Batteries Not Included – Mind as Machine
art – artificial intelligence – artificial life

The world's first stored program computer was built in 1947. By December of that year it had 2048 bits of memory and on 21 June 1948 it ran its first program. It was variously known as the Manchester University Small Scale Experimental Machine and the Mark 1 Prototype but is best remembered by its nickname - *Baby*. It now resides in the Manchester Science Museum.

Just ten years later, in 1957 the British Computer Society was founded and so this year the CAS, in our role as a specialist group of the BCS, are please to join forces with the Shrewsbury Darwin Summer Symposium and the Whittigham Riddell Shrewsbury Open Art Exhibition to celebrate BCS 50. Appropriately enough these Shrewsbury events focus on Darwin's influence on the computational domain and especially within the arts-sciences convergence. It has been a remarkable half-century. Fifty years ago computers were room sized monsters that had less power than a modern wristwatch. Nevertheless they were being used to experiment with Darwin's ideas – as our keynote speaker George Dyson describes in his essay *Barricelli's Universe* on page 6.

In recent years the application of Charles Darwin's concepts of evolution and natural selection within the computational and cognitive arts and sciences has flourished and provides one of the roots of the alternative 'bottom up' methods of artificial intelligence that are now commonly referred to as artificial life or a-life. From the pioneering Senster - created by the artist Edward Ihnatowicz for the Philips Evoluon in 1970 - to today's evolutionary robotics and generative artworks the field promises autonomous intelligences that will be capable of existing in hostile and alien environments and learning as they go. The Shrewsbury Darwin Summer Symposium is an opportunity for artists, scientists and others to engage with the prospect of new, technologically robust life-forms that will be capable of augmenting human intelligence and enabling experiences that would not otherwise be possible.

We have been fortunate to recruit a fascinating and authoritative line-up of speakers from both the UK and overseas and they promise us a memorable day which we will be video recording and making available on the internet for those who are unable to make it in person.

And whilst we are speaking of history let's not forget that the Computer Arts Society will celebrate its 40th birthday next year. For more about that watch this space!

I'd like to finish by thanking the Heritage Lottery Fund for their support of the Symposium program and the BCS for funding CAS' participation. Many many people have worked behind the scenes to make today's events happen. They are far too many for me to thank individually and so I hope they won't be upset by a blanket, but nonetheless sincere *thank you!*

Paul Brown

Curator, Shrewsbury Darwin Summer Symposium
Chair of Jury, Whittigham Riddell Shrewsbury Open Art Exhibition
Chair, the Computer Arts Society
Visiting Professor, University of Sussex

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Supported by the Heritage Lottery Fund

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The Music Hall
Friday 13 July 2007
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Margaret Boden in conversation with Ernest Edmonds

AI, Creativity and the Arts

In our conversation, we discussed the reasons why some computer artists have used evolutionary programming in making their artwork. -- We almost wrote "... in making their own artwork", but one of the questions we talked about is whether the artwork really is fully theirs, or must be at least partly attributed to the computer. In other words, where does the creativity lie?

That question arises with respect to computer art in general, or anyway in all those cases where the final artwork is largely generated by the program. Whenever the artist 'tells' the computer precisely what to do, using it--one might say--as a sort of extra paintbrush, such questions are irrelevant. There, the computer is a mere tool, or at best an aid, or accessory, to the artist. We were more interested in cases where the computer itself actually does something that's to some extent independent of the artist.

Evolutionary art is the paradigm case, here--which is why we chose to focus on it. There are lots of questions to be asked. For instance, what difference does it make to the aesthetic value of the work, and/or to the perceived role of the artist in producing it, if the 'natural selection' at each 'generation' is automatic rather than interactive? In practice, evolutionary artists typically do the selection at each generation interactively. In other words, they take the responsibility for selecting new images for further breeding, even though those images will of course have been *generated* by the computer. This gives them more control over what happens--and, presumably, more claim to be regarded as the true creator of the result. But even if the selection is automatic, it's the artist who decides the criteria involved (that is, who writes the program's fitness function). How much of the 'creative credit' should go to the human being as a result, and how much to the computer system?

One of the issues we discussed was that of radical, or transformational, change. A computer can evolve a myriad of images (and sounds ...) by exploring a given style, perhaps even pushing that style towards perfection--or anyway, towards images that couldn't even have been imagined, never mind executed, by the human artist involved. But could evolutionary art ever come up with a radical stylistic change? Could it ever, in effect, start with a Rembrandt and end with a Manet? Radical changes are certainly possible in principle, and occasionally they happen (Karl Sims' early graphics work showed many examples). But if the 'mutations' allowed are so great as to enable such changes to take place, they can also destroy the new style almost immediately. In other words, it was actually a radically new *image* rather than a radically new *style*. We spent a while discussing whether it's possible to evolve a genuinely new style, as opposed to exploring an existing one.

Another topic we discussed was the creativity of biological evolution. In one sense, we said, it's the most creative process of all. All the human artists who have ever lived, taking their work as a whole, can't even begin to match the beauty, complexity, and *surprises* that biology has provided. Yet biological 'creativity' is very different from the sort of creativity we see in art. There's no particular goal in mind, and no deliberate self-monitoring and self-correction. At present, there's no deliberate self-correction in evolutionary programs either, and any 'self-amendment' must come from the intervention of the human artist. Whether tomorrow's computer art will differ in this respect is an interesting question.

Not all computer artists, of course, use evolutionary methods. Ernest himself does not. As we agreed, however, it's still the case that the computer enables a much fuller exploration of a given style than could be done by the artist alone. So it's not only evolutionary methods which can offer surprises: the more familiar, more 'straightforward', computing techniques can offer them too.

In short, there's much of interest--and also much of beauty--in computer art as a whole. Our conversation touched on many of the relevant issues, probably without resolving any of them. We hope you find that it sparked off some questions you see as especially intriguing.

Margaret Boden is a philosopher and Research Professor of Cognitive Science at the University of Sussex. She is an authority on Artificial Intelligence, Creativity and Cognitive Science and has written extensively on AI and the arts. Her most recent publication is the two-volume Mind as Machine: A History of Cognitive Science, OUP, 2006.

Ernest Edmonds is an artist and professor of computer science and director of the Creativity and Cognition Laboratory at the University of Technology, Sydney, Australia. He is the Editor of the journal Knowledge-based Systems (Elsevier), Editor-in-Chief of the new Transactions section of the Leonardo Journal (MIT Press) and convenor of the biannual ACM Creativity and Cognition conference series. His pioneering computational artworks have been exhibited internationally since the late 1960's.

Creator and Observer

The ways in which we build models, test theories, and judge the successes of how machines `are creative', `make art' and `enable new modes of creative thought' will naturally be heavily dependent on how terms like `art', `creativity' and `novelty' are defined. No consensus view exists on the formal definitions of these terms, quite the opposite of the physical sciences. It is hard to imagine how successful models, particularly computational models of creativity, can be devised without formal definitions of basic terms such as `art' and `creativity'. Yet a significant proportion of research into computational creativity has, probably deliberately, overlooked these issues and simply focused on an exploration of visual or auditory pattern-generating processes that empirically people find interesting or creatively rewarding. This is a sensible approach if your goal is to make an autonomous creative system that satisfies your own personal aesthetic ideas (and probably those of others). That is, you want to develop a new artistic system that makes art for people to enjoy. While some research has considered concepts about art, aesthetics and creativity in more formal ways, this often involves narrow definitions, simplistic approximations, and possibly important omissions. Simplification is often necessary when beginning to tackle new and complex problems, and creativity does beckon some very difficult problems.

Most systems involved in the generation of creative novelty do so by appropriate recombination of basic primitives. This is a `combinatory' emergence of complex wholes constructed from combinations of irreducible primitives. It is `one-way' in the sense that once the primitives and their combinatory rules are specified, the resultant combinations have no effect on the primitives themselves: there is no feedback from the macro-states to the micro-states. The set of primitives and their functions are fixed, hence the set of possible outcomes is determined exclusively by the combination of these base primitives. In any computer simulation this set of possible outcomes will be a fixed, finite set, although it may be well beyond astronomical proportions.

In the case of "creative emergence" fundamentally new primitives enter the system, i.e. we want the emergence of new primitives in our system, not just the combination of a fixed set. Therefore, the main question is: can new primitives arise in a computational simulation, and if so, how?

By necessity, primitives in a computer program must be symbolic. While it is easy to dynamically add new symbols, automating the production of new interpretations of these symbols is difficult in any non-trivial sense. In fact, in any modern programming language it is impossible, because symbols must ultimately be interpreted in a semantic context, determined by the programmer/observer, not the program itself. There are two related issues at play here:

- How to conceptualise then abstract a creative process in a way suited to computer simulation;
- The difference between a computational simulation and a physical instantiation.

In general, our conceptualisation process involves some form of observation frame and sets of state-spaces. By necessity, all non-trivial models will involve abstraction (hence simplification and reduction) and recontextualisation, normally by analogy. In any physical instantiation we automatically get physics (and chemistry, biology, etc.) thrown in `for free'. In fact, we cannot avoid it. Computational simulation is a physical process, but in terms of the interpretation of the simulation (the instantiation of the model), any physics (and chemistry, biology, etc.) must become an explicit part of the model, i.e. they do not come `for free'. Almost everything comes from our intuitive notions of what is art and what is creative, limited by what we can represent and simulate in computation. We might hope that if the simulation is sophisticated enough at one level (e.g. physics), other levels (e.g. chemistry, biology) will emerge in the simulation without the need to explicitly include them in our model. Organisms are physical entities, down to the atomic level and beyond. Complete simulation at this level is currently practically impossible. Hence the search for appropriate models and abstractions suitable for practical simulation is crucial. Moreover, there are arguments from philosophy regarding the ontology of emergent levels, so any one-way, bottom-up simulation, no matter how complete or low-level, may not capture the essential properties of higher levels. A debate continues about the significance of emergence and the limitations of computer simulation in realising emergent processes.

More research is needed on how we can define creative behaviour in artificial systems, perhaps even some formal (measurable) properties so we can quantify what is currently determined largely by observation and opinion.

Jon McCormack is an Electronic Media Artist and co-director of the Centre for Electronic Media Art (CEMA) and a Lecturer in the School of Computer Science and Software Engineering, Monash University, Melbourne, Australia.

Impossible Nature - a book about his work was published by the Australian Centre for the Moving Image (ACMI) in 2004.

Image from "Eden" - An Evolutionary Sonic Ecosystem, Jon McCormack 2000-2006

Darwin's theory of evolution describes the most awesome generative system known to man. Since the 1960's computer scientists, engineers, artists and other researchers have tried to harness this generative power by developing computer systems that approximate important features of natural evolution.

In computer models of evolution, a population of individuals is simulated. Each individual has an artificial 'genotype' are composed of genes represented as numbers. Each genotype is expressed as a 'phenotype', which in a computer system can be complex data structures, e.g. a spreadsheet, or even small computer programs. The phenotypes of all the individuals in a population are evaluated against each other using a 'fitness functions', which is typically a mathematical expression that captures the aspects of the problem that we wish to solve. The fitness function acts like the environment in the natural world, selecting those individuals that survive to produce the next generation.

In computer science and engineering, the application of evolutionary computing has shown itself to be remarkably useful when applied to a wide range of difficult problems. In art and design, the application of evolutionary computing is often complicated by the need to include some notion of fitness that are cannot be captured in mathematical expressions in the evaluation of phenotypes, e.g., aesthetics. In these types of systems, interactive evolutionary systems are often developed where a person acts as a fitness function to select fitter individuals within a population.

In many cases, the application of evolutionary computing has resulted in the development of software that has exceeded the ability of their designers to solve a given problem. The use of evolutionary computing is not without its problems however. Ironically, it is the ability of the evolutionary systems to generate many good solutions to a given problem that causes some of the biggest problems in applying them. In particular, when assessing the output of an evolutionary system to discover what has been produced, the large numbers of solutions that an evolutionary system produces can quickly overwhelm.

My research with evolutionary systems has focussed on the need to solve this 'information overload' problem. My approach has been to develop a computational model of 'interest' so that we can build evolutionary systems that can identify the most interesting solutions to a problem and to give these a higher importance when presenting solutions. Interest is defined relative to the amount of 'surprise' that an individual embodies relative to those of others that has been evolved by the system. Informally, the more surprising an individual is the more it tells us about the world constructed within the computational system.

Incorporating a notion of interest in computational models of evolution takes it beyond models of natural evolution, where there is no reflection on the value of evolved individuals other than an implicit ability to survive. Developing evolutionary computing systems with a notion of interest opens up new possibilities for extending their behaviour to develop models of motivations like curiosity. In particular, systems that model an interest can just as easily model 'boredom', where insufficient interest is experienced over a relatively long period of time. When such a system gets bored it can decide to take some radical action in order to relieve its boredom, this may include trying radically different solutions to a problem, or trying to solve a new problem entirely.

My research has shown that by extending computational models of natural evolution to incorporate models of cognitive functions more commonly associated with human designers we can provide an interface between the awesome generative power of evolution and the reflective processes of human creativity. Potentially, we may also develop computational systems with autonomous creative abilities that can set their own goals and solve them, driven by a curiosity in their world--much like humans do today.

Rob Saunders (University of Sydney, Australia) is an Artificial Intelligence researcher who develops computational models of individual and social creativity.

BARRICELLI'S UNIVERSE

And the evening and the morning were the fifth day...

At 10:38 pm on March 3, 1953, in a one-story brick building at the end of Olden Lane in Princeton, New Jersey, Italian-Norwegian mathematical biologist Nils Aall Barricelli (1912-1993) inoculated a 5-kilobyte digital universe with random numbers generated by drawing playing cards from a shuffled deck.

"God does not play dice with the Universe," Albert Einstein, a permanent resident at the Institute for Advanced Study, whose new computer was hosting these experiments, had advised. There was no proscription against cards. "Every red card (hearts and diamonds) has been recorded as +1, every black card (spades and clubs) has been recorded as -1," Barricelli explained. A viral geneticist by training, Barricelli was convinced that numerical "symbioorganisms", given access to the metabolism of an otherwise lifeless digital universe, might begin to evolve.

"According to the theory of symbiosis of genes, the genes were originally independent, virus-like organisms which by symbiotic association formed more complex units," he announced. "A series of numerical experiments are being made with the aim of verifying the possibility of an evolution similar to that of living organisms taking place in an artificially created universe."

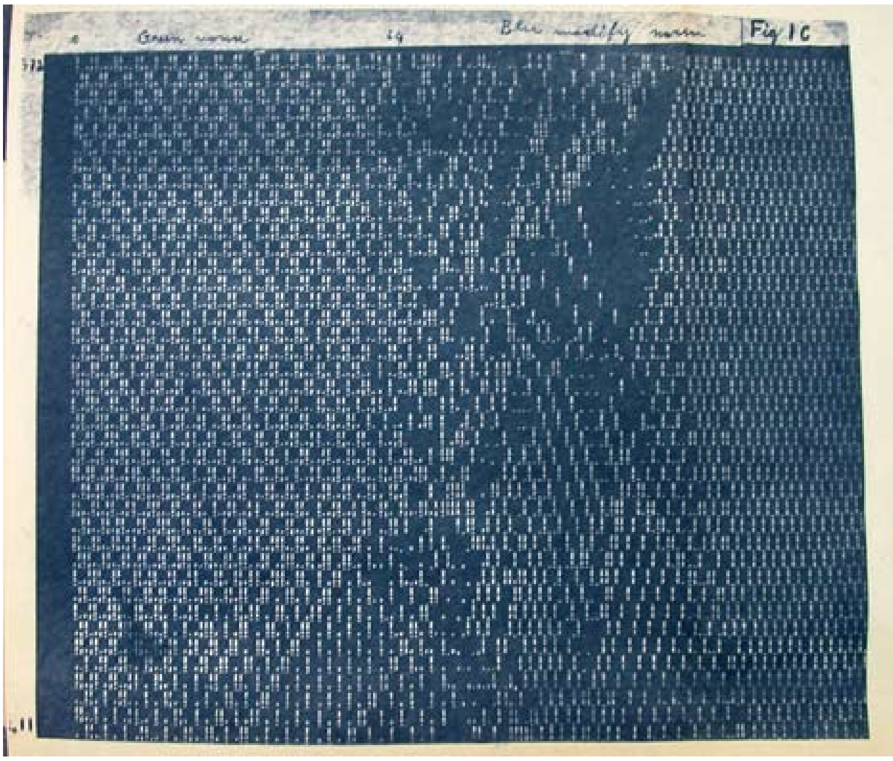
In March of 1953 there were a total of 53 kilobytes of high-speed random-access memory on planet earth. Five kilobytes were at the Institute for Advanced Study (IAS), 32 kilobytes were in the eight completed clones of the IAS machine, and 16 kilobytes were in a half dozen unrelated machines, including those in the UK.

Barricelli's universe consisted of a 32 x 32 x 40 bit matrix of charged spots on the face of 40 "Williams" memory tubes, made from modified 5-inch oscilloscope displays. During World War II it had been noted that binary data could be stored on the face of ordinary cathode ray tubes, as long as the pattern was refreshed a few times a second by a regenerative trace. The spots become positively charged (i.e., deficient in electrons) as a result of secondary electron emission by the phosphor, and the state of an individual spot could be distinguished by briefly "interrogating" that location and noting the character of a faint secondary current, of less than a millivolt, induced in a wire screen positioned close to the outside face of the tube.

Frederick C. Williams, having worked on pulse-coded IFF (Identification Friend or Foe) radar systems in both the UK and the USA, developed a serial-access cathode-ray memory tube in 1946 and constructed a small computer at Manchester University, under the direction of Max Newman and with the assistance of Alan Turing, that demonstrated CRT-based storage and a rudimentary stored program in June 1948.

The IAS engineering group, after consultation with Williams in Manchester in July of 1948, developed switching circuits that could read or write to any location at any time, appropriating a few microseconds before resuming the normal scanning cycles where they left off. The resulting memory was, as chief engineer Julian Bigelow noted, "one of mankind's most sensitive detectors of electromagnetic environmental disturbances." The ability to distinguish a dot (0) from a dash (1) depended on the secondary emission characteristics of the phosphor coating, and the slightest imperfection would cause the memory to fail. The faint signal was amplified 30,000 times before being passed to a Discriminator that made a decision as to whether the waveform represented a 0 or a 1.

Today's (or yesterday's) cathode ray tubes display the state of a temporary memory buffer whose contents are produced by the Central Processing Unit (CPU). At the dawn of the digital universe, however, cathode ray tubes delivered the instructions that drove the operations of the CPU, not the other way around. The flickering array actually

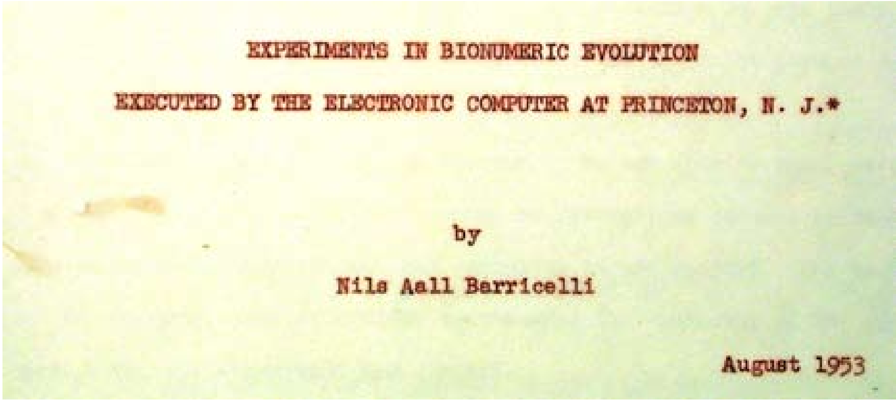


was a universe, not merely the display of a process occurring somewhere else.

These experiments were conducted under the auspices of Hungarian-American mathematician John von Neumann, who, after the success of the Manhattan Project at Los Alamos, decided that digital computing was next. “I am thinking about something much more important than bombs,” he had explained in 1946. “I am thinking about computers.” Actually, he was thinking about both. The new computer, though publicly devoted to meteorology, was instrumental to the design of hydrogen bombs and the prediction of weapons effects. In the midst of this effort to devise new ways of destroying existing life, Barricelli sought to spawn new forms. It was 1953, and the elucidation of the structure of DNA was about to enable the *decoding* of life, from the top down. It seemed logical, to Barricelli and von Neumann, to also attempt the *encoding* of living processes, from the bottom up.

“Are they the beginning of, or some sort of, foreign life forms? Are they only models?” Barricelli asked. “They are not models, not any more than living organisms are models. They are a particular class of self-reproducing structures already defined. Unless some other severe limitation is imposed by the conditions of the experiment or the type of universe in which the organism exists (computer, planet, or test tube), there is no a priori reason for assuming that other classes of symbioorganisms could not reach the same complexity and efficiency characteristic of living organisms on this planet.” Barricelli knew this would take some time. “A question that might embarrass the optimists,” he had warned in 1954, “is the following: ‘If it’s that easy to create living organisms, why don’t you create a few yourself?’”

George Dyson is the author of Project Orion: The Atomic Spaceship 1957-1965 and Darwin Among the Machines (1998) where he suggested coherently that the internet is a living, sentient being.



EXPERIMENTS IN BIONUMERIC EVOLUTION

EXECUTED BY THE ELECTRONIC COMPUTER AT PRINCETON, N. J.*

by

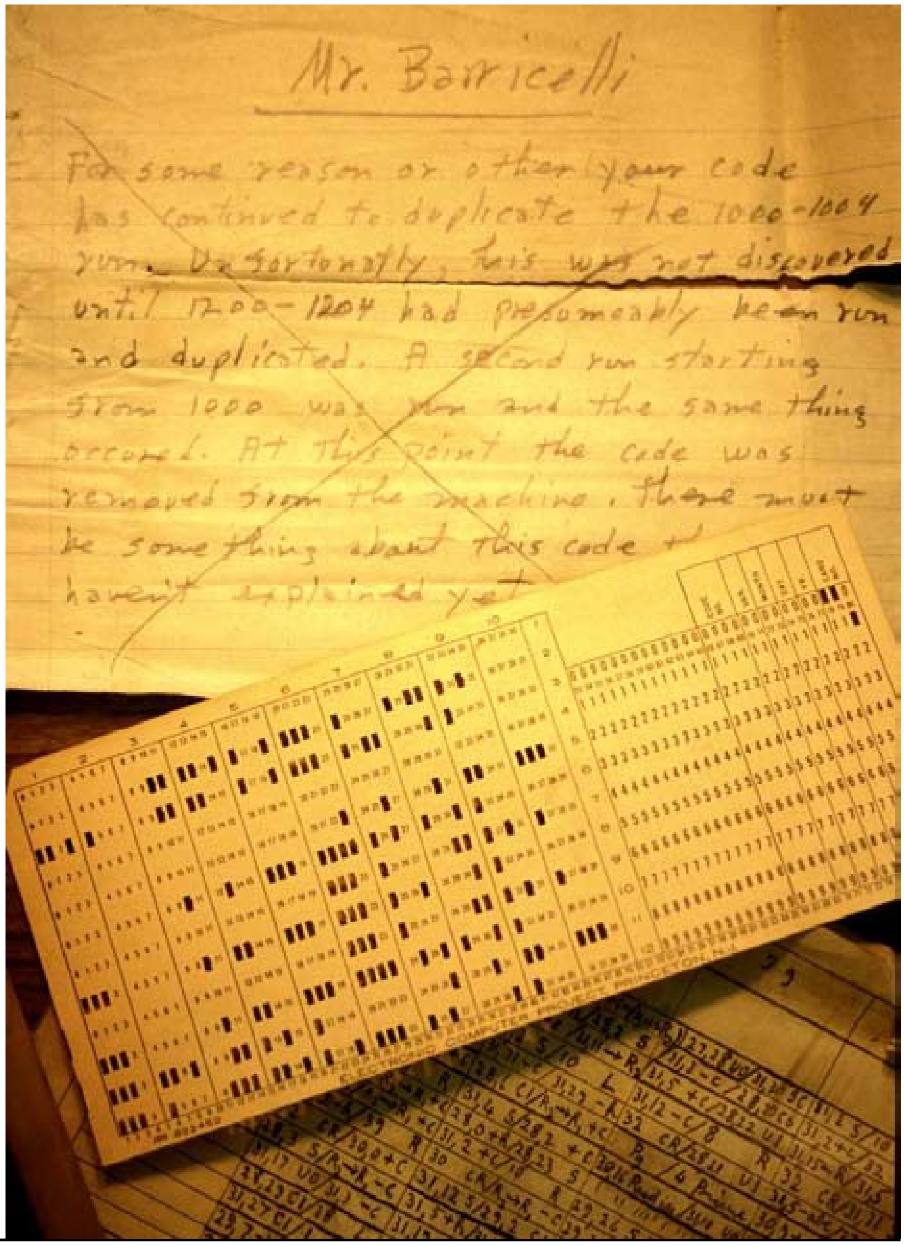
Nils Aall Barricelli

August 1953

ILLUSTRATIONS
photos by G. Dyson, with the permission of the Archives, Institute for Advanced Study

1) August 1953: Experiments in Bionumeric Evolution Executed by the Electronic Computer at Princeton, N. J. (Barricelli’s first report)

2) Engineer’s note, output cards, and input code, ca. 1954. The note reads: “ Mr. Barricelli: For some reason or other your code has continued to duplicate the 1000-1004 run. Unfortunately, this was not discovered until 1200-1204 had presumably been run and duplicated. A second run starting from 1000 was run and the same thing occurred. At this point the code was removed from the machine. There must be something about this code that you haven’t explained yet.”



Michael O'Shea
in conversation with
Phil Husbands

EASy Arts
artists in residence at the CCNR

Since its inception in 1996, The Sussex Centre for Computational Neuroscience and Robotics (CCNR) has collaborated with a variety of artists and hosted several artists in residence including: Stelarc, Paul Brown, Jon McCormack, Sol Sneltvedt, Rachel Cohen and Anna Dumitriu. Our presentation at the Darwin Summer Symposium will consider the relationship between the arts and the sciences with particular reference to work carried out in the CCNR.

The Arts and Sciences are the same in the sense that both endeavour to reveal true insights about the real world in which we all live our lives. Moreover, the task of both artists and scientists is to communicate these truths so that others might benefit from their insights. But while they have a commonality of purpose, most artists and scientists say that the domains of reality to which the semantic content of works of Art and Science pertain are not the same. Thus it is a commonly stated belief that Art addresses the less tangible transcendental inner private world of subjectivity, perception, emotion and thoughts. Science, on the other hand, is often thought of as addressing the objective reality of the outer physical world - the public world in which we all live.

A deeper inspection suggests however that the two worlds are in fact aspects of a continuum – within which a strict dichotomy is unsustainable. Any work of art or science can have a semantic content (reference to knowledge) operating at different points along the continuum. Scientific works may in general occupy a different part of the continuum's spectrum than is usually occupied by a work of art, but their zones are not mutually exclusive.

In order to clarify the comparability of art and science a little more, let's take two examples of creative endeavour; one that is firmly scientific - Neuroscience, and another that is firmly artistic – namely Music.

Neuroscience has contributed to unprecedented advances in our understanding of how the brain works. Neuroscience therefore has the potential to close the imaginary gap between the inner and outer realities of the world we inhabit. Like no other science, neuroscience is concerned explicitly with the inner world of thinking, perception, memories, imagination and consciousness. Most importantly it accounts for this inner world in terms of the physical laws that govern the outer world. Thus modern neuroscience undermines the notion of a dichotomy very directly by speaking explicitly about the inner world with outer-world objectivity and precision.

Music, perhaps more than any other artistic discipline, has its primary affect within the inner world of the mind. Precisely how the semantic content of music manages to acquire meaning in the mind is not understood. But surely the meaning of music must ultimately find its explanation in the physical structure of the brain – after all "mind" is something the physical brain does and music is a means of changing the mind. Whatever goes on in the mind, being influenced by music or anything else for that matter, can be due to nothing other than lawful interactions between physical entities, operating according to the laws that were formulated with reference to the external world.

So the meaning of music is not fundamentally different in its terms of reference than the meaning of Newton's Laws of Motion. It's just that right now it is much more difficult to explain in words (explicitly) the meaning of the creations of Mozart than of the laws attributed to Newton. But a Mozart sonata contains "knowledge", albeit implicit, about how our brains work in exactly the same way that Newton's laws of gravity contain "knowledge" about how our solar system works.

Hence, at a certain level, we can think of art and science as dealing with different aspects of the same venture: revealing the world. But in doing this there are a number of way in which they can interact much more directly, most of which we have experience of in the CCNR.

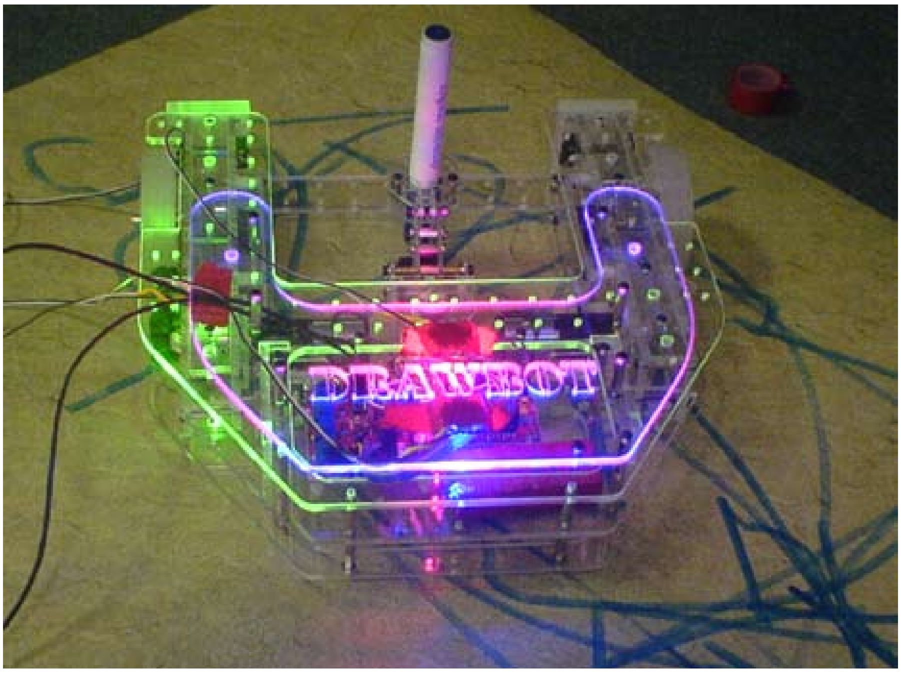
The ways in which we perceive and interact with the world are to a large degree determined by our biology. There are various natural biases in the ways we see and hear: our minds and bodies have evolved in such a way that we are set up to respond preferentially to certain kinds of stimuli. Most of this occurs at a subconscious level and many of the biases are hidden deep within the huge complexities of our nervous systems. Hence the scientific study of the perception and creation of art might give insights into ancient and important workings of the mind. In such a case art becomes the inspiration and subject matter of science. The reverse of this is equally important, where science provides the inspiration and background material for an artwork. An example of this is "Mindscape"- an Arts Council of England and AHRB supported audio-visual installation produced in collaboration between CCNR neuroscientists and artists Sol Sneltvedt and Charlie Hooker.

Mindscape is first and foremost an artwork, but one with resonance in the science of the brain. The aim was to represent in sight and sound the dynamics of the brain – the engine of the mind - in action. One scientific idea we have tried to realize in Mindscape is that brain activity proceeds in space and time with very variable dynamics. Different brain regions communicate with each other through the diffusion of chemical messengers that can spread through the brain over considerable distances. This is why we have introduced into the Mindscape project an impression of the ability of one part of the brain to communicate with another, not just by very rapid electrical signalling but also by a slower and more regionally generalized chemical signalling system. The idea is that together the two very different types of signals provide some sort of answer to the problem of how fragmented aspects of cognitive processes are brought together in the generation of seamless streams of thought – one of the most difficult and important of the unresolved problems in neuroscience today.

A related kind of interaction involves the artist seeing the aesthetic in what the scientist may regard as merely data. An interesting example of this occurred when Paul Brown first had a residency in the CCNR. One of our researchers, Kyran Dale, was presenting some graphical representations of the flight paths of some artificially evolved virtual insects that he was studying to try and gain insights into the ways the real insect brains work. Paul saw these as rather exquisite drawing and was inspired to develop the DrawBots project – now underway in the CCNR – in which we are attempting to artificially evolve robots to create drawings.

The fundamental preoccupations of

Figure 2: A prototype DrawBot



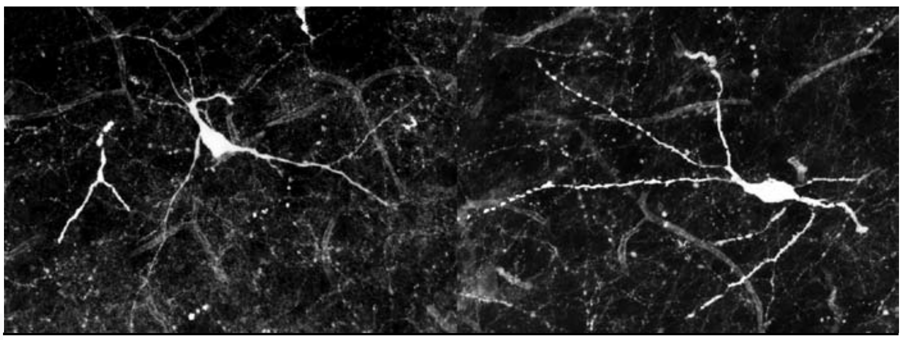
the scientists and artists in the CCNR have often overlapped to a considerable degree. For instance in exploring the ways in which simple interacting adaptive processes can give rise to complex patterns in space and time, or in questioning how we, as embodied intelligent agents, interact with our surroundings. In some cases this leads to another, very direct, kind of relationship between art and science: the development and use of technology and scientific tools for artistic expression. In these cases the boundaries between art and science are considerably blurred as researchers in the group develop and apply biologically inspired adaptive technology to creative domains – for example in the composition and performance of music, design of sounds or creation of visual art works. In some cases the boundaries are completely dismantled as art and science are merged into a single enterprise– for example in the DrawBots project mentioned above.

A further kind of interaction, which is often overlooked, is where art foreshadows science. An example of this, which has special resonances for the CCNR, is the development of the field of robotics. The popular image – and indeed the very idea – of a robot comes from the world of fiction. The notion of embodied mechanical intelligence was, quite literally, thrust centre stage in the years between the world wars when Karel Kapek's play R.U.R. (Rossum's Universal Robots) – premiered in 1921 – introduced the world to robots, in the process forging the associated myths and images that now permeate our culture. It was a world-wide smash hit capturing the popular imagination as well as sparking much intellectual debate. The dreams and myths were further developed in science fiction literature and films. Collectively, these have undoubtedly had a major influence on the scientific work in the field of intelligent robotics.

The main focus of the CCNR – work at the interface between the biological and computational sciences aimed at better understanding natural and artificial adaptive systems – is intrinsically interdisciplinary with much of the territory uncharted. Perhaps this attracts a certain kind of creative scientist and encourages wider collaborations across traditional boundaries. Similarly, the exploratory, rather unconstrained, nature of some of the work in this area makes it attractive to a certain kind of technologically savvy artist. This research field has strong links with the Cybernetics movement of the 1940s and 1950s and it is interesting to note that that movement inspired new directions in art and prompted several important collaborations between scientists and artists. Then, as now, the intersection between art and science was sometimes embodied in individuals who freely moved between the two spheres: they were both artist and scientist and united the two in their work. Today this seems to be an increasing trend and long may it continue – art and science have much to offer each other.

Phil Husbands and Michael O'Shea are co-directors of the Centre for Computational Neuroscience and Robotics (CCNR) at the University of Sussex. The CCNR is one of the leading international centres for research into evolutionary and adaptive systems (EASy) and artificial life and hosts an influential and longstanding artist-in-residence program. Phil Husbands was originally a musician and is now a computer scientist and has an international reputation for his work with genetic algorithms and evolutionary robotics. Michael O'Shea is a neuroscientist who is interested in how the human brain evolved and in the biological origins of creativity, the selective advantage of creativity and consciousness. He's collaborated with computer scientists, notably with Phil Husbands, in developing/evolving artificial brains, inspired by neuroscience, for mobile robots. In collaboration with Sol Sneltvedt he helped produce the AHRB/Arts Council supported SciArt installation called Mindscape, an attempt artistically to visualise the workings of the human brain and mind.

Figure 1: A still from one of the Mindscape video projections. A highly magnified image of two communicating neurons.



Jon Bird in conversation with Dustin Stokes

Overcoming inductive bias in a noisy world

An evolutionary robotics approach to modelling creativity

Philosophically, there are good reasons to be sceptical about conceptualising creativity on the basis of case studies of geniuses. Our conceptual analysis focuses on minimal, everyday human creativity and identifies two necessary conditions for creativity. Creative behaviour must result from autonomous agency and must display novelty (Bird and Stokes, 2006, 2007). A strong candidate for a third necessary condition is that the mechanism must be able to evaluate what it produces. Creative behaviours must be autonomous and generate novelty. How can we translate these conditions into mechanisms?

In the Drawbots project we employ a bottom-up approach and try and build the simplest mechanisms that display creative behaviour. We thus take a novel conceptual and evolutionary design approach to studying creativity. Even if we fail, we expect that the attempt will provide some useful first steps, or at least help to identify unfruitful directions.

We can achieve a ‘no strings attached’ level of autonomy by embodying the mechanism in a robot whose behaviour is not remotely controlled but driven by an onboard control system that co-ordinates the sensors and actuators. However, sixty years of research in Artificial Intelligence has demonstrated that building robots that can operate autonomously in the real-world is a non-trivial task. Our focus here is to outline two of the reasons and show how they motivate our evolutionary robotics (ER) approach to designing minimally creative robots.

First, the world is noisy, dynamic and hard to model. One approach is to control the complexity of the world and make it predictable – as is done on factory assembly lines – but this diminishes autonomy. If we want our robots to operate autonomously in the real world, rather than in a ‘toy’ one of our making, then we have the difficult task of designing mechanisms that can deal with the unpredictable and the unknown.

Second, functional decomposition, the standard engineering design approach, is not particularly good for designing autonomous robots. This methodology involves breaking down an overall design goal or function into constituent, semi-independent sub-functions that only interact in well-specified ways. Each sub-function may in turn be decomposed into simpler sub-functions, until eventually the design consists of very simple functions. This approach has been successfully used to design many things, for example, most of our electronic devices. In fact, electronic components are built to facilitate just this sort of design approach.

However, it is unclear how to decompose desired robot behaviours into control mechanisms. How should a goal such as ‘avoid obstacles’ be decomposed into functions? Should there be a sensing module, a planning/ thinking module and an acting module a la Good Old Fashioned AI? Nouvelle AI in the 1990s argued that the traditional sense-think-act cycle was not a good way to design robots; rather, the focus should be on implementing behaviours by closely integrating sensors, control systems and actuators.

These questions illustrate that any robot design is based on the explicit and implicit assumptions of the designer. In the case of robots, these prejudices might influence the architecture of the software controller and the particulars of the hardware (such as the number and type of sensors), limiting exploration of the possible space of designs, potentially in unproductive ways.

Designing robots makes us aware of another more implicit prejudice of human designers: we tend to assume that our particular perspective on the world, provided by our perceptual systems, is universal. However, our perspective is not shared by most mobile robots: they employ very different sensory modalities (for example, infra red or ultrasound) and move in very different ways (for example, using wheels). Successful robot designs are based on a robot’s, rather than a human designer’s, perspective on the world.

We can deal with a noisy world and overcome our prejudices when designing robots by using an evolutionary approach. Evolutionary robotics (ER) has established that search algorithms inspired by Darwinian evolution can be used to automatically create robots that perform relatively complex tasks in dynamic, real-world environments.

Typically, a population of agents is tested for their ability to perform some desired behaviour and the fittest individuals tend to get selected to produce the next generation of robots. This process continues until either the robots perform at a satisfactory level or an experiment has been carried out for a large number of generations (typically thousands). An initial population of genotypes (generally a string of numbers) that encode the controller and other properties of the robot design are usually randomly generated. An experimenter defines a fitness function for automatically measuring the fitness of each agent. The genotype of each agent in turn is instantiated as a robot (phenotype), placed in a test environment, and its fitness tested. The testing process is carried out in simulation, in the real world or in a combina-

David Plans Casal

Remembering the future

applications of genetic co-evolution in music improvisation

Musical improvisation is driven mainly by the unconscious mind, engaging the dialogic imagination to reference the entire cultural heritage of an improvisor in a single flash. This talk introduces a case study of evolutionary computation techniques, in particular genetic co-evolution, as applied to the frequency domain using MPEG7 techniques, in order to create an artificial agent that mediates between an improvisor and her unconscious mind, to probe and unblock improvisatory action in live music performance or practice.

David Plans Casal is a musician and researcher, and digital technologist at Brunel University. His research focuses on artificial intelligence and music. He has given concerts at IRCAM (Igor Stravinsky Hall), the Sonic Arts Research Centre in Belfast, and several London venues.

tion of both. For example, as a robot moves around an arena it might gain fitness for avoiding obstacles or collecting objects or performing phototaxis. The new population is created by applying genetic operations to the genotypes of selected agents. Mutation involves randomly changing some of the numbers in the genotype. Crossover, inspired by sexual reproduction, consists of combining parts of two individual's genotypes to create a new genotype different from the two 'parents'.

ER can potentially exploit any constraints arising from the interaction between the robot and its environment. Furthermore, if we allow the evolutionary algorithm to construct the controller out of low-level building blocks then it can help limit the influence of our design prejudices on the control architecture. In terms of modelling creativity, then, evolutionary robotics is the right methodology for overcoming inductive bias in a noisy world.

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Bird, J. and D. Stokes. 2006. Evolving Minimally Creative Robots. Proceedings of The Third Joint Workshop on Computational Creativity, European Conference on Artificial Intelligence, edited by S. Colton and A. Pease 1-5.

Acknowledgements

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Jon Bird and Dustin Stokes, both at the University of Sussex, are members of an AHRC funded research team, where they are currently researching creative behaviour from the angle of evolutionary robotics and computation.

Jon Bird is an artificial life researcher, specializing in evolutionary and adaptive systems. He is founder and co-organizer of Blip, a Brighton-based New Media Arts organisation.

Dustin Stokes is a philosopher, specializing in philosophy of mind and cognitive science, and philosophical aesthetics.

Catherine Mason
in conversation with
George Mallen

Origins

The 1950s and 1960s saw a flourishing of interdisciplinary science and technology. The field of cybernetics came to encompass the ideas of complex systems, self-organisation and the growing impact of computer modelling on scientific method. This also heralded new frameworks for collaboration between the arts and sciences.

Dr George Mallen and Catherine Mason discussed some of the origins of computing and digital technology in the arts, including the seminal exhibition Cybernetic Serendipity (to which Mallen contributed) at the Institute of Contemporary Arts, London in 1968 and the founding of the Computer Arts Society, which grew out of this and other initiatives.

The complexity and rarity of computing technology during this early period meant that any art form based around them was bound to be a specialised branch of art, highly dependent upon support and funding to exist. This was not least because of the expensive, large-scale nature of much early equipment and the resulting technical expertise required to operate it. The Computer Arts Society, guided by computer professionals, negotiated access, instituted training programmes, organised exhibitions and published its journal PAGE.

As the 1970s progressed, academic institutions and in particular art schools picked up the baton and began to play the central role in the incubation and development of computer arts. Before the onset of user-friendly systems, proprietary software and personal computers, artists learned to write code, constructed their own hardware and built relationships with scientists and technicians. Formal and informal networks organised by practitioners were able to address the challenge of exhibition and dissemination of work in a field that tended to be marginalised from widespread, mainstream critical review and acceptance.

Catherine Mason is an art historian who has recently researched the early development of the computational arts in the UK from 1960 – 1980.

George Mallen is a cybernetician and was a co-founder in 1968 of the Computer Arts Society. In the 1960's he worked with the UK arts/cybernetics pioneer Gordon Pask and in 1969 helped create the pioneering Ecogame for the a special CAS exhibit at Olympia in 1970 and subsequently at first World Economic Forum at Davos in 1971.

Richard Brown

Sci-art and beyond

Using a wide variety of media, for many years I have produced hybrid art-science creations that exhibit independent complexity and interaction with their environments. Whether these can be viewed as art works, or devices that embody a philosophical or pseudoscientific idea is a matter of debate. Some of the creations are pure entertainment and designed to evoke a sense of wonder and magic, harking back to the child within us all.

My first interest in the wonder of science was through Chemistry, exploring the magical ability of materials able to transform from one thing to another, to change colour, to crystallise, to create noxious smells and to explode. My second interest was that of electronics, electromagnetism, relays and the creation of a very primitive 4 bit computer built from over 30 EX GPO relays and a uni-selector.

At school I was faced with an A-level choice between Mathematics and Art, the art science schism made educationally manifest. I chose Mathematics, whilst Art came second place as a pleasurable pastime.

Now many years on, the schism continues, the Wellcome Trust Sci-Art scheme represented a bold attempt to marry the two. With specialisation and a rarefication of both Scientific Research and Fine Art, the two disciplines appear to be moving further away, and only unite in rare moments when maverick sciartists straddle the divide.

Who defines whether a creative act influenced by science or art has value, and to whom?

Are the underlying process that brought the work into being more interesting than the end product?

Is it possible to create a work that has equal value as an artwork and a piece of scientific research?

I ask these questions of my own work, reflecting on the past, the present and the future.

Richard Brown creates works that explores interactivity, complexity and emergent processes using a variety of media including mould, electrochemistry, electronics and digital computers. His work has been supported by Intel, The Arts Council, Sci-Art Wellcome Trust and NESTA. He is currently Research Artist in Residence at the School of Informatics, Edinburgh University.

Erwin Driessens
and Maria Verstappen

Automatic Art and Artificial Evolution

There is unmistakable evidence that in nature complex structure spontaneously emerges without the need for an intelligent designer. Emergence is the appearance of novel behaviour from the coherent actions of many small components. Despite the viewer having full information about the underlying interactions that govern a system's behaviour, the emergent phenomena that arise are not obviously implied by the superposition of these interactions. In our work we explore the expressive potential of such self-organisation and what the underlying mechanisms of these processes can offer for art, by implementing them as a purely visual and image-generating system. These autonomous systems produce unusual and unpredictable results with a minimum of human intervention.

In addition to working with physical and chemical processes generating morphological transformations, we use the computer for the development of artificial worlds with emergent properties. In these projects we want to see what happens when you can describe all the aspects of a development and growing process yourself. Not simulating the laws that exist in the physical world, but instead defining an artificial nature, with fictive laws that constitute a world of its own. These software systems are parallel universes that have their own creative principles and expressions.

Just as in the world around us, these artificial worlds generate fascinating, strange but also tedious phenomena. We therefore need a powerful mechanism to enable us to explore the field of possibilities and which will enable further development of areas potentially interesting to us. In the world around us the process of evolution takes care of the multiformity of biological life and the creation of new species from old ones. The species become increasingly better adapted to the changing ecosystem by a process of mutation and selection. If we can link a mechanism of artificial evolution to a morphogenetic system then we have an effective manner of giving direction to the image generating properties, without pre-determination of how the results deriving from this are going to look.

Carrots and Tubers

Species used for large-scale food production have been subject to an evolutionary process spurred on by industry for a long time, with far-reaching control of environmental factors. While the natural process of evolution is usually engendering multiformity and diversity so that species remain strong and adaptive, industry manoeuvres the process as much as possible in a direction of uniformity and homogeneity. In spite of that control, some potatoes or carrots do escape this imposed uniformity. Normally speaking, these deviant growths disappear into potato starch or they serve as cattle fodder. Sorting takes place in large distribution centers and on location, we made a selection out of a great number of rejected products, representing the variety in form within the species.

Breeding complex sculptures

Is it possible to breed industrial products via a technological route whereby multiformity is achieved instead of uniformity? In 1995, we began the project titled Breed with this question as a starting point, which ultimately led to a system that automates both the design and the production of three-dimensional sculptures. To attain multiformity without designing each individual form in detail, we focused on a system able to generate a large number of morphogenetic rules independently. The rules prescribe how a detailed spatial form arises from a simple elementary form, or rather "grows". However, not all rules lead to a spatial object that is executable as sculpture. The system therefore comprises an evolutionary component that seeks solutions for this problem completely independently.

Image Breeding Machine

We wondered if we could design an artificial evolutionary process that would not be evaluated based on a set of objective criteria hard-coded within the system, but on the basis of subjective selection criteria introduced by user interaction. In this way you obtain a very open system, where you can explore a great many different paths within the gigantic realm of possibilities. The project E-volver has expanded this idea into a working system. E-volver encompasses an alliance between an image breeding machine on the one hand and a human breeder on the other. The user directs the process based on visual preferences, but they can never specify the image in detail, due to the unpredictability within the morphogenetic system.

While we applied artificial evolution in Breed as an optimising technique, in E-volver it has become an inherent content aspect of the work. The aim of the evolutionary process is not described, but any imaginable fitness criterion can make surprising and significant properties of the system visible. In the first instance, the spectator is inclined to impose his personal taste on the system. Gradually we see that fathoming of the generative system more and more interferes with taste and judgement. The selection criteria themselves are subject to change, they co-evolve in interaction with the E-volver system.

Concrete Approach

The visual structures of Breed and E-volver do not represent anything but they arise from a logical and direct use of the medium and its formal visual means. This testifies to an approach that is related to concrete art, which has its origin in early Modernism. The art-

Breed 1.1, #045, #156, # 235 and # 266, 96 x 96 x 96 mm. Selected Laser Sintering, nylon, 2001

work itself is the reality. Jean Arp: “We do not wish to copy Nature; we do not wish to reproduce, but to produce. We want to produce as a plant produces its fruit.(…) Artists should not sign their works of concrete art; they form a part of Nature’s great workshop as do trees and clouds, animals and people …”[1] Concrete art does not reject the increasing prevalence of technology and industrialisation, but it wishes to provide new times with a fitting visual language. We share this approach but in contrast to modernistic artwork – that attempts to reveal the underlying harmony of reality by rational ordering and reduction of visual means – we are actually striving for complexity and multiformity in the final result. The harmony model has been replaced in our case by the conviction that chance, self-organisation and evolution order and transform reality. The concrete and formal approach have now entered into a union with new possibilities of vivification. Vivification in the sense of bringing a work of art literally to life. Mitchell Whitelaw: “Evolution, an idea that has become the most powerful organising narrative of contemporary culture, appears to unfold on a screen. Artificial Life proposes not a slavish imitation of this or that living thing but, at it strongest, an abstract distillation of aliveness, life itself, re-embodied in voltage and silicon.”[2]

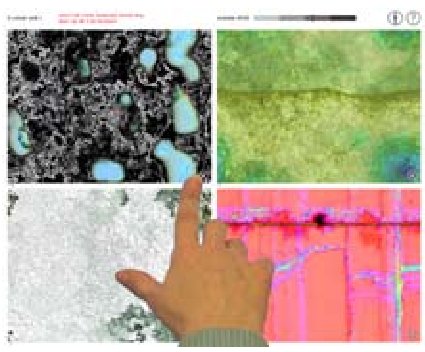
[1] Jean Arp, 1942, Abstract Art, Concrete Art, In: Art of This Century, New York
[2] Michell Whitelaw, 2004, Metacreation, Art and Artificial Life, MIT Press, pp. 5

Erwin Driessens and **Maria Verstappen** have worked together since 1990 and are based in Amsterdam. Their research focuses on the possibilities that physical, chemical and computer algorithms can offer for the development of image generating processes. Their most recent work is E-volver a large-scale projected public artwork for the Leiden University Medical Centre that uses evolutionary software to “breed” images.

Morphotheque #8, painted aluminium, 1994
28 elements
1:1 copies of potatoes (cultivar Jaerla)

Morphotheque #9, painted plaster/copper wire, 1997
32 elements, 1:1 copies of carrots
collection of Anne Marie and Sören Mygind, Copenhagen

E-volver, permanent installation at LUMC Research Labs, Leiden, 2006
in assignment of LUMC and SKOR Amsterdam, photo Gert Jan van Rooij



E-volver, evaluation takes place via the touch-screen

MANFRED MOHR

Winner of the d.velop digital art award [ddaa] 2006

Broken Symmetry

an exhibition at Kunsthalle Bremen 24 April to 1 July 2007

Catalogue edited by Wulf Herzogenrath, Barbara Nierhoff and Ingmar Lähnemann

Broken Symmetry is the brilliant, illuminating title chosen by Manfred Mohr for this winning entry and the consequent exhibition and catalogue.

His work has been known to me since about 1970, and while I have seen it develop, mainly from exhibition catalogues, it was only in the gallery in Bremen that the sweep of it over half a lifetime, the accumulation, the force of his single-mindedness, were clear to me. And always with meticulous style.

The early use of little more than random numbers in simple but striking drawings with a pen plotter led to the systematic arrays of signs and alphabets in the early 1970s. These were easy to read, sometimes playful, teeming with invention. But this “gradually became too easy and also boring” Mohr said in his Conversation with Barbara Nierhoff, in the catalogue (of which more below). He then began to use wire-frame drawings of a cube as his basic resource, with many works showing subsets of the cube’s edges in various orientations. Some of these drawings are compared to works by Sol LeWitt (who died in April this year) by Ingmar Lähnemann in his essay Two-dimensionality versus Multi-dimensionality, also for the catalogue, but Mohr says that LeWitt was not an influence. Just as he disavows any relationship of his work to constructivism or minimalism.

In 1977 Mohr took two projections of the cube in different orientations, cut each in half and juxtaposed one half from each to make a new image. There followed a series of works based on variants of this method. These made me uncomfortable. The parts were pushed together in a seemingly arbitrary way. I was craving that symmetry which was being fractured. It was a rich new vocabulary, one that has taken me nearly 30 years to appreciate.

Another major step a few years later was to use the hypercube, the body in four dimensions equivalent to the cube in three, again in wire-frame form. But this was not as a mere aid to visualisation but rather a more complex resource to be rotated, dissected, manipulated, reassembled. The hypercube has 16 vertices, 32 edges, 24 square faces, 8 cube faces and 1 4-dimesional element (itself), adding up to 81 components in all, three times as many as the cube, which has three times as many as the square. If you are interested in aids to visualising the hypercube there are several websites to be found by searching with “rotating hypercube”, some for stereo viewing. Or make a 3-d model with a molecular kit and rubber bands, as I did last year.

Almost all this work was in black and white, with some grey. In the last 20 years Mohr has gone on to use the hypercubes in 6 and 11 dimensions, this last having 11264 edges, though Mohr uses only comparatively small subsets in any image. Along with this increasing complexity, and to some extent to help clarify and to compensate, have come the use of colour and motion. The exhibition has two works space, color, motion each realised on a PC with LCD screen. The images move almost imperceptibly and I was told that they captivated the picture-hanging crew, usually indifferent to any artworks. These animations are the cool culmination of a wonderful show. One quibble. It is said that the images are unique and “never repeat themselves and are always surprising”. But repetition is always possible and eventually inevitable: the PC has a finite number of states, and the screen a finite number of pixels and possibly 256 levels for each one.

One room is devoted to about eight large works, including irregularly shaped, wall mounted panels of relief cardboard, coloured plotter drawings, and paintings of remarkable precision.

The bilingual catalogue has 95 pages, most devoted to the illustrated list of works. The article already mentioned by Lähnemann deals amongst other things with the mathematical nature of Mohr’s work. In the Conversation with Barbara Nierhoff, also in the catalogue, she asks the difficult question “what qualifications should the ideal viewer bring to your works? How important is mathematical knowledge, how central is knowledge of art history?” Mohr’s reply begins “Actually there is no definitive answer to that question.” I answer to an earlier question he says “It is only since reading the text by Ingmar Lähnemann that I have been aware of what I did myself. I am delighted if I contributed something to art history, even unconsciously.”

In another response to Nierhoff, Mohr says “Symmetry ... is said to be beautiful. But in my work I am not interested either in beauty or ...”. But elsewhere he writes of aesthetics and his works are undoubtedly beautiful, visceral. There’s contradiction, isn’t it. He embraces paradox and ambiguity in another reply. “The paradoxical aspect of my work, if you like, is that I invent two-dimensional signs that only assume their true force and uniqueness through ambiguity when they are ‘folded down’ from higher dimensions.”

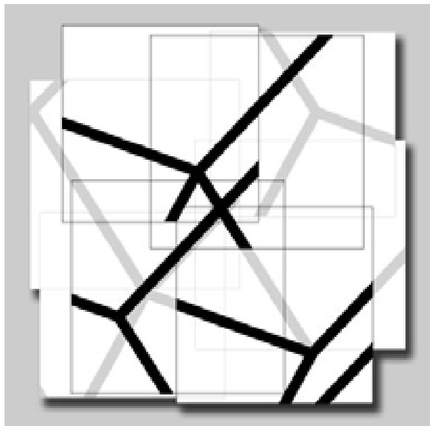
The catalogue is dedicated to Estarose Wolfson. Mohr’s life’s companion. In their early years she worked at the Meteorological Office in Paris, where Mohr was given access at night to computers and a large flatbed Benson plotter - for a period of over 10 years.

As is usual for catalogues, some of the illustrations are smaller than is desirable. For better reproductions, Manfred Mohr by Keiner, Kurtz and Nadin. published 1994 by Waser Verlag, Zurich is still available. It too is in German an English, and expensive: I recommend being given it for Christmas as I was. A second edition is now needed.

This life-work so far unfolds like an epic symphony and I’m longing to see the next movement.

review by Alan Sutcliffe

P-407D, Acrylic on canvas, 155cm x 156cm, Wilhelm Hack Museum, Ludwigshafen 1987 Manfred Mohr



Rudolf Arnheim

1904-2007

Rudolf Arnheim, a pathbreaking psychologist of visual experience in the arts, died at the age of 102 in Ann Arbor, Michigan on June 9 2007. His last academic post was at the University of Michigan, where he was Visiting Professor in the Departments of Art, History of Art, and Psychology from 1974 to 1984. The previous American years of his long academic career were spent at Sarah Lawrence College from 1943 to 1968 and at Harvard in the Department of Visual and Environmental Studies from 1968 to 1974.

Born in Berlin in 1904, where his father was a manufacturer of pianos, Rudolf Arnheim took his doctorate at the University of Berlin in 1928, with a dissertation of the experimental psychology of visual expression, and secondary studies in musicology and history of art. At the time Arnheim was enrolled in Berlin University's Institute of Psychology, it was the center of experimentation in Gestalt Psychology, with Max Wertheimer, Wolfgang Kühler, and Kurt Lewin the central authorities.

Arnheim conducted some of the earliest experiments in the application of Gestalt theory in the perception of a work of art. Between 1928 and his departure from Nazi Germany in 1933, he was on the editorial staff of Die Weltbühne, the influential weekly magazine then edited by Carl von Ossietzky and suppressed with the advent of the Third Reich. It was in this publication that Arnheim ventured into film criticism, a medium that became central to his theories of vision. Between 1933 and 1938, Arnheim worked in Rome as an editor at the League of Nations' International Institute for Educational Film. With the declaration of the racial laws in Fascist Italy in 1938, Rudolf Arnheim went to England, with the assistance of Herbert Read, where he worked as a translator at the Overseas Office of the BBC in London. Along his paths he termed rises and descents, twists and vistas, he migrated to the United States in 1940. Assisted by a Rockefeller Foundation Grant, by ! 1941 he was associated with the Office of Radio Research at Columbia University and from 1942 to 1943 held a Guggenheim Fellowship in New York. The latter year also marked his entrance into academe. While on the faculty of Sarah Lawrence he also taught at the New School for Social Research and from 1959 to 1960 held a Fulbright Lectureship at Ochanomizu University in Tokyo.

Numerous schools awarded honorary degrees to Rudolf Arnheim, including Sarah Lawrence, the University of Michigan, the Rhode Island School of Design, and the University of Padua in Italy. Recently his doctoral degree from Berlin, annulled during the Third Reich, was restored to him by Humboldt University, Berlin, soon to be followed by the creation of the Arnheim Guest Professorship for Contemporary Art History. Chairs in his name have also been established at Harvard University and the University of Michigan. The University of Bielefeld, Germany, established the Rudolf Arnheim Institute for International Art, Music and Cultural Economics in 2001.

Arnheim's books on the psychology of vision include Art and Visual Perception (1954, revised 1974), Toward a Psychology of Art (1966), Visual Thinking (1969, and The Power of the Center (1983). His influential writings on cinema appeared in 1932 and in a reissue as Film as Art (1957). His most recent books are Parables of Sunlight, Observations on Psychology, the Arts, and the Rest (1989)., To the Rescue of Art (1992), and The Split and the Structure (1996).

Rudolf Arnheim served terms as president of the American Society of Aesthetics and of the Division on Psychology and the Arts of the American Psychological Association. In 1976 he was elected to the American Academy of Arts and Sciences, and in 1978 he was a Resident Scholar at the American Academy in Rome.

The architectural historian James Ackerman, a colleague at Harvard, wrote: From the perspective of the 1990s, Rudi Arnheim emerges as the quintessential voice of modernism in the sphere of psychology - a discipline virtually coeval with the modern movement. He clarified to tens of thousands readers and students the relevance of perceptual processes to their responses to the arts and especially to the abstract aspects of art. On his retirement it proved impossible to identify a successor of his stature and scope.

Rudolf Arnheim's wife, Mary Elizabeth, died in Ann Arbor in 1999. He is survived by his daughter Margaret and her husband Cor Nettinga and their children Kees, Naomi, son-in-law Gerard Castelein, and great-grand-daughter Ella, all of whom reside in the Netherlands.

This obituary was originally written by Professor Marvin Eisenberg for the Ann Arbor News.

The editor would like to thank Rudolf Arnheim's daughter Margaret Nettinga for giving permission for us to reproduce it here.

COMPUTER ARTS SOCIETY

British Computer Society Specialist Group

SPECIALIST GROUP

Bringing together artists and technologists
Exchanging techniques and ideas
Formulating needs for support
Helping to get works known
Exploring new forms

ABOUT THE COMPUTER ARTS SOCIETY

Aims

The Computer Arts Society (CAS) promotes the creative uses of computers in the arts and culture generally

It is a community of interest for all involved in doing, managing, interpreting and understanding information technology's cultural potential.

Membership & fees

Membership is open to all who are interested in the aims and activities of the group. To join go to www.jiscmail.ac.uk/CAS and subscribe to the e-list.

There is an optional annual contribution of £10 (€15 or $20 overseas) for which members receive a printed copy of each issue of PAGE

The British Computer Society (BCS)

The CAS is a Specialist Group of the BCS

The CAS receives funding from the BCS

Website

www.computer-arts-society.org

Publication

PAGE the Bulletin of the Computer Arts Society appears quarterly and can be downloaded from the CAS website

Archiving computer arts

The CAS was founded in 1968

There are significant archives of material from this early era, mainly stored in homes and offices of people then active in the group. The main CAS archives were donated to the Victoria & Albert Museum in 2007.

The CAS has worked closely with CACHe, a project in the Art History Department of Birkbeck, University of London, documenting UK computer arts in the years to 1980. CACHe ended formally in 2005 but the work continues

This leads to a wider interest in the archiving, study and presentation of computer arts from earlier years.

Present & future computer arts

With so many novel and exciting developments in the creative uses of computers in the arts the society will continue its original aims of bringing together those active in this area

Collaboration

The society plans to hold joint events with other BCS Specialist Groups and to collaborate with other organisations

Education

The CAS plans to have an educational role in making students more aware of early work in computer arts and in helping artists to use computers creatively

CAS COMMITTEE

Chair
Paul Brown paul@paul-brown.com

Vice-chair
Dr George Mallen george@ssl.co.uk

Treasurer
Dr Alex Zivanovic alex@zivanovic.co.uk

Minutes Secretary
Dr Nick Lambert n.lambert@hist-art.bbk.ac.uk

Webmaster
Stephen Boyd Davis s.boyd-davis@mdx.ac.uk

Editor of PAGE
Alan Sutcliffe nsutcliffe@ntlworl.com
4 Binfield Road
Wokingham RG40 1SL England +44 (0) 118 901 9044

Catherine Mason catherine.mason@dsl.pipex.com

Christos Logothetis christos@logothetis.co.uk

John Sharp sliceforms@yahoo.co.uk

Sue Gollifer S.C.Gollifer@bton.ac.uk

Dr Tony Mann A.Mann@gre.ac.uk

Tony Pritchett tony@agmp.net