phases of Cybernetics, followed by a critique on notions of homeostasis, autopoiesis and emergence and respective computational models used in computational design. We make use of Peter Cariani's (2008) distinction between combinatorial and creative emergence, and John Protevi's (2009) schema of synchronic, diachronic and transversal emergence. Our critical position towards the existing computational paradigm in respect of its account of radical novelty will allow us to proceed by proposing a diagrammatic computational model for design.

2 Novelty and Radical Novelty

Edward W Dijkstra (1988) presents two forms of novelty, and identifies different ways to cope with them. The first, 'novelty' (which we will term relative novelty) is of slow and gradual change. In dealing with 'relative novelty' we build metaphors and analogies to link old with new, whereby the less familiar is correlated with the familiar. Radical novelty is what Dijkstra terms that which is a break, a disruption, or 'sharp discontinuity' with an existing habitual pattern. If coping with relative novelty means to stretch and adapt vocabularies within metaphors and analogies then to cope with radical novelty requires "creating and learning a new foreign language that can *not* be translated into one's mother tongue"(p. 2). Novelty, he claims, is not something present in a previous scenario or condition constructed by a purposeful machine.[1] It is something that emerges out of current (and a potential product of previous) circumstances which an observer cannot account for by deconstructing the machine or analysing the trajectory of states before the change arose. We thus look to the work of John Protevi (2009) and Peter Cariani (2008) to gain a firmer basis for the occurrence of novelty in complex systems.

John Protevi distinguishes between 'synchronic' and 'diachronic' emergence. He states "synchronically emergent structure is that which enables focused systematic behaviour through constraining the action of components" while diachronic emergence "is the production of novel functional structures" (Protevi 2009, p8). In other words synchronic emergence refers to the actual performance of the system in real time. Peter Cariani (2008) makes a distinction between 'combinatoric' and 'creative emergence'. Combinatoric emergence refers to "a set of primitives that are combined in new ways to form emergent structures" (Cariani 2008, p.7). The fixed set in this sense defines a space of possibilities that is also fixed even if new combinations of existing primitives take place. On the other

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1 We use the term systemic-assembly in this text to denote an entity with a given organisation and established state of affairs.

hand creative emergence assumes the creation of a new primitive that restructures the possibility space of the system. Cariani, in a similar way to Protevi, proceeds to the distinction between combinatoric and creative emergence.[2]

For Deleuze radical novelty is the result of cleaves present in a self-replicating systemic-assembly which enables that assembly in every instance of the time to open up to radical new potentialities. He names this process as "absolute deterriorialisation". Deleuze's use of the term deterritorialisation stems from the conception of a system as a territory; as having a given organisation and fixed state of affairs. It is in this sense that a systemic-assembly is a territory and consequently is caught in processes of deterritorialisation and reterritorialization. If the first term denotes an escape or departure from a given territory, the second denotes the constitution of new relations among the elements of the deterritorialised systemic-assembly. In that sense deterritorialisation is inseparable from processes of reterritorialization. Not every process of deterritorialisation however opens up the systemic-assembly to radical novelty. For this reason Deleuze constructs an elaborate schema of deterritorialised processes in order to reveal specific particularities and so to avoid generalisations. Deleuze's discussion on deterritorialisation takes place in regards to two distinctions. In the first, deterritorialisation can take a negative or a positive form while in the second can acquire a relative or absolute movement. The first distinction is a direct reference to the notion of feedback in complex systems. A Deterritorialisation is negative when the process of reterritorialisation obstructs the opening of the systemic-assembly to new potentialities and recuperate it by a conservative process of reterritorialization. The positive form consequently is acquired when new relations are formed and new adaptive techniques are learned. However, what complexifies further the account of radical novelty in any kind of systemic-assembly is the second distinction. A distinction between relative and absolute movement of deterritorialisation. The two types of movement are correlated with Deleuze's ontological distinction between the actual and the virtual. It is suffice for the moment to say that relative deterriorialisation operates at the level of actual elements of the systemic-assembly. It never leaves the corporeal order of the system. On the contrary the absolute movement of deterritorialisation takes place in an incorporeal order of the potentialities that Deleuze names as virtual. In an incorporeal order that is yet immanent in the material and corporeal order of the systemic-assembly. It is this absolute movement that Deleuze will name as the 'absolute line of flight' the radical opening of the systemic-assembly to radical new potentialities. In this sense the absolute deterritorialisation is an immanent vector of transformation; an immanent process that accounts for radical novelty.

Radical novelty therefore finds its genesis in an order of reality different from the actual state of affairs concerning the systemic-assembly in its environment. It as an immanent yet transcendental force of transformation, that finds itself in a relation of reciprocal presupposition with the actual assembly.

3 Origins of Axiomatisation

The history of logical reasoning conjoined with empirical observation starts with Auguste Comte. However, it is *Principia Mathematica,* one of the most important projects of the 20th Century that exemplifies the role of science and logic in formulating the industrialising world.

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2 It is worth mentioning though that for Peter Cariani Emergence is more "than simply the creation of new structures of behavior. It also includes the formation of fundamentally new organisation of matter - life - and the formation of fundamentally new informational processes -- nervous systems and minds -- and the concomitant appearance of a new aspect of the world -- conscious awareness." (Cariani, 1998 p.1)

It is in this ambitious project of Russell and Whitehead in which axiomatics became the origin of a certain conception of the world that renders its influence in developments in architecture and urbanism as well computation. It has significant influence on design with the inclusion of members of Logical Positivism in the Bauhaus curriculum and on computation with the apparent significance given to Turing's work, which became the foundation of modern computing, and thus the basis for computational design thinking (see Coates 2010). It is with Principia Mathematica that we identify the origin of a split. On the one side we have axiomatics and determinacy , (which continues the premise of *Principia Mathematica),* seeking rationalisation and on the other we have problematics and indeterminacy, which breaks with crystal clear axioms while requesting more of human insight and intuition. The former takes a direction towards general/universal truths that in their turn are imposed on the material world. The latter tends towards the induction of local and simple rules governing the interactions of elementary components of any kind of systemic-assembly observed in the bio-physical and material world. It is the historical events surrounding Principia Mathematica that we unfold in search for radical novelty.

Comte's Positivism was introduced in urbanism and architecture in the 19th century by Ildefons Cerda and Gottfried Semper. The Vienna Circle introduced logical positivism into these field in 20th Century. A mutual influence between the Vienna Circle and the Bauhaus is evident in two events.[3] The first regards the *Wittgenstein Haus* and the second concerns the integration of Rudolf Carnap's thinking, into Bauhaus' curriculum. The *Wittgenstein Haus* and Carnap's involvement in Bauhaus testify a distaste towards metaphysics and decoration and a redirection of the then contemporary world towards a scientism that unites all aspects of life; whilst at the same time excluding the entropic tendency of complex systems. This trail of thinking, highly influenced by logical positivism, is evident in the way architects organise a building and urban planners devise the city to manage space and effect order and control. It is the era of streamlined planning that can be found from the linear city plans of the Russian disurbanists (Mumford 2002) to the work of Le Corbusier (1946) and the orientation of the Bauhaus.

The Vienna Circle (also known as the Ernst Mach Society) was formed in Vienna in 1922 just after the completion of Principia Mathematica and Ludwig Wittgenstein's influential *Tractatus Logico-Philosophicus.* The aim of this group of philosophers was to establish principles of logic and science. The consequence of which had far reaching influence in the sciences and humanities. The Bauhaus became a testing ground for the application of logical positivism in design (Galison, 1990) and the school hosted lectures by Rudolf Carnap; one of the key theoreticians of the Vienna circle. His "*The Logical Construction of the World"* (Carnap, 2003) oriented the schools philosophical direction. The work of Adolf Loos at that period proffered the same philosophical orientation in design, sharing, in this sense, the new anti-philosophical movement heralded by Wittgenstein and integrated later by Logical Positivism. "You are me!" Loos said to Wittgenstein (Galison 1990, p.725). Loos's and Wittgenstein's critique on the 'superfluous' is culminated in the *Ornament and Crime* (Loos 1998) and *Metaphysics and Crime* as a kind of text that Wittgenstein had written (Galison, 1990, p.725).

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3 For a detailed account for this relationship see the work of Peter Galison Aufbau/Bauhaus (1990)

4 Incompleteness and Incomputability

Russell and Whitehead's Principia Mathematica project sought to establish a conceptual machinery to define mathematical truths; free of ambiguities, contradictions and undecidables. Principia Mathematica was an example of an axiomatic system of crystal thought for almost twenty years, which lead to David Hilbert making three claims:

- Mathematics is complete: every system can either be proved or disproved.
- Mathematics is consistent: a statement is either true or false, and therefore mathematics is free of contradiction.
- In mathematics (or in any axiomatic system) there are definite methods that can be applied to a statement to decide whether that statement is provable or not.

Hilbert's belief that mathematics could solve all the problems and make the world knowable was so strong that he expressed it by saying: "We must know. We shall know" (Cooper, 2004, p.3). However, the Austrian logico-mathematician Kurt Gödel, who was a student in Vienna at the time of the Vienna Circle, questioned not only the Principia Mathematica but any axiomatic system being a universally truth system. Gödel's Incompleteness Theorem proved definitively that Principia Mathematica or any such system could never achieve the author's ambition, or indeed fulfil the claims of Hilbert.

Kurt Gödel, and Alan Turing later destroyed Hilbert's certainty and any hope for axiomatics to be rendered complete, consistent and decidable. Gödel proved that all axiomatic systems are incomplete and inconsistent. Turing later devised a thought experiment, known as Universal Turing Machine, to prove that undecidability is inherent in axiomatic systems. Two conclusions stemming from Turing's experiment are that:

- No formal language can express all possible proofs: there are, therefore, incomputable problems, and
- All programming languages are capable of expressing essentially any algorithm.

Instead of focusing on the limits that Turing's paper places on computability scientists and mathematicians turned their focus towards the second conclusion; that of universality. The algorithmic theorist Gregory Chaitin comments on Turing's Universal Machine: "[o]n the one hand he taketh away, on the other he giveth" (2010, p1). "The concept of computability" Cooper argues "is basic to modern science, from quantum gravity to artificial intelligence. It is also relevant in the everyday world, where it is useful to distinguish problems that are merely difficult to compute in practice from those that are intrinsically impossible with any machine" (2012, p.465). The latter are incomputable problems. Chaitin (2006),[4] Cooper (2012) and Soare (2009) argue about the importance of incomputability in Turing's work. They point specifically to Turing's lesser known oracle-machine, which was like his Turing machine except it presupposed the presence of an oracle. In other words a black box that could compute the uncomputable, and thus solve the unsolvable problems that Turing machines could not. "Let us suppose we are supplied with some unspecified means of solving number-theoretic problems; a kind of oracle as it were … this oracle cannot be a machine." (Turing, 1939, p.172-173).

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[4] Gregory Chaitin doesn't make an explicit reference to the oracle Machine but he implied it in his description of his Omega number he states: "Omega's properties suggest that mathematicians should be more willing to postulate new axioms, similar to the way that physicists must evaluate experimental results and assert basic laws that cannot be proved logically" (Chaitin, 2006, p.76)

The idea of the o-machine "was to allow the machine to compute relative to a given real, which may or may not be computable" (Cooper 2004, p.6). The concept of the o-machine makes possible the introduction of intuition in the computational process. Turing was clear about the role of intuition in his work. It was only a small paragraph in his text 'Systems of Logic Based on Ordinals' in which he claimed:

> *"Mathematical reasoning may be regarded … as the exercise of a combination of … intuition and ingenuity… In pre-Gödel times it was thought by some that all the intuitive judgments of mathematics could be replaced by a finite number of … rules. The necessity for intuition would then be entirely eliminated. In our discussion, however, we have gone to the opposite extreme and eliminated not intuition by ingenuity, and this in spite of the fact that our aim has been in much the same direction"*
> *(Turing 1939, p.134-5)*

However, the theory of computability flourished while that of incomputability has been neglected (Longo 2010). It can therefore be argued that it is the coupling between logical positivism and the selective appropriation of universality, (stemming from the conclusions Turing drew of his *Universal Machine)* that define not only the development of computation and consequently the inception of cybernetics, but also the typical conception in architectural discourse that refers to the cybernetic view of the organism as an analogy for designing: ie the systemic conception of buildings and cities.

5 Cybernetics

Cybernetics[5] was the name for an interdisciplinary research project aiming to study the control and communication in animals and machines through feedback functions. The epistemology of Cybernetics though will be developed through broad and abstract issues of communication and control by feedback processes in machines, organisms, and social organisations. At the onset of Cybernetics we argue that we witness a change from the concept of discipline to that of control. The logic of axioms in the pre-war period suggested the logic of 'discipline' that in the age of Cybernetics will give its place to the logic of 'control'.
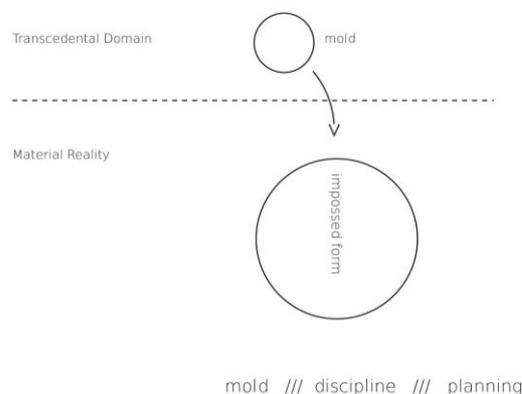

Figure 1: Preconceived Forms discipline bodies.

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5 Cybernetics as a research project does retains a scientism present in the agenda of Positivism that was looking into synthesising all sciences. As Hayles claims: " [In Cybernetics] Wiener entertains the possibility that cybernetics has provided a way of thinking so fertile that it will allow the social and natural sciences to be synthesised into one great field of inquiry". (1999, p.108)

Part of this shift was effected by the futility, proffered by Gödel's and Turing's proofs, to construct a crystal clear, complete and consistent axiomatic system free of indeterminacies. Incompleteness, uncertainty and randomness are immanent in formal systems; as is entropy in bio-physical systems. Claude Shannon's Information Theory will become the second factor responsible for the shift from discipline to control. It is the positive charge that Shannon assigned to entropy by equating it with information that renders entropy as the origin of life and not as its unavoidable heat-death.[6] Entropy becomes Information, a positive force that drives systems to their self-organisation and their increase in complexity. By encountering and managing randomness and entropy, the molds that ward off and discipline bodies in a world constructed through the thermodynamic perception give their place to continuous modulations. These modulations operate through trial and error on the elementary parts of the bodies allowing them to self-organise and acquire higher levels of complexity. This same perceptual transition can be traced in the domain of the actual devices. We can **observe** this change even at the level of machines, for example: the Babbage machine gives space to the Universal Turing Machine and ENIAC (the physical implementation of Turing's Universal Machine).

It is a similar path that architecture and urbanism traces after the Second World War. The notions and methods of cybernetics inform the work of many architects and urban planners. The Metabolists, Constant Nieuwenhuys and Cedric Price were influenced by cybernetics with varied political orientations while approaching the notion of control (of the turbulent entropic world) differently. An intellectual attitude of that time that refused to embrace any metaphysics of life and the formalisation/axiomatisation of all the processes has influenced a whole generation of architects, since Christopher Alexander's *Pattern language.* Alexander (1978) and Negroponte's (1970) influential work accompanies the twists and turns of logical positivism prompting further rationalisation. Rationalisation led into an approach to design that reveals its connections with axioms through the use of mathematics while introducing computational methods at the core of design. Architecture, in the era of cybernetics, leaves its mechanical conception of the machine and opens it up to the idea of turbulence, with an implicit emphasis on control. In the next sections we will follow closer that relationship between the machine and entropy in relation to control and novelty.

5.1 Homeostasis

Norbert Wiener is strongly influenced by Willard Gibbs'[7] probabilistic understanding of the entropic world. He was concerned with the prospective of the 'heat-death' of the planet due to its entropic tendency and he assumed that in the midst of chaos and turbulence there are islands of order where "[l]ife finds its home" (Wiener 1989, p12). Cybernetics abstracts reality from the messiness of matter and perceives life as an informational pattern [8]. Biological organisms and mechanical devices in a cybernetic framework will become machines[9] capable to react to a stimuli that disturbs and threatens their unity and their

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6 This shift is traced and mapped in the book of N.Katherine Hayles(1999) "How We became PostHuman" and in the joined article by Luciana Parisi andTiziana Terranova(2000) entitled "Heat-Death".

7 Weiner (1989) will write about Gibb's understanding of Entropy: "... Gibbs had that this probability tended naturally to increase as the universe grows olders. The measure of this probability is called entropy, and the characteristic tendency of entropy is to increase."(p. 12)

8 Pattern and Chaos will become two notions that their charge will be exchanged in the course of the second half of the 20th century. If Pattern was the positive request in the birth of Cybernetics, The "local enclaves" or "islands" in the midst of whirlpools as Weiner wanted it

9 It is the anti-entropic processes of that allow Wiener to name mechanical and biological systems as machines. "When I compare the living organism with such a machine, I do not for a moment mean that the specific physical, chemical, and spiritual processes of life as we ordinarily know it are the same as those of life-imitat-ing machines. I

boundaries. Entropy is the measure of disorder for Wiener and he associates information with the measure of organisation (1958). Negentropy, the opposite of entropy, is equated with information. It can be argued that Wiener still conceives those machines in a thermodynamic context with a tendency towards the heat-death terminal condition of sameness and disorder. The protection of the organisation of those machines is achieved by homeostatic mechanisms provided by feedback functions and managed through continuous modulations. In this first instance of cybernetics entropy is warded off.
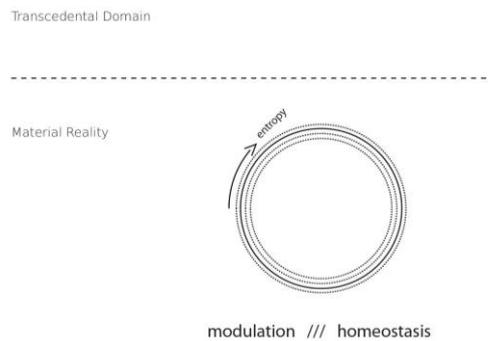

Figure 2: Diagram of the first phase of Cybernetics: Closed Boundaries

Spatial organisation in architecture and urbanism emphasised the impetus for homeostasis. The Metabolist movement embraced the departure from the mechanical world of the Modern Movement. Kishu Kurokawa, one of its key members, states that his own thinking at that time was an attempt "to understand the shift from a mechanical to biodynamical age."(Koolhaas & Obrist 2009, p19) The Metabolists coupled this shift with traditional Eastern philosophy; that sees permanence through change. Kenzo Tange's radical proposal for the post-war Tokyo (Lin 2010) embraced mobility and communication as the driving force behind the project, using biological analogies to justify his proposals for the city's radical transformation.
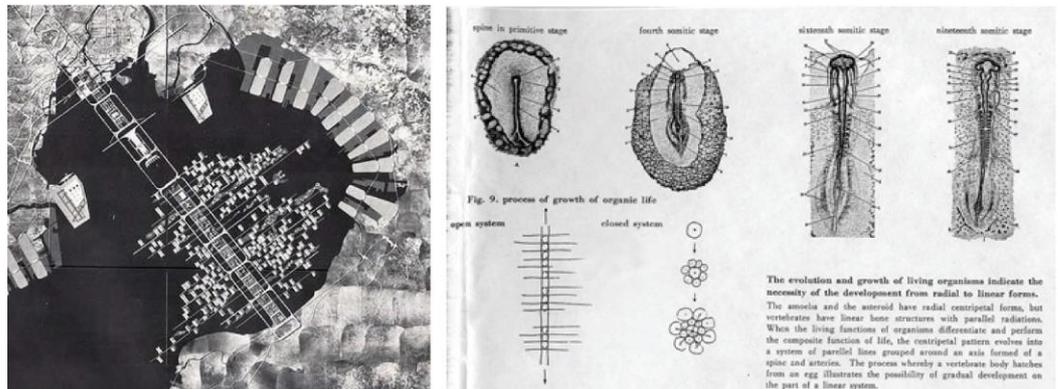

Figure 3: Tokyo Plan and Biological Growth (Lin, 2010)

Computation at this point is perceived as a closed system. A formal language able to describe any bio-physical process, which could be turned into an algorithm without having to be acted upon by the external environment. This is a closed, self-sufficient set of programmed instructions able to predict the future behaviour of system in terms of pre-set probabilities. It is on such computing machine that anti-aircraft machinery was built on in

mean simply that they both can exem-plify locally anti-entropic processes, which perhaps may also be exemplified in many other ways which we should naturally term neither biological nor mechani-cal."(Wiener, 1958, p.32)

Wiener's time.[10] "[C]omputing machine whose instructions are all set forth in advance on the "tapes," and which has next to no feedback mechanism to see it through the uncer-tain future" (Wiener, 1989, p. 57). A closed axiomatic system that operates on fixed set of data effectively pushes incomputability away from computation. This can suggest an almost homologous perception between incomputability in computation and entropy in physics governed by thermodynamic laws.

Change and novelty in the birth of Cybernetics are implied concepts buried under the notion of homeostasis. Still though, the first instance is highly conservative. Novelty appears as progress and learning in the writings of Wiener but is always relative to an existing organisation and reluctant to the radical transformations of it through the process of "metamorphosis" (Wiener, 1989, p.53). Small changes that build on past experiences allow machines to learn, to adapt, without dissipating in the entropic universe. The model of learning or better that of adaptation in machines is transposed by the models of ontogenetic and phylogenetic changes in organisms[11]. It is in this sense that any behaviour based on the 'law of requisite variety' (Ashby 1957) is equated with adaptation, rather than radical novelty. Deterritorialisation of the machine is therefore relative, momentary and negative. Processes of reterritorialisation secure the return to a homeostatic posture. The purpose of learning in a machine is the preservation of its identity. This paradigm is continued in the second phase of Cybernetics, but through major conceptual advances (such as autopoiesis) the process of self-making becomes an important concept in the attempt to accommodate the significance of the observer.

5.2 Autopoiesis

The notion of homeostasis although present in the second phase of cybernetics, moves to the background. The concept of Autopoiesis (Maturana and Varela 1980) takes centre stage. Autopoiesis in this sense can be considered as an intriguing concept to look to and to embrace as a means to engage with biological creativity or novelty, because it demonstrates how a living system is created, and is self-generating (Maturana and Varela 1980). An autopoietic system according to Maturana and Varela has no other purpose than to persist, and if the dynamic circularity is interrupted then it disintegrates.[12] Coupled to its environment an autopoietic system draws from and thus conveys to its environment, meaning the system has identity, because it is different from that which surrounds it – for it must be different to exist. The boundary between system and environment is therefore pivotal for the autopoietic understanding of the organism. The boundary is a 'component' of the system which is distinguished through its 'form', which is determined by its structure and the difference between itself and the environment (Luhmann 2006). The boundary between the self and other is essential for the system to exist. "[The] point of departure for all systems-theoretical analysis must be 'the difference". The way in which systems are perceived through the concept of autopoiesis is spatial, in that the components of a system are a complex of

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10 That was the problem that Wiener faced during the war "... in the pursuit of a target as rapid as an airplane, there is not time for the computer to take out his instruments and figure where the plane is going to be. ' All the figuring must be built into the gun control itself. This figuring must include data which depend on our past statistical experience of airplanes of a given type under varying flight conditions. The present stage of anti-aircraft fire consists in an apparatus which uses either fixed data of this sort, or a selection among a limited number of such fixed data. The proper choice among these may be switched in by means of the voluntary action of the gunner." (Wiener, 1989, p. 62)

11 In Cybernetics Wiener will write: "Both ontogenetic and phylogenetic learning are modes by which the animal can adjust itself, to its environment". (1961, p. 169)

12 Maturana and Varela will argue that the purpose of the autopoietic system is "to produce and reproduce the organisation that defines them as systems. Hence that not only are self-organising but also are autopoietic or self-making" (Hayles, 1990, p. 10).

interactions distinguished by their structure which determines a closed unity. A boundary condition is thereby defined, through which the system is structurally coupled with, but has autonomy from, the environment. The system is intrinsically different and being distinguishable has identity. The concept may be seen to share similarities with the notion of buildings as systems of spatial relations, and one may at this point be drawn into thinking about social systems and architecture autopoietically (Luhmann, 1986; Schumacher, 2011). Autopoiesis is an intriguing concept because it's central concern echoes what Henri Lefebvre argued about space; that it is something which is produced as well as productive (1995). Space is thus perceived as an active phenomenon which manifests itself and persists. It is this aspect which offers architects a new conception of space and the capacity to generate spatial formations.
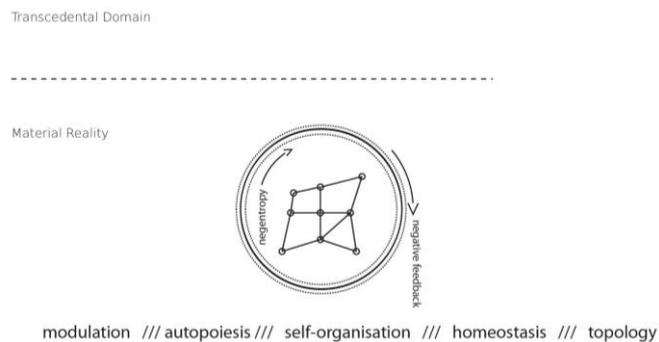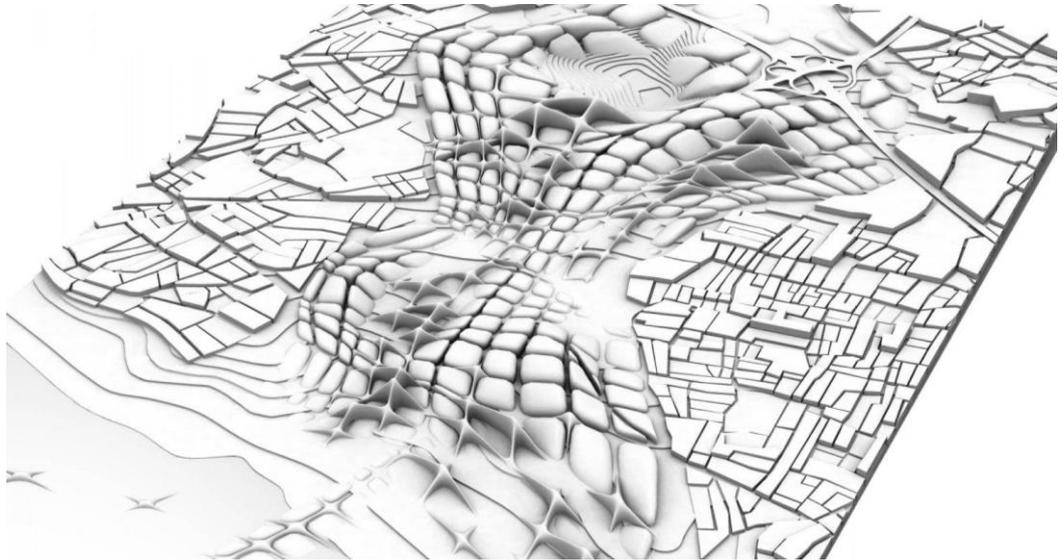

Figure 4: Diagram of the second phase of Cybernetics: Negentropy and Self-Organisation

The influence of autopoiesis can be traced back to what became known as blob architecture (Lynn, 1999). Patrick Schumacher (2011a) recognises the work of Lynn as the precursor of his parametricism movement. If the Struggle of Wiener was to retain order in the midst of entropic flows then Schumacher's struggle is how to demarcate architecture with a comprehensive and unified theory in the midst of the dissolution of the grand narratives. An ordering principle that will retain the identity of the discipline of architecture while at the same time will become a common communicative system within large practices. Parametricism and Schumacher reawake the ambitions of Modernism to converge the world of architecture in a closed organisation; this time not fixed and static but dynamic and adaptive. To integrate everything in a convergent, non-conflictual way, to naturalise change, relativising novelty and maximising the effectiveness of performance appears to be strategies that are introduced into architecture and urbanism via parametricism. It is this emphasis on the self-maintenance and survival that guides Schumacher's conception of the autopoiesis of architecture and the autopoietic architecture and the position to state that architecture should have "the autonomy to adapt to an environment and to stay relevant in it."(Schumacher 2011a). Autopoietic organisation "constitutes a closed domain of relations" that are "specified only with respect to the autopoietic organization that these relations constitute" Maturana and Varela 1980, p.88). Computation in design followed the same tendency. Closed, although temporal, and topological systems prevail in the use of computers in architectural and urban design.

Computation can be thought as the reiterative application of the same invariant function that describes a fixed topological organisation and produces variable structures of the same organisation. An invariant mathematical function secures the organisational closure of the algorithm and in the most linear perception of processing it maps the inputs into outputs. The incomputable nature of computation again is ignored. Captivated with what

is computable within the closed systems of invariant functions architects explore that world of digital architecture. Architectural animations, such as that of Greg Lynn's 'Animate Form' (1999) and Schumacher's 'Parametricism' (2009) seems to render visual the autopoietic

attitude of computational processes.

Figure 5: Kartal Pendik Masterplan (Zaha Hadid Architects, 2006)

That second phase of cybernetics negates the role of the entropy through processes of self-organisation and self-making and it is focused on the constitution of an identity and autonomy. In any other case as the autopoietic theory suggests there is only death and dissipation. Novelty is a notion that is not accommodated by autopoietic theory. The deterritorialisation is negative and its movement relative to the extent that the purpose of retaining the same organisation of the machine is a priority. It takes therefore a further, third instance of Cybernetics to account for the unsuspected complexifications and unexpected transformations that emerge out of coupling of heterogeneous systems.

5.3 Emergence

Hayles (1999) in her periodization of Cybernetics argues that the autopoietic circle turns into a spiral and the concept of autopoiesis gives primacy to 'emergence' in the third phase of Cybernetics. The entropic environment now affects the autopoietic entity but the feedback loop, previously focused on the homeostasis, now points also towards the production of difference through self-organisation. In Bateson's words, it is "the difference that makes a difference" (2000, p 459). The small deviations are quickly amplified and the complex feedback functions can now be recognised as positive. The system leaves its comfort zone and is compelled to create a novel behavior. Deviation, mutation and variation don't necessarily lead to entropic death as the previous instances of cybernetics were suggesting or implying. On the contrary, for this third phase entropy is being dissociated by Wiener's thermodynamic reading to become information; according to Shannon's understanding. As a result entropy is conceived to be the origin of life. As Hayles states:

> *"Entropy will be reconceptualised as the thermodynamic motor driving systems to self-organisation rather than as the heat engine driving the world to universal heat death[...] Chaos went from being associated with dissipation in the Victorian sense of*

dissolute living and reckless waste to being associated with dissipation in a newly positive sense of increasing complexity and new life" (1999, p102-103).

Information at critical points is capable to generate systematic behaviour that is supervened by functional structures in a circular causality. Upward causality generates capacities for the system as a whole that are not possessed by the individual components, and downward causality affects the behaviour of the components and becomes the 'constraint' that enables the capacities of the whole.
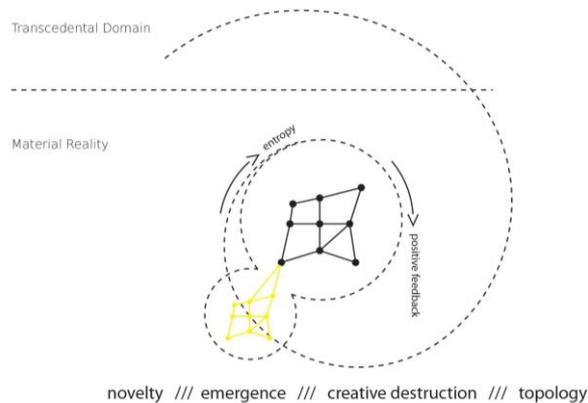

*Figure 6: Diagram of the third phase of Cybernetics*

Computation in design is biologically inspired in this third phase of Cybernetics, operating bottom up. Artificial life simulations become generative; following Langton's claim that life operates at the edge of chaos (1995). The idea of the unexpected pattern out of the self-organisation of computational agents becomes the new computation model. Even the shift from the procedural logic of the algorithm to the object-oriented programming makes apparent that change of focus from the invariant function to the generative aspect of the interactions with local rules. Recursivity and synthetic simultaneity or pseudo-parallelsism underlie the set-up of the interactions for most of artificial life computations. Multi-agent based models and cellular automata operate at the edge of chaos. The initial instability provided by the heterogeneous field of data is the originator of the turbulence that drives the self-organisation of the computational model. If we consider the computational models as complex dynamic systems then it can be argued that the phase space of the computational system is already given as a possibility space. That means that certain attractors have been distributed in the phase space where the model will end up constituting in this sense a behaviour in the form of a pattern. The positive feedback that we saw that govern those computations have also the capacity for new patterns to emerge. That means that the system adapts or learns. In other words either the system moves to a different attractor or a new attractor is added in its phase space. In this sense we do argue that we still have a relative novelty in terms of Dijkstra but a creative emergence in terms of Cariani since a new primitive, in Cariani's terminology, has been added into the system. The move to another attractor or the creation of a new one still accounts for small incremental changes.

A series of design projects have included Artificial Life computational models in their methodologies for the sake of novelty of the emerged outcome. Kokkugia's Prairie House project (Snooks 2012) is a computational project that introduces Mutli-agent models in the design methodology.

Figure 7: Prairie House project: Multi-Agent Computational Model (Kokkugia, 2012)

This strategy operates as "a negotiation between local interactions of multi-agent models and the global evaluation of structural analysis" (Snooks 2012, p61). The behaviour that emerges from the upward causation is not only 'constrained' by the constituted functional structures but also from the application of gravity that affects "the flow of load through the form that is continuously analysed at the global level" (Snooks 2012, p61). Structural performance is fed back into the system and the agents adapt their behavior based on heuristic structural rules. Novelty in Kokkugia's project is effected through the process of adaptation on small incremental changes in the synchronic level. Agents do not learn by
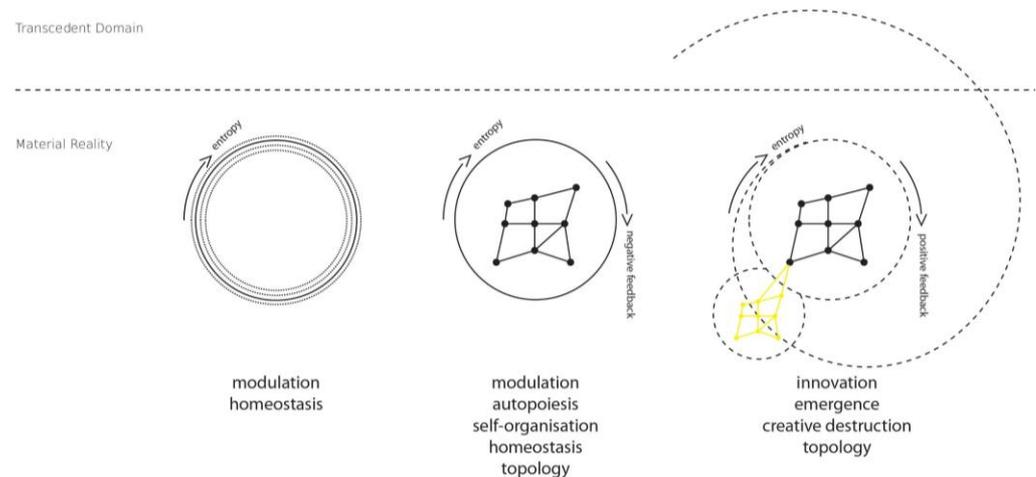
their previous experiences but rules are handed to them by designer's knowledge.

Figure 8: Three phases of Cybernetics: Entropy / Novelty

6 Computational Models: a critique

The three phases of the history of the second half of the 20th century within the framework of cybernetics and the respective treatment on entropy and the incomputable should be considered not in a very strict and isolated way. Overlapping and transferences of concepts

pass from one phase to the other. It is as if, in the three distinct phases, elements and concepts are passed into every new phase while at the same time old principles are repeated. Three different computational models emerged in the three phases described above.

▪ The knowledge based model in which a closed set of procedures operates on a closed set of data (Gero and Lou Maher, 1988) which leaves no room for new elements to be created.
▪ The autopoietic model (Lynn, 1999; Shumacher, 2010), is an invariant procedure that operates on a dynamic set of data which it reconfigures. Novelty, in this sense, is apparent since what is produced is always the result of the procedure. The outcome of the autopoietic model is, however, synchronically emergent (Ireland and Zaroukas, 2012).
▪ The emergence model, in contrast, is open ended. A closed set of computational components which operate on, and produce, a set of data through interaction. (Coates, 2010) Novelty, is thus considered to be relative to the procedure, because it is effected by interaction between components that operate at every instance on the data set provided.

In the emergentist paradigm we are faced with two problems regarding radical novelty. The first has to do with the fact that architects are falling sort by stopping only on what emerges out of components' interactions in a synchronic level, repeating in this sense the problematic aspect of autopoietic computational model. The other problem has even deeper affiliations with the theory of autopoiesis of which is concerned with persistence. Novelty, thus, is conceived to emerge only as encroaching perturbations that challenge system's structure. In other words they agitate and inflict disruption on a system in order that it may shake up and reorganise. The problem here is that the homeostatic purpose of systems is implied. Kokkugia's project discussed above reintroduces homeostasis through the back door. It would seem that systems tap on novelty when they are forced to change. Shaviro points out that this implicit homeostatic conception of organic being sees novelty as something that organisms do "when they are absolutely compelled to, and as it were in spite of themselves" (Shaviro, 2009, p. 93).

Radical Novelty we argue in the next section is immanent in biological systems and living processes, which we will show is viable computationally. As expounded by Deleuze's deterritorialisation, radical novelty has to presuppose relative novelty. We look to Whitehead who make novelty central to his process philosophy; which reiterated by Deleuze.

7 Reductive model the locus of radical novelty

Deleuze in his collaborative work with Felix Guattari asks "Is there absolute De[territorialisation], and what does absolute mean?" (Deleuze & Guattari, 1988, p. 509) As mentioned earlier Deleuze devises a schema to articulate different means by which a systemic-assembly may open up to new potentialities. The most radical dimension of his schema is his idea of absolute deterritorialisation. In other words the opening of the relations, and the conditions of, a systemic-assembly. The absolute, as described above, refers to a form of movement which is qualitatively different from relative movement. With relative movement the relations of a systemic assembly untie in such a way that they maintain reference to their previous condition. Absolute deterritorialisation on the other hand opens a systemic-assembly to influences its organisation previously prevented and therefore becomes difference-referenced. It becomes alien-referenced. Deleuze, in his geological terminology, will name the excluded world: 'earth'. It is in this sense that we understand a systemic-assembly as territory, its opening up as deterritorialisation and the
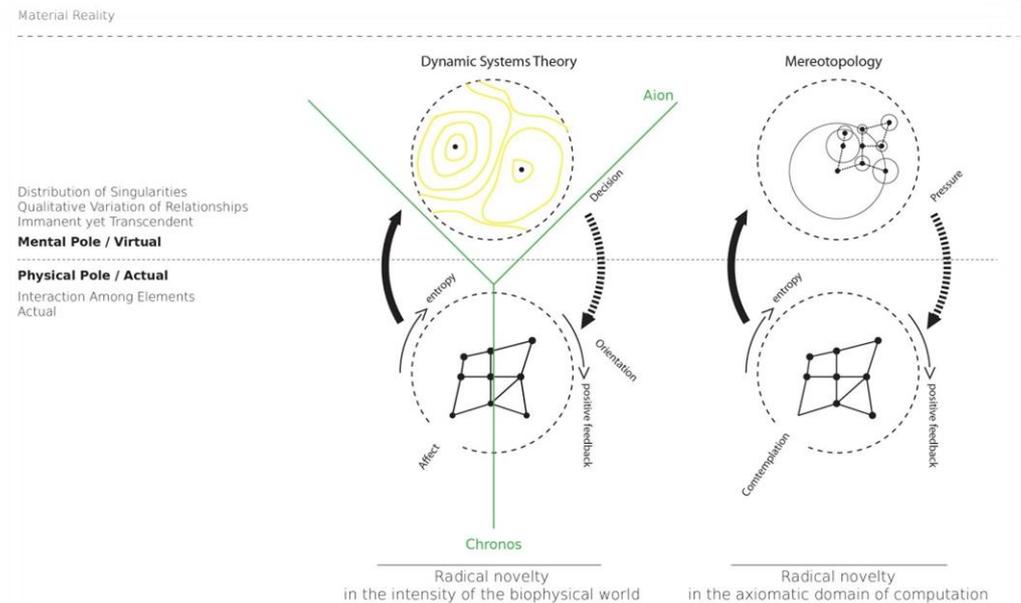
absolute movement of its escape as communication with the earth. Systemic-assemblies are not totalities. On the contrary, a systemic-assembly has cleaves and is incomplete, inconsistent and incoherent. Even the most rigid can be opened to new potentialities. Vectors, untying given relations and established states of affairs, are inherent within a systemic-assembly, which emerge, either because of internal dynamic movement or because it is open to, and thus forming new assemblies with another systemic-assembly.

Deleuze argues that, either, the connections in a given systemic-assembly, and given state of affairs, are qualitatively different or they are intertwined with other assemblies causing different systemic-assemblies to emerge through transversal communications[13]. We can therefore identify two distinct possibilities for vectors of deterritorialisation. To explain the first one we need to move beyond topology, as discussed above with regard to the autopoietic conception of systems, to account for variation and difference in a relation. Topological configurations that arise out of component interactions, do not take into account the quality of spatial relations. Spatial relations are more varied than the typical topological focus allows for. We must move beyond topology to incorporate the mereological aspect of parthood (Varzi, 1996). By allowing for parthood we enable variance into the system and thereby allow for differences to occur, on the basis that 'a difference is a difference that makes a difference'; which 'perceived over time' is what we call 'change' (Bateson, 2000). Difference is required to alter or affect new states and create asymmetry in the system.

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13 Systemic-assemblies are always caught in relations with other assemblies reconstituting a new space of potenitalities for the newly created assembly.. In this sense machinic assemblages are not hybridisations of the actual, phenomenal part of the systemic-assemblies but the meshing of their potentialities. It is in this sense that communication between potentialities is transversal.

Although Deleuze would account for difference in terms of 'intensive differences', that means through the mathematics of differential calculus, the reading of parthood relations through formalistic approach will allow us to extend our search for novelty from biological

Figure 9: Two Diagrams for the genetic locus of Radical Novelty. Gilles Deleuze, Alfred N. Whitehead

organisms to computational code. A similar shift is evident in Francisco Varela's *Principles of Biological Autonomy* (1979), in which he explains his attraction to dynamical systems modelling, whilst at the same time recognising such an approach as limited to the molecular. He therefore turns to algebraic/formal recursive systems. By the time the organism is perceived as an informational pattern (after the birth of cybernetics) formal ontology, and modelling, seems to be an adequate approach to discuss radical novelty. Formal ontology and modelling were first introduced by the philosopher Edmund Husserl (1970) as framework to "study formal structures and relations – above all relations of part-whole" (Smith 1998, p.20). Whitehead's "theory of extensions" (1978, p.281) formalises those relations while provides a framework for an ontology and the means for modelling. It is this same tension between the two ontological schemes of Deleuze and Whitehead; that has appeared in computational design and marks a turn from molecular to formal ontology. Both ontologies question the notion of "limit"; in terms of, either the entropic organism or the incomputable. We therefore put forward two schemas (to be read in parallel) to which account for radical novelty, as immanent in both biological and computational domains.

In Whitehead's (1978) process philosophy there are 'actual entities' and 'eternal objects'. Actual entities are, "the final real things of which the world is made up" (p. 18). Thus we should not limit our understanding of the actual entities only to the corporeal entities. Computational data sets and abstract procedures can also be conceived as such. In order to avoid the confusion we can use Whitehead's alternative terminology for these entities as 'actual occasions'. "Each actuality is essentially bipolar" (p. 108). They have two poles: one that is 'mental' and another that is 'physical'. The latter is what allows the actual occasions to sense their world, they are responsible for what Whitehead calls 'prehensions'. The former is where the 'eternal objects' find their reality. Eternal objects are "pure potentials for the specific determinations of fact, or forms of definiteness" (p. 22) and their functioning in "the self-creation of an actual [occasion] is their 'ingression' in the actual entity". The 'eternal object' of the 'mental pole' as it ingresses in the self-making of the actual entity in every

instance affect the parthood relations. It is for this reason that parthood relations introduce variance into the system and therefore effectuate a novel orientation in every single moment. The fact, that those pure potentials that provide new orientations to the system, are not coming from a transcendental domain but are immanent in the topological relations allow us to name them dark orientations. The information that passes from the abstract pole to the physical pole and gives the latter an orientation is named 'decision'. The fact that this decision is provided by an abstract and alien entity allow us to name it as alien decision. The two poles are connected and communicate in a quasi-causal relation breaking the causal circularity of Autopoiesis. A circularity that has as a purpose the conservation of the organisation and therefore the identity of the systemic-assembly. The quasi-causality allows the introduction of orientations and repositions the physical pole into a novel fresh start. In biological sense this moves away from the neo-Darwinian Synthesis that sees innovation of the organic being as an inescapable compulsion triggered by some external pressure (Shaviro, 2009, p. 93). In every interaction of concrete entities there is always a decision that although it is alien to the physical pole that is to interaction between corporeal components is still immanent in it. The alien decision therefore is what Whitehead called 'final reaction':

> *"The doctrine of the philosophy of organism is that, however far the efficient causation be pushed in the determinations of components of concrescence – … – beyond the determination of these components there always remains the final reaction of the self-creative unity of the universe. The final reaction completes the self-creative act by putting the decisive stamp of creative emphasis upon the determinations of efficient cause" (Whitehead 1978, p 47).*

It is at this decisive moment in which an alien decision supervenes the efficient causality, where radical novelty enters into the systemic-assembly. "Decided conditions are never such as to banish freedom. They only qualify it. There is always a contingency left open for immediate decision" (Whitehead 1978, p. 284). And so Deleuze will add a new concept to encapsulate that contingency: "It is the mute witnesses or the dark precursors which do everything – or at least, it is in these that everything happens" (2004a, p.319). The mental and physical pole can find their homologies in Deleuze's ontological scheme as virtual and actual domains where Deleuze emphasises time instead of spatial relations as locus of novelty. The virtual supervenes the actual domain in a quasi-causal relation and gives it orientation allowing in the same time contingency to be introduced at the paradoxical coexistence of the instance of moment named 'chronos' that opens up to the unlimited time of 'Aion'. In Deleuze's terms, that will entail the restructuring of the potentialities of the systemic-assembly in the unlimited time and the distribution of new potentials -- new singularities and new dark precursors. Deleuze's dark precursors are therefore the incorporeal entities that select which of the potentialities will become actual at every instance of time. That opening to the unlimited time though takes place as a paradox in the instance of time. It is in every instance that those new potentialities will supervene afresh the process towards a new actual systemic-assembly. We would like to think that by shifting the attention from emergence to the decisions 'made' by a dark precursor this restores novelty on the basis of the existence of a systemic-assembly in the presence of contingency immanent in the 'earth'. This is the absolute deterritorialisation that entails radical novelty.

There is though a second presupposition in Deleuze's process of deterritorialisation which has to do with the deterritorialisation that opens up systemic-assemblies; the transversal communication with other deterritorialised systems at the level of potentialities where a new systemic-assembly emerges with a new space of potentialities. John Protevi

(2009) names this type of emergence transversal. Transversal emergence is the result of a transversal communication that takes place at the moment where two systemic-assemblies are meshing their potentialities while also creating new by forming in this sense a new systemic-assembly. This meshing invokes a merging, a construction of a new virtual domain effectuating radical novelty in the constituted systemic-assembly. If those assemblies are computational then it is within this transversal communication that the incomputable ingress in the process. The actual dataset, if we are allowed to rephrase Deleuze, will become the 'earth'. The 'oracle' kicks in and computation continues based on relative given real number. It is the ingress of the incomputable in the computation that effectuates radical novelty in the form of a speculation by the oracle and constructs in this sense a radical abductive computational model that we call raductive.
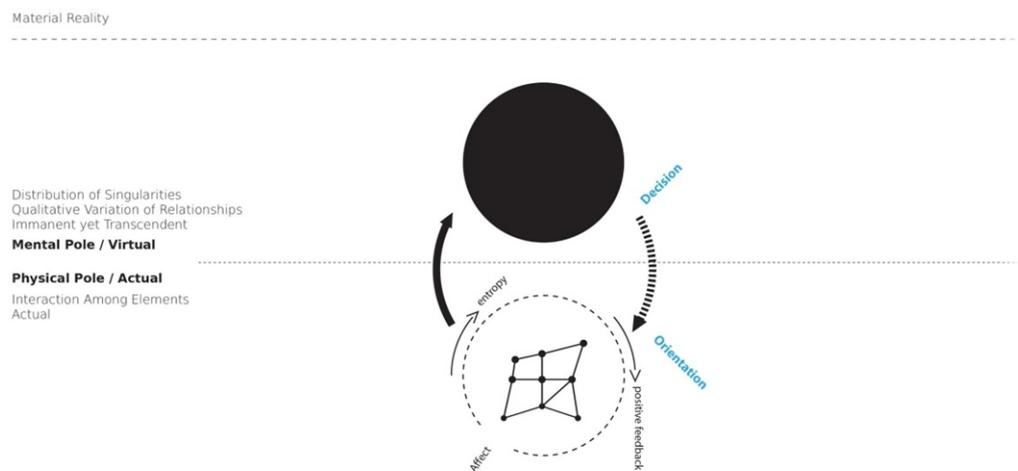

Figure 10: An ontological diagram for a Raductive Computational Model

It is by Actuating Auto(poiesis) that a diagram of raductive computational model is proposed and radical novelties can be re-established, immanent, at this time, within the computational process. The crucial alien decision effectuated by the ingress of the incomputable can redirect a computational process as a speculative force for a spatiotemporal construct yet to come. We therefore propose a diagram of a reductive computational model that in contrast to Autopoietic computational model, to Parametricism and to Emergentist models, embraces radical novelty as inherent in systemic-assemblies instead of just accounting for relative novelty as compulsory adaptations and self-modulations. If Deleuze's diagram would allow us to think radical novelty in the intensity of the biophysical world then Whitehead's adequately introduces novelty in the axiomatic domain of computation.

8 Conclusion

We have questioned the apparent faith in the generative capacity of computing for design and argued that this capacity is unquestioned. Rather, it is accepted and no accounting for the presence or emergence of novelty is made within the community; or at least is evident. The paper started with an account of novelty, to define the notion, in an attempt to render its dimensions visible. The Deleuzian input, with note to his concept of deterritorialisation and his account of the 'absolute' was pivotal to this definition, particularly with regard to the pattern of thought apparent therein with Whitehead. Our review of the notion of novelty was

coupled with the story of computation, which we considered broadly in terms of how notions of logic, rationalisation, formalisation and axiomatisation influenced computing and its application for design. Key events that have influenced this trajectory where pinpointed: Principia Mathematica, Gödel's incompleteness theorem and Turing's theory of incomputability were identified as seminal events that prompted fundamental limitations with regard axiomatic systems and computation. Three phases of Cybernetics were surveyed with respect to the key focus informing these phases: entropy, computation and the consequent repercussions in urban and architectural design. Each phase was complemented with a diagram showing how control, entropy and potentials of emancipation are distributed within reality. Our critique was then directed, not at computation per se but the unquestioned capacity to generate novelty. By resorting in a philosophical line of thinking that links Whitehead and Deleuze we proposed a diagram of a computational model. The diagram of the reductive model takes into account an extra domain of reality that is in mutual presupposition with any actual dataset in computation. However the peculiar communication between those two domains of reality allows incomputable data to enter in to the existing dataset and to affect the next step of computation. Indeterminacies in this sense enter computation as alien decisions that provide dark orientations to the next step of the computational systemic-assembly. We offer two conclusions, which may be deemed starting points for further consideration. (1) Radical novelty is found at the level of the alien decisions and dark orientations at the reciprocal presupposition between 'virtual' and 'actual', 'mental' and 'physical'. (2) Radical novelty, as Deleuze and Whitehead point to, is immanent in every systemic-assembly (see figure 10). Moving beyond autopoiesis, we seek to break the identity of such systemic-assemblies to compute the incomputable and think the unthinkable; to speculate!

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