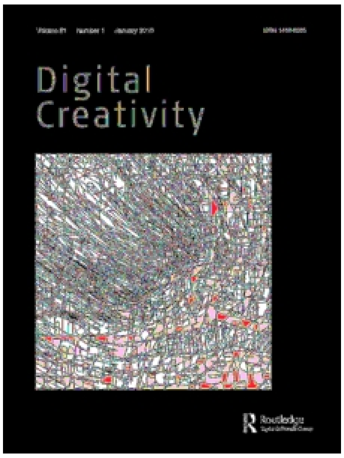

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What is generative art?

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Abstract

There are various forms of what's sometimes called generative art, or computer art. This paper distinguishes the major categories and asks whether the appropriate aesthetic criteria—and the locus of creativity—are the same in each case.

Keywords: computer art, generative art, interactive art, computational creativity

1 Introduction

Since the late-1950s, an ever-diversifying set of novel art practices has arisen which are still little known or discussed in aesthetics and art theory. (For a wide variety of examples, see: Krueger 1991; Wilson 2002; Candy and Edmonds 2002; Whitelaw 2004; Woolf 2004; Popper 2007.) As Jon McCormack, one of the artists concerned, has put it,

> *[M]uch of the innovation today is not achieved within the precious bubble of fine art, but by those who work in the industries of popular culture–computer graphics, film, music videos, games, robotics and the Internet (McCormack 2003, p. 5).*

The "bubble of fine art" refers to a shifting socially accepted norm. Artists often work outside the norm of their day, as famously illustrated by Marcel Duchamp and his ready-mades or John Cage and silence. The novel approaches that McCormack mentions are closely related, both theoretically and methodologically—so much so, that they are often all lumped together under one label: "computer art", "electronic art", or "generative art". One aim of this paper is to clarify how they can be distinguished.

Theoretically, this new art originated in cybernetics and general systems theory. The young painter Roy Ascott, later to be highly influential in the field, identified the novel activity as "a cybernetic vision" (1966/67). And the exceptionally creative cybernetician Gordon Pask was a key influence. For besides producing and/or imagining some of the first artworks of this general type (in the 1950s), he provided much of the theoretical impetus that inspired the more philosophically minded artists in the field (Boden 2006, p. 4.v.e).

Very soon, the "cybernetic vision" was bolstered by ideas about structure and process drawn from computer science. This paper's co-author Ernest Edmonds, for instance, turned

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from paintbrush and easel to the computer in the1960s: he thought he could produce more interesting art in that way (see Section 3). At much the same time, music and visual art was produced which reflected AI's computational theories of mind. Indeed, Harold Cohen, a renowned abstract painter in 1960s London, deserted his previous working practices largely because he felt that doing computer art would help him to understand his own creative processes (McCorduck 1991; Boden 2004, pp. 150–166, 314f.).

Over the past twenty years, this artistic field has been inspired also by ideas about emergence, evolution, embodiment, and self-organisation. These concepts are borrowed from various areas of cognitive science and in particular from artificial life (A-Life). However, the theoretical roots of A-Life reach back to mid-century cybernetics and automata theory (Boden 2006, p. 4.v.e, 15.iv-v). In short, the theoretical wheel has turned full circle.

The methodological wheel, meanwhile, has climbed an ascending spiral. For the art practices outside the bubble are grounded in technologies for communication and information processing whose power and variety have burgeoned over the last half-century. (Often, this means that the customary lone artist is replaced by a team, some of whose members may be computer scientists and/or tele-engineers.)

Most of them rely heavily on digital computing and in particular on methods drawn from AI/A-Life. Specifically, they have employed both symbolic and connectionist computation, and—more recently—cellular automata, L-systems and evolutionary programming too. This is an ascending spiral, not a linear ascent, because two of those 'recent' methods were foreseen (by John von Neumann) in 1950s cybernetics, and all three had been mathematically defined by the 1960s—but none could be fruitfully explored, by artists or scientists, until powerful computers became available much later (Boden 2006, p. 15.v-vi).

The resulting artworks are highly diverse. They include music, sonics, the visual arts, video art, multimedia installations, virtual reality, kinetic sculpture, robotics, performance art and text. And whereas some of these outside-the-bubble activities place ink or paint onto a surface, others involve desk-top VDUs or room-scale video-projection. Yet others eschew the virtuality of cyberspace, constructing moving physical machines instead.

The labels attached to these new art forms vary and have not yet settled down into a generally accepted taxonomy. The names preferred by the artists involved include: generative art, computer art, digital art, computational art, process-based art, electronic art, software art, technological art and telematics. All of those terms are commonly used to denote the entire field–and (although distinctions are sometimes drawn) they are often treated as synonyms. In addition, there are names for subfields: interactive art, evolutionary art, video art, media (and new-media and multimedia) art, holographic art, laser art, virtual art, cyborg art, robotic art, telerobotics, net art . . . and more. Again, the extension of these labels is not always clear.

It's partly for that reason that "a satisfactory critical framework of new forms in art technology has yet to be developed" (Candy and Edmonds 2002, p. 266). We hope that the distinctions made in this paper may help towards such a framework. Mainly, however, we aim to outline some philosophical problems that arise with respect to the art that lies outside McCormack's "precious bubble".

In Section 2, we sketch the history and current usage of some of the new labels within the artistic community concerned. Then, in Section 3, Edmonds gives a brief autobiographical account of why he chose—and now chooses—one name rather than another for his own art.

Section 4 distinguishes various categories, focusing especially on computer art, generative art, evolutionary art, robotic art and interactive art. The terms we define here use words that are already being used by the artists in question. Indeed, we hope that our analysis may help readers to interpret these artists' discussions of their work. But we are not aiming to offer a report of common usage because, as already remarked, such usage is not consistent. Rather, our account is intended as a theoretical tool with which to highlight certain distinctions that have philosophical and/or aesthetic interest.

The philosophical issues concerned are indicated in Section 5. We'll see that judgements concerning creativity, authorial responsibility, agency, autonomy, authenticity and (sometimes) ontology are even more problematic outside the precious bubble than inside it. To explore these matters fully would be beyond the scope of this paper. But we identify some pertinent questions and some possible responses to them.

2 A terminological history

The terms 'generative art' and 'computer art' have been used in tandem, and more or less interchangeably, since the very earliest days. For the first exhibition of computer art was called *Generative Computergraphik* (see the description of the event in Nake 2005). It was held in Stuttgart in February 1965 and showed the work of Georg Nees. Four years later he produced the first PhD thesis on computer art, giving it the same title as the exhibition (Nees 1969). That thesis was soon widely consulted by the small but growing community, harnessing the words *generative* and *computer* together in its readers' minds.

In November 1965 Nees showed again in Stuttgart. On this occasion, the exhibition also included the computer graphics work of Frieder Nake. Both artists used the term 'generative'. The word was used here to identify art that was produced from a computer program and, hence, was at least in part produced automatically. In that sense, the work of the graphic artist Michael Noll that was exhibited in New York between the two German shows was also generative.

Others pioneering the activities outside McCormack's bubble also adopted the term. For example, when Manfred Mohr, who knew Nake, started producing drawings with a computer program in 1968 he termed it 'generative art'. (Mohr still uses that description of his work and uses it in the same sense.) And the philosopher Max Bense—who had composed the manifesto for the original Stuttgart exhibiton of 1965—was writing about what he called 'generative aesthetics' (Nake 1998). Alternative tags were already being offered, however: an influential discussion by the art historian Jack Burnham (1968), for instance, identified the new work as 'process art'.

In music, the use of computer systems to produce work started very early on. By 1957 Lejaren Hiller and Leonard Isaacson had created the *Illiac Suite for String Quartet* (Hiller and Isaacson 1958) and in 1962 Iannis Xenakis completed the *Stochastic Music program*. Xenakis published essays on formalised music, including this program in the same year (in English, Xenakis 1971) and was a key figure in the development of computer-generated music. Probably as a result of this early start, the development of computer-generative music preceded that of computer-generative visual art.

Not all generative visual art involves computers. Pre-computer examples include such clear cases as Kenneth Martin, whose 1949 abstract painting used basic geometrical figures (squares, circles, diagrams) and rules of proportion (Martin 1951/1954). Later, his 'Chance and Order' and 'Chance, Order, Change' series combined rule-driven generation with random choice. Whilst chance events–such as selecting a number out of a hat–determined the course of the work, everything else was determined by the rules that Martin had devised. Other non-computer generative artists are identified in Section 4, where we'll see that the generative processes involved vary widely in type.

Today, the term 'generative art is still current within the relevant artistic community. Since 1998 a series of conferences have been held in Milan with that title (Generativeart.com) and Brian Eno has been influential in promoting and using generative art methods (Eno 1996). Both in music and in visual art, the use of the term has now converged on work that has been produced by the activation of a set of rules *and* where the artist lets a computer system take over at least some of the decision-making (although, of course, the artist determines the rules).

Rules are at the heart of this type of art. But what computer scientists call rule-based programming (e.g. Kowalski and Levy 1996) is not necessarily implied. The computer-art community regards it as important that the artwork is generated from a set of specified rules, or constraints, rather than from a step-by-step algorithm. But the detailed implementation method (i.e. the specific computer system that's being used) is not normally seen to be significant.

To understand this point, consider an over-simplified illustration of the programming concepts just mentioned. When a program is written in a step-by-step (algorithmic) way, the programmer instructs the computer to "do A", then "do B", then under certain conditions "do C", otherwise "do D" and so on. When a programmer writes rules (constraints), however, they tell the computer that (for example) "Z should always be bigger than Y", "X must never equal W', and so on—but they leave it to the computer system to work out how to apply those rules.

So in the step-by-step approach, the programmer is explicitly directing the actions of the computer. In the rule-based approach, by contrast, the translation from the specified rules to computer actions is not immediately clear. To know just how the specification of a rule determines computer behaviour we need to be aware of the details of the computer system that interprets the rules—which even a professional computer scientist may not know. Another way of putting this is to say that the artist leaves the computer to do its own thing without knowing *just what it is that* the computer will be doing.

One could argue that the art-community's objection to a step-by-step algorithm is more a matter of taste than anything else. For even when a programmer has written explicit step-by-step code, he or she does not necessarily–or even usually–know the outcome. If they did, there would be no bugs (except those due to typing mistakes and punctuation errors). After all, the earliest programming was often done in order to calculate numerical values that were almost impossible to obtain otherwise. Those early efforts were relatively simple: most programs today are hugely more complex. So despite the differences between the two programming approaches described above, there is no distinction at the most fundamental level. Both types of program are unpredictable by their programmer.

However, computer artists—and computer scientists, too—know from their own experience that when writing algorithmic code there is a 'feel' of fully controlling the computer. This 'feel' does not carry over to systems where they are specifying sets of rules, or constraints.

In other words, rule-driven systems appear to have a greater degree of autonomy, relative to the conscious decisions of the human artist. That phenomenological fact is significant because autonomy is a concept that's closely connected with art-making (see Section 5). This explains why computer artists are more comfortable in speaking of 'generative art' where the system is rule-driven, not algorithmic—and why they usually avoid step-by-step programming.

The concepts of generative art and (programmed) computer art were assimilated right from the start. With the recent appearance of art using methods drawn from A-Life (for examples, see Whitelaw 2004; Tofts 2003; 2005, pp. 80–103; Popper 2007, pp. 118–129), the label 'generative art', as used in the community concerned, has acquired biological overtones. In biology, the key word is common in discussions of morphological development and growth in plants and animals, and in references to reproduction. One or both of those meanings is/are sometimes explicitly stressed by self-styled generative artists whose work focuses on emergence, self-organisation and/or evolution. McCormack himself is one such example (e.g. Dorin and McCormack 2001; McCormack et al. 2004). Even so, the formal-mathematical sense remains a core aspect of the label's meaning.

3 A terminological autobiography

Addendum by M.A.B.: *The core of Edmonds' artistic oeuvre is an exploration of the possibilities inherent in colour as such. (As for his computer-science oeuvre, that includes one of the first logic-programming languages.) The subtlety of his colours, and the sequence of their changes, cannot be conveyed here, and nor can their audio-aspects–but they are indicated on his website (www.ernestedmonds.com). It's worth noting that the curators of a major Washington DC festival in 2007 celebrating the 50th anniversary of the "Color-Field" painters—Mark Rothko, Clyfford Still, Kenneth Noland and the like—have chosen to include live showings of some of his recent work in the Experimental Media series at the Corcoran Gallery and The Ellipse Arts Center.*

I (that is, Ernest Edmonds) had been committed to painting since my early-teenage years, strongly influenced by the constructivists. I started to use a computer in my artwork in 1968, when I wrote a program that searched for an arrangement, a layout, of a given set of picture elements.

At the time, I was working on some problems in logic that involved finding sets of numbers that displayed, or revealed, certain conditions. The problem was to show that various axioms were independent by demonstrating that values existed that showed that no one of them could be derived from the others. The details of what this means do not matter here. Suffice it to say that I realised that I could write a computer program that would search for such numbers, and I did so. This resulted in the publication of my first research paper, which was in the *Journal of Symbolic Logic* (Edmonds 1969).

An interesting thing to notice is that the paper makes no mention of computers or computer programs. The program had enabled me to find the required set of numbers. All I had to do in the proof was to provide them. Whilst the computer was used to help me solve a problem in a non-computing domain, the computer itself was not part of the solution.

This is exactly how it was to turn out in my first use of the computer in art. I wrote a program to search for a visual layout which satisfied a set of conditions that I was able to specify. As with the logic, the computer could be dispensed with once the problem was solved, and the work itself neither used nor referred to a computer program at all. It is just that I could not have made the piece, called *Nineteen*, without the use of the computer.

With respect to a more specific concern for generative art, a crucial step was actually made conceptually in 1980. I realised that my long-standing interest in time could lead to a new kind of art, with the use of computers. Music, particularly serial music, had been very influential on my visual work; and I was fascinated by film. During the 1970s, I made some abstract films the hard way, by filming static abstract images and splicing the film together from very many such still clips. I started working on what I came to call video constructs. These are time-based, generative, abstract works (Edmonds 1988). The generative rules at the core of these works were, and are, based on the rules that I started to formulate when making *Nineteen* and which I used in my painting through the 1970s and on.

I did not show such a work publicly until 1985, but in many ways that showing was the culmination of much of the work of the 1970s.

Fragments was the generative work shown at Exhibiting Space, London, as part of my exhibition *Duality and Co-Existence*, in 1985. In 2004, a restored version of *Fragments* was issued as a limited edition DVD and shown in the exhibition *Australian Concrete Constructive Art* (at the Conny Dietzschold Gallery, Sydney).

Why were generative processes interesting in my art? Well, there are many answers to that question, but I will start with the most pragmatic of them.

Making art is an iterative process. One makes a mark, for example, looks at it and then makes another (or not, of course). Art-making is a continual process of conception, action and perception followed by re-conceptualisation–and so on. An important issue is that of matching the time and effort of the making (the laying down of a mark, for example) with its appropriate place in the cycle. Time-based work is very hard to make if each step has to be explicitly constructed. Using the computer as a generative engine magically removes this major problem. So, from a pragmatic point of view, I constructed a generative engine to make my time-based work so that the cycle of making, evaluating and refining the work was faster and tighter.

My pragmatic answer to the question begs many points, of course. The key underlying issue is that of the order and use of rules in the works in the first place. That makes the generative solution possible. My motivations are not ideological or political. I understand and am sympathetic with many computer-artist colleagues who use rules and generative methods in order to distance themselves from the art-making, and who do this for ideological reasons (see Boden and Paul Brown in preparation). For me, however, it is simply a matter of reducing the enormous decision space of art-making tosomething manageable.

Ever since *Nineteen* my work has involved rules. Often, they were constraint sets, as described in Section 2. But, with the advent of the time-based work, they became generative. The distinction here is important.

The use of rules in art-making does not necessarily imply that the art is generative in the sense that I have used the word in the past. (Note that we define G-art in a different way in Section 4.) The function of the rules in the process is a crucial issue. Where the rules are constraint sets, the art-making on the part of the human artist is as free, or almost as free, as ever. It is just that conditions are placed upon what is successful, whose results lie beyond the artist's intuition. A satisfactory work must not violate the constraints. As in mathematics or computer science, the fact that the problem space (of making the artwork) is bounded by clear constraints does not necessarily lead to any method or process for designing or making art.

In what I count as generative art, by contrast, the rules must be constructive. There are parallels here with mathematical logic (Goodstein 1951). That is to say, they must provide or imply a specific process that can lead to the desired outcome. That is the defining feature of generative art as I came to see it. Only if the rules are constructive does the artist hand over to the computer a significant element of the decision-making that is at the core of the art-making.

There is no doubt that I am interested in the rules themselves, not merely in what they might generate. Early on, I saw that they were more than just a convenience. The rules define the form. Think of a fugue, or of serial music. Think of perspective, or the golden section. This is the second answer to the question of why I found generative processes artistically interesting. Generative art enables the artist to concentrate on the underlying rules themselves: the structures that define the artwork, as against the surface. (This is a position clearly associated with distaste for decoration and ornament.)

It is all a little more complicated than this, however. In generative art that follows the evolutionary A-Life approach (see Section 4), for example, sometimes the 'fitness function' is not automated. Sometimes a human operator, whether audience or artist, makes the fitness decision on the basis of who knows what: their intuitive judgement, one might as well say. In such cases, the rules are not fully constructive, because their deployment requires the intervention of a human agent.

This compromise to the core concept of generativity is normally accepted by computer artists, and I accept it also. It applies more widely than in A-Life evolution. In general, it is a matter of enabling *interaction* to come into the picture without dropping the term 'generative art'.

I was interested in interaction from the beginning of my concern for the role of computers in my art. Indeed, I made interactive work as early as 1970. However, when I started to use logic to generate time-based works in the 1980s, I was not working in that way. Later on, and independently of evolutionary art (which I have never personally pursued), I made a simple extension to my generative approach in order to accommodate interaction.

It did not involve a fitness function and nor did it involve any other explicit evaluation step. What I did was to introduce the notion of 'external data'. These were values, stored in the computer, which were set and changed from time to time as a result of various sensor systems. For example, such an item could be the room temperature. Alternatively, it could be the degree of animation of people in front of the artwork. I made these external data available to the generative process and wrote rules (constraints) that took account of them. I saw those rules as meta-rules, because the values detected at a given time were used to select which rules or rule-set should be used.

In my more recent work, I have added yet another mechanism. Again, in principle it is simple enough. It is, in effect, a state vector that can be varied by inputs (such as sounds picked up by a microphone and detected behaviours by the audience), and which can be referred to just as the external data are. Thus, memory of a sort is made possible. Inputs or sensed data can cause changes at first only in the vector, but in ways that will influence the artwork's behaviour later – possibly much later (Edmonds 2007). Because of this delay, which precludes instantaneous effects on the system's behaviour, I talk about such works in terms of 'influence' rather than 'interaction'.

4 A taxonomy of generative art

Our taxonomy distinguishes eleven types of art. We call them Ele-art, C-art, D-art, CA-art, G-art, CG-art, Evo-art, R-art, I-art, CI-art and VR-art. Some of these activities, having been located within our classification, are then ignored. We pay most attention to various forms of CG-art, because these raise the most interesting philosophical issues.

This 'taxonomy'is a decidedly non-Linnaean structure. Quite apart from the fact that our definitions, like most definitions, admit borderline cases and even anomalous counter-examples, there's no neat and tidy hierarchy of genus and species within which these eleven types can be located. Although there are some part-whole relations here, there are also untidy overlappings.

One type of overlapping concerns links with more traditional, or familiar, categories of art. Most cases of such art do not fall under our classification at all. But some of our concepts – namely: G-art, I-art, Evo-art and R-art – cover artworks both inside and outside McCormack's "precious bubble" Admittedly, those which lie inside the bubble are relatively maverick examples, as we'll see. Indeed, some of them (produced by the 'conceptual' artists) were specifically intended to undermine the notion of "fine art" in terms of which the bubble is defined. For shorthand purposes, however, we locate *all* examples of non-computer art inside the bubble.

A summary list of our definitions is given at the end of this section. Meanwhile, we'll introduce them one by one, giving illustrative examples of each category.

Let us start with electronic art, or Ele-art. This wide concept covers *(df.) any artwork whose production involves electrical engineering and/or electronic technology.* So it ranges from simple analogue devices of the 1950s and 1960s such as Pask's *Musicolour* and *Colloquy* (Pask 1971; Mallen 2005) and Edward Ihnatowicz's kinetic sculpture SAM (Zivanovic 2005, p. 103)—all pioneering examples of interactive art, or I-art—to the highly sophisticated man-robot integrations recently embodied by the performance artist Stelarc (Smith 2005). And along the way, it covers the whole of computer art and media art, including those examples which exploit the advanced computational techniques of virtual reality.

Unlike mechanical art, such as Leonardo da Vinci's metal lion (who "after he had a while walked vp and downe, stoode still opening his breast, which was all full of Lillies and other flowers of diuers sortes"—Marr forthcoming, p. 66), electronic art could not appear until the mid-twentieth century. But, as the previous paragraph implies, the technologies concerned have diversified richly since then. Accordingly, the highly inclusive label Ele-art is not very interesting for our purposes.

Surprisingly, perhaps, neither is the concept of computer art, or C-art. By C-art, we mean *(df.) art in whose productive process computers are involved.* This concept is apt for general art-historical purposes, because it covers every example that anyone might want to call computer art—including many that are commonly given other labels. It's less useful for us here, however, for two reasons.

First, it includes analogue as well as digital computers. Some of the earliest C-art work combined digital methods with specially-built analogue devices. Ihnatowicz' giraffe-like kinetic sculpture *Senster* is a case in point (Zivanovic 2005). As for analogue computers as such, these were used in the early days. For example, in visual arts by Ben Laposky's work of the 1950s (Laposky 1969), and in the growth of electronic music at the same time, famously encouraged by the invention of the Moog synthesiser (Pinch and Trocco 2002).

Today, a few computer artists sometimes employ analogue *processes*, namely electro-chemical reactions like those pioneered by Pask. Some of their work, including Pask-inspired 'sculptures' by Richard Brown (2001, 2006) and Andy Webster (2006-ongoing), will feature in a 2007 Edinburgh exhibition on "Gordon Pask and his Maverick Machines". (In addition, a video on this theme called *Tuning Pask's Ear* has been shown in several European art galleries: Webster and Bird 2002.) But analogue *computers* are another matter—and are very rarely used by artists today. Because of the huge flexibility that is afforded by the general-purpose nature of digital computers, it is those machines which underlie most C art. Indeed, to speak of computer art is typically to assume that digital computers are being used.

In other words, computer art is (usually) tacitly classed as digital art, or D-art. D-art *(df.) uses digital electronic technology of some sort.* It includes not only artworks generated by computers but also digitally manipulable (but human produced) music and video. Common usage sometimes treats 'digital art' and 'computer art' as near-synonyms. In our taxonomy, they are analytically distinct—with most, but not quite all, C-art being included within D-art. (If the word 'electronic' were removed from our definition, the nineteenth-century Pointillistes would count as D-artists; for their pictures were composed not of continuous brush-strokes or colour-washes but of myriad individual spots of paint.)

D-art is more wide-ranging than may appear at first sight. For instance, some C-artists use visual software that is *intuitively* analogue and so relatively 'natural' to work with. (One example is continuous vector-mapping, used instead of pixel-editing (Leggett 2000)). But they are relying on methods/hardware that are digital at base. In fact, most people who said today that they are using an

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analogue method (i.e. an analogue virtual machine) would actually be working on a digital computer, used to simulate an analogue computer.

Similarly, most 'neural networks' or connectionist systems, whether used by cognitive scientists or by computer artists, are actually simulated on von Neumann machines. That's true, for instance, of Richard Brown's interactive *Mimetic Starfish*, a millennial version of the *Senster* that was described by *The Times* in 2000 as "the best bit of the entire [Millennium] dome". The starfish was built by engineering visual imagery, not metal: it is a neural-network based virtual creature (an image projected onto a marble table) that responds in extraordinarily lifelike ways to a variety of hand-movements. In short, digital technology reaches further than one might think.

The second reason why the definition of C-art given above is too catholic for our purposes is that it includes cases where the computer functions merely as a tool under the close direction of the artist, rather like an extra paintbrush or a sharper chisel. Artists in the relevant community sometimes speak of this as 'computer-aided' or 'computer-assisted' art, contrasting it with what they call 'computational' art—where the computer is more of a participant, or partner, in the art-making (e.g. Brown 2003, p. 1). We call this CA-art, wherein *(df.) the computer is used as an aid (in principle, non-essential) in the art-making process.*

Consider video art and music videos, for instance. These popular outside-the-bubble activities qualify as CA-art in our sense. For the human-originated images and/or music are digitally stored and (usually) manipulated/transformed by the artist, using the computer as a tool. Other cases of CA-art include someone's doing a line drawing by hand on the computer screen and then calling on a colouring program such as PhotoShop to produce a Limited Edition of identical prints—or, for that matter, a unique image. This is an upmarket form of painting-by-numbers, wherein the hues for each area are chosen by the individual artist. Yet other examples include computer music that's so called because it uses electronic synthesisers and 'virtual' instruments.

In practice, the computer 'aid' may be necessary for the art-making. It's impossible, for instance, to alter video-images in certain ways except by using a computer. Similarly, some visual effects delivered by Photoshop could not have been produced by using oils, water-colours, or gouache. And synthesised computer music exploits sounds that had never been heard before synthesisers were developed. Nevertheless, the computer is not essential *in principle.* The relevant visual/sonic effects are specifically sought by the human artist and might conceivably have been produced in some other way. Much as a species with iron-hard finger nails would not need chisels, so our vocal cords (or wood, metal, or cats' sinews . . .) might have been able to produce the sounds produced by synthesisers.

The sub-class of C-art which interests us is the type where the computer is not used as a tool to effect some idea in the artist's mind but is in a sense (*just what* sense will be explored in Section 5) partly responsible for coming up with the idea itself. In other words, the C-art that's most relevant here is a form of generative art, or G-art.

In G-art, *(df.) the artwork is generated, at least in part, by some process that is not under the artist's direct control.* This is a very broad definition. It does not specify the minimal size of the "part". It does not lay down just what sort of generative process is in question. It does not say what counts as being outside the artist's direct control. And it is silent on the extent (if any) to which the processes concerned may have been deliberately moulded by the artist before 'losing' direct control. In short, our definition of G-art is largely intuitive. In general, it picks out cases of art-making in which personal control is deliberately diminished, or even wholly relinquished, and relatively impersonal processes take over.

Those impersonal processes vary greatly. They may be physical, psychological, sociocultural, biological, or abstract (formal). And if abstract, they may or may not be implemented in a computer.

For example, in the dice-music written by Haydn and Mozart the exact order of the precomposed phrases was decided by throwing a die. Although a human threw the die voluntarily, he/she could not influence, still less determine, just how it fell. That was due to purely physical forces. Such forces also constructed the various versions of Bryan Johnson's (1969) novel *The unfortunates*, published as 27 separate sections in a box: all but the first and last were to be read in a random order, decided by shuffling or dice-throwing. One might even say, thanks to 't least in part', that Jackson Pollock's paintings examplified G-art grounded in physics. For although he certainly was not throwing (still less, choosing) paint at random, he did not have direct control over the individual splashes—as he would have done over marks made with a paintbrush.

Even more control was lost, or rather deliberately sacrificed, when Hans Haacke, in the 1960s, began to exploit – and even to highlight – the physical behaviour of water/vapour/ice, of waves and of weather conditions. He wanted to make "something which experiences, reacts to its environment, changes, is nonstable . . ., always looks different, the shape of which cannot be predicted precisely . . ." (Lippard 1973, p. 38, 64f.). He saw these works not as art *objects* but as "'systems' of interdependent processes"—which evolve without the viewer's interaction or "empathy", so that the viewer is a mere "witness". A few years later, Jan Dibbets placed eighty sticks in the sea, a few inches below the surface, and watched them oscillate in the water from fifty feet above: "That", he said, "was the work" (Lippard 1973, p. 59).

The Surrealists of the 1920s, by contrast, had exploited psychological processes – but of a relatively impersonal kind. Inspired by Freud, they engaged in automatic writing and painted while in trance states, in order to prioritise the unconscious mind—which Andre Breton declared to be "by far the most important part [of our mental world]". Indeed, Surrealism was defined by Breton as:

> *Pure psychic automatism [sic] by which one proposes to express . . . the actual functioning of thought, in the absence of any control exerted by reason, exempt from all aesthetic or moral preoccupations (Breton 1969).*

The unconscious thought was taking place in a person's mind, to be sure, but voluntary choice and personal "preoccupations" (i.e. the reality principle and ego-ideals) were not directing it.

More recently, the conceptual artist Sol LeWitt was also recommending G-art when he said that art should be designed by some formulaic rule. The crucial idea, he said, "becomes a machine that makes the art," where "all of the planning and decisions are made beforehand and the execution is a perfunctory affair" (LeWitt, 1967, p. 824); once the plan has been chosen, "The artist's will is secondary to the [artmaking] process he *initiates* from idea to completion" (Lewitt, 1969, item 7, italics added). He even added that "His wilfulness may only be ego". That artmaking process was nevertheless psychological, in the sense that the implications of his abstract rules were discovered not by computers but by conscious reasoning. Conscious rule-based reasoning (combined with chance) was used also in the G-art of Kenneth Martin, who – as remarked in Section 2—made some artistic choices by picking numbers out of a hat.

Sociocultural processes—in the form of the United States postal system—produced Douglas Huebler's artwork called *42nd Parallel*. Here, items were posted from 14 different towns spanning 3,040 miles on latitude 42, all sent to the Massachusetts town of Truro. The work, according to Huebler, was not the conception in his mind, nor the posted items, nor even the acts of posting. Rather, it was the widespread pattern of activity within the US postal system. But, he said, the work was "brought into its complete existence" through documents: the certified postal receipts (for sender and for receiver) and a map marked with ink to show the geographical relations between the 15 towns. Its nature as G-art is evident in his remarks "An inevitable destiny is set in motion by the specific process selected to form such a work, freeing it from further decisions on my part", and "I like the idea that even as I eat, sleep, or play, the work is moving towards its completion" (quoted in Lippard 1973, p. 62).

The artist Hubert Duprat turned to biology for constructing the work of art. He put dragonfly larvae into an aquarium containing not pebbles and pondweed but tiny flakes of gold, plus a few small pearls, opals, and sapphires—and left them to 'sculpt' opulent little protective cases, held together by caddis-silk (Duprat and Besson 1998). Some thirty years earlier, Haacke had experimented with the growth of grass and the hatching of chickens (as well as with water and weather), to make something "natural", which "lives in time and makes the 'spectator' experience time" (Lippard 1973, p. 38).

Others have even exploited physical and biological *de-generation* to produce their G-art. The environmental sculptor Andy Goldsworthy sometimes highlights effects caused by undirected physical change: in his gradually melting ice-sculptures, for example. And in Gustav Metzger's "auto-destructive" art (notorious for the occasion on which an overnight gallery cleaner innocently threw Metzger's bag of rotting rubbish into the dustbin), the point of the exercise is to remind us of the deterioration that awaits all human constructions—and human beings, too (Metzger 1965). The artwork is originally assembled by a human artist, but it attains its final form, and its significance, through the natural processes of damage and decay.

However, such inside-the-bubble (albeit unorthodox) cases are not what the new artists normally have in mind when they refer to 'generative art'. Their phraseology is borrowed from mathematics and computer science, with which the maverick artists just named were not concerned. These disciplines see generative systems as sets of abstract rules that can produce indefinitely many structures/formulae of a given type and which (given the Church-Turing thesis) can *in principle* be implemented in a computer. The GA-community outside the bubble put this principle into practice. That is, their artmaking rests on processes generated by formal rules carried out by computers—as opposed to physical, biological, or psychological processes, or abstractions personally discovered by conscious thought.

In other words, the instances of G-art which most concern us here are also instances of C-art. They are computer generated art: CG-art, for short.

A very strict definition of CG-art would insist that *(df.) the artwork results from some computer program being left to run by itself, with zero interference from the human artist.* The artist (or a more computer-literate collaborator) writes the program, but does not interact with it during its execution. In effect, he/she can go out for lunch while the program is left to do its own thing.

Such cases do exist. Cohen's AARON program (see below) is one well-known example. Nevertheless, that definition is so strict that it may be misleading. We saw in Section 3 that generative artists allow a 'compromise' in the core concept, so as to include interactive art. This is such a prominent subclass of what's called generative art that, even though we are not aiming to capture common usage, it would be highly anomalous to exclude it.

To be sure, the definition given above does cover most interactive art, because it insists on zero interference from "the human artist", rather than from "*any* human being, whether artist or audience". However, it would be very easy for readers to elide that distinction–which,

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in any case, makes a questionable assumption about authorial responsibility (see Section 5). Moreover, the overly strict definition of CG-art excludes those cases (also mentioned in Section 3) wherein artists rely on their intuitive judgement to make selections during an artwork's evolution.

We therefore prefer to define CG-art less tidily, as art wherein *(df.) the artwork results from some computer program being left to run by itself, with minimal or zero interference from a human being.* The word "minimal", of course, is open to interpretation. It necessitates careful attention to *just what* interference goes on, and *by whom*, in any particular case. (Attention need not be paid, however, to the distinction between rule-based and step-by-step programming explained in Section 2: our definition of CG-art allows for both.)

Most of what people call 'computer art' is CG-art, in this sense. Indeed, the phrases 'computer art' and 'generative art' are often regarded as synonyms. Notice, however, that in our terminology not all C-art is CG-art. CA-art is not, because the computer is there used as a tool subject to the artist's hands-on control (and is of no more philosophical interest than a paintbrush or a chisel). That's why we called this paper 'What is generative art?', rather than the seemingly synonymous 'What is computer art?'

CG-art is intriguing on two counts. First, the generality and potential complexity of computer programs means that the possible space of CG-artworks is huge, indeed infinite. Moreover, most of the structures in that space will be images/music which the unaided human mind could not have generated, or even imagined—as the artists themselves admit.

A sceptic might object that much the same is true of a trumpet, or a cello: not even the most skilled stage-impressionists could mimic these instruments plausibly. In short, human artists often need help from machines. Trumpets, computers . . . what's the difference? Well, one important difference has just been mentioned, namely, the generality of digital computers. In principle, these machines can (and do) offer us an entire symphony orchestra, and an infinite set of visual images and sculptural forms – indeed, an infinite range of virtual worlds. McCormack (2003, p. 7) goes so far as to compare this infinite space of possibilities, way beyond our comprehension, with the Kantian sublime.

The second point is even more pertinent. Whereas there's no interesting sense in which a trumpet, or a cello, can be "left to do its own thing", a computer certainly can. And it is part of the definition of CG-art that this happens. As we'll see later, this aspect of CG-art raises some tricky problems concerning concepts such as autonomy, agency, creativity, authenticity and authorial responsibility.

Especially well-known cases of CG-art include the successive versions of AARON. This is a drawing-and-colouring program developed over the last forty years by the one-time abstract painter Cohen (1995, 2002), and exhibited at venues all around the world—including the Tate Gallery. It has shown clear progression along various aesthetic dimensions. Indeed, Cohen (p.c.) describes the 2006 version as a "world-class" colourist, whereas he himself is merely a "first-rate" colourist: "I wouldn't have had the courage to use *those* colours", he sometimes says. (At earlier stages, colouring-AARON mixed liquid dyes and used 'painting blocks' of five different sizes to place them on paper; the current version prints out computer-generated colours instead of using liquids, but these colours too are 'mixed' at the program's behest.)

An almost equally famous example is Emmy, a computer-musician developed over much the same period by the composer David Cope (2001, 2006). This generates music in the styles of many renowned composers, and very convincingly, too—see Hofstadter 2001, p. 38f. (Nevertheless, Cope has recently abandoned it, because of the prejudiced reactions of audiences: see Section 5.)

Both of those programs were based on methods drawn from what the philosopher John Haugeland dubbed GOFAI, or Good Old-Fashioned AI (although the mature Emmy also uses connectionist AI). More recent methods for constructing CG-artworks, as remarked in Section 1 include cellular automata, L-systems and evolutionary programming—all widely used in A-Life research.

Cellular automata are systems made up of many computational units, each following a small set (usually, the same set) of simple rules. In such systems, surprising patterns can emerge from the simple, anodyne, base. Further variations ensue if another 'level' of rules is added to the system. Examples in CG-art include the tesselated visual constructs within Paul Brown's *Sandlines* and *Infinite Permutations*, and other works by Paul Brown (Whitelaw 2004, pp. 148–153; Tofts 2005, p. 85f.; www.paul-brown.com).

L-systems are automatically branching structures, used by botanists to study plant form and physiology (Lindenmayer 1968; Prusinkiewicz and Lindenmayer 1990; Prusinkiewicz 2004). In the hands of CG-artists, they have led (for instance) to McCormack's *Turbulence* installation (McCormack 2004; Tofts 2005, p. 80ff.). This generates images of un-natural yet lifelike vegetation growing in front of one's eyes–and in response to one's actions (thus qualifying as interactive art). Another example is the use of a 'swarm grammar' based on L-systems to generate structures in (simulated) 3D-space, comparable to the decentralised yet organised constructions of social insects such as termites (Jacob and von Mammen 2007).

As for evolutionary programming, this has given rise to an important sub-class of CG-art: evolutionary art, or Evo-art. Examples include Karl Sims' *Genetic Images* and *Galapogos* (Sims 1991, 2007), plus many others (Whitelaw 2004, ch. 2). In Evo-art, the artwork is not produced by a computer program that has remained unchanged since being written by the artist. Rather, the artwork is *(df.) evolved by processes of random variation and selective reproduction that affect the art-generating program itself.*

Evo-art relies on programs that include self-modifying processes called genetic algorithms. To begin, a 'population' of near-identical artworks–or, to be more precise, the mini-programs that generate them–is produced by the computer. There can be any number: 9, or 16, or even more. In aesthetic terms, these first-generation artworks are boring at best and chaotic at worst. Next, each of these first-generation programs is altered ('mutated') in one or more ways, at random. Usually, the alterations are very slight. Now, some selective procedure—the 'fitness function' (decided by the artist/programmer)—is applied to choose the most promising candidate/s for breeding the next generation. And this process goes on repeatedly, perhaps for hundreds of generations. Provided that the mutations allowed are not too fundamental (see Section 5), what ensues is a gradual evolutionary progress towards the type of structure favoured by the artist.

Occasionally, the fitness function is fully automatic, being applied by the computer itself. (If so, there may be scores, or even hundreds, of 'siblings' in a given generation.) This is a prime example of the computer's being 'left to do its own thing'. More usually (as remarked in Section 3), the selection is done hands-on by the artist—or by some other human being: a gallery-visitor, for instance—using intuitive, and often unverbalised, criteria. (If so, the population-size rarely rises above 16, because people cannot 'take in' more than a limited number of patterns at once.) In other words, and for reasons touched on in Section 5, there is usually no *programmed* fitness function. In such cases, the Evo-art also counts as I-art.

One might argue that our definition of Evo-art is faulty, on the grounds that evolutionary art need not involve a computer. It's certainly true that the very earliest G-art works of William Latham, who later became famous as a *computer* artist, were generated by repeated dice-throwing and hand-drawing. At that time, he had no idea that computers might be able to do the job for him—and do it better (Todd and Latham 1992). But that is highly unusual: virtually all art that's produced by an iterative process of random variation plus selection is computer-based. Indeed, we do not know of any non-computerised example besides early-Latham. (Someone might suggest Claude Monet's water-lily series: but although these showed gradual improvement by way of small changes, those changes were far from random.) Even Richard Dawkins' simple "Biomorphs, which were hugely seminal for Evo-artists, were computer-generated (Dawkins 1986, pp. 55–74). We have therefore chosen to define Evo-art as a sub-class of CG-art, even though this excludes the early-Latham efforts.

Another sub-class of CG-art is robot art, or R-art. By R-art, we mean *(df.) the construction of robots for artistic purposes, where robots are physical machines capable of autonomous movement and/or communication.* We hope we shall be forgiven for not attempting to define "artistic purposes". As for "autonomous", the word may be understood intuitively here. At some point, however, it should be considered carefully—not least, because the concept of autonomy is closely connected also with agency and creativity (see Section 5).

Clearly, not all R-art is Ele-art. Indeed, R-art covers examples built many centuries ago. A few of these ancient machines could move as a whole from one place to another–such as Leonardo's mechanical lion that "walked vp and downe" the room, or Daedalus' mercury-filled Venus which (according to Aristotle's *De Anima*) had to be tethered to prevent it from running away. Most, however, could move only their body-parts–like the moving statues of nymphs and satyrs in the grotto fountains at St. Germain, which enthused Rene Descartes as a young man.

Electronic R-art is highly varied (Whitelaw 2004, ch. 4). It includes Ihnatowicz's eerily hypnotic *Senster*, Stelarc's thought-provoking man-robot hybrids and Ken Goldberg's *TeleGarden*—wherein living plants are watered by a robot that is controlled by Everyman via the Internet (Popper 2007, pp. 379–393).

In all those cases, only one robot is involved. Sometimes, however, groups of interacting ('distributed') robots are constructed. Usually, such groups employ the techniques of situated robotics, wherein the machines respond directly to specific environmental cues–here, including *the behaviour of other robots* (Boden 2006, p. 13.iii.b and iii.d). Occasionally, they exploit self-organising techniques whereby the system gradually reaches an equilibrium state. (Futuristic though they may seem, both these methodologies were first used by mid-century cyberneticians: Grey Walter and Ross Ashby, respectively.) One example of the latter type is Jane Prophet's *Net Work* installation (Bird, d'Inverno and Prophet 2007). One might think of this as a hi-tech version of Dibbets' oscillating sticks. But instead of eighty 'isolated' sticks, placed below the surface of the sea, *Net Work* consists of 2500 floating, and intercommunicating, buoys–each of which is colour-emitting and wave-sensitive. (More accurately, it *will* consist in 2500 such buoys: it has been tested in a 3X3 miniature on the Thames, but is planned to surround the pier at Herne Bay.)

Such mutually interacting robot-groups *do not* count as interactive art on our definition (given below), unless they are also capable of interacting with the human audience. *Net Work* does have that capability: the audience can affect it by shining torchlight on the buoys, or by remote control over the Internet. Other examples of interactive (and interacting) robot-groups include Kenneth Rinaldo's works in what he calls eco-technology. His R-art (and I-art) installation called *TheFlock* comprises three wire-and-vine robotic 'arms' suspended from the ceiling, which interact with each other and with the moving/speaking human audience. Similarly, his *Autopoiesis* has fifteen

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robot wire-frame 'arms' distributed around the room, which sense the observer's movements and communicate with each other so as to coordinate their behaviour in various ways.

This brings us to our ninth category: interactive art. In this genre, the human audience is not a passive observer but an active participant. Audiences are never wholly passive, of course, since art-appreciation involves active psychological processes. Indeed, Marcel Duchamp (1957) went so far as to say:

> *The creative act is not performed by the artist alone; the spectator brings the work in contact with the external world by deciphering and interpreting its inner qualification and thus adds his contribution to the creative act (Duchamp, 1957).*

Even for Duchamp, however, the spectator's contribution concerns only the work's "inner" qualification (its role, he said, is "to determine [its] weight on the aesthetic scale"). The work's perceptible nature—or, many would say, the artwork itself—does not change as a result. In interactive art, by contrast, it does.

In I-art, then, (*df.) the form/content of the artwork is significantly affected by the behaviour of the audience.* And in CI-art (i.e. the computer-based varieties), *(df.) the form/content of some CG-artwork is significantly affected by the behaviour of the audience.* Again, we are speaking intuitively here: worries about just what counts as "the artwork" are left to the next section. The word "significantly" is needed, even though it is a hostage to interpretative fortune, so as to exclude performance art—for performance is usually subtly affected by audience reception. As for the word "behaviour", this must be interpreted with generosity. In CI-art it covers voluntary actions (such as waving, walking and touching the computer screen), largely automatic yet controllable actions (such as the direction of eye-gaze) and involuntary bodily movements (such as breathing). It even includes arcane physical factors such as the radiation of body-heat.

(Occasionally, the 'interaction' involves not the audience but the physical environment: aspects of the weather, for example. Such cases fall outside our definition, unless–which is usually the case—they a*lso* involve interaction with the human audience.)

CI-art is generative art *by definition*. But it is not 'generative' in our strictest sense (above), as AARON is. For although the artist can go to lunch and leave the program to do its own thing, the audience cannot. However, it qualifies as CG-art in our broader sense, since the artist has handed over control of the final form of the artwork to the computer, in interaction with some other human being. The degree of control attributable to the audience varies: they may not realise that they are affecting the artwork, nor (if they do) just what behaviour leads to just which changes. We'll see later that this variability is an important dimension in the aesthetics of CI-art.

I-art is not an entirely recent phenomenon: remember Haydn's dice-music, for instance. But it became prominent in the mid-twentieth century. (This was often justified in political terms: I-art was seen as offering valuable *human-human* communication, in societies where the sense of community had been diluted—Bishop 2006.) It was made possible largely by cyberneticians such as Pask applying their theory of communicative feedback to art, and by the new electronic technology developed in World War II.

That's not to say that all these I-art efforts were examples of Ele-art. Many artists, indeed, eschewed such technology for (counter-cultural) ideological reasons: it was too strongly linked with the military-industrial complex. Even Ascott's first I-art had nary an electron in sight: it consisted of canvases with items/images on them that could be continually moved around by hand, so that the viewer of the resulting collages was their *maker* too. *SAM* and the *Senster* were early examples of I-art that did use electronics. But, as we have seen, they did not involve computers.

Today's I-art, however, is overwhelmingly computer-based. That's because the generality of digital computers enables them, in principle, to support an infinite variety of human-computer interactions.

The types of interaction explored in CI-art are already widely diverse—hence the inclusiveness of the term 'behaviour' in our definition. The by-now-countless examples range from interactive CD-Roms viewed on a desk-top and altered (for instance) by touching the screen (Leggett and Michael 1996), to room-sized video or VR installations—such as Christa Sommerer and Laurent Mignonneau's *Trans Plant*. In this case, a jungle gradually appears on the walls as the audience moves around the enclosure: grass grows when the viewer walks, and trees and bushes when he/she stands still; the plants' size, colour, and shape depend on the size and bodily attitudes of the human being; and the colour density changes as the person's body moves slightly backwards or forwards. *Trans Plant* is driven by the viewer's movements, but some CI-art-works are modified also, or instead, by the sound of human voices or footsteps. This is reminiscent of the *Senster*—but these computer-generated changes are much more varied and complex than those which could be engineered in the 1960s by Ihnatowicz.

Sometimes, the relevant interactions involve on-line access to the Internet, automatically incorporating into the artwork items that happen to be present on the world-wide-web at that particular moment. One example is *The Living Room*, another installation built by Sommerer and Mignonneau. Unlike *Trans Plant*, this CI-artwork does not undergo changes that depend systematically on what the viewer is doing. Instead, random images and sounds, picked up from the Internet, appear in the room as a result of the viewer's movements and speech.

It's usual, as in that example, for the change in the CI-artwork (whether systematic or not) to be near-simultaneous with the observer's triggering activity. In Edmonds' most recent CI-art, however, the effects of the viewer's behaviour are delayed in time (see Section 3). Partly because of the lesser likelihood that the viewer will realise—and be able to control—what is going on, Edmonds speaks of 'influence' rather than 'interaction' in these cases. As we'll see in Section 5, whether mere 'influence' can be aesthetically satisfying is controversial even *outside* the precious bubble.

Certainly, mere influence, as against instantaneous interaction, would not be enough for our final category, namely virtual veality art, or VR-art. VR-art is the most advanced version of CI-art (for examples, see Popper 2007, chs. 4–6). Already foreseen in the mid-1960s, it was not technologically possible until the late-1980s (Boden 2006, p. 13.vi).

In VR-art, interaction leads to illusion–of an especially compelling kind. In other words, *(df.) the observer is immersed in a computer-generated virtual world, experiencing it and responding to it as if it were real.* We do not pretend that this definition is clear: just what is it for someone to experience/respond "as if it were real"? Some relevant issues will be indicated in Section 5. Meanwhile, we'll continue to rely on readers' intuitive understanding of such language.

Someone might want to argue that VR-art was initiated centuries ago. For pseudo-realistic mimetic worlds have been depicted in various forms of *trompe l'oeuil* (including 'realistic' panoramas) for many centuries and even appeared in some of the wall-paintings and architecture of Classical Rome. But there's a crucial difference between the relevant aesthetics in times ancient and modern. As Oliver Grau (2003, p. 16) has pointed out, the "moment of aesthetic pleasure" in *trompe l'oeuil* comes when the viewer consciously realises that they are *not* experiencing reality. In VR-art, by contrast, the enjoyment lies in feeling as though one is really inhabiting, and manipulating, an alternative world. The longer the awareness of its unreality can be delayed, the better. In other words, the experience of past forms of mimetic art was based only on illusion, not on immersion. Although one can say that the viewers were invited/deceived into responding to the *art as if* it were real, that "as if" was much less richly textured, much less sustained, and therefore much less persuasive, than it is now.

(Cinema is a half-way house—Grau 2003, ch. 4. It often elicits an emotional/narrative 'immersion' in the filmgoer and sometimes—using special screens and techniques—leads to near-veridical experiences of inhabiting the cinematic world. These tend to exploit our reflex bodily responses to visual images that suggest falling, or imminent collision: so roller-coasters, white-water-rafting and tigers leaping towards us out of the screen are familiar favourites. But there's little psychological subtlety in this 'inhabitation' and no detailed interaction with the alternate world—still less, any physical manipulation of it.)

In general, VR-art aims to make the participants (often called 'immersants') feel as though they are personally present in the cyberworld concerned. Normally, this world is visual or audio-visual, being presented on a VDU screen or projected onto the walls/floor of a real-world room. (McCormack's *Universal Zoologies* VR-artwork is an exception: here, the images/sounds are projected onto two large 'talking heads', in an attempt to provide a realistic illusion of human conversation–Tofts 2005, p. 81f.). But sometimes, VR-art leads also to convincing experiences of touch, pressure and motion by providing the observer with special gloves and other equipment (Boden 2006, p. 13.vi). Sometimes, too, the observer experiences utterly *unreal* capacities, such as being able to fly or to activate highly unnatural causal chains within the virtual world.

Even when the viewer is not presented with such shockingly unfamiliar experiences as those, something about the virtual world will be perceptibly *unlike* the real world. And this is deliberate. For VR-artists are not aiming to achieve a fully detailed mimesis: what would be the point of that? Rather, they use near-mimesis to cast some aesthetically/conceptually interesting light on our usual experiences and assumptions. (Detailed mimesis may be appropriate for other purposes, of course: for instance, a VR-brain used in training neuro-surgeons provides nicely realistic sensations of touch and vision when the trainee's virtualised surgical tool prods, pinches, or cuts different parts of it.)

In sum, our eleven definitions are as follows:

1. Ele-art involves electrical engineering and/or electronic technology.
2. C-art uses computers as part of the art-making process.
3. D-art uses digital electronic technology of some sort.
4. CA-art uses the computer as an aid (in principle, non-essential) in the art-making process.
5. G-art works are generated, at least in part, by some process that is not under the artist's direct control.
6. CG-art is produced by leaving a computer program to run by itself, with minimal or zero interference from a human being.
   NB: We chose to reject *the stricter definition of CG-art (art produced by a program left to run by itself, with zero interference from the human artist).*
7. Evo-art is evolved by processes of random variation and selective reproduction that affect the art-generating program itself.
8. R-art is the construction of robots for artistic purposes, where robots are physical machines capable of autonomous movement and/or communication.
9. In I-art, the form/content of the artwork is significantly affected by the behaviour of the audience.
10. In CI-art, the form/content of some CG-artwork is significantly affected by the behaviour of the audience.

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11. In VR-art, the observer is immersed in a computer-generated virtual world, experiencing it and responding to it as if it were real.

5 Some questions for aesthetics

Various aesthetic and/or philosophical problems arise with respect to CG-art in general and others with respect to particular varieties of it. None of these can be explored at length here. (We have discussed them elsewhere, however. Some answers to the questions raised below are offered in: Boden 1999, 2004, 2006 13.iii.d–e and 16.viii.c, 2007, in press (a,b,c); Boden and Paul Brown in preparation; Cornock and Edmonds 1973; Costello and Edmonds 2007; Edmonds 2006 in press; Muller, Edmonds, and Connell 2006.) Instead, this section merely indicates the wide range of puzzles that attend the consideration of generative art.

One obvious question can be put informally thus: Is it really the case that a computer can ever 'do its own thing'? Or is it always doing the programmer's (artist's) thing, however indirectly?

To answer that question seriously requires both general philosophical argument and attention to specific aspects of particular CG-art examples—in the underlying program, as well as in the observable artwork. That sort of attention is not appropriate in cases of G-art that are not computer-based. For the physical, psychological, or biological processes in which they are grounded are not specifiable in detail—not even by scientists, let alone by artists. Computer programs, in contrast, are so specifiable. That's why one can make sensible comparisons between the extent to which different CG-art programs are or are not 'under the artist's direct control' and the extent to which, and the points at which, they are subject to "interference from a human being". However, one can do this only if one knows something about how the program and/or installation works. Merely observing, or even participating in, the resultant artwork is not enough.

Whether it *appears* to participants that the program/installation is independent, or autonomous, is of course another question (one which may not be easy to answer, in practice). So too is the question whether it ever makes sense to ascribe autonomy to a computer. Remember Edmonds' remarks about rule-based programming in Section 3: does it really matter what the 'feel' of this activity is, if in fact it is no less directive, no less determinate, than algorithmic programming? Irrespective of the artist's phenomenology while writing the program, and/or of the participants' phenomenology when experiencing it, do some categories of CG-art have more autonomy than others? What of Evo-art, for instance: does the self-modification involved, and the automatic selection (in cases where that happens), mean that evo-programs are more autonomous than (say) AARON? With respect to AARON, can we ascribe at least a minimal level of autonomy to the computer, given that Cohen has no hands-on control over what picture will be drawn, or how?

Insofar as a program is 'doing its own thing', does it take on the authorial responsibility? (Let us ignore the fact that 'authorial responsibility' is often unclear here anyway, since most CG-art is produced by a team, not a lone artist.)

For instance, did AARON generate those magnificent 'world-class' coloured drawings, or did Cohen do so? He admits, after all, that he himself "wouldn't have had the courage to use *those* colours". On the other hand, he says he is happy that there will be more of "his" original artworks appearing well after his death (Cohen 2002). Is he right, or is he deluded? The answer will depend not only on one's philosophy of the self but also on one's views as to whether any computer program can be seen as an author/artist. Douglas Hofstadter, for example, would be content to ascribe the posthumous works to Cohen himself (and would even deny that they

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are in the fullest sense *posthumous* (Hofstadter 2007)); if he was emotionally moved by them, he would also resist ascribing authorship to the computer (2001).

Does Evo-art leave more room, or less, for human authorship than AARON does? That is, does the artist's choice of fitness function suffice to give him/her the authorial credit for whatever artwork emerges after many generations of random (i.e. undirected) change? Is the credit greater, or less, if instead of relying on a programmed fitness function the artist does the selecting 'by hand'?

One reason for the Evo-artist's choosing to do the selection by hand is in order to produce only works in his/her own style. This is also the reason why the mutations that are allowed are usually very slight. For an artistic style is a sustained pattern of activity, lasting over time. In Evo-art that allows radical mutations (and which does not 'ration' them to once every 2,000th generation, for instance), no pattern can be sustained for long—not even if the human artist is trying to shape the results by making the 'fitness' selection at each stage. On the contrary, huge structural changes can occur in a single generation (cf. Sims 1991). This leads to fascinated amazement on the part of the gallery audience. Nevertheless, Evo-artists do not normally allow such mutations. They prefer to explore a stylistic space which, despite many surprising variations, remains recognisble as 'theirs' to someone with an experienced eye.

There are some exceptions. The CG-artist Paul Brown (with others, including the authors of this paper) is involved in an ongoing Evo-art project whose aim is to evolve robots that will make aesthetically acceptable drawings which *do not* carry Brown's general style, or 'personal signature' (Bird et al. 2007; Boden forthcoming). Whether that can be done remains to be seen: Brown, after all, will be setting the fitness functions as the work proceeds.

This project raises questions also about the relation between CG-art and embodiment. Many philosophers of mind discount AI/A-Life in general (as models of mind or life) for being concerned with virtual, body-less, systems. However, these R/Evo-art creatures are robots moving in the real world and are therefore subject to physical forces. It's known that truly fundamental changes—i.e. new types of sensory receptor—can evolve in robots as a result of unsuspected physical contingencies (Bird and Layzell 2002). (Compare the biological evolution not of a primitive eye into a better eye, but of a light-sensor where no such sensor existed before.) In principle, then, a fundamentally new style [sic] might develop in this way, whereas (arguably) that could not happen in a purely virtual, programmed, system.

Similar puzzles about authorial responsibility arise in CI-art in general, of which 'hand-selected' Evo-art is a special case. Just where, in the man-machine system concerned, is the true author? That worry affects all I-art, of course– but is there any extra difficulty where CI-art is concerned? (For present purposes, let us ignore Duchamp's suggestion that *all* art is multi-authored.) And what difference, if any, does it make if—as sometimes happens–the audience provides feedback during the construction of the CI-work, so that its final form depends not only on the decisions of the artist but also on the reactions of the audience/s who encountered it in its prototype stage? Perhaps our distinction between "decisions" and "reactions" is crucial here, debarring the audience from earning any 'extra' authorial credit in such cases?

To speak of a 'worry' here, however, is perhaps to counteract what CI-artists are trying to do. Despite its sturdy roots in cybernetics and computer technology, CI-art has attracted favourable notice from post-modernists precisely because of the ambiguity of authorship involved. Ascott (2003), in particular, has always seen the value of CI-art as its democratising ability to engage the viewer/ participant *as creator*. In his words, "creativity is shared, authorship is distributed. . ." (1990, p. 238). If authorship is deliberately distributed, then to worry about its locus (about ascribing the status of *author*) is to miss the point.

(For all the heady talk of creative participation, some CI-art is fairly limiting (Kahn 1996). That's so, for instance, where the possible changes in the artwork are explicitly pre-set by the artist, as opposed to their emerging from the program's "doing its own thing". The limitation is especially great where they are selected by the participant's choosing from a Menu.)

Another way of putting questions about authorial responsibility is to ask where the creativity lies. But what, exactly, do we mean by creativity?

It certainly involves agency—which is why considerations of autonomy and authorial responsibility are inevitable. But what is agency? The interacting 'arms' and floating buoys identified above as examples of R-art are typically described by the artists and technicians concerned as agents—a word borrowed from AI/A-Life research on distributed cognition. But does that research misuse the concept? Even if it does, does it include 'agents' of interestingly different types (Boden 2006, p. 13.iii.d-e), some of which are more deserving of the name than others? If so, should we at least reserve the term – and the ascription of creativity – for those cases of CG-art where the agents involved are of the more plausible variety? Again, such questions cannot be answered without careful attention to the details of the programs and communications involved.

It's commonly assumed that creativity—and art, too—involves unpredictability (Boden 2004, ch. 9). But what is its source? Is it merely lack of predictive power on the part of human minds? We have seen (in Section 3) that CG-art, like complex programs in general, is indeed unpredictable for that reason. But CI-art and Evo-art are unpredictable for other reasons as well. CI-art, because the artist cannot predict the sequence of interactions that will take place, even if he/she can predict what would happen at a given moment if *that* audience-movement were to occur; and Evo-art, because of the many *random* changes to the program and because of the choices made at successive generations by the artist. Does the unpredictability of traditional art have any deeper source? And if so, is this something which cannot be ascribed to, or even simulated in, computers?

Another set of questions concerns ontology. How can we identify 'the artwork' when an artist's computer program generates countless unique images, or musical compositions, none of which have been seen/heard by the artist? Is each image/music produced by AARON or Emmy an artwork – or is the artwork the program which generates them? In Evo-art, does one and the same artwork exist at differing levels of sophistication at different generations? Or does every generation produce a new artwork—or, perhaps, a new population of (sibling) artworks?

What counts as the artwork when the uniqueness is due not only to a richly generative computer program but also to the contingent (and ephemeral) behaviour of a participatory human audience? Perhaps the familiar concept of artwork is well-suited only to the unchanging artefacts that form the overwhelming majority of the cases inside McCormack's bubble? A traditional artist can fully comprehend the painting or sculpture that they have executed so carefully (although whether this applies to the G-art dimension of Pollock's paintings is questionable), but CI-artists cannot fully know the CI-artwork that they constructed with equal care. This is not merely a matter of the unpredictability of detail: in sufficiently complex cases, it is not even clear that they can recognise the general potential of their own work. With regard to CI-art, then, perhaps we should speak not of the 'artwork' but of the 'art system'—where this comprises the artist, the program, the technological installation (and its observable results), and the behaviour of the human audience?

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(And perhaps, if the concept of the 'artwork' falls, then that of the 'artist/author' falls too?)

Or maybe we should think of each occurrence of CI-art as a performance and the program/installation as the score? If so, the 'performance' is more like a jazz improvisation than the playing of classical music, for it can vary considerably from one occasion to another. Even if the form of each particular human-computer interaction can be completely determined by the artist (which is not so, for instance, when the computer's response can be modified by its memory of the history of previous interactions), the *sequence* of such events cannot.

Yet another problematic area concerns aesthetic evaluation. Are entirely novel aesthetic considerations relevant for CG-art in general, or for some subclass of it? And are some aesthetic criteria, normally regarded as essential, utterly out of place in CG-art: authenticity, for instance?

The devotees of CI-art, in fact, do not use the familiar (inside-the-bubble) criteria to judge different interactive installations. Or insofar as they do, these are secondary to other considerations. The criteria they see as most appropriate concern not the nature of the resulting 'artwork' (the beauty of the image projected on the wall, for example, or the harmoniousness of the accompanying sounds), but the nature of the interaction itself. There's general agreement on that point. But there's significant disagreement on just what type of interaction is the most aesthetically valuable.

Some CI-artists, especially those engaged in VR-art, stress the disturbing sense of unreality involved, and the participant's new 'take' on everyday experience that ensues. Many value the participant's conscious control of the artwork; others aim to highlight their sense of personal embodiment; while yet others stress the audience's disconcerting experience of unpredictability triggered by their own actions. All of those criteria concern the participant's e*xperience* —but difficulties arise if one asks how that experience can be discerned, or 'logged', by anyone other than the individual participant. (As we saw in Section 3, if the observers can never come to realise that they are affecting what happens, then the 'I' in 'CI-art' might better be thought of as the initial letter of 'influence', not of 'interaction'.)

There are some especially jagged philosophical rocks lying in wait for VR-artists. The concept of virtual reality has been defined in various ways (Steuer 1992). Most, like our definition of VR-art, refer to the participant's experience of being immersed in a real world and reacting accordingly. This notion seems to be intuitively intelligible, especially if one has actually encountered a VR-installation. But just what it means, whether in psychological or philosophical terms, is very difficult to say. It is not even clear that it is coherent. Several leading philosophers of mind have addressed this hornet's nest of questions in writing about the film *The Matrix* (see especially the papers by Hubert Dreyfus and Andy Clark on the Warner Brothers website: http://whatisthematrix.warnerbros.com). That's not to say that *The Matrix* counts as VR-art, for it does not. Nevertheless, it raises some of the same questions that would attend highly plausible instances of VR-art. (Whether these would also be highly successful instances is another matter: we have seen that VR in art typically highlights some *unreal* dimension of the experience.)

As for authenticity, this is a tricky concept. There are several reasons, of varying plausibility, why someone might argue that it is not applicable to any instance of CG-art. And CG-artists have suffered as a result. For example, Cope (2006) has been continually disappointed by people's failure to take his music seriously– not because they dislike it on hearing it (sometimes they even *refuse* to hear it), but simply because it is computer-generated. Even when they do praise it, he has found that they typically see it less as 'music' than as 'computer output'—a classification which compromises its authenticity. For instance, even though each Emmy-composition is in fact unique, people know that the program could spew out indefinitely many more tomorrow. (The fact that human composers die, says Cope, has consequences for aesthetic valuation: someone's oeuvre is valued in part because it is a unique set of works, now closed.) As a result of this common reaction, Cope has recently destroyed the data-base of dead composers' music that he had built up over the last twenty-five years and used as a crucial source in Emmy's functioning. (Emmy's successor will compose music only in Cope's own style; whether audiences regard this is significantly more authentic remains to be seen.)

Finally, what of the claims made by many CG-artists to be exploring the nature of life? It's clear from Rinaldo's choice of the titles *Autopoiesis* and *The Flock* (plus the rest of his oeuvre—Whitelaw 2004, pp. 109–116), for instance, that his R-art works are not intended as mere fairground toys but as meditations on significant aspects of life. He is not alone in this: many of the CG-artists who have been influenced by A-Life see their work in that way. Concepts such as emergence and self-organisation, and of course evolution, crop up repeatedly in their writings and interviews—as does the key concept of life itself. One may well agree that their work throws light on, or anyway reminds us of, important—and puzzling—properties of life. But one need not also agree with the claim sometimes made by these CG-artists, that purely *virtual* life (a.k.a. strong A-Life) is possible—and that their work, or something similar, might even create it.

6 Conclusion

We have mentioned a number of philosophical questions. But we have ignored what is perhaps the most obvious one of all: "But is it art, *really*?"

Many people feel that computers are the very antithesis of art. Indeed, some philosophers argue this position explicitly (e.g. O'Hear 1995). On their view, art involves the expression and communication of human experience, so that if we did decide that it is the *computer* which is generating the 'artwork', then it cannot be an *art* work after all. A closely related worry concerns emotion in particular: if computers are not emotional creatures then—on this view—they cannot generate anything that's properly termed 'rt' (Hofstadter 2001). Another common way of discrediting computer art in general is to argue that art involves creativity and that no computer–irrespective of its observable performance—can *really* be creative (for a discussion, see Boden 2004, ch. 11). And both authors of this paper have often observed someone's aesthetic approval of an artwork being instantly renounced on discovering that it is, in fact, a CG-artwork. Cope was so disturbed by this reaction, as we have seen, that he destroyed the data-base on which Emmy's—or should we rather say 'his'?—CG-music rested.

It would not be appropriate to burden this already lengthy paper with a discussion of the slippery concept of art. But it is not necessary, either. For we have given many illustrations of the continuities between CG-art and non-computer art. Several of our analytic categories include examples drawn from both inside and outside McCormack's precious bubble–although, admittedly, most cases of traditional art elude our definitions. And those categories which apply only to CG-art cover many individual cases that are aesthetically related to traditional artworks.

Moreover, the art world itself–however suspicious it may be of computers in general, and however dismissive it may be of particular CG-art efforts–does sometimes award these new activities the coveted status of art. Sometimes, this happens in a specialised corner of the art world: for instance, London's *Kinetica* gallery (opened in 2006), which is devoted to interactive, robotic and kinetic art. But we have also mentioned two examples (others could have been cited) where major 'traditional' galleries clearly accept that traditional and CG-art are players in the same cultural ballpark. These were the Tate's one-man show of Cohen's AARON and the Washington exhibition featuring Edmonds' work as a development of that of the ColorField painters. The latter example is especially telling, precisely because it is not a show celebrating only CG-art. On the contrary, the Washington exhibition is putting CG-art alongside the precious bubble—or even inside it.

In response to the sceptic's challenge "But is it art, *really*?", we therefore rest our case.

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