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# Hacking Design: Novelty and Diachronic Emergence

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**Abstract**

The concept of emergence has had a significant effect on architectural theory instigating a paradigmatic change in design, affecting the way a building is perceived. In practice the practicalities of procuring a building that satisfies necessities, renders engagement with the concept largely academic. Otherwise, the physical properties of a building tend to limit engagement with emergence at the synchronic level. In this paper we consider how we might engage with the creative capacity of emergence at the diachronic level. As an artificial system a building may be perceived at different scales. Through computation we can conceive a systemic whole, which we may hack to explore the spatio-temporal capacities of the system, bending and leveraging behaviour in order to discover new tendencies of space and form.

The formation and generation of spatial configuration is a complex task, which conventional approaches tend to quantify, flattening the matter into something manageable. Emergence is a concept to explain the manifestation of something which occurs without external influence commanding the manner in which it should be. As an approach to designing something it is antithetical to the traditional solipsist Cartesian notion of space and form. The concept of emergence is of central interest to architecture and the design of artefacts because it is a way of considering the configuration of patterns ontologically. It is a perspective which embeds an artefact in a systemic manner, such that the perspective is of the components constituting the system, the manner in which they interact and how they are affected by context. In this way we might embrace the complexity of spatial problems using the complexity as an engine to drive the generation of spatial formation, an approach conceived in architecture by mavericks such as Gordon Pask, Cedric Price and Paul Coates.[1]

The term "pattern" refers to a particular, organised arrangement of components in space and time. Components which self-organise thereby define space as an underlying property of natural and animate systems,[2] illustrating the creative capacity of autonomous spatial configuration for architecture. Being a consequence of a system these patterns are not only structural, or sculptural (in the sense of appearance) — they are also behavioural, because the components constituting the system are autonomous. In this way our definition of space is determined by the properties of action and being, a perception informed by Jakob von Uexküll's proto-semiotic *Umwelt* theory[3] and the bio-cybernetic view of Gregory Bateson.[4] In applying this thinking to spatial formation we establish the condition of an entity-in-its-environment and how this condition may be conceived at different scales: at the local level of components in a system, between systems, and at the global level of wholes. The focus of this paper is the way in which complex dynamical systems determine spatial formation, and the differentiation between the systemic properties that determine their physical being and the design of artificial (or human-made) form. Through the capacity to distinguish a difference we consider how patterns of spatial formation may be effected at different scales. Our concern is *physical* emergence and how the concept (coupled with the capacity to distinguish a difference) affects the conception of space and form in architecture. We will start by looking at how the concept of difference can determine the manner in which we look at the way an entity engages with its context,[5] and how the distinction of a difference applies to the concept of emergence. The distinction of a difference illustrates the significance of boundaries: a condition which determines heterogeneity and defines spatial formations. The concept of autopoiesis is a spatial process to which the condition of a boundary is significant, but the transfer of autopoiesis to social systems is a moot issue, and in the end unnecessary. Thinking in terms of autonomic systems we escape the pitfalls and establish a means of thinking about self-organisation in natural and artificial systems congruently.

Balance is the chief activity of natural systems—in the sense that they maintain homoeostasis. By operating at the diachronic level we seek to affect the balance to topple the system into new domains. The system may cease, or it may fluctuate and bend to a new equilibrium. Through computational methods we can tap the potential of (diachronic) emergence to affect the production of novel properties and capacities in a system. To do this we introduce the idea of hacking, as a way of creating new interactions and associations between otherwise disparate entities of a system: to push a system beyond its homoeostatic tendency. As a hacker we engage with complexity, tweaking and bending the self-organising configuration of a system to mash up its tendencies in order to affect new spatial formations. The spatial salience of autonomous entities should be engaged with at this level in order to explore the capacities and affordances of a system. Once hacking effects an actualized configuration, involvement becomes synchronic. One's engagement with a system turns to the exploration of the capacities of spatial formations. The exploitation of these capacities can become suggestive for re-describing practical architectural requirements. The paper sets a speculative position, which the authors are developing through computational methods, to rethink design theory through practice.

## The Notion of a Difference

Gregory Bateson identified the capacity to determine a difference as the essential feature of complex dynamical systems, established through a coupling with the environment. He defined the process a matter of trial and error, through which differences occur. Perceived over time, being what we call "change". What is intriguing about Bateson's concept is how we can apply it to thinking about things at different scales, which is pertinent to architecture, and how from a systems point of view it enables one to maintain a view on an element at the local scale whilst considering the behaviour of a system (or between systems) at another scale. In essence it determines a perception as to how any entities, be they cells, organisms or entities in a computer model, engage with *their* world. It places an emphasis on the properties of something, the way in which these properties may "effect" and be affected, and thereby the capacities which are afforded.

> In the hard sciences, effects are, in general caused by rather concrete conditions or events – impacts, forces and so forth. But when you enter the world of communication, organisation, etc., you have to leave behind that whole world in which effects are brought about by forces and impacts and energy exchange. You enter a world in which "effects" – and I am not sure one should still use the same word – are brought about by *differences*.[6]

Figure 1 shows a rectangle with a line separating two disparate conditions: i.e., a blue and a yellow square. The boundary is implicit, so the line simply exaggerates its presence. The boundary declares a contrast between disparate conditions: two states which are variants to one another, which the border between distinguishes. The boundary defines order and creates structure, which may be perceived to facilitate and maintain the variance between one condition and another. In a static example like this the idea of the boundary being an active component may seem excessive, but if the boundary is perceived to be between a system (say a cell) and its environment then the boundary becomes something through which differences between internal and external boundaries (the cell's internal environment and the environment external to the cell) are affected. In such an example the boundary is a membrane, which is sensitive. In other words the differential between varied conditions is represented by a boundary which emerges as a consequence of a difference.

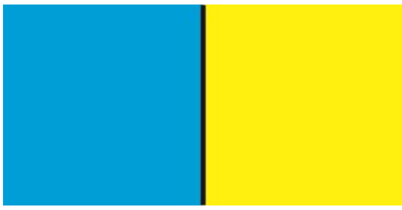

Figure 1

### *Distinguishing a Difference*

Bateson argues that it is differences that get onto a map, in that something which is perceived, being the condition of something being different to something else, is what is distinguished on a map. We comprehend the world through difference - A concept difficult to explain without resorting to the word "difference". It is a kind of self-referential notion of perception: an abstract matter which Bateson extends to the concept of information. "[W]hat we mean by information – the elementary unit of information – is 'a difference that makes a difference'."[7] He extends the distinction of a difference such that information is seen as a difference which instigates a change, a change of state instigated by the recognition of there being a difference between one state and another (or the present state and some other). This is how time alters the concept of difference, such that a change in state is a difference between one moment and another. So information is something which incites change – a difference. It is a pattern of interplay (structure) between "things" (heterogeneity) that enables the difference to occur, inducing a difference such that the condition of difference is implicit. We will come to see how the distinction of a difference is significant to thinking about spatial formation, and how by thinking systemically about spatial configuration we can manipulate and steer the capacities of a system. First we look at how the simple distinction of a difference can be affected at different levels to determine a correlation between capacities at the local scale, and between local and global scales.

### *Systems as Difference*

The difference is a boundary, a form having two sides, a notion Niklas Luhmann coupled with the concept of autopoiesis to explain his theory of "systems as difference".[8] He determined the systemic identification of a distinction to be the capacity to interpret a difference.[9] No system can exist without an environment, and for there to be a system there has to be a difference between it and its environment, which the system distinguishes. It is an obscure concept because the formulation begins with a difference and ends with a difference – but the matter is only a paradox if we consider something coming into being through a difference in the first instance.[10] The position taken in this paper is not the first instance (this implies the genesis of space) but the generation of spatial formations which stem from given conditions of environment. Besides, any design problem is already embedded in a heterogeneous context. In looking at the chemical basis of morphogenesis Turing emphasises something tends to develop from one pattern into another, rather from homogeneity into a pattern.[11] There needs to be something which is different, however slight, which something else will react to, to generate change. We can see this by distinguishing one cell in a grid having a different state to others, which will respond by changing their state in relation to the condition of those cells surrounding them (Figure 2). In this way the simple division represented in Figure 1 can evolve into complex patterns, such as shown in Figure 3.

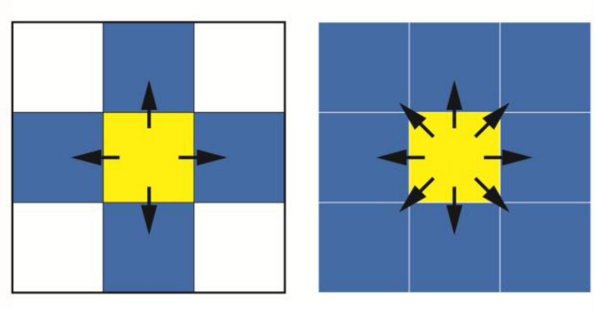

Figure 2: Von Neumann and Moore local neighbourhoods with arrows indicating the direction of influence.

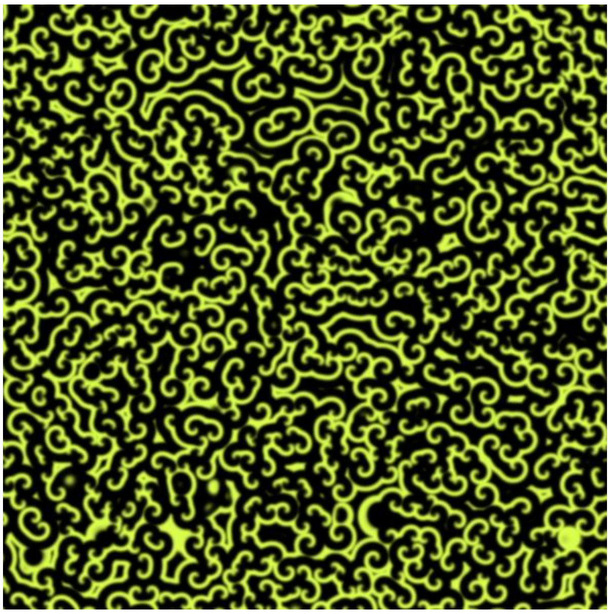

Figure 3: Spiral pattern generated through cellular automata model of Belousov-Zhabotinsky reaction.[12]

A boundary is a precondition and essential to the maintenance of a system, defining the difference between a system and its environment. A unity is formed through the correlation of the difference, through which space is constituted, such that the process defines "a space in which it can be realized as a concrete system, a space whose dimensions are the relations of production of the components that realize it".[13] This operative aspect of the condition of a boundary is summarised by Luhmann, who argued that a system is distinguished through form, which is determined by its structure and the difference between itself and the environment. "[The] point of departure for all systems theoretical analysis must be 'the difference between system and environment'. Systems are oriented by their environment … They constitute and maintain themselves by creating and maintaining a difference from their environment, and they use their boundaries to regulate this difference."[14] Heterogeneity is prerequisite, for through heterogeneity and the distinction of a difference further heterogeneity arises, and subsequently the elaboration of spatial configuration. A boundary is therefore a distinct component of a system or form, an entity distinguishing the coincidence between alternatives: things, states, properties, or qualities.

### The Spatial Saliency of Systems

We thus determine how our definition of space, which is characterized by the properties of action and being, is effected and may be engaged with systemically. It is a process of interaction which is determined through perception and action, which emphasise the spatial salience of something: a component in a system, an organism interacting with its environment, or an entity in a computer model. In this way we are able to think about the condition of something and how it may interact with its environment at a variety of scales. At the lowest level we can consider how a water molecule will behave in relation to variable levels of water between two reservoirs which are connected: the example which DeLanda uses to explain Mills' "Composition of Causes".[15] At another scale we may consider how the different aspects of a thunderstorm interact: the differences between periodic air flows, temperature or pressure gradients. In his paper DeLanda points out that the way in which the components which constitute a system interact, and the way in which systems interact with other systems (such as the organs of the body), are "with each other through their own external surfaces or membranes, by excreting biochemical substances or sensing them through embedded receptors".[16] DeLanda echoes the significance of boundaries and the capacity of an autonomous entity to distinguish a difference. We refer here to the semiotic nature of an entity's integration with its environment. A matter illustrated in von Uexküll's model of the functional cycle (Figure 4), which extends from his notion of *Umwelt*.[17] The manner through which this is effected is the capacity (receptors which sense) to distinguish a difference, which determine, through the existence of a boundary (surfaces and membranes), the distinction of a difference.

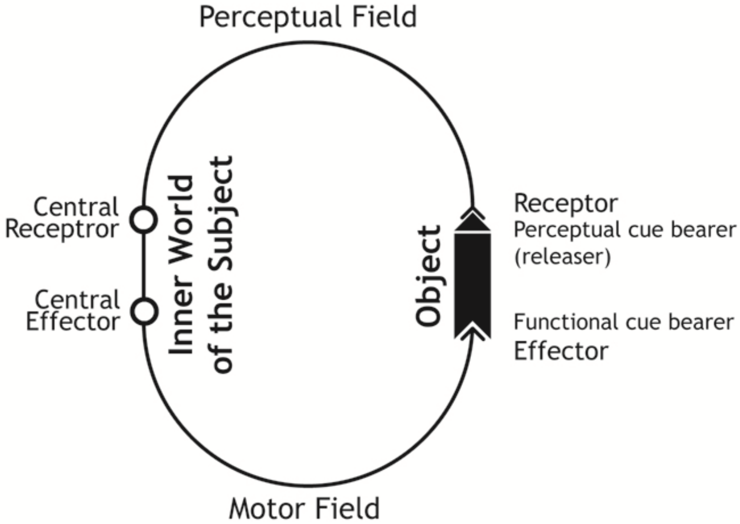


Fig 4: Uexküll's model of the functional cycle

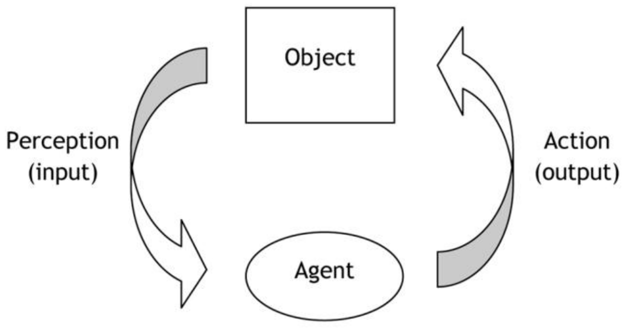


Fig 5: Perception-action is a loop describing agent behaviour.

Uexküll's functional cycle illustrates interaction as a loop which Pentti Määttänen has explicated as a simple condition of an entity's distinction and effectuation of change. Määttänen explains that in action modification of other things is more prominent than their affect on the entity, compared to perception, where the affect on the entity is greater than on the object.[18] A loop can therefore be visualised (see Figure 5) where ongoing action (output) is controlled with the help of received perceptual input. Perception is taken here not as cognitive but simply as the distinction of a difference: the capacity to distinguish a difference between different conditions. So, a boundary is conceived when a distinction is determined between variants, creating a form: a thing that has two sides. A system, being autonomous, distinguishes, in the sense of a cell reacting to its context. For example an amoebae reacting to levels of cyclic AMP,[19] a snowflake crystallising, or the reactiondiffusion processes of substance concentrations through space and time (see Figure 3).

Looking back to Figure 1, one side is determined as different from the other through focus on one of, or an aspect of one of, the conditions present. Luhmann argues that in drawing a distinction the two sides cannot be surveyed simultaneously, because distinction is an operation. The process is asymmetric in that one side of a boundary is surveyed before the other. A distinction is effected by a differentiation and the discrimination of the difference from one side. "Boundaries given in experience are in many cases 'asymmetrical' (so that we might in certain circumstances talk of 'oriented boundaries')."[20] In terms of a system, its coupling and communication with its environment, the notion of oriented boundaries is a significant description: whether it is from the perspective of an external observer distinguishing the difference between an area of blue or yellow or the monitoring of cyclic AMP by an amoeba – reacting to effects external to it, i.e. environmental constraints. It is a matter of interpretation determined by the state of the interpreting entity and its context - the interpreter being a system which is itself a difference. So from this perspective we consider the capacities of an entity locally, thereby enabling interaction through which the distinction of a difference enables boundaries and spatial formation.

**Looking at Artificial Systems: Naturally**

William Mitchell refers to architecture as "an art of distinctions". Distinctions between solid and void, internal and external, and so on determine boundaries between categories around which differences are recognised. "When such distinctions are made an amorphous world is transformed into a world that has distinct parts organised in some particular way".[21] The condition of spatial relations being wholes and parts, parts of parts, and the boundaries between is the description of how one entity relates to another. Looking at human-made products as wholes, constituted by the arrangements of parts which fit together in some way, we can determine a pattern of organisation in which we perceive the whole's gestalt. We do not refer here to the general understanding of gestalt theory that posits the form of something to be greater than the sum of its parts. As DeLanda highlights in his essay, the perception of a condition is not a matter of the "sum" of its parts.[22] The general definition of gestalt, and its relation to the concept of emergence, is misplaced because, from a systems theory point of view, it places emphasis on a particular aspect of a system. It is a misconception which Kurt Lewin disputed, contending the sum is not greater than its parts but rather is different.[23] Understanding the products of human design as systems of association between discrete components which are combined in some manner to form a whole, we comprehend the whole as an (artificial) system which has different properties to the sum of its parts but is not superior.

Looking internally there is a distinction between components constituting something which is natural and animate and a human-made artefact. In the former the components are autonomous. This is what defines the system as animate, whilst the latter form of system is inanimate, even in the case of an animised *product*, such as a piece of machinery – because the parts have no autonomy. One can enhance artefacts by embellishing components with independence. Such is the case with interactive architecture, in which buildings, or more specifically aspects of them such as façades, are manufactured out of components which are in some way aware of their context. A typical example is the component which is fabricated to alter its state in relation to that of its neighbours, in the same way a cell is conceived in John Conway's Game of Life (figure 2). But whilst such installations produce kinaesthetic artefacts they are not autonomous in the same way as a living animate entity. An artefact may be structurally open and organisationally closed, properties which Maturana and Varela define as critical for autopoiesis, but what is affected is state change. It is not truly animate in the sense of having the capacity to change through evolutionary processes – because the components of the system only have the power to self-organise between specific levels of composition. What this means is that the creative capacity of the system is constrained. Whilst the composition is adaptive, the (animate) form operates within particular limits.

To escape these constraints we need to think of architectural artefacts as artificial systems. In so doing we approach their ontology in a manner akin to natural complex dynamical systems. Given architectural artefacts are coupled to the behaviour of users, they are inherently determined by the complexity of users' spatial tendencies – tendencies which are complex. Embracing complexity we perceive physical space as a complex dynamical system. In so doing we engage with the self-organising tendencies and the adaptive behaviour emerging through the contextual interrelation of autonomous entities' interactions. The conditions of architecture become a unified complex of interacting systems with which we can engage – like mavericks tuning the improbability drive.[24]

## Engaging with Emergence

Paul Humphreys notes that "[a]pproaches to emergence are often divided into two broad categories, those of diachronic and synchronic emergence. The first approach primarily, but not exclusively, emphasizes the emergence of novel phenomena across time; the second emphasizes the co-existence of novel 'higher level' objects or properties with objects or properties existing at some 'lower level'."[25] Synchronic emergence is the focused interplay between upward and downward causation,[26] enabling "focused systemic behaviour through constraining the action of components".[27] Diachronic emergence is the production of new patterns and thresholds of behaviour over time. The system evolves – which is only possible through organic or computational processes. It may be thought of as truly creative. Through programming code and the capacity of the computer to emulate natural systems we can engage with diachronic emergence by considering the capacities of a system, and components within, engaging with their properties at the level of differences. Considering the implication of emergence to architecture our concern is the manner in which the differential properties of a system affect and are affected. Emergence is a property effected by the whole (or configuration, of constituent parts), such that none of the constituents possess the property individually, and that the property is characteristic of the system's configuration.[28] In this way we consider the means by which a system is effected in relation to the two categories of emergence outlined, and focus our attention on which is most pertinent to our design needs. Protevi argues discourse on emergence is typically subjugated to synchronic emergence, as a means to focus the self-organising tendencies of a system, but diachronic emergence is a means to tap the potential capacity of systems to generate novel spatial formations.

### *Autopoietic Configuration*

Protevi points out that synchronic emergence is what Thompson and Varela refer to as "reciprocal causality", that is, "the mutual constitution of local-to-global or 'upward' causality that produces focused systemic behaviour and the global-to-local, or downward, causality that constrains the local interactions of components".[29] A braiding together of local and global processes, of which autopoiesis is a prime example: a concept responding to the question "what is life?", explaining how a system can self-organise and self-maintain through a structural coupling with its environment. A spatial condition determined by a closed unity, establishing a boundary through which the system is structurally coupled with but has autonomy from its environment. Autopoietic organisation is an appealing model constituting a closed domain of relations, but its transfer to social systems is a moot issue. The concept is explicitly related to biology. Whilst autopoiesis has been applied to human social systems we are satisfied with Maturana's reasons for opposing the extension of the concept beyond biology.[30] Although concerned with self-organisation as a means of generating and configuring spatial formation, the issue of self-creation (which is the focus of autopoiesis) is a matter beyond our concern. The concept cannot be applied as is, the main points of contention being that the concept is (a) essentially a cognitive model (decoupled from the world) and (b) a machine-like abstraction. It is an abstract representation of biological systems, describing processes (such as cell metabolism) cybernetically. Whilst the machine metaphor is useful, it conjures a Cartesian notion of determinism and predictability.[31] Without wanting to align oneself with the philosophy in which Maturana and Varela embed their theory of autopoiesis, the concept itself can be extremely useful.[32]

The appealing aspect of autopoiesis is that spatial organisation is an inherent property of a system: by constituting a closed domain of relations which are specified only with respect to its constitutive organisational and structural patterns. The system exists, or more specifically, functions and behaves as a result of its environment – and the capacity of the system's parts to distinguish a difference. The process of interaction between the system and its environment, which shapes the system as well as the environment, is a structural coupling: congruence between system and environment. A plasticity of structure, through which change arising in one may prompt change in the other as well as a structural change in the system, which may affect a change in the system's behaviour. By focusing on the aspect of a system being a unity structurally coupled with its environment, to which it is different, we may side-step the problematic transfer of autopoiesis beyond biology. Of particular significance to the issue of space and form is the operative condition of a boundary. "[A] necessary feature [of autopoietic systems] is the presence of a boundary which is produced by a dynamics such that the boundary creates the conditions required for this dynamics",[33] creating the closed condition which enables the system to maintain itself. Luhmann emphasised this aspect, stating "a 'system' can always be called a 'form' under the condition that the concept of form must always apply to the difference between system and environment".[34] By ignoring the issue of self-creation we are left with the characteristics of an autonomic system.

### *Autonomic Organisation*

How a system comes into being is a principal concern of autopoiesis. An autonomic system is not so profound. The focus is on a system's actions and the way it shapes *a* world into significance. Autonomic systems are defined by what they do, what purpose they serve. They are complex dynamical systems, classified so as to emphasise the aspect of autonomy. Typical examples of an autonomic system are the immune system, ant colonies and organisms. Autonomic systems have a function (and perform tasks) and are able to operate independently: the immune system detects and defends the body against foreign bodies and infection; an organism strives to survive, as does an ant colony. Common characteristics of autonomic systems are that they are independent, distributed, emergent, adaptive and self-organising.

The components which constitute the system are central: the cells of the immune system; ants in an ant colony. Being autonomous, they define the autonomy of the system. If a system is considered to be autonomous then "the centre of attention is placed on emergent behaviours and internal self-organising processes which define what counts as relevant interactions".[35] Computationally, Liu and Tsui specify that an autonomous entity consists of a detector(s), effector(s) and a repository of local behaviour rules.[36] Detectors enable an entity to sense and measure external differences, which stimulate or influence the entity to do something. Effectors enable it to express action(s), which can be internal changes of state or external display of actions. Von Uexküll's functional cycle is a model describing detector-effector interplay, explaining the congruence between an entity and its environment (Figure 4), which effects behaviour (Figure 5).

## The Physicality of Spatial Formation: An Innate Constraint

The environment plays a significant role in two ways. Firstly it is where the components of the system reside and behave (the system is itself a domain as well as the environment which the system inhabits); and secondly the environment (in the case of systems such as ant colonies) can act as a medium for indirect communication between the entities constituting the system. This is the significance of distributed representation – for example, how systems such as ant colonies communicate through pheromones. Being different from its environment, an autonomously organised system is distinguishable. It has the capacity to respond to external perturbations and differences in its environment by performing actions. To think about an autonomic system is to think about a system on a variety of levels:

- in relation to its context, and thereby about what the system does, how it behaves and what effects prompt it towards particular behaviours;

- as a unity which is different from the sum of its parts but which exists because of agency between its parts, which are independent entities (that may form separate component systems intrinsic to the system generally) that form a network of interactions; and
- in relation to how its parts behave and respond to the environment and other systems with which it is connected or resides alongside.

Bourgine and Varela outline the significance of autonomy, with regard to computation (in the field of artificial life), stipulating two hypotheses: every autonomous system is (1) operationally closed, and (2) behaves as an abductive machine with a hermeneutic acquired capacity close to unity along its trajectory of states. By employing the model of an autonomic system one can engage with the virtual capacities of a system, by taking into account “the structure of the possibility spaces involved with tendencies”.[37] Two aspects, significant to architectural concerns, which transfer from the conception of an autonomic system, are:

- that space is a constraint, and
- that we can focus the capacities of such systems towards some condition – thereby evoking the potential capacity of novel spatial formation by stimulating the inherent spatiality of the system.

**Systems Thinking in Architecture**

The built environment, the setting for everyday life, renders buildings restrained to practicalities and functionality: restraints which define “instances”. Whilst architects draw on the biological processes of morphogenesis and evolution to generate interactive architectural assemblies, a building is a product. It is an assembly, and thereby can only adapt in some way within specific parameters. For example a facade may change under different conditions and constraints;[38] a wall or internal structure may react to movement or environmental events;[39] or a building may be conceived robotically.[40] Experiments in self-configuring buildings (such as the robotic structures of d’Estree Sterk) suggest a future in which the autonomous built environment is a reality. The Generator project (by Cedric Price, John and Julia Frazer) proposed how the conditions of architecture could be set through user interaction, or the building might configure itself if it got bored.[41] Whilst enchanting, the practicalities of furniture, equipment, toys, inhabitants and pets prevent such innovation – today at least. The matter is not so much a technological issue as a philosophical one.

Architectural scenarios are inherently complex. By embracing this complexity we look to evoke the ontology of novel spatial formations, in a manner which unifies theory with practice. When the design process begins to focus on a solution we are dealing with an “instance” - what DeLanda calls an “actual”, a material form. Prior to this point what one is doing is exploring the “virtual”.[42] Once the actual is ascertained, the way we can conceive a design in relation to the concept of emergence becomes constrained. At this point one is concerned with exploring the virtual field of an instance to influence the direction of an “actual”: concerned with how the properties of the system may be manipulated to direct the outcome of the self-organising process. This is exploring the synchronic capacities of the system: the domain of manipulating, coaxing and tweaking instances.

Looking to natural systems to express the creative capacity of (diachronic) emergence we note the example given by Protevi regarding the distinction between weather and climate: the weather is variable, while the climate is stable. Our current climate is the condition determined by one attractor of a global system, which consists of various attractors in a particular relation. Perturbations could change the current condition towards another attractor, radically altering our climate, perhaps to another ice age or to something else – or to a new condition that may arise from a restructuring of the phase space, creating a new distribution of singularities at the global level. Climatic conditions may therefore be considered a repertoire – and our current climate is but one expression.[43]
Emergence is a means to reapproach design. It allows one to engage with the virtual, redefining theory in a way that disintegrates boundaries between art and science, focusing our understanding of space and thereby of the generation of form. In so doing it is most productive and beneficial to engage with the concept, in the design process, at the diachronic level, in order to understand the

affordances of the system one is involved with. To do so we need to focus on the capacities of components and the systems which they constitute. We need to focus on interaction at different scales, and between wholes. By engaging with emergence at the diachronic level design has the potential to engage with the creativity of complex dynamical systems.

### Tapping Novelty

We have illustrated how we can perceive the interplay between entities at different scales through the distinction of a difference, and how this may be effected through the concept of autopoiesis. By focusing on the autonomy of components we reapproach spatial formation in architecture, ontologically, through engaging with the organisational capacities of complex dynamical systems. In so doing we manipulate the agency of components in a system and focus the constraints so that we can steer the system's properties towards some purpose. But with regard to the different categories of emergence, we tend to only engage with emergence at the synchronic level when working with self-organising systems. Only through diachronic emergence can we provoke the production of novel patterns or the new distribution of singularities that would restructure the tendencies of the system and enlarge its virtual capacities. As noted, synchronic emergence is useful to focus the capacities of a system to determine the actual, because the processes of the system are homeostatic. Balance is the chief operation of such systems – in the sense that they perform to maintain homeostasis. If perturbed beyond certain limits then they expire. If we are to explore the creative capacity of systemic interplay and the potential affordances between entities, it is therefore necessary to enable the system to cope with encroaching perturbations which challenge its structure. In other words we want to agitate and inflict disruption on a system in order that it may shake up and reorganise.

#### *Hacking the System*

Keith Ansell Pearson examines the "machinic"[44] character of systems in an attempt to grasp the virtuality of the actual entities entering into differential relations.[45] Pearson argues that it is possible to dislocate a system from its homeostatic circularity and expose its organisation to allow examination of its virtual tendencies, and the capacities of its virtual domain. The machinic character of entities, in other words their capacities to form relations with other entities, and their capacities to affect and be affected, enable transversal communication and the formation of assemblages. "Machinic assemblages"[46] mesh together social, technological and biological entities present, both in the design process and the inhabitation of the architectural artefact. The practice of hacking therefore is becoming relevant in the attempt to dismantle the autonomic system where its organisation is a constraint to exploring the creative capacity.[47] One of the main practices of a hacker is "to produce or apply the abstract to information and express the possibility of new worlds, beyond necessity".[48] To hack is not a purposeful action steering a particular event in a certain direction; rather, it is the opening of new domains where new capacities of the system might find a way to be expressed. We see the architect as a hacker. The task is to problematise the normal functioning of the computational model. Every hack produces a common plane for different things to enter into relation and therefore to differentiate the normal functioning of their shared goal. The action of hacking is to push the system beyond a certain threshold where positive feedback triggers diachronic emergence. It is for this reason that we see hacking as a means to operate on the virtual to transform the actual.

> The virtual is the true domain of the hacker. It is from the virtual that the hacker produces ever-new expressions of the actual. To the hacker, what is represented as being real is always partial, limited, perhaps even false. To the hacker there is always a surplus of possibility expressed in what is actual, the surplus of the virtual. This is the inexhaustible domain of what is real without being actual, what is not but which may be. To hack is to release the virtual into the actual, to express the difference of the real.[49]

By conceiving architecture as a complex of dynamical systems the architect is able (through computation) to tap "the surplus of virtuality". In other words the architect-hacker thinks at the level of system components, recognising processes in formation. Thereby, being able to affect the stage of dynamism and be affected by it, the architect taps on the emergence of potential capacities that trigger the production of novel spatial arrangements. Hacking the system in our understanding is the imaginative use of computational systems to map the virtual capacities of a system. Architects are able to experiment with collective behaviour by drawing on natural systems such as swarms and neural networks. Through computation we can engage with low-level interactions of a system to map emergent capacities in the production of spatial configurations and forms. Through emulating and tailoring natural systems we can map "the structure of the real virtuality associated with the capacities"[50] and utilise them in architectural practice. Spatial formation is reapproached through interplay between different conditions and interrelated entities, effecting boundaries which emerge through the capacities of the system. It is, therefore, not purpose or transcendent ideas that govern the production of space and form but the quasi-causality[51] of the distribution of singularities in a systems phase space which the architect-hacker brings together, by linking the differential relations of interacting computational entities.

## Conclusion

In nature there are two forms of materiality: (1) living and animate beings, for which form takes shape through interaction between autonomous entities and their context; and (2) inanimate objects, whose form is directed by forces acting upon them. The shape and structure of living and animate beings arise through interplay between systems which are determined by the actions of discrete physical entities. The autonomy of these entities is effected through agency, creating patterns through which regularities emerge. In other words living and animate beings are systems whose form is effected through the autonomy of entities constituting the system, and their properties. Inanimate objects have no autonomy; their form is determined through forces acting upon them. The properties constituting a physical entity, such as a rock, are still. Other than having properties of malleability they play no part in their actual forming and shaping. They are physical entities which are dormant: akin to dumb actors in a play, which is being acted out around their physical being. Human-made forms are products, in that they are assembled from parts in some manner to configure a whole. They are most akin to inanimate objects found in nature, but by approaching their design through distributed representation we are able to perceive the capacities and engage with their properties in a manner which lies between the two forms of materiality in nature.

Philosophical debate on the concept of emergence concerns science and art as a whole, with particular reflections from the fields of biology, social science and cognitive science having particular effect on the manner in which the notion of emergence is applied in architecture: extending the theory to practice. In this essay we have considered *physical* emergence and how our understanding of the concept affects the manner in which we conceive spatial formation. The generative capacity of code emulates the autonomy of the living, through artful mechanisation emulating natural materiality.

We have drawn a course through varied concepts, pertinent to architecture, to show how in relation to the concept of emergence we might reapproach the generation of space and form. We have shown how architectural problems of spatial configuration can be understood systemically by focusing on the capacity of an entity to distinguish a difference. Through autonomy spatial formations emerge through local-to-global interactions, which an architect can engage with. Traditional approaches to configuring space quantify problems, flattening them to define a problem as manageable. We do not know what richness is lost. We argue that this complexity should be embraced and used as an engine to drive the design process. Embraced at the initial stage of design we can scrutinise the affordances of a system, exploring its virtual capacities to cause imbalance - potentially creating (or rather discovering) new conditions and system formation. In so doing we engage with the concept of emergence diachronically. After which the practicalities of steering a solution towards a particular resolution renders engagement with the concept of emergence synchronic. This is based on the premise that a problem is a system when perceived ecologically. Hacking is a way to experiment with the virtual capacities of a system. The architect-hacker explores the spatio-temporal dynamisms of a system in a manner which enables the production of new singularities. This in turn enables the mapping of a systems repertoire, in a way which applies Bateson's dictum that "differences are the things that get onto a map".[52] We can therefore affect the system's repertoire, exploring how one set of variables might influence the system in one direction or another. This is one way in which we as architects can really engage with emergence and evoke the potential creativity of complex dynamical systems.

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[1] Pask at the level of the machine, Price of a building as a machine and Paul Coates in terms of code. See Gordon Pask, "The Architectural Relevance of Cybernetics", in *Architectural Design*, September, 1969, 494–96; Paul Coates, *programming.architecture*, London: Routledge, 2010.

[2] Scott Camazine, Jean-Louis Deneubourg, Nigel R. Franks, James Sneyd, Guy Theraulaz, and Eric Bonabeau, *Self-Organisation in Biological Systems*, Oxford: Princeton University Press, 2001.

[3] Jakob von Uexküll, "A Stroll Through the Worlds of Animals and Men: A Picture Book of Invisible Worlds" (1934), in Claire H. Schiller (ed.), *Instinctive Behaviour: The Development of a Modern Concept*, London: Methuen, 1957, 5–80.

[4] Gregory Bateson, *Steps to an Ecology of Mind*, Chicago: University of Chicago Press, 2000.

[5] Gregory Bateson, "Form, Substance and Difference" (1970), in *Steps to an Ecology of Mind*, Chicago: University of Chicago Press, 2000, 454–71.

[6] Bateson, "Form, Substance and Difference", 458.

[7] Bateson, "Form, Substance and Difference", 459.

[8] Niklas Luhmann, "Systems as Difference", *Organization*, 13, no. 1 (2006), 37–57.

[9] Based largely upon the elementary "mark" in George Spencer-Brown, *Laws of Form*, London: Allen & Unwin, 1969.

[10] Following the logic of Spencer-Brown, Luhmann is confined to the notion that "a universe comes into being when a space is severed or taken apart"; Spencer-Brown, *Laws of Form*, v. Spencer-Brown demonstrates the genesis of form through the distinction of a circle's boundary. The paradox lies in the fact that for a difference to exist and for some entity to distinguish the difference the difference must exist in the first place. The example only makes sense if the difference exists cognitively – in the imagination of the person drawing the circle. See Glanville's "musing" of the way in which space is assumed and the agent is implicit in Spencer-Brown's argument; Ranulph Glanville, "A (Cybernetic) Musing: The Boundaries of Distinction? The Distinction of Boundaries?", *Cybernetics and Human Knowing*, 18, nos. 1-2 (2011), 123–33.

[11] Alan Turing, "The Chemical Basis of Morphogenesis", *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 237, no. 641 (14 August 1952), 37–72.

[12] Alasdair Turner, *A Simple Model of the Belousov-Zhabotinsky reaction from first principles: Implementation note,* http://discovery.ucl.ac.uk/17241/1/17241.pdf .

[13] Humberto R. Maturana and Francisco Varela, *Autopoiesis and Cognition: The Realization of the Living*, Dordrecht: D. Reidel, 1980, 88.

[14] Niklas Luhmann, *Social Systems*, trans. John Bednarz, Jr., Stanford: Stanford University Press, 1995, 16–17.

[15] Manuel DeLanda, *Emergence, Causality and Realism*, in 'Architectural Theory Journal', 17:1, Special issue on 'Architecture and Emergence', Michael Tawa and Lee Stickells (eds.), Taylor and Francis, 2011.

[16] DeLanda, "Emergence, Causality and Realism".

[17] von Uexküll, "A Stroll Through the Worlds of Animals and Men", 10. Original diagram redrawn by author's.

[18] Pentti Määttänen, "Habits as Vehicles of Cognition", http://www.nordprag.org/nsp/1/Maattanen.pdf (Helsinki, 2010).

[19] AMP stands for adenosine monophosphate, an organic compound which acts like a signal.

[20] Barry Smith, "Boundaries: An Essay in Mereotopology", in L. Hahn (ed.), *The Philosophy of Roderick Chisholm (Library of Living Philosophers)*, Chicago: Open Court Publishing, 1997, 533–61; p538.
[21] William J. Mitchell, *The Logic of Architecture: Design, Computation and Cognition*, Cambridge, MA: The MIT Press, 1998, 1.
[22] DeLanda, "Emergence, Causality and Realism".
[23] Kurt Lewin, *Field Theory in Social Science: Selected Theoretical Papers*, Dorwin Cartwright (ed.), London: Tavistock, 1952.
[24] The improbability drive is a means of manipulating space, used by the Heart of Gold, a spaceship in Douglas Adams, *The Hitchhiker's Guide to the Galaxy*, to fold two points in space together so as to move from one point to another quickly. Adams explains the drive was invented "following research into finite improbability, which was often used to break the ice at parties by making all the molecules in the hostess' undergarments leap one foot simultaneously to the left, in accordance with the theory of indeterminacy", but many respectful physicists wouldn't stand for such a scenario "partly because it was a debasement of science, but mostly because they didn't get invited to those sort of parties"; London: Picador, 2002, 78.
[25] Paul Humphreys, "Synchronic and Diachronic Emergence", *Minds and Machines*, 18, no. 4, (2008), 431.
[26] "Upward causation" is "local-to-global" (also referred to as "bottom-up") and "downward causation" is "global-to-local" (otherwise referred to as "top-down").
[27] John Protevi, "Deleuze, Guattari and Emergence", *Paragraph: A Journal of Modern Critical Theory*, 29, no. 2 (July 2006), 19–39.
[28] Alexander Rueger, "Physical Emergence: Diachronic and Synchronic", in *Synthese* 124, no. 3 (2000), 297-322.
[29] Protevi, "Deleuze, Guattari and Emergence", 24.
[30] See Maturana's critique in introduction of Maturana and Varela, *Autopoiesis and Cognition: the Realization of the Living.*
[31] Robert Rosen, *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*, New York: Columbia University Press, 1991.
[32] Although the premise of constructivism (on which autopoiesis is founded) is appealing the constructive rational determines reality a system of causal relations, which stem from the mind. Our position is that we are (fundamentally) biological processes from which our capacities to sense and the mind have developed. Nevertheless Maturana and Varela's autopoietic concept still holds some appeal with regard to modelling systems.
[33] Francisco Varela, Humberto R. Maturana and R. Uribe, "Autopoiesis: The Organisation of Living Systems, its Characterisation and a Model", *Biosystems* 5, no. 4 (1974), 191.
[34] Luhmann, *Systems as Difference*, 45.
[35] Paul Bourgine and Francisco J. Varela, 'Introduction', in Varela and Bourgine (eds), *Toward a Practice of Autonomous Systems: Proceedings of the First European Conference on Artificial Life*, Cambridge MA: MIT Press, 1992, xii.
[36] Jiming Liu and K.C. Tsui, "Toward nature-inspired computing", *Communications of the ACM*, 49, no. 10 (October 2006), 59–64.
[37] DeLanda, *Emergence, Causality and Realism.*
[38] For example see: Jules Moloney, "A Morphology of Pattern for Kinetic Facades", in Temy Tidafi and Toma Dorta (eds), *Proceedings of the 13th International CAAD Futures Conference*, Montreal: Les Presses de l'Université de Montréal, 2009, 200–13; Marilena Skavara, *Learning emergence: adaptive cellular automata façade trained by artificial neural networks*, Master's thesis, University College London, 2009, http://eprints.ucl.ac.uk/19042/; Ernst Giselbrecht and Partner ZT GMBH, *Showroom Kiefer technic, Bad Gleichenberg*, 2007; Aedas UK Ltd, *Al Bahr towers, Dubai*, http://www.aedas.com/ADIC-Headquarters
[39] For example see: Krets (Marcelyn Gow, Ulrika Karlsson, Pablo Miranda Carranza, Daniel Norell

and Jonas Runberger), *SplineGraft*, 2006, http://www.krets.org/splinegraft.php; Mette Ramsgard Thomsen, "Robotic Membranes, Exploring a Textile Architecture of Behaviour", in *Architectural Design*, July/August, 2008, 93–95.

[40] Tristan d'Estree Sterk, "Building Upon Negroponte: A Hybridized Model Of Control Suitable For Responsive Architecture", in Wolfgang Dokonel and Urs Hirschburg (eds), *Digital Design: proceedings of 21st eCAADe conference*, Graz, 2003, 407–13.

[41] John Frazer, *Evolutionary architecture*, London: AA Publications, 1995.

[42] "Virtual" is understood here in terms of the ontological dimension of the Deleuzian schema. Deleuze makes a distinction between "possible and real" and "virtual and actual". Of the virtual he states: "The virtual is opposed not to the real but to the actual. The virtual is fully real in so far as it is virtual [...] The reality of the virtual consists of the differential elements and relations along with the singular points which correspond to them. The reality of the virtual is structure" and that "The virtual possesses the reality of a task to be performed or a problem to be solved: it is the problem which orientates, conditions and engenders solutions, but these do not resemble the conditions of the problem". Gilles Deleuze, *Difference and Repetition*, London: Continuum, 2004, 260–63.

[43] Protevi, "Deleuze, Guattari and Emergence", 23–4.

[44] A term stemming from, Felix Guattari, *Chaosmosis: an ethico-aesthetic paradigm*, Bloomington: Indiana University Press, 1995.

[45] Keith Ansell Pearson, *Germinal Life: The Difference and Repetition of Deleuze*, London: Routledge, 1999.

[46] A term stemming from Gilles Deleuze and Felix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, London: The Athlone Press Ltd, 1987.

[47] Hacking is understood here as an ethical approach to the relation of virtual tendencies and capacities with the actualized entity, rather than an action of criminality –to which it is typically related.

[48] McKenzie Wark, *A hacker manifesto*, Cambridge, MA: Harvard University Press, 2004. Para 14. Note: referencing relates to paragraphs.

[49] Wark, *A hacker manifesto*, Para 74.

[50] DeLanda, *Emergence, Causality and Realism.*

[51] In the neorealist philosophy of Deleuze physical systems have no teleological or goal-seeking behaviour. As Manuel DeLanda points out Deleuze needed to replace "final causes" with "quasi-causes". Quasi-cause is the operator that doesn't create the links in coupled differential relationships of disparate bodies, but is the operator that affects those links. Quasi-causes create what Deleuze calls "internal resonance" within the system, and "inevitable movement". See Gilles Deleuze, *The Logic of Sense*, London: Continuum, 2004, 9-30 and "The Method of Dramatization", in *Desert Islands and Other Texts: 1953-1974*, Cambridge, MA: The MIT Press, 2004.

[52] Bateson, *Form, Substance and Difference*, P457.