Art, Emergence, and the Computational Sublime

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Abstract

This paper looks at some critical and technical issues of relevance to generative art. In particular, it examines the concept of *emergence*, looking at its historical origins and salient issues surrounding its classification and meaning for developing generative art. These issues include the hierarchy of levels associated with emergence, recognition and ontology of patterns, prediction and determinism. Each of these are then related to attempts to create emergent phenomena with computers for artistic purposes. Several methodologies for developing emergent generative art are discussed including what is termed in the paper “the computational sublime”. This definition is considered in relation to historical and contemporary definitions of the sublime and is posited as a way for artists to suggest their work is more than the sum of its parts.

1. Introduction

As with a number of art movements, generative art draws from selected elements of Science and Philosophy as part of its basis, and as a primary influence on its motivation. Naturally, these “influences” are well known and widely discussed in scientific literature and from scientific perspectives. However, little attention has been paid to these influences from within generative art beyond the fact that they are seen to be part of Science’s way of describing the world. If such influences are important to the art form, they need to be addressed from the perspective of generative art itself.

In particular, this paper examines the concept of *emergence*, with a view to using it as a basis for developing strategies in generative art. The views presented here are influenced primarily by investigations in Evolutionary Biology, Philosophy of Science, Cybernetics, Systems Theory, and Artificial Life. These frameworks are not the usual basis for forming a discussion about art, but for generative art, they hold special significance, being the major foundations for developing artworks and ideas. This is partly due to the nebulous influence of concepts such as emergence, novelty, chaos theory, determinism, complexity, self-organization, and “natural” selection on generative works. If these are going to form part of the foundation of a practice, it is surely wise to ensure they are well constructed – lest whatever is constructed on them may collapse.

No doubt, there are other important criteria for thinking about generative art. The purpose here is to examine the concepts of art and emergence and propose possible strategies that the generative artist can use to exploit these. At the very least, this may provide a way of creating and, in parallel, critically evaluating generative art.

How might we think about generative processes in relation to an artistic practice? Oddly enough, this question has been asked many times before in relation to Cybernetics and Artificial Life. Often in these disciplines, less importance is attached to distinctions between Art and Science than is attached to the philosophy used to approach the endeavour [36].

1.1. Art in Context

This paper addresses technical and scientific issues from an artist's perspective. Fundamentally, art is understood as *experience in context*. Consider some implications of, and qualifications for, this definition. Firstly, experiences, though they may be shared, are ultimately subjective. Secondly, art is always experienced in a certain context[1], and this context of the experience may determine the artistic qualities. Perhaps, for example, a supermarket trolley in a supermarket is not art, but a supermarket trolley in an art gallery would be.

The above definition describes necessary but not sufficient criteria for defining art – how do we determine art from non-art within the context of experience[2]? Collectively, perhaps there is no such thing as non-art – any experience may have *some* artistic quality to *somebody*. Even if we accept this, we can still make relative judgements about our "experiences in context" from a variety of *shared bases*. Shared bases are beliefs, the reference points, and knowledge systems common to groups of people. However, what is considered "good art" by one person or sub-culture may not even be recognised as art[3] by others. Even if some artistic qualities are acknowledged in an artwork, these qualities may not incite the same modes of appreciation between different individuals or groups. Nevertheless, although the experience of art is subjective, people may still engage critically with art, and collectively recognize particular qualities and languages in various artworks. These shared bases are learned both formally (e.g. at art school) and informally through social interactions. The aim of this paper is to contribute to the shared base for the theory and practice of generative art.

To accept diverse cultural languages for art is not to deny the relevance of the biological origins and psychological relations of art. A number of authors see features in art, basic abilities and desires for art-making, that suggest it is a biological adaptation [6, 15-17, 29, 33, 45]. Some biologists see basic abilities and desires for art-making as adaptations because, for example, they increase one's social status through conspicuous consumption. This however, does not limit the potential for art to offer significant "experiences in context". Owning a Porsche to increase one's status through conspicuous consumption does not deny that a Porsche is a clever piece of engineering[4]. It remains, however, disappointing that the majority of present-day contemporary art courses do not include biology as part of their syllabus and that theories of the biological origins of art are largely unacknowledged in contemporary art discourse.

1.2. Artificial Life

The idea of giving life to inanimate objects is a consistent fascination for humans. Domains of enquiry such as Artificial Life (AL) suggest by their very name a kind of "Frankensteinian" fascination with mortality, a perceived reversal of entropy, and the super-human ability to breathe real

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[1] In this paper, we deny the ontology of platonic experiences.
[2] Art can also reference non-experiential modes, or suggest that which cannot be experienced, however while this may be its subject, it is still achieved within the bounds of experience.
[3] A recent newspaper story states how an art gallery cleaner "dismantled and discarded" an art installation by Damian Hurst, believing it to be garbage. The work was worth "hundreds of thousands of dollars", yet appeared to be nothing but rubbish to the gallery cleaner. New York Times, London, Monday 22 Oct 2001 (See: http://www.theage.com.au/entertainment/2001/10/22/FFX2WI063TC.html).
[4] This is not to ignore the obvious political implications about wealth, status, and the ownership of "great works of art" by a privileged few.

life into inanimate objects. Such modalities may be either conscious or unconscious forces in the AL artist's creative impetus.

Different interest groups have different interpretations and visions for Artificial Life (*Artificial Lives* as Bonabeau and Theraulaz call them [9]). The perspective presented in this paper is taken from that of the artist wishing to engage critically with AL. Therefore, important and cognisant ideas that compel the AL artist may centre, for example, on the concepts of control, inscape, the sublime, novelty, aesthetics, phenomenology, determinism, causation, and ecology.

When we express our relationship to "the natural" through poesis[5], explicitly or implicitly we express our concern about *control.* Nature is seen as a force that must be controlled, harnessed and tamed. This belief is reflected in popular notions of nature as "the chaos", the uncontrollable force, and is exemplified by its effects and their consequences (death). For example, the act of gardening is often quoted as a metaphor to describe aesthetic selection[6]. In some sense, gardening is about mastering the uncontrollable – harnessing nature and manipulating it for aesthetic purposes (from the perspective of the gardener). The issue of control translates from the biological garden to the digital garden; in the case of aesthetic selection, it becomes even more acute – the digital gardener selects what will "live" and what will "die".

Important also, is AL's original claim of broadening the definition of life and offering new or novel forms of life not currently observed in terrestrial biology – "life-as-it-could-be" [25]. Much of the life-as-it-could-be mode of investigation has been dismissed by scientists because it is ill defined [9] – if we were to create life-as-it-could-be that was significantly different from life-as-we-know-it, how would we recognise it as life? It is also easy to misinterpret life-as-it-could-be as simply a search for the novel or bizarre – how far can the phenomenological definition of life (particularly in an art context) be (un)reasonably extended in a postmodern view of the world?

Indeed, AL techniques form part of the broader category of generative art – art that uses some form of generative process in its realization.

1.3. Generative Art

A basic definition of generative art has been proposed previously [18]. To briefly summarise, the terms *genotype* and *phenotype* are borrowed from Biology as analogous representations of a productive methodology. Generative art practice focuses on the production and composition of the genotype and the media in which it produces the phenotype. When run, interpreted, or performed, the genotype produces the phenotype – the work to be experienced and the realization of the process encoded by the genotype.

Generative art usually involves poeisis, which suggests that it should reveal the world in ways that nature can't – hence technology seems a possible, but not necessarily unique, vehicle to achieve this aim. Implicate too, is the act of creation, but it is poignant to ask in a critical context what is being created, what is being revealed, and what is the difference between the two?

The role of the artist in a developing a generative artwork often involves creation and manipulation of the genotype and the developmental and (pseudo) physical process systems that "unfold" it into the phenotype.

[5] Poeisis is the process of bringing-forth via human hands, of revealing the world in a way that could not have occurred by natural processes (which are the processes of *physis*).
[6] Evolutionary artist, William Latham says "The artistic process takes place in two stages: creation and gardening. The artist first creates the systems of the virtual world…the artist then becomes a gardener within this world he has created;" see [42].

2. Emergence

In this section, one of the central concepts for developing and understanding generative art is examined: *emergence*. Emergence is an all-encompassing term, with a nexus of barely related meanings in different domains, making it a difficult term to clearly define, let alone understand. Since the term's early use, almost every author has provided his or her own sub-categorization for different types of emergence. There is little consensus between individual authors, much less between disciplines. Debate continues as to the merits of the concept in a number of areas, primarily trying to decide if emergence is a linguistic, epistemic or ontological construct (for a comprehensive overview and historical review see [5, 7]).

The common non-specialist interpretation of the term *emergence* refers to revealing, appearing, or ‘making visible’ an event, object, or the outcome of a process. In an art context, emergence also encompasses novelty, surprise, spontaneity, agency, even creativity itself – aspects of emergence we will examine more formally in this section.

2.1. History and Overview of Emergence.

Emergence has its origins in the nineteenth century studies of physical, chemical and biological systems. John Stuart Mill drew a distinction between “two modes of the conjoint action of causes, the mechanical and the chemical” [28]. Influenced by Mill, George Henry Lewes recognized Mill’s fundamental differences between heteropathic and homopathic effects, calling them *emergents* and *resultants* respectively [26]. As described by C. Lloyd Morgan [30], *emergent evolution* (*emergentism*) describes the “incoming of the new”, that is, emergence is defined as the *creation of new properties*. Emergentism was a philosophy about the nature of the universe and the way material elements combine to make structures of increasing complexity become increasingly complex. When the complexity of material configurations reaches a certain level, genuinely novel properties emerge that have not been instantiated before and could not have been predicted [4].

The oft-quoted example of Mill’s (from Morgan) relates to molecular chemistry: Carbon has certain properties, sulphur has certain properties; when the two are combined the result is not an additive mixture of the two but a new compound (carbon disulphide), some of the properties of which are quite different than those of either component – hence the interpretation that *the whole is more than the sum of its parts*. Morgan, referencing the work of Mill, Lewes and psychologist Wundt’s “principle of creative synthesis”, saw emergence as a phenomenon that occurs in many different systems or *hierarchical levels* including molecular interactions, life, mind, and self-consciousness. This concept of emergence has been described as “that reasonable aspect of vitalism which is worth to maintain” [21], that is, it removes vitalism’s non-materialist suppositions.

Emergence and emergentism have continued to rise and fall in popularity throughout the twentieth century. Important criticisms in Nagel’s *Structure of Science* [31] and Hemple and Oppenheim’s “Studies in the logic of Explanation” [23] saw emergence as a strong philosophical concept wane for many years. A key criticism of emergence as a phenomenon is that its usefulness as a classification method is limited because it tends to ignore the specific physicality of the individual systems – how similar is the emergence of new properties of carbon disulphide from its atomic components to the emergence of consciousness from cells?

The idea of separating phenomena and processes from substance nascent in emergentism became formalized in the systems-theoretic approach, in the 1940’s. Systems theory manifested itself in a number of areas, such as the Philosophy of Bunge, Bahm, and Laszlo; Information Theory of

Klir; Biology of von Bertalanffy, Thom and Waddington, Cybernetics of Weiner, Ashby and Rosenberg [3, page 898] and today in Artificial Life.

2.2. Levels and Patterns

Emmeche, Køppe and Stjernfelt [21], give a detailed epistemic analysis of Morgan's "creation of new properties". They differentiate between three different uses of the word "properties" – referring to *primary levels* (similar to Morgan, the borders between the major sciences), *secondary levels* (sub-fields within the major sciences), and aspects of *single entities*. These classifications suggest different types of emergence. In relation to the creation of levels, their *gestalt view* holds that the higher level manifests itself as a *pattern* or as a special arrangement of entities at the lower level.

The emergence of patterns is of concern to a number of authors. In the field of *emergent computing*, for example, Forrest [22] writes:

"In these systems interesting global behavior *emerges* from many local interactions. When the emergent behavior is also a computation, we refer to the system as an *emergent computation.* … Three important and overlapping themes that exhibit emergent computation are self-organization, collective phenomena, and cooperative behavior (absence of any centralized control)."

What Forrest calls "interesting global behaviour" suggests two important issues in understanding emergence – that of the possible, and that of the influence of the observer. As Forrest admits:

"The emergent phenomena of interest are often understood implicitly rather than explicitly. Currently, many emergent computations are interpreted by the perceptual system of the person running the experiment."

How do we implicitly recognise "interesting" patterns? What is the difference between emergent and non-emergent patterns? Dennett discusses the "reality of patterns" in [14]. Looking at how agents distinguish a particular pattern from noise, he makes important observations about the information-theoretic content of a pattern in relation to its ontological status. Visual systems evolved to distinguish pattern from noise, but the "level" of pattern recognition has evolutionary constraints – a balance between the fidelity of pattern perception, its costs and payoffs. If we rely on recognition of patterns to justify emergence in systems, could there be patterns that we as observers cannot recognise[7], yet may still be "interesting" in studying emergent phenomena?

Information-theoretic approaches to understanding patterns in emergent systems have been studied (for example) by Crutchfield [12]. He recognises that "patterns are guessed rather than verified" and so seeks information-theoretic measures to obtain a more objective analysis of pattern formation. Crutchfield defines *intrinsic emergence*, where the system itself capitalizes on patterns that appear (i.e. the patterns exploit their own dynamics).

Our natural perception[8] defines the concept of everyday things and objects (animals, plants, etc.) that we have evolved to perceive at a particular level, in order to function in the world. Science has added to this a means for us to "see" at other levels. Following on from Dennett, taking perception to its ultimate end, if we could "perceive" the universe in a kind of gods-eye view or "Laplacian inversion", with the recognition of every single sub-atomic particle over its spatio-

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[7] Dennett often uses Wimsatt's example that an ant-eater averages a collection of ants to their totality, hence "sees" them a whole rather than as a collection of individual ants [44].
[8] Meaning unaided by technology.

temporal configuration, we would have no need for patterns or levels?[9] These concepts are necessary conveniences, developed as the result of pragmatic evolutionary pressures, to assist our survival within the limitations of being perceptual entities that are part of the world.

Compare to this, the view that it is impossible to interpret a lower-level explanation without using some higher-level concepts to identify what is going on. That is, higher-level phenomena need to be recognized as a basis to identify what must be explained at the lower level [24].

2.3. Prediction, explanation, determinism

Life can only be understood backwards; but it must be lived forwards.
— Kierkegaard, quoted in [13]

Since the coining of the term *emergence* by Lewes, a distinction is made between those emergent properties that are explainable as products of lower level interactions, and those that are not. What does it mean to be "explainable"? This is the crux of the issue and the basis of the reductionist/emergentism debate. Emmeche et. al. refer to two kinds of processes: those that cannot yet be explained but are not, in principle unexplainable, and processes that are in some sense of the word, unexplainable [21]. It is this second sense that usually provokes the reductionists into retaliation, because this implies that such processes are ontologically irreducible. Further, how are we to know what *will* be explainable in the future? Hence, it becomes impossible to distinguish between the epistemological and ontological senses of emergence.

Consequently, the idea that "the whole is more than the sum of its parts" may be expanded to give *form* its own ontological status[10] – the term "more" being a "specific series of spatial and morphological relationships between the parts". Matter and form, "opposing but not contradictory points of view of the same reality."

Central to a modern concept of emergence are the relevance of *determinism* and boundary conditions. Von Neumann pointed out that physical laws are reversible in time, but that measurement is intrinsically irreversible [32], for a contradictory view see [35]. Modern physics has shown that even those systems that can be described deterministically are subject to a critical dependence on initial conditions (for example, the three body problem). Polanyi [34] recognised that while physics may be able to describe what is going on at a micro level, the macro emergent properties cannot be predicted from the micro level physics, because they are computationally irreducible – determined by boundary conditions at the macro level. That is, the lower level laws are *unspecific* [9] with respect to the higher-level phenomena they may produce. Emmeche et. al. use the example of the cell to illustrate this idea – "if you list all known chemical regularities and laws, it would be impossible for you, on the basis of this list and without any knowledge of the biological cell, to select those entities, regularities and types of behaviour which are specific to the biological cell." [20]

Thus, according to these views, Physics presents an immense phase space of possibilities, in which it is impossible to determine exactly *what* will emerge at higher levels. Emergence can only be recognised *after* it has occurred, since it cannot be predicted in principle.

[9] Such a fanciful proposition raises numerous difficulties, particularly given the fundamental uncertainty in measurement of sub-atomic particles.
[10] That is, non-subjectivist features.

2.4. Emergence for Generative Art

> *"Most electronic artists are looking for an out-of-control quality that will result in their work actually having outcomes that they did not anticipate. If the piece does not surprise the author in some way then it is not truly successful in my opinion"*
> —Rafael Lozano-Hemmer quoted in an interview with Heimo Ranzenbacher. [40]

The richness of emergence in the physical world serves as a great source of inspiration to generative artists[11]. Artists are often looking for surprise, novelty, agency and that "out-of-control" feeling in their work, what Ashby describes as *Descarte's Dictum:* how can a designer build a device which outperforms the designer's specifications [2]?

Artists can get away with much more than scientists can where emergence is concerned, since Art is not bound by the same obligations as Science. But in gaining such freedom, the artist also acquires new problems because, in general, the search space lacks *reference points*[12] and becomes potentially vast. Given that true emergence defies prediction, how can one begin to *design* works that *do* have outcomes that were not anticipated?

Langton's *life-as-it-could-be* seems like an excellent starting point for developing the concept of *art-as-it-could-be* – emergent creative behaviour in artificial systems. However, given the problems discussed in previous sections, achieving life-as-it-could-be seems difficult, life-as-it-could-be creating art-as-it-could-be even more so. Moreover, if we are going to find it tough to recognize life-as-it-could-be, surely art-as-it-could-be will be unrecognisable, incomprehensible, or just plain uninteresting.

The idea of autonomous systems making art might seem appealing, but how does it relate to our "experience in context" definition of art? Bowerbirds might be considered autonomous systems that make "art", but such activities remain principally of interest to biologists, not art critics. The creation of evolving agents that develop their own artistic practices should not be confused with the goal of widening the scope of art for human appreciation.

2.5. Creating Emergent Art with Machines

> *"But you know, all pictures painted inside, in the studio, will never be as good as the things done outside."*
> — Paul Cézanne in a letter to Emile Zola, 19 October 1866

Today, generative art is often implemented on a computer[13]. Thus it is poignant to consider the limitations and possibilities of computation for creativity, and of the computer as an "art machine" if we want to create emergent works. As discussed in section 1.2, some of AL's goals (e.g. emergent behaviour) are not dissimilar and there is much in biological and AL literature discuss-

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[11] From here on, when we refer to "art" and "artists" we are primarily referring to generative art and those who make it.

[12] By reference points, we mean events, relations and epistemologies that form the basis for developing a particular work. Science has the physical world and the scientific method as possible reference points. Normally, conventional artists will have their own personal reference points and those from art theory, but with works that attempt genuine emergent properties, these may not be appropriate, particularly if the artist does not wish to simply mimic the reference points of art or science.

[13] "often" does not necessarily imply the best. Some generative artworks have used other physical entities to set up process-based works with considerable longevity and critical success (see [18] for examples).

ing the limitations of using symbol processing machines to make, for example strong AL. This could be a suitable starting point for examining similar issues in generative art.

Pattee distinguishes between *simulation* – as a metaphorical representation of a specific structure or behaviour that we recognize as “standing for” but not realizing the system being simulated (weak AL) and *realization* – a literal, substantial replacement of that system (strong AL) [32]. Computers are symbol-processing machines and while they are capable of simulating physical systems and phenomena, a symbol processing simulation is not a priori grounds for a theory of what is being simulated.

This raises an important question in relation to computer-based generative art works. If they are simulations, their basis must come from simulating something known. Most current generative art works are developed in this way (they *tweak* the *conceptual space* in the terminology of Boden [8]). Since new emergent phenomena cannot be predicted, we must depend on the simulation of known emergent systems, or on intuition and heuristics based on existing systems in order to guess which particular configurations of micro properties will result in emergent macro-phenomena. Computation has a smaller phase space than that of Physics, what is practically computable, even smaller. Increasing computing resources has two simultaneous implications for this practical space: it enlarges its size, giving more potential configurations, and yet it increases the speed at which this space may be searched. This recent advance in search speed often makes searches that would be impractical to explore in physical systems possible in simulation.

This begs the question – is generative art made on computers just tweaking the simulation of existing systems, or is it exploring the phase space of computation in a genuinely novel way? Is our starting point in developing ideas about generative art based in the simulation of reality? Alternatively, do we begin with the more constrained possibility of exploring the symbol processing space of computation in general? The latter, while conceptually interesting, seems much more difficult in terms of locating a starting point. Nature – *life-as-we-know-it* – provides numerous starting-points that can be tweaked, subverted and distorted in our search for novelty (e.g. replication, evolution, fitness, form, matter, etc.). Computation is abstract and un-grounded, inevitably needing to be made concrete through some interpretation[14]. To date, these interpretations primarily reference the metaphors on which their processes are based.

Simplistically, some of these problems can be avoided by embedding our system in physical reality (e.g. by building robots or systems that interact directly with the world through measurement and action). However, in this case, while we loose the difficulties of simulation, we do not remove the problem of predicting genuine emergence, nor do we remove the granularity of digital computation. To reverse a common truism – a real system has the same or worse difficulties of prediction as a simulation of it does[15].

Artists and designers are always endeavouring to create works that are more than the sum of their parts. The “more” in this case is specific to the context of the artist’s concerns for the work, rather than to physical examples of emergence.

For example, Sanders defines: “Concepts derived from an existing knowledge base but which demonstrate significantly different properties are called emergent” [37]. However, such a definition seems too broad. By this definition, an image on a television may be considered an emergent property of phosphor dots excited by electrons. This definition does not distinguish between sys-

[14] Although one can imagine an uninteresting conceptual art work that consists of a process running on a machine with no directly perceptible output.
[15] For example, many evolutionary robotics systems spend much of their development time in simulation, as it is faster and cheaper than developing real robots.

tems in which there is no interaction between components at the micro level and those in which there are both *interaction* and *process relationships* at this level (this is the difference, for example, between a television image and a cellular automata simulation). Hence, this preferred definition is more specific about the category of phenomena it purports to distinguish.

Cariani refers to factors outside the frame of reference of the computer program in what he calls "emergence relative-to-the-model". This gives us an insight into one of the possible roles for emergence in generative art, where the "emergence" is not in the simulation itself; rather how it changes the way we think and interact with the world [11], and discussion in [20, Chapter 6].

British artist, Richard Brown, in developing his artwork *Biotica*, "wanted creatures to spontaneously emerge from a primitive soup, rather than craft them by hand" [10]. Such goals are similar for many AL artists and researchers alike who seek to develop *self-organizing* systems that lead to emergent phenomena. Self-organizing systems encode some form of physical (or pseudo- or meta- physical) relationships, including basic laws of how entities operate within the (simulated) physical system. The "trick" is in the selection of local rules that determine the nature of the resultant behaviour and the careful selection of initial conditions – this can prove illusive. By Brown's own admission, the work "did not produce any surprising emergent results". Adding complexity to the rules and simulated physical phase space of Biotica resulted in a more complex system, but not in results that created new levels of surprise, agency or novelty.

Sim's *virtual creatures* [38] on the other hand, do indeed produce novel and surprising results, but are they truly emergent? Sims designed a specific low-level infrastructure to support his conscious goal of creating block-like creatures that discover, via competitive evolution, solutions to specific goals (following lights, competing for objects), rather than spontaneously emerging. For open-ended evolution, much more consideration needs to be given to designing the environment. For genuinely new symbolic information to arise in the genome, the entire semantically-closed organization (genotype, phenotype and the interpretation machinery that produces the latter from the former, including the whole developmental process through which an adult phenotype is produced) – needs to be "embedded in the arena of competition" [41].

In a design sense, it is possible to make creative systems that exhibit emergent properties beyond the designer's conscious intentions, hence creating an artefact, process, or system that is "more" than was conceived by the designer. This is not unique to computer-based design, but it offers an important glimpse into the possible usefulness of such design techniques – "letting go of control" as an alternative to the functionalist, user-centred modes of design. Nature can be seen as a complex system that can be loosely transferred to the process of design, with the hope that human poiesis may somehow obtain the elements of physis so revered in the design world. Mimicry of natural processes with a view to emulation, while possibly sufficient for novel design, does not alone necessarily translate as effective methodology for art however.

3. Methodologies of Generative Art

Emergence, while part of the generative artist's impetus (as detailed in section 2.4), is too broad a goal in a general sense, due to a lack of reference points (unless we wish simply to mimic existing systems). What is needed are some reference points suited to creating generative works that aspire to some genuine sense of emergence. In this section, we discuss a number of methodologies that either might be, or have been, used to produce such emergent qualities in artworks.

3.1. The role of subversion

As discussed in section 2.5, computational phase space is too large to serve as a starting point alone for developing an artwork. Thus, it seems that the majority of generative art works have drawn from the palette of existing technical procedures and *subverted* them in order to expose some interesting, novel or previously unconsidered feature of such process, or to re-interpret the process for the artists own ends (tweaking the conceptual space). For example, in the works of Australian artist John Tonkin, evolutionary processes are subverted, and used by the artist to expose political and social concepts of evolution and its implications [43].

Other approaches may be to visualize, sonify, or create in unusual or context dependent ways, systems that revel the process in hitherto unknown ways. There is no doubt that subversion and the irrational play an important role in contemporary art, seemingly much the anthesis of the standard scientific mode of practice, or that of the teleological engineer. However, generative processes in particular, often appear most strongly to deny this conventional mode of thinking, providing a deeper connection with the seeming irreducibility of a strong emergent process.

3.2. Symbol Manipulation, Mental Models

Consider how the generative artist might think about the relation between the world, the computer program, and its outcomes. The diagram shown in Figure 1 captures aspects of a particular way of working, but one we believe general enough to be useful. Relationships between the generative artist, the computer, and the world, are expressed in terms of *concepts* and *information flow*. There are two key sets of concepts held by the artist: *how the world works* and *how the computer works*. In order to program the computer with a view to implementing aspects of how the world works (e.g. emergent behaviour), there must be a translation between the concepts of how the world works and how the computer works. Knowledge of how the world works is informed by the world. In developing concepts of how the world works, and implementing simulations on the computer, the computer simulation may inform us how the world works as well[16].

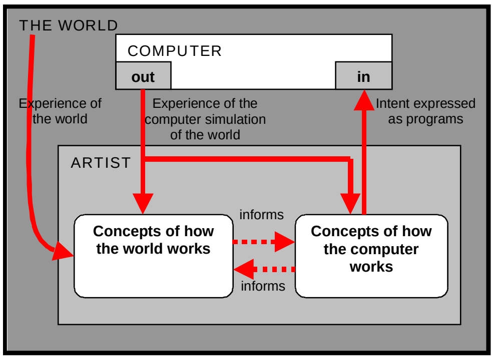

Figure 1: Development Mode. Information flow for the artist (with the intent of authoring a generative artwork) interacting with the computer working in the world. The red lines show key information flows.

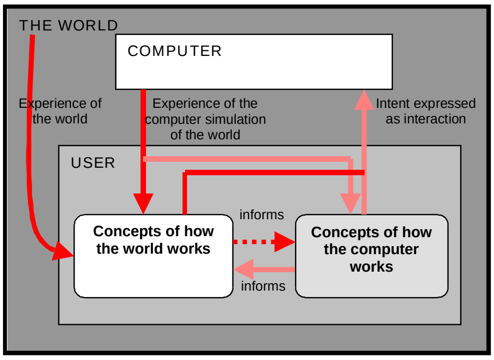

Figure 2: Experience Mode. Information flow for the user interacting with the computer, working in the world. The lighter shaded lines indicated weakened channels of information flow.

As the figure shows, there are two feedback loops operating. Concepts about how the world works inform concepts about how the computer works reciprocally. Concepts of how the world

[16] Of course, we make no assumption of the accuracy of the simulation, beyond its intent to simulate some aspects of the world, thus what the computer informs us about the world may possibly be incorrect or irreverent.

works must be mediated by concepts of how the computer works before they can be implemented as a program run on the computer. The output of such a program may inform both concepts of how the world works (as this is what the simulation or artwork is attempting to achieve) and how the computer works.

There are many observations we can make from these relations and feedback loops. As an example, consider the mapping or translation of concepts about the world to the more limited domain of the computer. Many AL simulations map concepts about the world to the purely symbolic domain of computation (birth, death, life), even the concept of the world itself is reduced to a finite, Cartesian, possibly discrete representation. If such representations go on to inform concepts about the (real) world, then clearly their usefulness may be limited.

Consider also, how we might achieve Cariani's relative-to-the-model emergence [11] and how our assumptions in Figure 1 will be different for the user/viewer of the artwork. This is shown in Figure 2. Some of the information flows are shown in a lighter shade to reflect the possibility that their effects may be diminished in the experience of the artwork. In this case, the feedback loops become minimal or disappear, meaning we may have to work harder to achieve emergent behaviour. One important way this can be obtained is by strengthening the connection between the user's interaction with the model and their concepts of how the world works. To achieve relative-to-the-model emergence, engagement with the computer needs to suggest that the work is *more* than its design intended it to be – it must be *informationally open*. For artworks, this might be achieved in a number of ways:

- through interaction (a feedback loop) with the work in real-time, where continuous re-assessment of the work suggests (for example) dynamics beyond the physical or virtual elements that compose the work;
- through suggestion of the sublime by an apparent vastness – that the simulation's representation of the world is more broad than the user's concept matching of the same phenomena. This is the subject of discussion in the next section.

A more problematic area is that of the user's concepts about how the computer works, what it is capable of, and so forth. Naively, people may find some things the computer does impressive because the computer is doing them (rather than a person for instance). We are fascinated and amazed in many cases, that a mere machine can produce things of seemingly un-machine-like qualities – technical prowess, even qualities we only associate with, for instance, nature itself. Of course, such assumptions reveal huge gaps in our analysis of both the world and the machine.

3.3. The Computational Sublime

The sublime has a long and well-explored history in art, particularly in the eighteenth and nineteenth centuries. Kant distinguished the *mathematically sublime* and the *dynamically sublime*. The mathematically sublime brings to our attention that which we *can* conceive of symbolically (through mathematics), but *cannot* experience sensorialy. The dynamically sublime suggests the incomprehensible power of nature. An important aspect of the sublime is the tension created between pleasure and fear – the pleasure of knowing that we can be aware of what we cannot experience and the fear that there exist things that are too vast or powerful for us to experience. In relating nature and aesthetics, the sublime formed a major critical and philosophical approach in western art in the eighteenth and nineteenth centuries (for an overview of the relation of the sublime to nature see [39, Chapter 7]). Bourke and Kant argued that it is possible for artworks to suggest the sublimity of nature – to suggest by experience of the artwork that which we cannot experience in totality.

In recent times, the *postmodern sublime* has contrasted *beauty* as a form that can be apprehended against the *sublime*, as that which is unrepresentable in sensation [27]. As discussed, emergence in computation is unrepresentable, in the sense of the product of elements interacting in ways that give rise to properties that cannot be predicted. Artworks that seek to give a sense of the processes of nature in machines, seek to give experience to that which cannot be experienced in totality – only suggested through a dynamic interaction.

Therefore the concept of the *computational sublime* is introduced – the instilling of simultaneous feelings of pleasure and fear in the viewer of a process realized in a computing machine. A duality in that even though we cannot comprehend the process directly, we can experience it through the machine – hence we are forced to relinquish control. It is possible to realize processes of this kind in the computer due to the speed and scale of its internal mechanism, and because its operations occur at a rate and in a space vastly different to the realm of our direct perceptual experience.

An example of a work that subverts standard technological processes and suggests the role of the computational sublime is that of the Dutch artists Erwin Driessens & Maria Verstappen [19]. Their work, *IMA Traveller* subverts the traditional concept of cellular automata by making the automata recursive, leading to qualitatively different results to those achieved through direct mimicry of technical CA techniques in other generative works. IMA Traveller suggests the computational sublime because it is in effect, an infinite space. It offers both pleasure and fear: pleasure in the sense that here inside a finite space is the representation (and partial experience) of something infinite to be explored at will; fear in that the work *is* in fact infinite, and also in that we have lost control. The interaction is somewhat illusory, in the sense that while we can control the zoom into particular sections of the image, we cannot stop ourselves from continually falling (zooming) into the work, and we can never return to a previous location in the journey. The work creates an illusion of space that is being constantly created for the moment (as opposed to works that draw from pre-computed choice-sets). The zooming process will *never* stop. That there is no real ground plane or point of reference suggests Kierkegaard's quote of section 2.3 – you are always going, but only from the point of where you've been.

4. Conclusions

Generative processes offer a rich and complex area for artists to explore. This paper has only touched upon a few issues, and ignored many of importance. The concept of emergence, though constantly changing and often criticised, is a recurring philosophical theme that evolved to supersede the vitalist philosophies of the nineteenth century. This philosophical theme links a number of schools of thought in the sciences of the twentieth century – Systems Theory, Cybernetics, and Artificial Life. If such a theme could be expressed succinctly, it would be as a *philosophy of process* – the inclusion of both mechanism and matter as fundamental properties of the universe.

It is important however, to consider the fate and usefulness of both Systems Theory and Cybernetics. Systems Theory was a cultural reaction to reductionism and highly specific modes and languages in Science. Cybernetics (as defined by Ashby) was a theory of machines, but it treats, not things, but ways of behaving [1]. Today, at the beginning of the twenty-first century, while both these disciplines still have their proponents, such a holistic approach is not the predominate methodology for training scientists.

The longevity of Artificial Life is yet to be determined. As the stepchild of Systems Theory and Cybernetics, AL, once again, is hedging its bets on the process philosophy. The real payoffs and long-term goals of AL, such as the creation of artificial systems that we can confidently call *alive*, have yet to materialize. AL may not have the same escape hatches as AI did.

Generative art draws from the philosophies of the process-based sciences. Its potential is rich: art-as-it-could-be, artworks that are autonomous, genuinely novel, emergent, active, self-renewing and never-ending. Yet, while many innovative generative artworks have given us glimpses into these possibilities, such lofty goals remain intangible at present, and with no guarantee of success. It remains for future generations of generative artists to determine if any of these goals will be achieved.

This paper has discussed some modes and methodologies for generative art to explore – the role of subversion, mental models of understanding for the artist and audience, the computational sublime. We do not suggest that these are the only issues for consideration, and inevitably, art-works will be judged not only on the themes explored here, but also in terms of the more com-fortable and fashionable theories of the electronic and new-media arts, and contemporary art in general.

Generative art seeks to exploit the out-of-control nature of nature, but to achieve this in a genuine sense, the artist is obliged to acknowledge that control must really be relinquished – still a very difficult thing to do, and a challenge to the conceptual processes of developing an artwork.

We have also acknowledged that computation, as it exists today, may never be able to give us true emergence, the likes of which we observe in the world around us. As a number of authors have shown, the dialectic of simulation and realization, of life-like and life, are still fundamental issues that, as yet, remain unresolved.

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