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The Blurring of Art and ALife

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Abstract

There has been recognition of the potential for mutually beneficial ALife/Art collaborations for at least 40 years [1, 2]. In this paper we focus on the application of ALife techniques as art generating systems and identify the current limitations of using aesthetic selection and individual-based models (IBMs) [3]. We consider how these limitations may be overcome and illustrate this by describing a concrete mechanism from the ALife literature that displays a strong form of emergent behaviour. We identify two fundamental properties of more powerful generative mechanisms: they are informationally open; and they consist of functionally open components. Devices with these properties can be steered using selective pressure to demonstrate epistemic autonomy: they determine the nature of their relation to the world by constructing their own sensors and effectors. We argue that epistemically autonomous generative systems may produce works that start to explore 'art-as-it-could-be'[1], as opposed to exploring programmer defined spaces. The process of developing epistemically autonomous devices, whether for scientific or artistic purposes, has two unavoidable consequences. Firstly, their construction necessarily requires an open-ended interactive approach [4]. Secondly, their operation has to be understood and manipulated at a behavioural, as well as a mechanistic, level. Consequently, the distinctions between art and ALife begin to blur.

Key words: artificial life, artificial evolution, emergence, models of creativity, evolvable hardware, conceptualism, interactivity.

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[1] This term was first heard in a talk, *Process Philosophies*, by Jon McCormack at the School of Cognitive and Computing Sciences, University of Sussex, September 24, 2001.

1. Introduction

"*the task, for oneself and for others, is to restore participation in the natural design through conscious emulation of its nonartistic features.*" --- Allan Kaprow[2]

Allan Kaprow, originator of Happenings in the 1960s, is associated with conceptual art. This is valid to the extent that his art and writing are a reaction against an overly formal, hermetically-sealed approach to art. However, Kaprow does not emphasise ideas or concepts over material substrates; his goal is not to 'dematerialize' the art object, which some have identified as the essence of the conceptualist project [5]. In direct contrast, as the opening quotation shows, Kaprow's aim is to ground art firmly in the physical world and emphasise the importance of environmental context. He believes the consequences of this methodology will be fruitful: "*something new comes out in this process---knowledge, well-being, surprise, or, as in the case of bionics, useful technology*" [6]. Kaprow's reference to bionics illustrates that for him, participating in "natural design", that is, emulating nature, is not an exclusively artistic or scientific enterprise. In fact with Robert Watts and George Brecht he proposed the setting up of an experimental laboratory, modelled on scientific and industrial practices, whose purpose would be to produce art [2]. This paper explores the common ground between art and ALife research. It explores two of the benefits of natural design that Kaprow highlights: *surprise* and *knowledge*.

We are interested in surprise as it is manifested in processes that lead to *novelty*, and which underlie such phenomena as innovations, transitions and spontaneous organizations [7, 8]. These phenomena are often classified as *emergent* because they involve the generation of new structures and functions that cannot be reduced to the properties of pre-existing ones [9]. ALife distinguishes itself from biology by adopting a synthetic approach to understanding complex biological phenomena such as these [10]. The aim is to capture the minimal set of properties that can generate the biological phenomenon being investigated. We consider how ALife techniques may be applied to the generation of surprising, emergent art works. Initially, we consider the limitations of current art generating systems that employ ALife techniques: essentially, they do not generate novelty and the art does not surprise us [3].

We consider how these limitations may be overcome and illustrate this by describing a concrete mechanism from the ALife literature that displays a strong form of emergent behaviour. We identify two fundamental properties of more powerful generative mechanisms: they are informationally open; and they consist of functionally open components. Devices with these properties can be steered using selective pressure to demonstrate epistemic autonomy: they determine the nature of their coupling to the world, and consequently, their knowledge of it, by constructing their own sensors and effectors [9].

We argue that epistemically autonomous generative systems may produce works that start to explore art-as-it-could-be, as opposed to exploring programmer defined spaces. The process of developing epistemically autonomous devices, whether for scientific or artistic purposes, has two unavoidable consequences. Firstly, their construction necessarily requires an open-ended interactive approach [4]. Secondly, their operation has

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[2] A. Kaprow. Education of the Un-Artist, part II, 1972. In J. Kelley, Editor, *The Blurring of Art and Life*, University of California Press, Berkeley, 1993.

to be understood and manipulated at a behavioural, as well as a mechanistic, level. For both art and science this raises two concomitant issues: the concept of authorship is undermined; and the emphasis shifts to the art [11] and science of experience [12]. Consequently, the distinctions between art and ALife begin to blur.

2. Art Generating Systems and ALife

The two primary ALife techniques that have been applied in art-practice are:

- *artificial evolution*, which is usually steered by *aesthetic selection;*
- *individual based models (IBMs)*.

This section describes these techniques and identifies some of their limitations for generating art work.

2.1 Artificial Evolution and Aesthetic Selection

Artificial evolution involves using some form of genetic algorithm (GA) to search for a solution to a problem. A population of solutions (phenotypes) is encoded as a string of numbers (genotypes). The initial population is usually randomly generated. Each phenotype in the population is tested and assigned a fitness. This is usually done automatically by a fitness function specified by the programmer. A new generation of solutions is generated by randomly selecting genotypes, with a bias towards the fitter ones, and carrying out various operations on their data. The major operators are mutation (randomly changing one of the numbers in the string) and crossover (swapping numbers between two strings). This process of generate and test is repeated until a solution is found to the problem. Aesthetic selection is a type of fitness function. A human user judges a set of phenotypes (for example, images or auditory samples) and decides which ones are the most aesthetically pleasing. The genotypes corresponding to the selected phenotypes (often just one or two) are manipulated (using mutation and crossover) to create a new generation of phenotypes which the user evaluates. This process continues until the user is happy with the image/music that has been generated.

The first system to use this method for generating visual images was Dawkins' *biomorph* software [13]. This placed symmetry and segmentation constraints on the possible forms that could be produced. Sims [14] used a genotype that encoded a less constrained set of parameters, giving more apparent freedom to the user, and a richer space to explore. Sometimes a more implicit fitness function is used. Rather than requiring a user to explicitly choose alternatives from a set, aesthetic value is calculated from how much interest a particular image/piece of music generates. For example, when Eden [15], which composes music through the sonic interaction of virtual entities competing for limited resources, was set up in a chill out room, McCormack used IR sensors to determine how many people were present in certain areas of the space. If numbers were low, the parameters of the system were changed in an attempt to provide a more aesthetically appealing experience. Woolf [16] also used this approach to apply the selective pressure for the artificial evolution of music, although in the initial system the spatial distribution of the audience was entered into the system manually.

However, although aesthetic selection systems can generate interesting results, there is a debate over how creative they are and how significant a role the user plays in their generation. Dorin [3] has compared aesthetic selection to the processes of pigeon breeding and garden weeding. These descriptions emphasise that it is merely a mechanism that enables a user to move through a *predefined* image space: selecting images is so heavily constrained that it is essentially a mindless process involving very limited, or no, creativity. Using the example of image generating systems, Dorin emphasises that the more interesting and creative aspect of the process is determining the variables which *define* the image space that users can explore. The programmer's choice of constraints, such as the basic graphical primitives and rendering methods, determine the form and define the style of the images that may be generated, leaving little room for users to take creative decisions.

2.2 Self-organizing primitives

ALife models often take the form of computer simulations because the phenomena being investigated are a consequence of dynamic, non-linear interdependencies between many elements, something that is difficult to model using equations. For example, [17] shows how the *spatial distribution* of individuals is critical for the development of cooperative behaviour. Individual Based Models (IBMs) such as this represent individuals as primitive elements and define what interactions can take place in the virtual environment. IBMs vary in the complexity of the individuals, the environment and the interactions between the two. Conway's cellular automata (CA) based Game of Life [18] exemplifies the most abstract end of the scale: individuals can only be in one of two states (on/off, alive/dead), the environment is a large array and the only interaction is spatial proximity of neighbours. The more complex end of the scale is represented by Holland's *Echo* system [19]. The environment contains a number of different resources that heterogeneous agents collect; if they acquire enough then they can reproduce, either asexually or sexually with another agent. The two other agent interactions are trading and combat. There is also a chance that an agent can be randomly killed and its resources returned to the environment.

Dorin [3] suggests that the limit of the "*all knowing controller*" may be overcome by harnessing the non-linear interactions of self-organizing primitives in combination with aesthetic selection. The aim is to generate complex higher level emergent phenomena. The artist specifies the basic elements and how they can interact and the user can steer the system into generating complex emergent structures that were not initially envisaged. The hope is that an open ended conceptual space can be generated.

However, there are several difficulties associated with using self-organizing primitives. The emergence of multi-levelled phenomena is a deep open problem in biology [8, 20] and therefore it is not clear what a good choice of primitives would be. ALife research has so far not succeeded in producing a truly open-ended digital generative system [21]. Furthermore, the behaviour of these systems has to be converted into an artistic form. For example, Eden [15] requires some complicated programming to turn the activity of the individuals competing for resources into music. Therefore, even though the aim is to minimise the influence of the programmer and give more freedom to the user, it is not clear that this is actually the case with any current art generating systems that use self-organizing primitives.

2.3 The Limits of Digital Art Generating Systems

It is useful to clearly define some terminology at this point. Following Ashby [22], a *state* of a physical system is defined as a distinction made by an observer about the system. It is a property that can be recognised every time it occurs. A *system* is the set of distinct states chosen by an observer. The *state space* of a system is the set of all possible combinations of states distinguished by an observer, each state defining a dimension of the space.

Using this more abstract framework, we can rephrase the limitations of ALife techniques as they are currently used to create art. The limitations of aesthetic selection are determined by the dimensionality of the space that it can explore. The fundamental limitation of using IBMs is that although the aim is to generate a high dimensional state space from the interaction of many simple elements (having a small number of states), ALife has not succeeded in creating an open-ended process of unbounded dimensionality. Generally, the state space is fixed and offers little in the way of novelty that was not initially programmed in.

Boden [23] introduces the useful idea of a *conceptual space* whose dimensions structure a given domain and are constrained by an underlying generative system. For example, the conceptual space of chess is structured by the rules of the game. She distinguishes two categories of creativity: *tweaks*, which explore areas of the conceptual space and *transformations*, which transform the space by changing the underlying generative system.

Current digital art generating systems are limited to tweaking the spaces initially defined by their designers. These conceptual spaces can be sufficiently large and rich that exploring them can generate interesting art. Arguably, the current tweaking approach may be more productive than radical transformations. Greenberg, writing on surprise in art, argues that a work can be so surprising that it becomes aesthetically inaccessible and as a consequence "*strikes you more as a sheer phenomenon, and an arbitrary one, than as something that has to do with art*" [24]. For example, Schönberg radically transformed the conceptual space of music by dropping tonal constraints but his atonal music is rarely performed.

Accepting this caveat, the next sections describe a mechanism from the ALife literature that can transform the space it explores by generating its own primitives. We give a hypothetical example of how such devices could be used to explore art-as-it-could-be and outline some of the implications of doing so.

3. Gordon Pask's Electrochemical Assemblages

In 1958 Gordon Pask demonstrated a number of remarkable mechanisms that were able to construct their own sensors and effectors and thereby determine the relations between their own states and the environment. In other words, these devices were able to generate and explore their own *state space*. Any observer trying to model the behaviour of these devices would be forced to *change* the dimensionality of their model over time as the devices could transform the underlying generative system.

3.1 Description of the Mechanism

The devices are electrochemical assemblages consisting of a number of small platinum electrodes that are inserted in a dish of ferrous sulphate solution and connected to a current limited electrical source. Depending on the activity of the system, these electrodes can act as sinks or sources of current. Metallic iron threads tend to form between electrodes where maximum lines of current are flowing. These metallic threads have a low resistance relative to the solution and so current will tend to flow down them if the electrical activation is repeated. Consequently, the potentials at the electrodes are modified by the formation of threads. If no current passes through a thread, then it tends to dissolve back into the acidic solution. The system therefore fundamentally consists of two opposing processes: one which builds metallic threads out of ions on relatively negative electrodes (sinks); and one that dissolves metallic threads back into ions. The trial and error process of thread development is also constrained by the concurrent development of neighbouring threads and also by previously developed structures. Slender branches extend from a thread in many directions and most of these dissolve except for the one following the path of maximum current. If there is an ambiguous path then a thread can bifurcate. As the total current entering the system is restricted, threads compete for resources. However, when there are a number of neighbouring unstable structures, the threads can amalgamate and form one cooperative structure. Over time a network of threads can form that is dynamically stable: the electrochemical mechanism literally *grows*.

It is possible to associate some of the electrodes with output devices that enable the behaviour of the system to be assessed by a user. Regardless of how the electrodes are configured, the assemblage will develop a thread structure that leads to current flowing in such a way that the user rewards the system. A reward consists of an increase in the limited current supply to the assemblage and is therefore a form of positive reinforcement. Importantly, there is not any specification of what form that growth should take, the reward is simply an increased capacity for growth.

Critically, the system is not just electrically connected to the external world: due to the physical nature of the components, thread formation is also sensitive to temperature, chemical environment, vibrations and magnetic fields. Any of these arbitrary disturbances can be viewed as an input to the system, especially if they affect the performance of the mechanism so that its current supply is changed. The system can grow structures that are sensitive to different environmental stimuli. Pask was able to train an assemblage to act as an 'ear' that could discriminate between a 50 Hz and 100 Hz tone in about half a day. He was also able to grow a system that could detect magnetism and one that was sensitive to pH differences. The development of sensors constitutes a change in the state space of the assemblage that was not specified by a designer explicitly.

3.2 Key Insights from Pask's Ear

Pask described his electrochemical devices as *organic control mechanisms* [25] and they share many properties of biological systems. The two key properties of the electromechanical assemblages that we wish to highlight are: they are *informationally open*; and they consist of *functionally open* components.

The first property is a consequence of the physical nature of the devices. This means that they are perturbed by a whole range of environmental stimuli that do not have to be prespecified by a designer, for example, electromagnetic, kinetic and gravitational energy. It might be argued that IBMs can incorporate a rich environment with which the individuals can interact independently of the programmer. However, for practical reasons the programmer necessarily restricts the virtual environment to consist of properties that will be 'useful' and therefore the space of possible interactions has been specified *a priori*.

The second property means that the devices initially consist of raw material, without any specified structure or function. Through the input of energy and interaction with an environment the raw material is transformed into metallic threads. These can be considered as components and ascribed functions; Pask identified threads acting as conducting pathways, registers, field constrictors and amplifiers [26]. However, given the dynamic structure of the devices, none of the threads could be said to have a *fixed* function.

These two properties lead to a device that can construct its own sensors and that is *epistemically autonomous*. The device determines the nature of its relation to, and knowledge of, the world, not a programmer or designer [9].

Pask's ear provides a concrete insight into the theoretical limitations of current art generating systems. Pask's ear is what Cariani [9] calls a *general evolutionary* device, having the capacity to form its own percept and action categories (adaptive semantics) and optimise its behaviour within these categories (adaptive syntax). It is therefore in principle a more powerful generative system than purely digital ones, which at best have determinate state transitions that can adapt within designer specified bounds.

3.3 An Application of an Electrochemical Device as an Art Generating System

In order to focus the discussion it is worthwhile considering an example of how an electrochemical device could be applied as an art generating system. This example system has not been built and its role is simply to illustrate the potential of electrochemical devices and how they differ from digital art generating systems.

Imagine that we arbitrarily associate a bank of tone generators with a proportion of the electrodes in an electrochemical device. We use the term 'associate' as there will not be enough current to directly drive tone generators from the electrochemical device itself. However, it is possible to set up an external power source so that each tone generator could be activated when the current reached a threshold level in the associated electrode. In this way some of the electrodes could effectively act as switches that determine which of the tone generators are on and off. If initially we randomly pass current into the system, then eventually threads will grow that will result in some of the tone generators being switched on. The resulting sonic output can be judged aesthetically and the system rewarded with more growth capacity if the results are pleasing.

It is clear that a digital system could be linked to a synthesiser in an equivalent way. However, as Pask demonstrated with his artificial ear, an electrochemical assemblage will be perturbed by the tones that it has generated and can potentially grow threads that respond to particular frequencies. Furthermore, the thread structures will also be sensitive to other environmental perturbations. An electrochemical system will construct feedback loops between itself and the environment that will affect future sonic output in order to increase future thread construction. These feedback loops are not prespecified by a designer, but are grown as a consequence of the electrochemical device selecting those aspects of its environment that further its growth. This is not comparable to linking a digital system to a number of microphones because that involves specifying the channels between the environment and the generative system *a priori* and consequently the system is limited to exploring a constrained state space.

4. The Implications of Developing Epistemically Autonomous Devices

The process of developing epistemically autonomous devices necessarily involves an open-ended interactive approach. The emphasis has to be on the dynamic process of interaction between an observer and an epistemically autonomous device. It is not possible to isolate the device from its environmental context, which includes the observer who is steering its growth. When they are employed to generate art there will be no clear sense of a 'creator' or an 'author', as the artist and the device will both play participatory roles in the creative process. Analogously, when these devices are constructed and studied in a scientific context, the concepts of ‘designer’ and ‘independent observer’ are undermined.

Epistemically autonomous devices can not be easily decomposed into functional components because their structures have multiple, changing functions. Analysis is further complicated by the fact that these devices determine their own relations with the world. However, the steering process requires the observer to recognise developing trends in the growing device and this involves interacting with the device in a manner akin to training animals [26], where understanding stems from interacting at a behavioural level, rather than analysis at a mechanistic level. Consequently, art generated with epistemically autonomous devices will necessarily “*explore the meaning of experience rather than the meaning of works of art*” [27]. Analogously, in science we face the “*inadequacy of the physical model paradigm for modelling organizations that are complex enough to themselves be observers and modelers of their world*” [28]. The distinction between ALife and art begins to blur.

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