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On Wonder and Betrayal: Creating Artificial Life software to meet aesthetic goals.

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Abstract

This paper examines the way in which works of generative computer-based art, specifically those which reference Artificial Life, may gain aesthetic appeal through instilling a sense of "wonder" in a viewer. This idea is examined from its roots in our fascination with natural phenomena and the sublime, through its representation in terms of the basic elements of drawing off and on-screen, and into the computational realm in which Artificial Life software finds its form. This paper explores the artistic potential of the approach which takes computationally-realized works with a single level of emergent organizational structure, to those capable of giving rise to interactions built yet again on top of these in an ever-increasing hierarchy of added complexity. The difficulties of coding such software systems successfully will be briefly discussed.

Introduction.

The techniques of Artificial Life based art form a subset of what is here referred to as *Generative Art*, this being an artistic practice which adopts an aesthetic of *process*. By this it is meant that not only does the final outcome of a work depend for its appeal on the aesthetics of an image, sound, sculpture or other form, but on the process which generated or continues to generate it. The generative artist is responsible for setting up initial conditions and a process to act upon them. The work which unfolds is the result of this series of changes. This is analogous to a phenotype being the result of the physical and chemical interactions which govern its development from a genotype. Hence, there are conceptual connections between Generative Art and Artificial Life as well as practical ones.

The first section below begins by discussing the sense of wonder people often feel whilst contemplating nature and/or simple physical systems. This is then related to the tradition of the *sublime* in aesthetics. The paper then discusses various means which may be employed to convey a sense of the *computational sublime* in order to approach the problem of devising a computational system emulating the physical world's seemingly inexhaustible capability to generate complexity and novelty.

On "wonder" and the sublime in art and nature.

People stare contemplating the ocean as it's swell rises and crashes on a rocky shore or gaze fixedly into a fire until the sting of smoke raises their awareness. People lie on their backs and follow passing clouds, or marvel at the glittering of stars. There are many things which fascinate us, which mesmerize us, which cause us to forget ourselves and our situation as we become lost in a timeless appreciation of nature.

There are also circumstances under which we may view such scenes and be reminded or even forced to consider our insignificance, our vulnerability or to contemplate our own mortality, yet to contrast with this sense the triumph of our own reason over fear. The feeling instilled by experiences of this type, for example of the vastness or ferocity of nature, have been termed by Kant the *mathematical sublime* and the *dynamically sublime* respectively [Feagin, 1995].

In his own writings on the sublime, Edmund Burke takes the view that the sensation of incomprehensibility, the fear of hopelessness or of danger, coupled with the knowledge that one *is* in actual fact able to reason about something beyond one's senses, or one is in fact *not* inadequate or in danger, causes a kind of delight through internal conflict – a sublime experience [Hibble 1957, pp83-98]. That is to say there is an element of the sublime, perhaps not an artistic element, in resisting the urge to flee as a tiger roars from behind bars. One's body responds with fear to the situation, but one's reason easily overcomes this and forces the body to stand its ground – generating a sense of delight tinged with terror. In the case of a painting, the viewer's separation from a wild scene of stormy seas or a vast desert is not enforced by iron bars, but by the picture plane coupled with the knowledge "it is only a picture".

How can a work of art, specifically a work of computer-based, generative software, approach the sublime? Whilst there is a vast amount of literature on the sublime in art dating back as far as Longinus [Longinus, 1963], the focus of this paper is a little more narrow. A recent publication [McCormack & Dorin, 2001] outlines the *computational sublime*. This arises from viewing the computer in terms of its capability to perform specific operations at a rate and on a scale vastly outside our own abilities in this area. Due to its speed, the computer is able to mediate between our human perceptual apparatus and (practically) infinite computationally-defined spaces. Yet, since we are the makers and programmers of these machines, our power of reason is not only able to overcome, but *define* these very spaces which our senses are unable to grasp fully.

Before discussing computer-based art in more detail, some much simpler artefacts, possibly just for a moment, rival natural wonders in the fascination they hold. How does this relate to the sublime? Maybe the simplest examples of our mesmerizing creations include a stream of liquid running from a water-clock (or fountain), the shifting sands of the hour-glass and the oscillating pendulum. Each of these marks time in its own manner: one a continuous stream; the next a finely particulate flow; and the last in clearly marked discrete stages. The eternal flow, the innumerable sand particles, the never-ceasing oscillations, confront us with the infinite through this visible marking of time which continues oblivious to all. Although these natural processes were utilized in desk ornaments to amuse the bored office worker of the 1980's, even in "serious" art, simple processes like this may give a sense of the sublime.

Prime examples of successfully employed processes appear within the art world in the form of the wire-suspended *mobiles* of Calder [Rower, 1998]. These playful pieces are captivating and elegant for all their simplicity. Their workings are laid plainly before the viewer, all that they are is apparent at a glance – and yet this is not so, for their movement brings a vitality and opens a space which the static sculpture does not possess. The universe a mobile sweeps out is contained within its wires, rods and solid forms, so in one sense they may be held in (and created from) the palm of a hand. Yet as they are touched by invisible air currents their inner complexity is exposed.

Many a visitor has been fascinated by the button-driven clockwork and gearing of the world's traditional science museums. Here arises not only a sense of wonder at the machine in its entirety, but also fascination with the intricacy of the mechanism. Each gear meshes with another, each component is configured "just so" and together the pistons and wheels turn in harmony to produce a composite which might drive a clock, crush a quartz boulder, pump water or power a vehicle. This is not the beauty of a crashing ocean or a sunset, but the charm of peering into an ant's nest or through a microscope at a drop of pond water. There is something in these systems which causes one to marvel, not only at the beauty of it all, but at a complexity which is just beyond grasp.

There is still another wonder to be described here, that of somehow defying the natural order of things: that a massive boulder might somehow come to be balanced atop a slender, eroded, rock column; that a gyroscopic top remains on its tip despite interference; that a bird (let alone a massive aeroplane) can remain suspended in the air or that a massive steel ship can float; that a magnet can push another away without touching it. These things of course are dealt with to some extent by simple science. Some of them are so commonplace that, sadly perhaps, mostly only children take the time to wonder. Yet implicitly these simple interactions remain in need of continual re-explanation since each instils a sense of fear through not being quite "right". That boulder or spinning top might topple at any moment. That bird should fall from the sky and the ship ought to take on water. The magnets are behaving unnaturally…all of these systems innately cause one to ponder, "How can this be?", even if one can reason about the answer through science.

In addition to the above phenomena, attention can also be held by riddles and intellectual pursuits. Included in this are mind games such as chess, paradoxes, and mathematical puzzles, but also scientific enquiry. These all captivate through our drive to learn *why* something behaves as it does, especially if it seems to defy the natural order of things. Of the Algorithmic Art exhibition at Xerox PARC in 1994, Bern writes, "The appearance of algorithmic visual art should raise the temporal questions of "How is this made?" and "Can this be extended?"" [Bern, 1999]. Whilst the use of the term *should*, is of questionable accuracy, nevertheless there is something of relevance in the idea that algorithmic art may invite a question and arouse curiosity as much as it satisfies visual aesthetic criteria typically associated with (for example) drawing, painting or photography.

Any of the devices dealt with above (and no doubt many besides) may be used to convey a sense of the sublime. All of them expose us to our own limitations in terms of comprehension, experience or endurance, whilst simultaneously presenting us with the power to reason about or to encapsulate a phenomenon in a word or representation, or the opportunity to walk away unharmed. Of course the context in which the occurrences and objects above are encountered will have much to say about the extent to which the sensation derived relates to art. However the potential to employ any of these basic devices for artistic purposes in search of the sublime experience is present.

On "wonder" and the sublime in computer software.

Now we return to the issue at hand – writing Artificial Life software for artistic purposes. There are of course an infinity of reasons why an artist might wish to do this, however, let us suppose in this instance that the goal was software which surprised, not only a viewer, but the artist who fashioned the work. The surprise required might not be a trivial one-off shock, but a genuine and continuing fascination with the novelty of the outcome which is generated, combined with a sense of being lost in a complex world beyond one's grasp – a sublime experience. The work requires an aesthetic quality at both the level of the clockwork mechanism (an assembly of intricately arranged components) and also at the level of an intellectual puzzle.

It so happens of course, that the techniques of Artificial Life are well suited to this application, Conway's *Game of Life* cellular automata (CA) being a case in point [Gardener, 1970]. CA's are fascinating for their ability to (practically, if not theoretically) produce ever-fresh patterns. Like clockwork automata or Calder's mobiles, the patterns produced may fall well within a limited domain, often even a cycle. However, especially in a large-scale configuration (in which many local interactions occur independently and influence the overall result), not only is there always some aspect of the system to discover, the universe these interactions define is vast.

The innovative design pair, the Eames, understood this aspect of a visual field beyond that which may be encapsulated in a single glance. They used their understanding effectively in the World Fair exhibit for IBM to build a cinema which had multiple screens. These displayed related material simultaneously in such a way as to make it impossible to view the entirety of the footage in detail, but which forced viewers to pick and choose the elements being observed – much as one examines a complex clockwork machine, a microscopic world or a beehive – piecemeal.

On a related topic, Tufte indicates the benefits for presenting information in parts grouped carefully together, "Panorama, vista and prospect deliver to viewers the freedom of choice that derives from an overview, a capacity to compare and sort through detail" [Tufte, 1990, p.38]. Such considerations also assist painters in creating worlds which reward careful study of their detail. For example, Hieronymous Bosch's *Garden of Earthly Delights* (c. 1500) portrays a world over which the eye may wander at will as it takes in relationships between couples, groups of people, sections of garden and so on. Of course where the object under study is static, a viewer may take the time to examine and re-examine the various parts of a display and avoid missing anything of importance (as Tufte would prefer). When the object is constantly changing, as with the Eames' multi-screen cinema or a *Game of Life* run, an investigation of one element results in irrevocably missed information about another. Under these circumstances, no matter where a viewer's attention is focussed, they are left with the impression that an abundance of chances were missed. Their faculties are fundamentally unable to absorb all that is before them.

Whilst one of the attractions of the *Game of Life* occurs at the visual level, the software is also an attractive subject for philosophical discussions concerning emergence and complex systems [Dennett, 1991]. It contains a seemingly vast universe of possibilities within the bounds of its simple virtual-physics. Whilst its transition rules may be considered in terms of biological analogy (over-crowding and mutual support of living cells for instance), the result is still an intrinsically digital system. Cells are in one of exactly two states and their behaviour is completely deterministic. Yet what results from this is a milieu of flickering forms which somehow *suggest* life, without mimicking it.

The question "How does it work?" is implied by any given run of the *Game of Life* in which it is recognized that the output is not at all random, but highly organized and structured according to its own internal rules. Even once these rules are known to the viewer, that they are capable of creating such a bewildering outcome remains a source of fascination to the Artificial Life researcher and to the newly-informed student alike.

On "betrayal".

Having briefly discussed the concepts of wonder and the sublime, this section now addresses the representational schemes which may be used to bring the digital realm to the realm of experience. Taking the lead of Kandinsky, the discussion begins with the geometric point, an invisible thing too perfect to exist [Kandinsky, 1979]. An artist may approximate it by instigating a collision between a sharp tool and a flat plane. The point may even be enlarged by application of a circular or short-lived linear force, or by utilizing a large tool, but this point has character. It is not one of Plato's Ideal Forms but it is nevertheless beautiful for all its imperfection. This point is honest and unpretentious. Even with a few companions of its own size and kind, the point seems to remain true to form, simple and honest.

The point may also be displayed on a CRT or LCD monitor. The size and shape of the smallest displayable shape are dictated by the display technology. Beyond a single pixel the size and shape, and thus the character of the point may also be altered, albeit with less potential for variation than in the analogue world.

Anyone familiar with Islamic or Roman mosaics, medieval tapestry, Pointillist painting, the television screen or a computer monitor, is aware that in vast numbers, the point may vanish in an ocean of its kind. Here it becomes simply one atom in a larger texture - the mob behaviour of a point might not be quite so honest as the behaviour of an individual.

If the draftsman drags her pen across the page another form results - a line. Like the point, the line seems unpretentious. It is just a line, there is nothing to it but what was placed by the draftsman. Even in concert with another of its own size and kind, the line seems unremarkable. However, place three lines together and one of two important transformations may take place. The first of these, the *triangle* is born of three lines and is eventful for its ability to enclose space on the plane and thereby define a boundary, and with it, an object. The second transformation of relevance here is the apparent shift into three dimensions brought about by the *Cartesian axes*. This is also born of three lines and is eventful for its ability to *suggest* space which extends beyond the plane in which the lines are drawn.

Under some circumstances the three lines which represent Cartesian space may appear simple and flat, under others however, the third dimension “pops” out of the plane at the viewer. It is outside the scope of this paper to discuss how this second transformation occurs, the interested reader is referred to [Hoffman, 2000]. For now it is sufficient if it be acknowledged that at least in some cases, the three Cartesian axes suggest a volume where there is none, this being (of course) the principle which underlies Renaissance painting and a host of styles up to and, of relevance to this discussion, including modern computer graphics. If one now combines a triangle and the Cartesian axes, one has a two-dimensional representation of an object in three-dimensional space.

To return at this stage to the *Game of Life*, the system is typically displayed as, strangely enough, a grid of circular (or sometimes square) points against a uniform background. The choice of the point as the basic element of the simulation excludes the misleading aspects of line drawings from a run – yet still, even within this limited visual space, the CA is successful at its evocation of life.

The sizeable points of a CA display have clear neighbourhood relations in the 2D plane which entice a viewer into believing (or comprehending) that interactions within this world may only occur at the local level as it is defined by screen space. Of course this is not the case! Even if the screen coordinates of the dots are scrambled, the internal logic which works “behind” the screen may remain as it was previously. The display then would present conflicting information about the interactions occurring between the many automata data-structures and the apparent patterns on display. Thus, although in one sense the CA is an “honest” representation of the underlying algorithm, this is not necessarily the case. This concept of “fake space” may be extended further, as shall be discussed below.

Faking a space beyond two-dimensions

Whereas the *Game of Life* and CA-based generative art such as *IMA Traveller* (see [Driessens & Verstappen, 2001]), work in the domain of points and suggestion, as outlined above, with a computer monitor it is easy to represent lines and surfaces through a multitude of similarly lit pixels. The CA-based *Sandlines* [Brown, 1999] does exactly this but remains planar. Its curving lines are mapped onto flat tiles, each orients itself according to the state of the automaton on which it rests. Dorin’s CA-based *LiquiPrism* [Dorin, 1999] plays on the point as a two dimensional element on a flat screen by mapping it in virtual three dimensions and allowing the viewer to alter the perspective. The point is still depicted using pixels on a flat screen, but somehow, especially as it is "rotated" it gains the extra dimension of the Cartesian axes by its arrangement in a grid on the surface of the cube.

IMA Traveller, whilst working with points in a plane, recursively sub-divides these, giving the viewer the sensation of an infinitely deep space into which they are falling uncontrollably (although they may guide the path of the fall). This is an interesting perceptual phenomenon when it is considered that by continuously zooming in on a two dimensional image (the points aren't modelled in three dimensional space) one can instil the sensation of motion through a continuous and infinite universe. Three dimensional space is here faked without any reference to the third Cartesian dimension.

Whilst the fractal zooms of the 80's are perhaps the most familiar (and tiresome) form of this trick, the Eames' pioneering cinema, *Powers of Ten* utilizes it to great effect. There is nothing like an infinite space and rapid computation to instil in a viewer the mixed sense of fear and of pleasure – a sense of the *mathematical* and *computational sublime* discussed above.

As outlined, the CA and its artistic derivatives draw attention for evoking natural phenomena, and for prompting the viewer to determine the underlying principles by which they operate. Not all Artificial Life software is of this type, even if it *is* important to the research field for other reasons. One may propose a full spectrum of works of which the CA-based software falls near the centre. This spectrum runs from more abstract or conceptual systems such as Ray's *Tierra* [Ray, 1991], to clearly representational systems such as Sims' *Virtual Creatures* [Sims, 1994].

Ray's work emphasizes the principles of selection and evolution through rapid reproduction, and has itself proved a useful model and a starting point for other researchers such as Pargellis [Pargellis, 2001] (discussed below) to further the study of evolutionary systems. However Ray's work does not have the visceral appeal which a CA may have, for its space of machine code instructions is abstract and not typically represented in such a way as to be comprehended by the eye. A fascination with *Tierra* arises through careful study and is predicated upon an understanding of the core workings of the system and the way in which the instructions interact and occupy memory. This contrasts with the CA in which the rules need not be known to understand the system at one level, and in that it is this first level of visceral comprehension which prompts theorizing what underlies it.

At the opposite end of the spectrum, Sims' *Virtual Creatures* have fascinated researcher and layperson alike since receiving rousing applause at SIGGRAPH in 1994. There is no denying the attraction of Sims' jumping, swimming, running and limping creations. They are so full of character that one easily takes a leap of faith by referring to them as "creatures", even though their bodies are clearly rendered cuboids. This leap erases any chance of a viewer posing the question "How does it work?" because it is implied by the visualization that these *are* creatures! Whilst a graphics researcher or software engineer may see this work and wonder at Sims' means of producing such marvellous results, this question is not implied in the visual outcome as it is in the CA. The virtual creatures do not operate according to unknown rules, we are tricked into believing that they operate according to the rules all creatures obey. There is seemingly nothing here to discover.

This aspect of Sims' creatures is largely due to the way in which they are visualized – the representations of three dimensional space, of solids and their surfaces, of friction and other forces are all those with which we are accustomed to recognize. In this case the visualization is prescriptive, rather than evocative. McCormack's *Eden*, which was constructed as an artwork (see article in this issue and [McCormack, 2001]), similarly represents organisms and their real-world behaviours. But it displays them using iconic forms on a two-dimensional grid (mapped to an "X" in three dimensional space) and in a world nevertheless governed by rules of survival, energy, mating and space based on those of the real-world. Unlike in Sims' work, this underlying link to the physical is not prescribed and takes some experience to decipher… if a viewer is able to decipher it at all. Although the system is still considerably more representational than the *Game of Life*, what remains is an aesthetic visual experience akin to viewing an intricate CA, coupled once again with the implicit question "How does it work?".

This discussion of Ray's, Sims' and McCormack's work is in no way intended as an evaluation of their worth. On the contrary, these examples serve to illustrate the various ways in which a viewer may contemplate a generative or Artificial Life-based process and its outcome, and therefore the various ways in which the devices may be employed for artistic purposes. The next section takes current generative artworks and Artificial Life software as a starting point, and explores areas into which they might move to further expand the sense of wonder they inspire.

Realizing a space beyond three dimensions.

An artist aiming to produce a work which moves beyond the CA (in any spatial dimension) by building a system capable of sustaining a continuous increase in complexity, shares a goal with many Artificial Life researchers [Bedau et al, 2000]. Why would an artist wish to do such a thing? To return to the ideas discussed above, the artist searching for the computational sublime would find it, perhaps in its ultimate form, by providing experience of an open-ended increase in complexity governed by processes instantiated on a computer. The loss of control is complete – the system builds its own structures and defines its own universe. It does this according to underlying rules, yet in a way which defies us to anticipate its outcome.

Simultaneously, this system is following the code the programmer laid down and runs on a machine engineers built. There is nothing to fear although this very creation appears capable of challenging the physical world in its diversity of outcomes. This device is behaving in a way about which we can easily reason – or is it? In this conflict lies the sublime, as well Mary Shelley knew (her friends and contemporaries were much interested in the sublime (for a historical overview of theories of the sublime in this period see [Hipple, 1957])) when she vividly penned Frankenstein and his monster [Shelley, 1989].

How *does* one write code which will produce the hierarchically-organized composite structures associated with life? If we consider the cells of a CA grid as analogous to molecules, and higher level emergent structures such as gliders as analogous to organelles (a far stretch when one considers the complexity of interactions a physical molecule or an organelle may undergo, and the feeble interactions between neighbouring cellular automata), can we code the system so that still larger-scale groupings of structure occur? Can it produce structures at the level of a single cells, a multi-cellular organism or an ecosystem?

In theory, even gliders, spinners and other structures of the *Game of Life* may be carefully arranged into larger scale units (such as a self-reproducing machine incorporating a universal Turing machine, if one has the patience to arrange its 10^{13} cells [Dennett, 1991, p109]). The question remains though, is it possible that such higher level structure will appear of its own accord? If software could be arranged to facilitate this, the structures which arose would do so on their own terms and might therefore behave in ways not envisaged by the creator. This might provide an effective source of seemingly infinite complexity to assist an artist in their search for the computational sublime.

If current theories about the process of natural increase in complexity (such as those extensively discussed by Kauffman for example [Kauffman, 1993]) hold true in virtual systems, then the elements in the virtual space might self-assemble into simple stable structures. Perhaps, if the virtual physics and chemistry of the world allowed it, simple reactions might occur, possibly some in auto- and cross-catalytic sets such as in the work described by Dorin [Dorin, 2000]. These might form the basis of a recognizable topology with the bare bones of a metabolism. What next?

As natural evolution demonstrates, one way to achieve an increase in complexity beyond this is to have the structures engage in a reproductive battle against one another for resources (see [Taylor, 2002]). Pargellis' system *Amoeba* manages to initiate reproduction randomly by setting up the system so that with practical amounts of CPU time and computer memory, there is a good chance that a replicator will spontaneously appear from the pre-biotic soup [Pargellis, 2001]. In a *Tierra* run such an event is much less likely than in *Amoeba*. Hence Ray initially seeded *Tierra's* population with a replicator, thereby allowing evolution to take hold. The problem of coding a simulation which can make the leap from self-organization of structures to spontaneous commencement of evolution of these structures seems (as far as this author is aware) not yet to have been made by any researcher.

Setting aside the leap from self-organization to evolution, even though systems solely employing artificial evolution are readily implemented, getting these to mimic natural evolution's progression from molecules to organelles to cells and on to multi-cellular creatures and ecosystems, has proved a stumbling block. Although worlds such as *SOCA* give rise to auto- and cross-catalytic sets, *Amoeba* may randomly give rise to replicators, and *Polyworld* [Yaeger, 1994] gives rise to simple communities, there has been limited success (arguably no success) in writing software which encompasses more than one of these important level-shifts without resorting to abstractions so high that the simulations they are contained within become trivial.

The reasons for this difficulty are not yet clear. In part, current computational resources may be to blame. However this is quite likely only a part of the story, and maybe only a small part at that. Rasmussen for instance, has suggested that the bottom level of our simulations are just not complex enough to give rise to the kind of multi-layered outcomes for which we are hoping. He proposes that only by adding complexity to the bottom-level elements of a simulation can we expect to gain extra levels of organized structure on top of any earlier ones [Rasmussen et al, 2001]. This claim seems to contradict the "complex systems dogma" which explicitly treats complex phenomena as emergent from simple interactions. Since in Rasmussen's paper notions of "complexity" and "adding complexity" are left loosely defined, it is not yet clear exactly how and to what extent this might be the case. Rasmussen supports his view with a claim about a model of multiple-level hierarchical structure which he has constructed. That this model does *not* in fact demonstrate the emergence of multiple levels, and that a similar outcome can be obtained without adding complexity at the base layer, is argued by Gross and McMullin [Gross & McMullin, 2001].

It is outside the scope of this paper to become too deeply embroiled in this battle. Rasmussen's suggestion may in some sense prove true. Either way, further questions need to be addressed simultaneously. Might there be a limit to all this "complexity adding"? How much added complexity is necessary to move from one level to the next? What is the relationship between the complexity needed to move from first to second order structures (such as from molecules to organelles), and from second order structures to third order structures (such as from organelles to cells). Is there some point at which enough complexity is present in the basic elements that any number of higher order structures can occur? If so, do the natural world's basic elements surpass this limit? What evidence is there to support or counter this? Perhaps the complexity of the elements is not of relevance but instead only the complexity of their environment and the kinds of interactions it supports matters. These questions remain open and will no doubt continue to be debated.

Besides issues of complexity of basic elements, there may be fundamental problems with current approaches to the problem. It is possible that simulations on current computer architectures and employing computer programs as they are currently understood, will turn out to be practically limited in their ability to produce the kind of truly open-ended complexity increase required. Issues of available resource consumption are an obvious reason why infinite increase is impossible, however are there reasons why *any* interesting string of increases in complexity may be impossible with current programming and computer technology? These questions remain a topic for a further paper and, in one sense (although counter to the claims of Vasari about the Renaissance artists' ability to surpass nature [Vasari, 1976]), the hope of one day creating a virtual space as multi-faceted as nature itself remains faint.

Conclusion

Although the limitations of our abilities to code multiple-level hierarchies are apparent, clearly this does not imply that our art is similarly constrained. The element of the sublime in a Caspar David Friedrich canvas does not arise from the intricacy of its mechanism, but from contemplating nature and our place in it from behind the safety of a picture plane. Even more apparent is the irrelevance of intricacy and nature to postmodern interpretations of the sublime such as those discussed by Jean-Francois Lyotard [van de Vall, 1995]. Hence works such as Rothko's *Blue, Green and Brown* may be discussed in terms of their contribution to the postmodern sublime. The sublime does not lie *in* a work, rather the work may act to trigger the experience of the sublime in a viewer. In the case of Lyotard's ideas, this relates to a sense of formlessness and therefore of things which may be better left un-presented.

As long as our machines are faster at mathematics than ourselves (a state of affairs set to continue) they will have the ability to play the role of mediator between us and the vast computational spaces outside our direct experience. Perhaps one day these same machines will be able to take us beyond spaces which look more and more familiar as we travel through them, into spaces which increase in complexity and continue to surprise us. Here the sublimity of the experience we have of nature's vastness and ferocity, may be rivalled through a sense of the computational sublime. We will be sensing a space rendered maybe with points on a plane and computed on-the-fly by our fastest machines, and it will seem to us as terrible and delightful as standing on an icy summit surveying all the world.

References

Bedau, M.A., McCaskill, J.S., Packard, N.H., Rasmussen, S., Adami, C., Green, D.G., Harvey, I., Ikegami, T., Kaneko, K., Ray, T.S., 2000, "Open Problems in Artificial Life", *Artificial Life 6*, Bedau & Taylor (eds), MIT Press, pp363-376

Bern, M., 1999, "Art Shows at PARC" in *Art and Innovation*, Harris (ed.), The MIT Press, pp259-277

Brown, P, 1999, "Sandlines", in *Process Philosophies*, Dorin & McCormack (curators) described in Brown, P., "Stepping stones in the mist", in *First Iteration: Proceedings of the first international conference on generative systems in the electronic arts*, CEMA, Dorin & McCormack (eds.) Melbourne, Australia

Dennett, D.C., 1991, "Real Patterns", *Journal of Philosophy*, 88, pp27-51

Dorin, A., 1999, "LiquiPrism", in *Process Philosophies*, Dorin & McCormack (curators), Melbourne (refer http://www.csse.monash.edu.au/~aland/liquiprism.html)

Dorin, A., 2000, "Creating a Physically-based, Virtual-Metabolism with Solid Cellular Automata", in *Proceedings Artificial Life 7*, Bedau et al (eds), MIT Press, pp.13-20

Driessens, E., & Verstappen, M., 2001, keynote presentation in Proceedings of *Second Iteration, second international conference on generative systems in the electronic arts*, Dorin (ed.), CEMA, Melbourne, Australia, pp12-13

Feagin, S.L., 1995, "Sublime", in *The Cambridge Dictionary of Philosophy*, Audi (ed.), Cambridge University Press, p774

Gardner, M., 1970, "The Fantastic Combinations of John Conway's New Solitaire Game, 'Life'", *Scientific American* 223(4), pp120-123

Gross, D., McMullin, B., 2001, "Is it the Right Ansatz?, *Artificial Life 7*, Bedau & Taylor (eds), MIT Press, pp355-365

Hipple, W.J., 1957, "The Beautiful, the Sublime, and the Picturesque in Eighteenth-Century British Aesthetic Theory", Southern Illinois University Press

Hoffman, D.D., 2000 "Visual Intelligence: How We Create What We See", Norton

Kandinsky, W., 1979 "Point and Line to Plane", Dover Publications, New York, (first published 1926)

Kauffman, S.A., 1993, "The Origins of Order", Oxford University Press

Longinus, 1963, "On the Sublime", translated by Havell, in *Aristotle's Poetics, Demetritus on Style, Longinus on the Sublime*, Everyman's Library, Dutton New York, pp.133-202 (first written c. 250 A.D.)

McCormack, J., 2001, "Eden: An Evolutionary Sonic Ecosystem", in Advances in Artificial Life, 6th European Conference, Kelemen & Sosik (eds), ECAL, Springer, LNAI 2159, pp.133-142

McCormack, J., Dorin, A., 2001, "Art, Emergence, and the Computational Sublime" in Proceedings of *Second Iteration, second international conference on generative systems in the electronic arts*, Dorin (ed.), CEMA, Melbourne, Australia, pp. 67-81

Pargellis, A.N., 2001, "Digital Life Behaviour in the Amoeba World", *Artificial Life 7*, Bedau & Taylor (eds), MIT Press, pp63-75

Rasmussen, S., Baas, N.A., Mayer, B., Nilsson, M., Olesen, M.W., 2001, "Ansatz for Dynamical Hierarchies", *Artificial Life 7*, Bedau & Taylor (eds), MIT Press, pp.329-353

Ray, T.S., 1991, "An Approach to the Synthesis of Life", in *Artificial Life II*, Langton, Taylor, Farmer, Rasmussen (eds), Addison-Wesley, pp.371-408

Rower, A.S.C, 1998, "Calder Sculpture", National Gallery of Art, Washington, Universe

Shelley, M., 1989, "Frankenstein, the Modern Prometheus", first published 1818, reprint, Joseph, M.K. (ed.), Oxford Univeristy Press

Sims, K., 1994, "Evolving Virtual Creatures", in Proceedings of SIGRRAPH 1994, ACM Press, July, pp15-34

Taylor, T., 2002, "Creativity in Evolution: Individuals, Interactions and Environments", in *Creative Evolutionary Systems,* Bentley & Corne (eds), Academic Press, pp. 79-108

Tufte, E.R., 1990, "Envisioning Information", Graphics Press

van de Vall, R., 1995, "Silent Visions, Lyotard on the Sublime", in *The Contemporary Sublime, Sensibilities of Transcendence and Shock*, Hodges (ed.), Art & Design, VCH Publishers, pp69-75

Vasari, G., 1976, "The Lives of the Artists", first published 1568, translated by Bull, G., reprint Penguin Books

Yaeger, L., 1994, "Computational Genetics, Physiology, Metabolism, Neural Systems, Learning, Vision and Behavior or Polyworld: Life in a New Context", in Proceedings, *Artificial Life III*, SFI Studies in the Sciences of Complexity, Langton (ed), Addison-Wesley, pp263-298