White Heat and Cold Logic:
British Computer Arts 1960 – 1980
An historical and critical analysis

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Figure 1 General view of the Nova 2 System in 1977

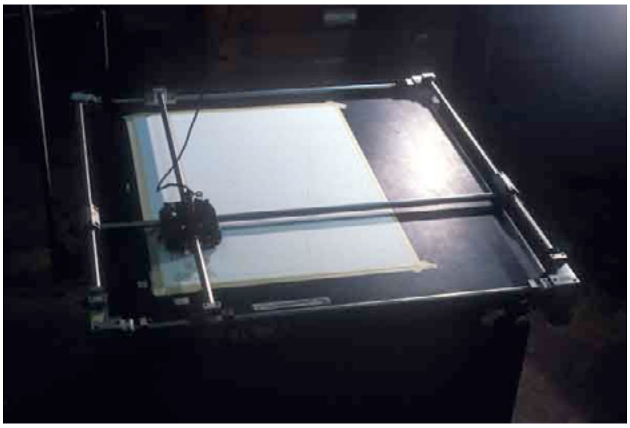

Figure 2 View of the flatbed plotter

Figure 3 Sullivan's 1-bit frame-store running Brown's Builder-Eater

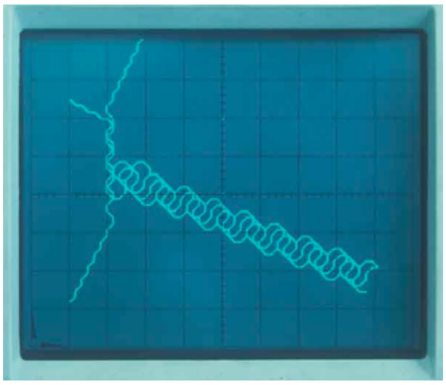

Figure 4 The 8 x 10cm storage oscilloscope with a drawing by Briscoe on the screen

From Systems Art to Artificial Life
Early Generative Art at the Slade School of Fine Art

Paul Brown

"The idea becomes a machine that makes the art" - Sol LeWitt[1]

In 1968 I was one of a generation of young artists who visited London's ICA (Institute of Contemporary Art) at their then-new premises in The Mall to see the Cybernetic Serendipity show [2,3] which had been curated by Jasia Reichardt. Like other exhibitions in the ferment of the 1960's Cybernetic Serendipity challenged many long-held attitudes to the visual arts and their place in culture and society. In particular works by scientists were shown alongside those of professional artists and Reichardt did not differentiate, at least on the level of the exhibited artefact, between the "two cultures". Like many of my contemporaries I was enthralled by the show and, after a period working with video and analogue electronic systems I have, since 1974, worked almost exclusively with computers and digital systems. Younger artists, like Ken Rinaldo, also credit the show for inspiring their interests in what Kay termed the computational metamedium [4]. Rinaldo saw the show as a child and only later, when he discovered the *Cybernetic Serendipity* catalogue [5] in a second-hand art bookstore, recognised what he had seen and was able to acknowledge the influence it had had on his development as an artist.

One of the works shown at Cybernetic Serendipity was Edward Ihnatowicz' [6,7] Sound Activated Mobile or SAM. Later Ihnatowicz worked on the ambitious and high budget Senster for the Phillip's Evoluon Museum in Eindhoven in the Netherlands. Kees Stravers maintains a web site about the Evoluon [8] and videos of Ihnatowicz' robotic artworks are available from Alex Zivanovic's Senster web site[9]. During the period he worked on these robotic pieces Ihnatowicz was a researcher in the Mechanical Engineering Department at University College London where the Slade School of Fine Art is also based. In 1973 the late Malcolm Hughes, who was a member of the System Art group and head of Postgraduate Studies at the Slade, established their Experimental Department (later renamed the Experimental and Computing Department –or- EXP for short). Ihnatowicz was a frequent visitor throughout the 1970's and often engaged in informal discussions with staff and students on topics of interest. I remember one such discussion about artificial intelligence (AI). Edward referred to the work of Piaget on infant learning and the importance of the tactile stage that precedes and is an essential prerequisite for later visual and metric learning. He stated his opinion that if machines were ever to become intelligent they could only do so by interacting with their environment. At the time this was an unpopular opinion. The AI field was dominated by the top-down internal-representations paradigm and funding for bottom-up machine-learning research had dried up after Minsky and Papert published their critical review of the connectionist field [10]. In retrospect it's possible to perceive that Ihnatowicz was an early proponent of embodiment in both the arts and AI and it's clear that he was also a pioneer of the discipline now known as artificial life (Alife). Contemporary roboticists and AI specialists working in the now re-acknowledged bottom-up methodologies (like for example evolutionary and adaptive systems) are often astounded to learn of Ihnatowicz' work, especially considering its early date. Ihnatowicz died in 1988.

Another regular visitor to the Slade's Experimental and Computing Department was Harold Cohen[11]. Cohen was a well-established artist who had represented Britain with his brother Bernard (who later became Slade Professor) at the 1966 Venice Biennale. In 1969 he began working at the University of California at San Diego (UCSD) where he became interested in computers and programming. From 1971 he was involved in the AI Lab at Stanford University where Edward Feigenbaum was developing Expert Systems. These systems get around a major problem in classical, top-down, disembodied AI research - the problem of context. The human mind has an amazing facility to quickly apply a multitude of contextual information to the cognition of ambiguities common in speech and other forms of inter-human communication. Even high-speed modern computers with their linear processing structures can't compete. Feigenbaum was one of a number of researchers in the late 60's and early 1970's who suggested that this could be overcome by limiting the area of intelligence to small, well-defined knowledge bases where ambiguities could be reduced sufficiently to enable the contextual cross-referencing to be resolved. Researchers at the Stamford Lab. developed many valuable expert systems like Mycin that was used to diagnose infectious diseases and prescribe antimicrobial therapy[12]. As a Guest Scholar and artist-in-residence from 1971-73 Cohen began to develop an expert system he called AARON. He continues to work on it and jokes that it's the oldest piece of software in continuous development[13]. AARON is a classical top-down AI package. It contains an internal database and set of rules that enable it to interpret its knowledge base to produce sophisticated and unique drawings. Although Cohen is interested in investigating issues to do with cognition and drawing in general his major achievement has been the externalisation and codification of his own drawing and cognitive abilities. AARON produces 100% genuine and original Cohen artworks without the need for the human artist's intervention.

For me Ihnatowicz and Cohen represent the first two great masters of the computational arts and it's interesting that they also epitomise the two main approaches to AI. Cohen's work builds upon classical methods of top-down internal data representation and analysis. Ihnatowicz is an early pioneer of the now-popular methods of bottom-up learning systems – an aspect of what's since become known as artificial life. In using the term computational to describe their work (and in general describe the work of the other members of the Slade community) I am differentiating their approach from the more usual computer-aided one. Computer-aided solutions offer the automation of existing techniques and methods – they are essentially productivity enhancers. By contrast computational solutions offer new methodologies that are unique to Kay's computational metamedium. This definition contrasts with the later denial by some post-modern commentators that the computer had any intrinsic nature. According to these critics the computer is only capable of being a facsimile device. For them the idea of an intrinsic computational nature was merely an illusion that resulted from the phenomenal speed at which computers operate. We see here one reason why many of the early pioneers of the computational arts (including Cohen and Ihnatowicz) were never adequately recognised by the mainstream artworld when it became increasingly dominated by the post-modern aesthetic paradigm during the 1980's. The idea of intrinsic nature was confused with modernist ideas of "truth to the medium" whilst more important concepts like emergence, which should have been acknowledged as central to post-modern concerns, were too far ahead of their time and in consequence were either misunderstood or ignored.

Throughout the late '60's and early '70's self-expression was perceived as an outdated romantic notion and many artists were exploring methods for removing themselves from the production process. The emerging idea of what later became known as the computational complemented other paradigms that dominated aesthetic debate during this period. Principal amongst these were the ideas that process precedes object and is the essential nature of the artwork and that content emerges from the process rather then being imposed by a human creator. This informed many new directions including Conceptual Art and Art Language and is eminently described by Lippard[14]. Ehrensweig[15] offered an alternative interpretation by psychoanalysing the process of art making rather than the resulting artefact. Hierarchies were being undermined by heterarchies and concepts of equipotent interdependent networks were beginning to emerge. Today's Internet took root in 1969 when Arpanet connected UC Los Angeles, UC Santa Barbara, the University of Utah, and Stanford Research Institute. Not long afterwards artists like Carl Loeffler, Roy Ascott and Kit Galloway & Sherrie Rabinowitz (who later founded California's influential Electronic Café) created intercontinental artworks using both computer and video networks[16]. The role of the spectator as a dynamic participant in the creation of the artwork was acknowledged as artists made works intended to be changed and reconfigured by their audience. Time was reconsidered as the early experiments of Moholy-Nagy, Duchamp, Calder, Malina, Schöffer and others were formalised into the Kinetics Movement. Several artists continued the Constructivist idea of art as an analytical, logical and experimental procedure that, like science was concerned with an exploration of nature. Many followed science and technology which introduced valuable subjects into to the debate including Analytical Philosophy, Cybernetics, Systems Theories, Communications Theory, cellular automata, deterministic unpredictable systems, Formal Grammars and Learning Systems. In 1967 Frank J Malina founded what remains the major journal addressing the convergence of art, science and technology – Leonardo. Many of us were also regular readers of the then recently established weekly news magazine New Scientist and the monthly Scientific American.

The Slade's postgraduate school was one of the top three graduate institutions in the fine arts in the UK (with the Royal Academy and the Royal College of Art) and was distinguished by its focus on an analytical and experimental approach. Elsewhere the amalgamation of the urban colleges to form polytechnics provided a unique opportunity for undergraduate art students to learn to program computers. A number of mature artists returned to study in order to exploit this potential and an increasing number of artists were seeking postgraduate opportunities that included access to computing facilities. They included Chris Briscoe, a mature art student who had learned about computing and digital electronics at Portsmouth Polytechnic where the Systems Artist Jeffrey Steele was then teaching. Briscoe was recruited by Malcolm Hughes to develop the computer program. With the support of the Slade Professor, William Coldstream, Hughes and Briscoe secured university funding to purchase an in-house computer system. Briscoe selected a Data General Nova 2 minicomputer. This consisted of a 6 ft. cabinet that held the main chassis with around ten 15 in x 15 in circuit boards that composed the computer itself. It also housed a high-speed paper tape reader and was interfaced to a electro-mechanical Teletype console via a 300-baud serial line. Compared to a modern computer the Nova was exceptionally primitive: it had 16 K words of 16-bit memory (32KB) and came with two programs on paper tape – a text editor and an assembler. The manual included a complete set of circuit diagrams. It didn't have an operating system. Recently Briscoe described the Nova as "more like a piece of laboratory equipment than a computer"[17]. He designed and built a general-purpose interface board that output analogue signals to a modified Tektronix 10 x 8 cm storage oscilloscope to provide graphic output. The same board could optionally output to a couple of waveform generators and supported real-time audio synthesis of up to six simultaneous voices in stereo. Briscoe also designed and built a flatbed plotter using bits of surplus recording equipment. A major supplier to the Slade EXP community was Proops Brothers shop on London's Tottenham Court Road. It stocked a bewildering and often magical range of surplus electronics and electro-mechanical devices and a couple of visits each week to check out new arrivals were mandatory for many of us. **Figures 1 & 2** show the Slade computer setup in 1977 when it had been augmented with an audiocassette I/O subsystem that including a BASIC interpreter then later with a 10MB disk drive and an operating system called RDOS (Real-time Disk Operating System) that supported a FORTRAN compiler. Later, in '78 a Tektronix 4016 green-screen vector graphics terminal was added then in '79 a bequest from the estate of Slade alumna Eileen Grey purchased an AED 512 colour frame-store. With a resolution of 512 x 512 of 8-bit memory (which offered 256 simultaneous colours from a palette of 16 million) the AED was one of the first commercially available colour graphics displays in the UK.

Creating a working program on the Nova was a tedious and time-consuming business. Briscoe often joked that his most significant contribution to the teaching program consisted of his attempts to convince students not to try! For those who persevered and then discovered Briscoe's generosity and support it was an immensely rewarding experience. Many of us had come from restrictive polytechnic environments with hand-off policies where interaction consisted of handing over a sheaf of coding forms or a stack of punch cards to white-coated acolytes who serviced the hallowed mainframe. Some had been more fortunate and had access to a real-time system via a sympathetic department (in my case the Dept. of Engineering at Liverpool Polytechnic who let me use their Digital Equipment Corp. – DEC PDP8 mini). So, despite it's limitations the Nova was like heaven on earth for most of us. We booked blocks of time and worked the system 24 hours per day seven days of the week. I often booked the night shift when I didn't have anywhere to stay so I could sleep on the floor whilst the Nova worked away. Those who were confident in developing their own hardware could interface it to the Nova and several wire-wrapped directly to the motherboard because they couldn't afford the UK£1500 interface boards. (About UK£6,500, or over US$12,000, at 2005 value – and this was just for the unpopulated printed circuit board!). For an artist this was an unparalleled access to a computing facility and the Slade was the only art school in the world then offering this kind of opportunity. In the USA Chuck Csuri had built up a powerful computing facility at the Ohio State University but had done this independently and largely unsupported by his faculty. At the Slade these facilities were tightly integrated into the program and profile of the postgraduate school.

And, in consequence EXP became a major attractor for artists and theorists throughout the UK and Europe, many of whom have contributed chapters to this book. In addition to Ihnatowicz and Cohen regular visitors included Tony Longson who went on to be the inaugural Arts Council Computer Artist in Residence at Hatfield Polytechnic[18] and Ernest Edmonds who was setting up a pioneering program investigating creativity and cognition first at Leicester Polytechnic then later at Loughborough University and more recently at the University of Technology, Sydney[19]. At the time PhD research opportunities were not available within mainstream art education and so several of the EXP students (including Scrivener, Stephen Bell and Dominic Boreham) went on to pursue PhDs under Edmond's mentorship and were amongst the first visual arts students to achieve this award in the UK. The Belgian experimental composer Peter Beyls visited and stayed for a year as composer-in-residence. Other visitors included the architect John Lansdown (co-founder of the Computer Arts Society) and many members of the Systems Group including Jeffrey Steele, Michael Kidner, Terry Pope and others. The art historian Stephen Bann and theorist Victor Burgin were regular contributors to the program. Later in the 1970's the Polish mathematician Andre Lissowski, returning from a residency at Harvard, saw an exhibition of my work and came to visit. He introduced us to the then blossoming world of what became known as Chaos Theory – including the work of Benoit Mandelbrot and his concept of fractal dimensions, self referential iterative systems and the unpredictable deterministic systems discovered by Edward Lorenz.

Amongst the first students in the department were Stephen Scrivener[20] and Julian Sullivan. Sullivan was a mature student who had previous trained as an electronic engineer in the Royal Navy before going to Hornsey College of Art to "get away from all that and become an artist"[21]. However Hornsey was about to amalgamate with Enfield College of Technology to form Middlesex Polytechnic and Sullivan, together with Darrell Viner, were amongst the first students to work with the computer graphics pioneer John Vince who was then beginning to develop his art-orientated graphics package PICASO[22]. Viner was also accepted into the Slade Postgraduate program but opted to major in Sculpture though he was a regular visitor in EXP both as a student and later as a visiting lecturer. With his early experience in electrical engineering Sullivan made a number of hardware extensions to the Nova system in order to support his own and others work. The first was a 16 x 16 x 1-bit frame store that displayed on a LED (light emitting diode) display he had also built. He later extended this into a 96 x 96 x 1-bit system that displayed on the screen of a standard monochrome video monitor (**figure 3**). In the later '70's with the growing interest in animation he designed and built a single frame computer-driven controller for an Arriflex S2 16mm cine camera. It was now possible to automate the recording of animation sequences by writing a program that would draw an image on the screen of the computer display then send a signal to the Arriflex controller that would expose the frame and advance the film. Then the second frame could be drawn and captured and the animated sequence built up frame by frame. This was used first with the Tektronix 4016 to create "wire frame" animations and later with the AED 512 to make full colour sequences. After graduating Sullivan joined the Dept. as technician and worked alongside Briscoe until his untimely death in 1982. At the time he was working to commercialise his film controller under the name ANCAM. Sullivan was interested in Kinetics and, with his strong technical background was frequently employed as an assistant by more established artists, including Dante Leonelli. He programmed the famous Neon Tower created by Phillip Vaughan and Roger Dainton for the Hayward's 1970 Kinetics Show and now a well-known feature of London's South Bank arts precinct skyline. Like many of the EXP community Sullivan became interested in cellular automata (CAs) that had been popularised by Martin Gardner's piece about John Horton Conway's "Game of Life" in Scientific American in October 1970[23]. His work on boundary detection using CA models was so robust that it was adopted by the image processing researchers at UCL.

Darrell Viner made many large-scale kinetic works during his career. The pieces he made for his post-graduating show from the Slade were later exhibited at London's Royal Academy where the moving legs scratched the precious wooden floor of this hallowed institution. When asked to investigate Viner recounted how he became fascinated by the structure of the repetitive scratches and their relationship to cross-hatching. One result was a computer-animated film Inside/Outside (1976) that was drawn by a virtual automaton he programmed to simulate the actions of the larger kinetic sculpture. It was made on UCL's IBM360/65 computer with the assistance of Allan Hume and output via their 16mm microfilm plotter. Like many other EXP members Viner made extensive use of the UCL central computing facilities (via an early interactive terminal management system called GUTS – Gothenburg University Terminal System) as well as the CDC (Control Data Corporation) systems at the University of London Computer Centre that supported a 35mm microfilm recorder. This latter access to what were expensive supercomputers intended for bleeding edge scientific research was highly privileged and was mediated by David Clark of London University's Central AV Unit who was another regular visitor at EXP. Clark was an early proponent of computer graphics in media communications and edited a early and influential book on the subject[24]. After post-graduating in Sculpture Viner became a part-time lecturer in the EXP dept. and went on to teach at Chelsea School of Art and Portsmouth Polytechnic. Unlike most of the other pioneers of the computational arts he achieved recognition by the mainstream artworld exhibiting widely and creating several important commissions. One of his final works, completed shortly before his untimely death in 2001, was “Is Tall Better Than Small?” that interacts with visitors on the staircase to the IMAX Theatre at the London Science Museum Welcome Wing.

The printmaker John (then Chris) Crabtree had joined the staff of the Slade’s Print dept. after graduating. He was also interested in computers and had a close relationship with EXP throughout the 1970s. Like Viner he was primarily interested in the materiality of the art object and less concerned with process. Several of his computer plots were finally printed using the etching process that gave them a strong objective presence. The experimental filmmaker Chris Welsby also taught part-time in the dept. He was interested in formal methods of film construction using weather phenomena like cloud cover and wind as input. He was an early member of the influential London Filmmakers Co-op. Mike Leggett recounts how Briscoe was a visitor to the Co-op in it’s first studio at the New London Arts Lab in Camden where he was helping Welsby build a wind powered controller for the camera he used to make the film Anemometer in 1974. This relationship with the Co-op illustrates the common ground shared by many experimental arts communities during this period. Several of the Co-op members shared our interest in process and formal methods as demonstrated by recent publications by Leggett describing the making of his 1976 film Red + Green + Blue[25], [26].

Chris Briscoe was interested in another important influence derived from contemporary scientific investigation – iterative, unpredictable, non-linear deterministic systems. In between helping others to use the Nova system Briscoe produced an impressive portfolio of drawings and a number of audio works. Each line or audio voice progressed incrementally by basing its decisions on its relationships with the other graphic or audio elements in the scene (**figure 4**). Sadly most of Briscoe’s work has been lost though several images and two audio pieces have been preserved in Jean Spencer’s Working Information 3[27] which featured the work of Briscoe, Sullivan, Scrivener, Crabtree, Viner and Beyls. Spencer was Malcolm Hughes partner and was also a member of the Systems Group. In 1978 she curated the Curwen Slade Print Portfolio "UCL 150th Anniversary 1828-1978" that contained work by all of the artists then teaching at the Slade and included computer-generated works by Briscoe, Sullivan and Crabtree. A copy was presented to UCL’s Chancellor – Her Majesty Queen Elizabeth The Queen Mother.

Amongst the students in the department who pursued an interest in the nascent field of generative art was Steve Bell who went on to complete a PhD with Ernest Edmonds at Loughborough[28]. Another was Dominic Boreham who produced two major series of works based on linear phase patterns that developed his interest in visual cognition. Boreham also played an important role in the Computer Arts Society (CAS) where he curated a number of exhibitions and edited several influential issues of the CAS bulletin PAGE. I was a contemporary of Bell and Boreham at the Slade where I studied from 1977-79. My primary interests were CAs and both deterministic and probabilistic systems. At the Slade I developed a system for interpreting CA output using tiling systems and this has dominated my practice over the past three decades[29],[30]. Other students who used the Nova system included Colin Gale, who went on to establish a computer arts program at Goldsmiths College and Carole Gray – now a Research Professor at Gray’s School of Art, The Robert Gordon University, Aberdeen. Later Nigel Johnston joined the program and created a number of large-scale interactive works that were inspired by Ihnatowicz’ robotic works from a decade earlier. In 1979 Hughes organised a show of student work at the Polytechnic of Central London (now Westminster University) called EXP at PCL. All of the students enrolled in EXP were included in the show which included other experimental genres and not just computer-based work. An illustrated catalogue was produced, where each student was allocated a double-page spread that they could do anything they liked with and it included an introduction by Hughes[31].

The Australian artist and theorist Mitchell Whitelaw suggests that a-life is a natural development of artistic practice throughout the 20th century[32]. In particular he quotes the work of Paul Klee and Kasimir Malevich. Many artists have claimed that that their work has an independent life of its own and that the artwork "tells" them when it's finished. Those artists associated with the Slade's computer studio in the 1970's felt they were building upon the traditions of constructivism, systems art and conceptualism and that the computer was a "natural" tool with which to continue this kind of work. Many of the more traditional artists associated with the program and who did not use computers themselves agreed. We did not use the term "artificial life" and would not especially have associated with the term as Langton defined it over a decade later as a form of "experimental biology"[33]. Our focus was more on procedure and process in their most general sense and moreover many artists actively resisted attempts to apply anthropomorphic interpretations to their productions. However references to life and physical and biological processes were often implicit in many of the works. Examples would include Conway's "Game of Life" which had a major influence or my own time-based work "Builder + Eater" (1977, **figure 3**) where two concurrent processes dynamically competed for possession of a digital image. Nevertheless it has been interesting (and reassuring considering the ongoing lack of recognition by the arts mainstream) to find that we are now being rediscovered by a new generation of a-life researchers who are seeking the origins of their discipline. Many of the members of EXP had strong relationships with the science and technology community at UCL and elsewhere. It was often much better than the relationship we had with the other fine art departments within the Slade itself! Sullivan worked closely with the image-processing program, Briscoe with Engineering and Welsby with Astronomy. Ihnatowicz, of course, provided a strong bridge between Mechanical Engineering and EXP. There were many more informal links built by attendance at obscure meetings where a multidisciplinary community were discussing new ideas like Chaos Theory. Via the Computer Arts Society we met a diverse community with a common interest in the potential of generative and adaptive processes in graphics, AI, cognition, visualisation, simulation and modelling[34, 35]. Many of the scientists respected our work and our contribution and we engaged in a common dialogue with them about the emergent computational paradigm. It's one of the only examples I can think of where an art community, while pursuing the dominant aesthetic concepts of the period, were also able to contribute so dynamically to the development of a new scientific field. And, given the resurgence of interest in Code Art and Generative Art in the 1990's and 2000's, it is worth emphasising the Slade's pioneering role in first developing the concepts that define the field and which still inform the area. Sadly many current practitioners are unaware of this important historical precedent - something that this book will, I hope, address.

By 1980 EXP had been run down by cuts in funding which reflected a change in emphasis in the school and Hughes eventually took early retirement. Chris Briscoe and I formed a company called Digital Pictures within the Slade to do commercial work and to generate funding for the dept. It was the UK's first specialist computer effects company servicing the film and video industries. I was given an honorary research position to justify my presence in the building and we split our time between supporting the student program and doing short commercial video clips. Students of the time included Liam Scanlan, who worked nights for Digital Pictures and who went on to work for LucasFilm's Industrial Light and Magic, and Tim Macmillan who developed 3-D cameras, the output of which was the precursor of the 3-D freeze-frame sequences popularised recently by films like The Matrix. The company was successful but the Slade was not sympathetic. In 1982 we left, reluctantly, and became a fully commercial operation based in Covent Garden. After a fertile and influential decade the experiment called EXP was over.

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